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Second International Visual Field Symposium

Second International Visual Field Symposium
Tübingen, September 19-22, 1976

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INTRODUCTION

The International Perimetric Society, I.P S., was founded in Marseille, in May 1974, during the First International Visual Field Symposium.

The objectives of the I.P.S. are

1. to stimulate, compare and coordinate research concerning V.F. (Visual Field);
2. to develop guidelines for routine methods of visual field examination (V.F.E.),
3. to develop recording and equipment standards;
4. to promote the development of new methods and instruments;
5. to promote the diffusion of knowledge and understanding of V.F.E. and its important place among other methods of examination of the visual functions;
6. to collect and compare knowledge about visual field defects as found with different methods of examination;
7. to increase knowledge about the relationship between certain visual field defects and their pathogenesis;
8. to promote, encourage and cooperate in the education of specialized visual field examiners (through courses and handbooks);
9. to meet at regular intervals.

The activities of the I.P.S. are stimulated and organized in the following Research Groups:

1. Standardization	Chairman J. M. Enoch (USA)
2. Methodology	Chairman: H. Matsuo (Japan)
3. Fundus and Optic Disc, Toxic Amblyopias	Chairman: E. Aulhorn (W. Germany)
4. Glaucoma	Chairman: S. M. Drance (Canada)
5. Neuro-Ophthalmology	Chairman· H. Bynke (Sweden)
6. Colour	Chairman G. Verriest (Belgium)
7. Automation	Chairman: F. Fankhauser (Switzerland)
8. Objective Perimetry	Chairman: G. H. M. van Lith (The Netherlands)
9. Binocular Perimetry	Chairman. V. Herzau (W. Germany)

Louise Sloan, H. Goldmann, H. Harms and G. Jayle were elected honorary members of the I.P.S. because of their outstanding contributions to perimetry.

Since its formation the IPS has been active in the organization of its Research Groups and the Second International Symposium in Tübingen. The local organization was in the experienced hands of Professors Aulhorn and Harms and their collaborators. We wish to thank them gratefully for their fine organization and for the happy hours that they gave us in Tübingen. No doubt this second symposium will remain in the memories of the partcipants as one that combined expert knowledge and great friendship.

Our thanks go also to Miss Els Mutsaerts and Mr. Bill Miller of Amsterdam who assisted extensively in the organization of the scientific programme.

Finally, the cooperation of the publishers, Dr. W. Junk bv, was as ever efficient and pleasant.

It is hoped and expected that the Third International Visual Field Symposium in Japan (Tokyo, May 1978) will be as great a succes as this symposium in Tübingen.

For Tokyo a special type of symposium was chosen: a topic-symposium, to find a consensus about certain urgent perimetric questions. The young I.P.S. will continue to work in the same atmosphere of enthousiasm that has characterized it until now.

Erik L. Greve

SUMMARY OF THE MEETING OF THE IPS RESEARCH GROUP ON STANDARDIZATION ON 19-9-1976

Present. Aulhorn, Dubois-Poulsen, Enoch (chairman), Friedmann, Greve, Harms, Matsuo, Verriest (acting as secretary), Weale, Zingirian. As guests Campos, Eisfeld, Fulmek, Laszyk, Leibowitz, Lynn, Maione, Pashley.

The chairman first reported about the activities of Research Group between the 1st en 2nd IPS Symposia, and more particularly about the responses to the questionnaires and the liaison with Mrs. Birch-Cox, chairman of the Standardization Committee of the International Research Group on Colour Vision Deficiencies.

The first main topic of the meeting concerned the use of luminance vs radiance as primary reference standard in perimetric studies. Enoch reviewed the arguments favouring luminance, especially from the responses to the questionnaires and from a letter of Mrs. Jo Ann Kinney (chairman of CIE TC 1.4).

Weale brought new arguments favouring radiance, as the study of radiation injuries and the possibility of cheap radiation measurement. Verriest underlined that energetical calibration is often necessary in colour perimetry, and that both luminance and radiance figures generally need to be completed by a spectral distribution curve. Dubois-Poulsen stressed the necessary of such specifications in dark adaptation studies. Accordingly the chairman draws the following conclusions: 1. The current specification for office practitioners is to be based on a luminance standard. 2. For dark adaptation studies or when non-white sources are involved, and in all basic research, calibration is to be made in terms of radiance, luminance and spectral distribution. 3. The same holds for the specifications to be made by the manufactures of instruments; they must concern the light entering the examined eye in the plane of the pupil. 4. The question will be reviewed in 4 years. Furthermore Weale suggested that luminance should be calculated from radiance and spectral distribution curve using the CIE $\bar{y}$ 10 (λ) (10 degree) function rather than the CIE ($\sqrt{\lambda}$) one (2 degree).

The second main topic concerned the specification of the target size. It appeared that if, for an orthogonal presentation at 0° eccentricity, the visual angle in arc-minutes is θ, the target diameter in mm is d and the distance between the target and the examined eye in mm is d', the size of a (round) target could be fully specified by a notation as [tg θ = d/d '], whereby the

0° eccentricity and the type of instrument are to be remembered.

The third main topic concerned the specification of preferred background adaptation levels. Because of the lack of discussion time, the only actual conclusion was that pupil diameter must always be measured, this in order that the retinal illuminance could be known (and calculated). The chairman reviewed several factors entering into this decision and urged careful studies so that a rational choice(s) can be made at a future meeting.

Finally it was decided that, in order to obtain a more orderly process for the development of a full perimetric standard, a small working group should prepare primary documents. Weale and Wheeler offered themselves to work out the duration of target presentation and individual threshold problems; Fankhauser will concentrate on target size and background-luminance problems, Friedmann on target size and pupilarea problems; Matsuo for background luminance and adaptation level problems; Greve on mesopic levels.

Further discussion ensued after the meeting and it was informally suggested that a small group convene in Europe, at a date to be decided later, to prepare a draft document for presentation to the Research Group on Standards at its next full meeting.

Guy Verriest

SUMMARY OF THE MEETING OF THE GLOSSARY COMMITTEE OF THE IPS RESEARCH GROUP ON STANDARDIZATION ON 19-9-1976

Present Aulhorn, Eisfeld, Enoch, Fankhauser, Frisen, Greve, Harms, Laszczyk, Maione, Matsuo, Pashley, Verriest (chairman)

It was decided.

1 that the actual 3rd draft (July 1976) of the glossary should undergo only minor changes for what concerns the terms in English and in French (e g that for the English version the UK spelling should always precede the USA one), and that the translation in German, Spanish, Italian, Dutch, Polish and Japanese should be completed,

2. that this version in 8 languages should be printed by the IPS as soon as it is completed, the items being numbered and with a supplementary alphabetical list of the terms in English, the separata being page-mated as in the original edition in the journal with no copyright (so that the glossary could be partly or wholly reprinted by other editors) and if possible under the authority and with the financial add of the International Council of Ophthalmology,

3 that a subsequent edition should be provided with definitions of some or of all terms (in English), and with a translation of the terms in Russian

G. Verriest

THREE YEARS OF EXPERIENCE WITH THE OCTOPUS AUTOMATIC PERIMETER*

F. FANKHAUSER, J. SPAHR & H. BEBIE

(Berne, Switzerland)

The achievements to be described are the result of some three years of practical experience with the automated perimetric system Octopus. Seven-hundred-fifty-seven examinations were carried out on 27 pathological (481 tests) and 29 normal eyes (276 tests). Out of this data-material comparative studies were performed which have been discussed by Koerner et al.

It should be mentioned here that during the development of this apparatus there came a point at which a dichotomy had to take place, insofar as a commercial version had to be split off from the research apparatus as used by us so far. Since that time, both developments have been running parallel. This, indeed, is the usual way of development of scientific equipment. Sophisticated experiments with complex apparatus are indispensable in order to gain basic knowledge which eventually makes sensible, simplified and practical solutions possible, solutions which ought to fulfil the condition that the capabilities of the pure research apparatus should be retained as much as possible. The development and manufacturing of the commercial version has been turned over to a highly reputed engineering corporation, widely experienced in the field of automation.

The scheme of our present research apparatus is shown in Figure 1. The master control unit, the process computer (1), is seen at the top. Multiple connections couple this 'brain' with the other components of the apparatus, which temselves are interrelated by a large number of feedback loops. We shall not go into detailed explanations about the function of these connections; (2) is a magnetic tape cassette recorder, (3) is the library of magnetic tape cassettes containing cassettes with search programmes and also data cassettes for the results of analysed visual fields, (4) is a display terminal and (5) a hard copy unit which provides for immediate copying of the data appearing on the display screen. The connecting lines indicate that any data on the visual field, whether in the stage of processing by the computer or stored in the computer memory (1), or stored in the external memory, i e. in the magnetic tape cassettes (2, 3) can be called into the display terminal with very little delay (4) and printed out, if desired. Electromagnetic storing

* This work has been supported by the Schweizerischer Nationalfonds zur Förderung der wissenschaftlichen Forschung

of visual field data thus provides tremendous speed when displaying and manipulating data. Conventional storing on paper charts, however, will probably continue to be of importance for a long time because the receiver of machine-made visual fields will continue to depend on paper copies. Box (6) contains the electronics for the step motors which are symbolized by (7). The step motors themselves are for moving the mirror (8) which is able to shift the stimulus in large or small jumps at high speed anywhere in the visual field up to an eccentricity of 90°, the smallest reproducible space interval being 0.1°. Box (9) contains the general controlboard of the perimeter (11). (10) symbolizes the push-buttons for the patient's answers. The integrating sphere (11) is illuminated by light source (12). (13) is the light source for the test target.

Hitherto it has been the custom to use the same light source for both target and background illumination in order to compensate for deviations of the radiance of the light source from its nominal value. Continuous monitoring of the lamp supply sources now makes this precaution unnecessary. At postion (14) we have a set of field stops providing round test targets of the same sizes as the traditional Goldmann test targets. At position (16) a set of neutral grey filters is located; the components in the filter battery are such that a range of 5.1 log units is covered, the intensity spacing being 0.1 log unit. The filters are under the continual control of the computer by feedback loops.

Deviations from the nominal test target luminances are therefore prevented. At position (17) we have one of the two lenses of the objective of the test target projection system. The scanning beam of the infrared sensitive TV camera (19) is deflected by one of the mirrors at position (18) and the monitor (20) displays the image of the eye at a magnification of 6x. The final ideal form of the automated eye position detector has not yet been

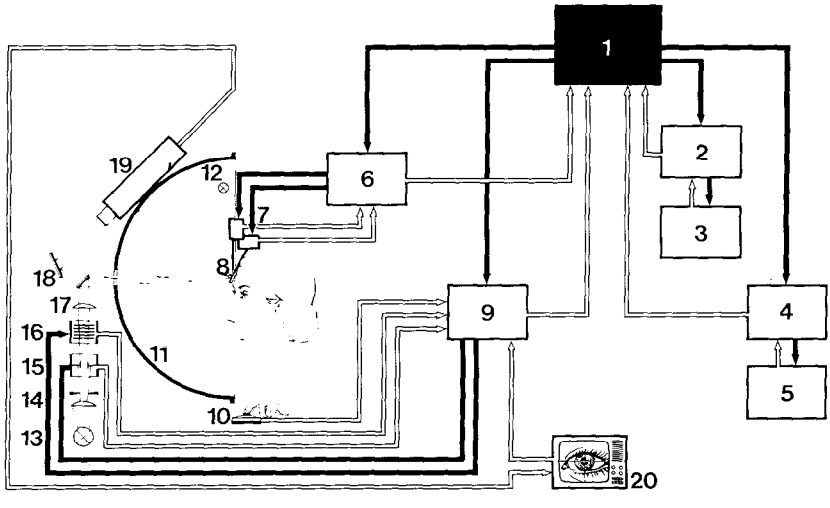

Fig. 1 Block diagram of the computer perimeter Octopus For details see text.

found. The chief source of our difficulties arises from present spectacle lenses correcting for distance and ametropia.

At the present time fixation deviations are monitored and controlled by the operator using the TV screen mentioned above. It is our definite impression that watching the eye movements on the 6x enlarged image on the screen is infinitely superior to looking through an eyepiece, because it is much less fatiguing and gives the operator freedom of movement for other duties. As a result, the eye to be watched is monitored more frequently and reliably than with the previously used method of looking through an eyepiece in a horizontal direction as, for example, in the Goldmann and Tübinger perimeter where the designer was much more concerned with the economy of the solution than with the comfort of the perimetrist. Although the technological differences between a research and a commercial instrument are rather large, the functional differences are, in essence, small. In the design of the commerical form of the Octopus (Figure 2) the tendency has gone in the direction of adaption to the new inventions and achievements of the computer industry.

Let us once more take a quick look at the basic research instrument and consider what has been changed in the commercial Octopus. The 5 years old HP 2114B, 8.000, 16-bit words mini-computer has been replaced by an Intel MDS 800 microprocessor with an internal random access memory of 32,000, 8-bit words, apparently with some loss of versatility As most of you know, microprocessors, at the present time, accept machine language on

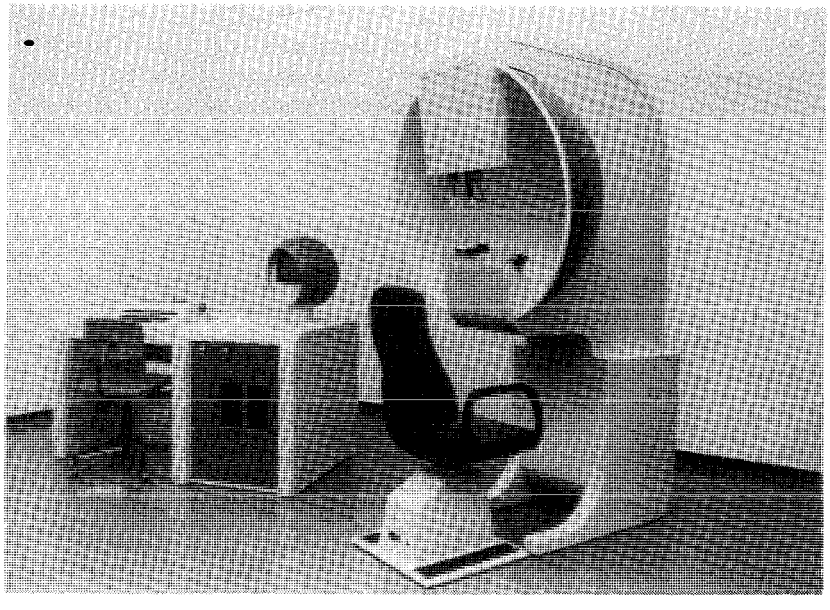

Fig 2 The commercial version of the Octopus, manufactured by Interzeag, CH-8952 Schlieren

their input side only, the development of new programmes in a high level language only being possible with the aid of additional equipment. In contrast, minicomputers may be programmed in a high level language by the user himself. Hence, in principle, tailoring programmes by the user according to his specific needs, problems and wishes will no longer be possible with the microprocessor system. Instead, he will be invited to choose from a series of standard programmes, implemented in the microcomputer by the manufacturer, ready for use, the one best fitting his intentions. The series of available programmes has been made large enough to cope with practically any problem he may meet, but any thinkable or exotic programme possible can be ordered from the factory. In the table we have listed the programmes which will be provided with the instrument in the first place. This list as it stands should according to our experience, satisfy the needs of any possible clinical task. However, it may well be that, with increasing experience on a large population, modifications of these programmes, or the addition of supplementary subroutines, may become necessary and it is our intention, to enlarge this list gradually and to create an additional series of programmes for very special purposes. For the function of these programmes, the reader is referred to the forthcoming literature at present in preparation. We are convinced that, in working with a set of fixed programmes of sufficient size, no flexibility is lost. On the contrary, many difficulties will be avoided. In our experience it is infinitely easier to choose an existing programme, fitting best the problems being considered, than to design programmes oneself – all too often a tremendous and difficult task which requires not only a considerable amount of knowledge of visual field search strategies, but also of computer technology in general.

When a visual field analysis has been completed, we have to store the data somewhere in an external memory. The magnetic tape cassettes used hitherto have been replaced by floppy discs in the commercial model, particularly because of their rapid access times. Also, for the display of data the commercial model will use an IBM typewriter which is able to produce half-tone displays and profile sections.

The sensitivity values on the half-tone displays are read from a series of symbols, corresponding to discrete threshold values as shown on Figure 3, which shows the central visual field of a case of retrobulbar neuritis with irregular sensitivity depressions.

When the symbols are viewed so as not to be resolved (by defocusing, as in Figure 4, or by observing from a distance), areas of variable shades are seen, the borders corresponding to isopters which, however, originate from static threshold determinations. In the lower parts of the same Figures 3 and 4, two isopter lines have been actually drawn in. As soon as the symbols are resolved on close inspection, the sensitivities of discrete points may be directly read out.

In Figure 5, contrast-resolution of the half-tone display has been decreased by reducing the number of symbols. As is evident from this figure, we have traded intellegibility against information content.

There is no complete equivalence between conventional isopter displays and half-tone areas as shown here, which are obtained from static examina-

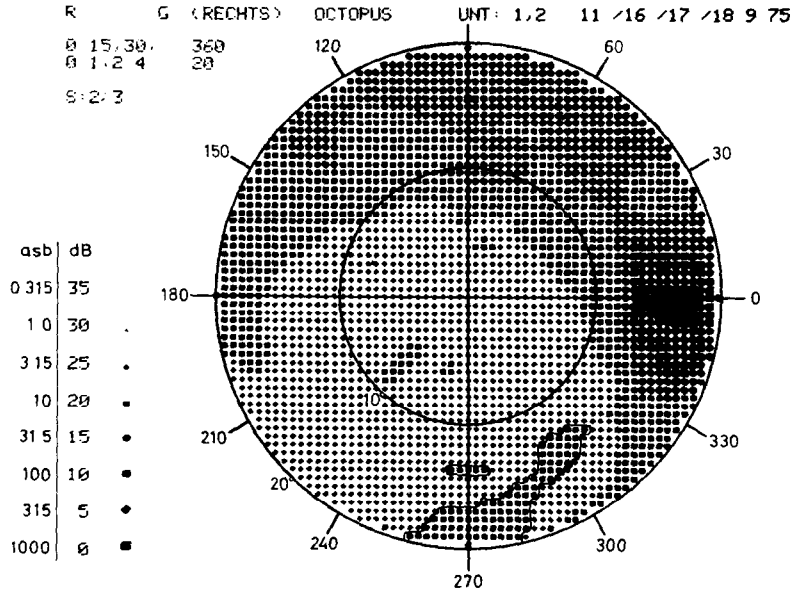

Fig 3 Half-tone display of sensitivity distribution for a case of retrobulbar neuritis. The threshold values have been averaged over two successive examinations. Resolution: the determination points have been placed along meridians spaced at 15° intervals. Density of the points on the meridians: 2°. Separation of points on display: 2/3°.

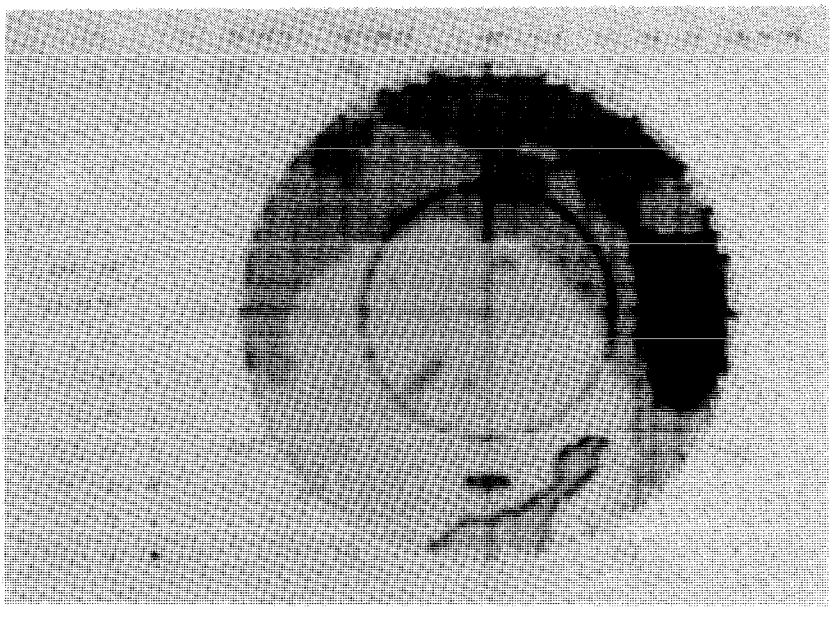

Fig. 4. Defocused display of Figure 3. The symbols are not resolved any more and have fused into half-tone areas

Table I. List of computer programmes which will be available together with the commercial version of the Octopus

OCTOPUS PROGRAMMES			
Programmes for visual field analysis		Programmes for data processing	
static perimetry	modified kinetic perimetry	display programmes	synthetic programmes
(1A) Static perimetry of the centre of the visual field	(1B) General kinetic screening	(1C) display of the analytical protocol	(1D) general data-processing programme
(2A) General static screening	(2B) Specific kinetic screening	(2C) display of figure tables	(2D) Integration of kinetic data (1B) into the entire visual field
(3A) Static perimetry of the central visual field (0-30°)		(3C) display of halftone fields	(3D) Integration of static data (1A-6A) into the entire visual field
(4A) Static screening of the intermediate part of the visual field (30°-60°)		(4C) display of sensitivity profiles	(4D) Combination of selected static data and synthesis of such data blocks in order to produce a specific display
(5A) Static perimetry of the outer part of the visual field (60°-90°)		(5C) display of isopters	
(6A) Static precision perimetry			

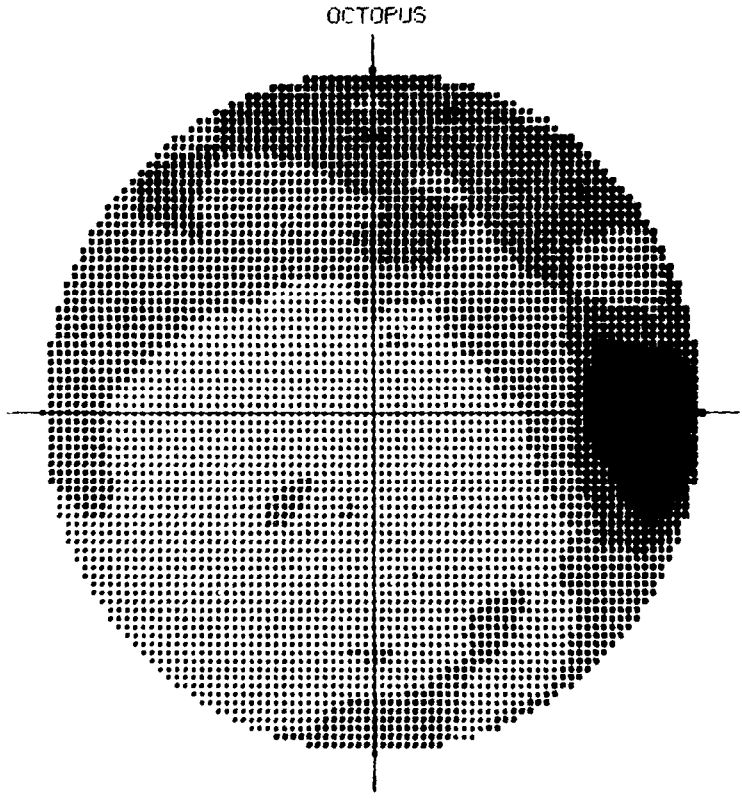

Fig. 5. Same sensitivity distribution as shown in Figure 3. The number of symbols on the display has been decreased as compared to Figure 3.

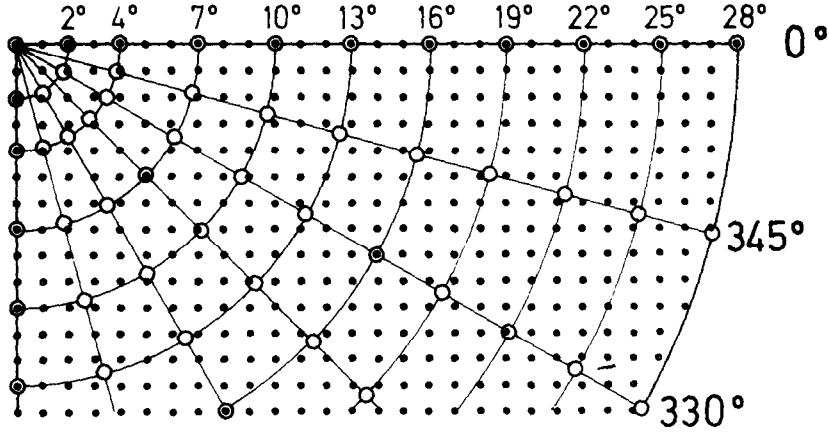

Fig. 6 The relation of determined and interpolated threshold determination points as a function of eccentricity ○ determined ● obtained by repeated interpolation.

tions. The half-tone displays are defined at every point at which a static measurement has been carried out, the intermediate symbols being provided by interpolation procedures. Figure 6 shows the relation of actually determined and interpolated data points as a function of eccentricity anywhere within the central visual field of 30° radius. The relation of determined to interpolated points may be varied within wide limits according to the degree of security required for a specific area of the visual field.

Finally, one advantage of computer perimetry is shown in figure 7: by means of one single order, the profile sections are printed out at any meridional resolution required. In this Figure (7), the profiles are given at 15°

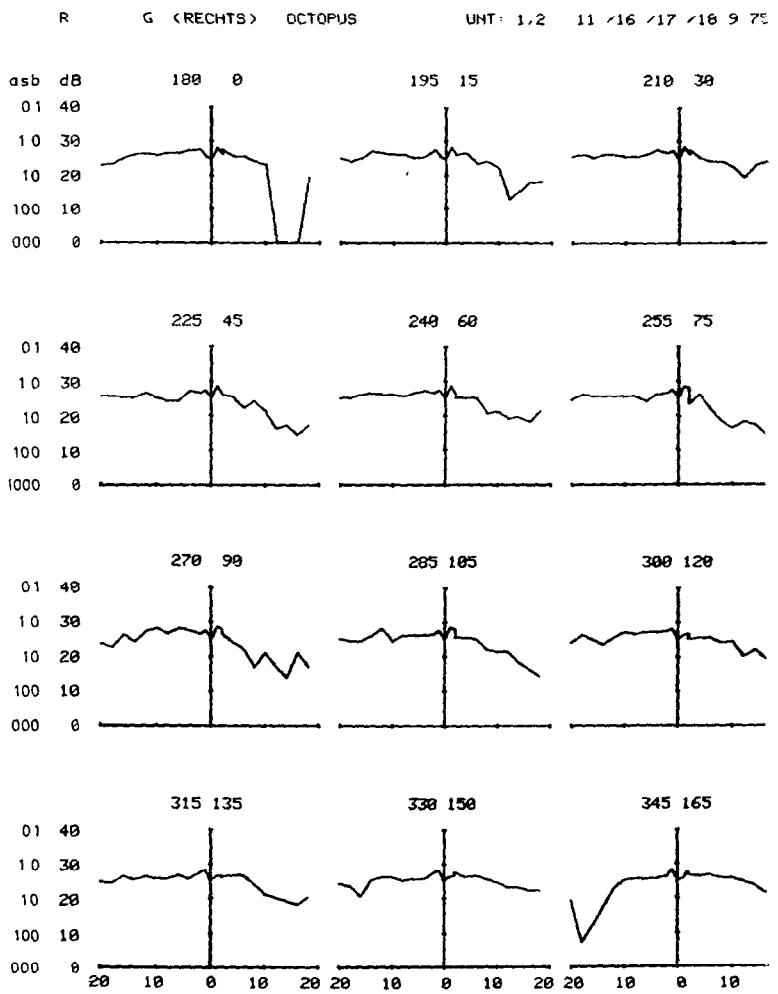

Fig. 7. Alternative representation of same sensitivity distribution as shown in figure 3. Profile sections at 15° meridional intervals are shown.

meridional intervals. The intelligibility of computer synthesized graphical displays is important, since they often form the starting point for planning the further processing and mathematical manipulation of the data.

SUMMARY

The instrumental improvements of the automated perimeter Octopus achieved during the past three years are described. From the original research apparatus, a commercial version has been developed which – in contrast to the original apparatus – is equipped with a microcomputer unit and uses, as external memory, a floppy disc system.

A set of programmes is offered, which should cope with almost any conceivable problem of visual field analysis. The data are printed out by a modified IBM typewriter as half-tone displays or as conventional profile sections.

ACKNOWLEDGEMENTS

The authors would like to thank Alfred Jenni for his important participation during the construction of the Octopus research apparatus. The computer perimetric examinations were carried out by Bettina Stocker The drawings, as far as not generated by the computer, were made by W Hess. We are greatly indebted to Dr. B.H. Crawford for his help and advice during the course of this work.

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COMPARATIVE INVESTIGATION OF AUTOMATIC AND MANUAL PERIMETRY IN DIFFERENT VISUAL FIELD DEFECTS

E. AULHORN & W. DURST

(Tübingen, W. Germany)

The automatic perimeter, of which the examination results are reported here, was developed on the basis of the Tübinger Perimeter in the course of approximately four years in collaboration with the Stuttgart Institute of Telecommunication and the firm 'Oculus' It has been ready for operation for one year. Alterations and improvements on the strategy of examination, however, are made continuously, brought about by the preceding examination results. Therefore, the development of the instrument cannot be said to be concluded as yet.

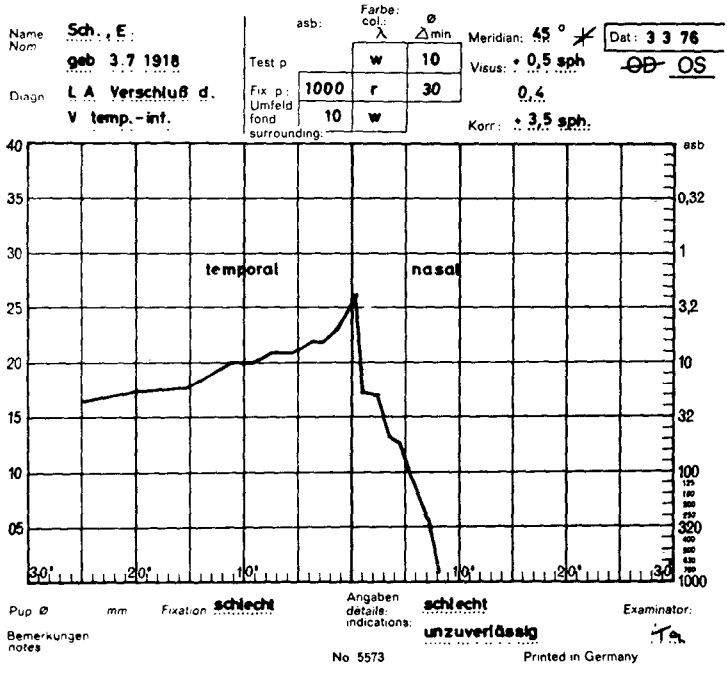
The computer controlled examination programme can be altered in nearly all its features. Position and number of meridians, type of threshold determination, duration of presentation of the test-point, interval between test-point presentations, and many other parameters can be determined before the examination of a patient, so that an adaptation to the requirements of the patient and to his disease is possible, within certain limits.

The programme of examination can be applied to the whole visual field or to the central section of 30° only. It can run in the form of profile perimetry along visual field meridians or in the form of isopter perimetry, but always on the basis of the static method of examination.

Adequate experience of examination with the automatic perimeter is not yet available for isopter perimetry, but for profile perimetry it is, and below we should like to give an account of this.

Sixty-nine visual field meridians in 59 patients were examined successively in a comparative study using the Tübinger manual perimeter as well as the Tübinger automatic perimeter, with an interval of at least 20′ between the examinations (Fig. 1). First of all, manual perimetry was carried out in the form of an isopter visual field and of one or two meridian examinations. Automatic perimetry then followed, in which four meridians are always examined simultaneously. Their positions were selected in such a way that the meridians examined in manual perimetry were always included.

Of the 69 profile curves examined in a comparable manner with both instruments there were 33 normal curves, and the other 36 showed defects of different genesis. The ages of the patients lay between 15 and 71 years. Patients of different degress of intelligence and occupational categories were deliberately chosen for examination. Only very weak patients, of whom it



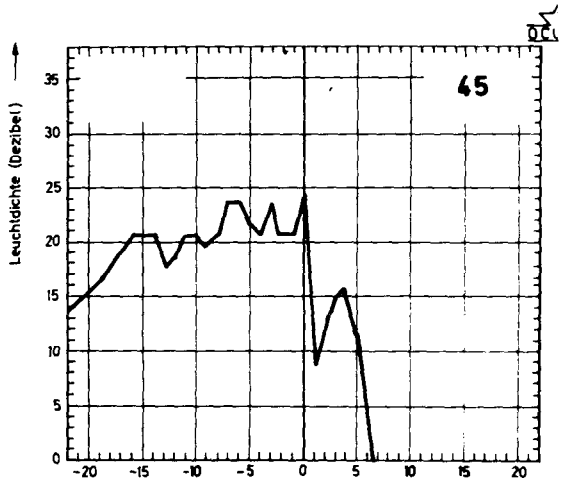


Fig. 1. Static perimetry in the 45° meridian of the visual field of a patient with occlusion of the retinal vessel Left: manual perimetry Right: automatic perimetry

would be unreasonable to expect two successive examinations, were excluded from the study.

One of the 59 patients examined gave such bad responses with both instruments that his results were excluded from the assessment. All other results were usable.

The comparative evaluation of results was done from the following points of view.

- level and slope of curve
- location and extent of blind spot
- location and extent of scotomas
- fixation
- deviation of response
- duration of examination
- extent of exhaustion
- instrument preferred) response of patients

The level of curve was measured at three points in one half of the meridian, i.e., at 0, 10 and 20 degrees eccentricity. The result can be seen from Tables 1a-c. Greater deviations of the level of curve are found in a few cases only in both the centre and with 10 and 20 degrees eccentricity. The deviations are approximately the same in all measured spots. This means that *the slope of curve*, measured with both instruments, shows no substantial deviation either.

The location and extent of the scotoma also proved to be similar in most examinations with both instruments (Table 2). However, absolute defects were concerned with all scotomas examined; this was found in examinations using both methods. The extent of the scotomas – as shown in Table 2 – was the same in most cases, or showed only slight deviations up to 3 degrees. Greater differences were found in three cases only with regard to the width of the scotoma. In all these cases very strong correction glasses were worn during perimetry. The differences in scotoma width can easily be dependent on the different distance of the eye from the correction glass, since other conditions of enlargement in the visual field are given as a result.

From Table 2 we can also see that in most cases the position of the middle of the scotoma within the examined meridian was also very similar. In the four cases in which the middle showed a greater difference in position in an examination using both instruments, three patients were again concerned with very high corretion lenses, and the fourth also had a slightly higher correction.

On the whole, however, the result of scotometry in examinations using both instruments is practically the same if the results with high correction

Table 1a Level of curve in the centre with 57 meridians

equal, or only 0.1-0 3 log E diff.	51
automatic perimeter higher (to 0 7 log. E)	2
manual perimeter higher (to 0.7 log E)	4

glasses are disregarded. The latter problem can be easily removed in future through better technical devises of lens fixture.

In some cases, using automatic perimetry, narrow ring-shaped absolute defects were found in a narrow region which were not there with manual perimetry. These were very clearly caused by the projection of a test-point onto the edge of the spectacle glass. This mistake, however, can also be eliminated once one has become aware of it.

At this point it should also be said that the only relative scotoma, found with manual perimetry, was not clear when automatic perimetry was performed. This was a case of a central serous retinitis with a flat paracentral ring scotoma. With automatic perimetry the course of curve was so jagged that such a flat depression of curve could not be detected.

The location and extent of the blind spot was found to be practically the same in examinations by both methods, similar to the case with the absolute scotomas. Only in two cases did the difference in size have somewhat higher values. Both times the patients concerned had again very high lens corrections (+ 14.0, respectively, 7.0 dptr).

The assessment of deviation of the patient's response was the biggest problem for us, for it became apparent that the reproducibility of response was very much better in the automatic perimeter, with repeated threshold determinations in one retinal area, than was to be expected after the big differences in threshold value with the points of curves lying next to each other. In manual perimetry the examiner always gave a more level curve than in automatic perimetry, where the course of curve nearly always showed stronger indentations. We do not yet wish to make any binding statement conveming the problematic nature of deviation with our automatic perimeter. At present this is still a reason for constant improvement of the examination strategy.

Only approximate details can be given of the *duration of examination*, since only one meridian is examined with manual perimetry, whereas four meridians are tested simultaneously with automatic perimetry. Consequently, we divided the length of examination by four. It is, however, clear that for this reason a comparison of the duration of examination in both methods is very restricted. Nevertheless, we can say that the duration of

Table 1b Level of curve with 10° eccentricity with 56 meridians

equal, or only 0 1-0 3 log E diff	53
automatic perimeter higher (to 0 7 log. E)	2
manual perimeter higher (to 0 7 log. E)	4

Table 1c Level of curve with 20° eccentricity with 56 meridians

equal, or only 0.1-0 3 log E diff.	51
automatic perimeter higher (to 0 7 log E)	4
manual perimeter higher (to 0 7 log E)	0

examination in both methods does not differ very strongly. For one meridian in manual perimetry it comes to between 5 and 18 minutes, and in automatic perimetry to between 6 and 16 minutes. With most patients there was an average time of approximately 10 minutes per meridian.

The evaluation results of a questionnaire was particularly interesting. Each patient was asked two questions, which had to be answered in writing without the influence of either examiner. The first question was: how exhausted do you feel? The patient had the following categories of assessment to choose from: not at all, moderately, very, unreasonable. The result is shown in Table 3. It can be seen that, on the whole, automatic perimetry is felt to be much more exhausting, but none of our patients rejected automatic perimetry as unreasonable.

The second question was: which of the two instruments do you prefer for the examination? 56 patients replied to this. As you can see from Table 4, about 65% of the patients favoured the manual perimeter, 9% found no difference between the two instruments, and 27% favoured the automatic perimeter.

The results of our comparative study showed us the points where the problem of automation lie. On the other hand, the fact has emerged that the decisive task of perimetry, i.e., the discovery and measurement of visual

Table 2. Location and extent of the absolute scotomas in 23 meridians

Depth of scotoma equal	23
Width of scotoma	
Equal or difference up to 3°	20
Difference more than 3°	3
Location of scotoma centre in meridian, equal or difference up to 2°	19
Difference 2 5-3 5° [3]	4
Difference more than 3 5°	0

Table 3 Extent of exhaustion (response of 56 patients)

	manual	automatic
1 not at all	13	1
2 moderately	36	20
3 very	7	35
4 unreasonable	–	–

Table 4 Which instrument is preferred? (response of 56 patients)

manual perimeter	36
automatic perimeter	15
neither	5

field defects, can, in principle, also be accomplished adequately by an automatic perimeter.

Today, automatic perimetry is still in its infance. But the results presented here are encouraging, and give hope that automatic perimetry represents a useful further development of this important ophthalmological examination method.

SUMMARY

A report is presented on the results of a comparative study of about 100 profile curves which were made with the new full automatic Tübinger Perimeter as well as with the normal Tübinger Perimeter. This study contains normal visual fields as well as abnormally changed visual fields. The advantages and disadvantages of full automatic perimetry are discussed in detail.

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SIMULATED AUTOMATIC PERIMETRY*

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(Amsterdam/Soesterberg)

When considering the automation of visual field examination various aspects of the subject have to be studied:

1. study of the patients' behaviour;
2. determination of suitable stimulation apparatus;
3. study of the examination procedure and computer programmes;
4. study of the graphic representation;
5. study of the storage of results;
6. study of the returns.

In recent years we have been occupied with several of these aspects, and the study of the patients' behaviour (instrument-patient interaction) seemed to us to be most important.

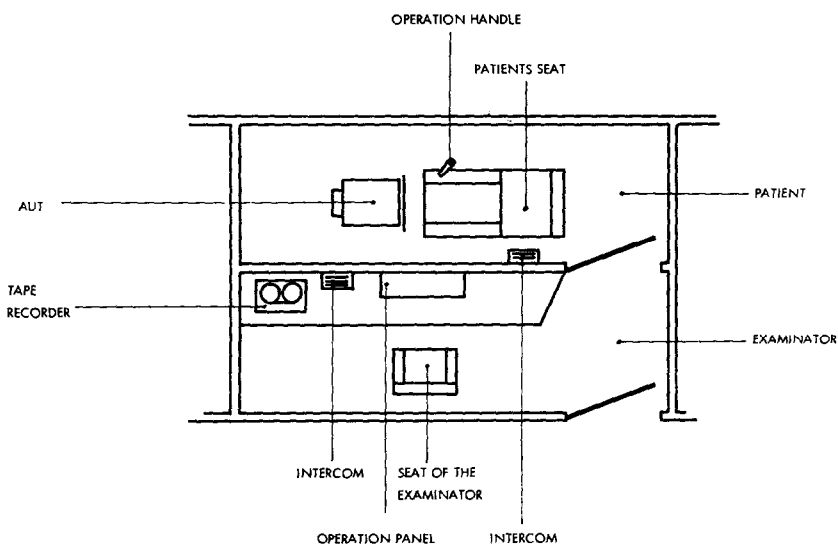


Fig. 1. Drawing of separate rooms for patient/apparatus and examiner

* This investigation was supported by grant no. GO-711-77 of the organization for Health Research, T.N O

A second question which interested us is whether Multiple Stimulus Static Perimetry (M.S.S.P.) is suitable for automatic visual field examination. In this connection we intentionally chose a different approach to that described in the literature so far.

In order to answer these questions, we first adapted a Visual Field Analyser (Friedmann) for remote control and placed it in a separate room, i.e., apparatus/patient and examiner were in different rooms (Fig. 1).

The results of this examination, carried out on 110 subjects with normal visual fields and 114 patients with glaucomatous visual field defects, were: the simulated automatic M.S.S.P. examination failed in only about 4% of the normal subjects and in 16% of the glaucoma patients, in the age group above 60 years the percentage of failures was 27% (Greve et al. 1976).

Considering the favourable results obtained with M.S.S.P. in both the non-automatic and the automatic situation, we decided to use this method with new stimulation apparatus. An oscilloscope was chosen because. a) it can easily be used for M.S.S.P., and b) it can easily be connected to a computer. Again intentionally, we chose a different method from the Fankhauser, Aulhorn, Coherent Radiation and Krakau Heyl groups.

The oscilloscope and the patient were placed in one room; the examiner, who worked the apparatus at a distance according to a fixed programme, was in another room. This is essentially different from other methods in which the patient and the examiner are not separated.

The patient fixates on a cross in the centre of the oscilloscope. As soon as a group of 2, 3 or 4 stimuli is presented the fixation cross changes to a question mark.

The patient reacts to the stimulus by indicating with the help of a handle the number of stimuli which he has seen. The number which he has indicated appears in the position of the question mark-fixation point. After the answer the fixation point automatically appears again, followed by a new presentation of stimuli.

79 normal subjects and 40 patients with glaucomatous visual field defects were examined with this newly-developed apparatus by remote control.

This article reports the results of the simulated automatic visual field examination (M.S.S.P. -oscilloscope) and only deals with the patients' behaviour. The technical details of the stimulation apparatus will be published elsewhere.

The examination procedure followed was as follows.

1. Visual Field Analyser, normal examination.
2. Simulated automatic visual field examination (oscilloscope)

a) instructions and trial presentations

b) determination of Individual Normal Sensitivity Curve (I.N.S.C.) by presenting 3 groups

c) determination of significant decrease in sensitivity; presentation at level of I.N.S.C. + 0.4 log. unit, i.e., 0.4 *supra*-threshold

d) if necessary further M.S.S.P. presentations (saw-tooth method)

e) determination of the intensity by means of S.S.S.P.

3. Check with S.S.S.P./Tübinger Perimeter, classical method.

RESULTS

The assessment of the results covered 2 points:
I. Comprehension of the procedure and apparatus, reaction to the instrument, etc. The examination was considered to be a *partial failure* when the automatic visual field examination could be completed but only with difficulty. In these cases the examination had to be interrupted one or more times in order to give further instructions. In a situation of complete automation this would mean that the examination would not go well at first but could be completed after additional instructions. The examination was considered to be a *complete failure* if it was not possible to finish it, even after additional instructions.
II. Comparison of the Simulated Automatic Perimetry (S.A.P.) with the V.F.A. on the one hand (M.S.S.P.) and the Tübinger Perimeter (T.P.) on the other hand (S.S.S.P.), concerning the intensity of defects.

Re I. In 66 of the 79 normal subjects the simulated automatic examination did not give rise to problems (ca 83%). In 6 cases (7.5%) the examination was a partial failure and in 7 cases (9.0%) it was a complete failure.

The results obtained with the 40 patients with visual field defects are shown in Table 1.

RESULTS OF THE EXAMINATION OF 40 PATIENTS WITH A DEFECT VISUAL FIELD

AGE	NUMBER OF PATIENTS	COMPLETE FAILURE	PARTIAL FAILURE	COMPLETE + PARTIAL FAILURE
> 60	27 = 67.5%	6 = 22.0%	4 = 15.0%	37.0%
≤ 60	13 = 32.5%	1 = 8.0%	0 = 0.0%	8.0%
TOTAL	40 =100.0%	7 = 17.5%	4 = 10.0%	27.5%

Table 1 Results of the examination of 40 patients with a visual field defect.

TYPES OF GLAUCOMA DEFECTS	NUMBER OF PATIENTS	COMPLETE FAILURE	PARTIAL FAILURE	COMPLETE + PARTIAL FAILURE
RELATIVE DEFECT → DEFECT FOR MAX. L.	19 = 47.5%	2 = 10.5%	2 = 10.5%	21.0%
DEFECT FOR MAX. L.	13 = 32.5%	2 = 15.4%	2 = 15.4%	30.8%
CENTRAL REST	8 = 20.0%	3 = 37.5%	0 = 0.0%	37.5%
TOTAL	40 =100.0%	7 = 17.5%	4 = 10.0%	27.5%

Table 2 Types of glaucomatous defects
A relative → max L defect is a partial nerve fibre bundle defect with relative defects and sometimes also parts with maximum luminance intensity The maximum luminance defects were complete or almost complete nerve fibre bundle defects

The visual field defects are subdivided into 3 types (Table 2)·

a) relative defects → defects for maximum luminance;
b) defects for maximum luminance;
c) central islands.

In this way an attempt was made to answer the question whether the type of defect affects the results of the automatic visual field examination.

As appears from Table 1, 7 examinations were a complete failure and 4 examinations were a partial failure. The complete failures were 2 cases with relative defects, 2 with defects for maximum luminance and 3 central remnants. The type of defect would appear from this investigation to have no obvious influence on the result. The examination of a patient with central remnants can either go very well or go badly when the remnant is very small.

A second influencing factor is age (Fig. 2). 13 patients were below the age of 60 years. With one exception all failures were in the group above 60 years of age!

The percentage of total failures is 17.5%. This is in agreement with earlier findings. In the group above 60 years of age the percentage is circa 22%.

The reasons for failure are:

1. 'O-fear': the subjects became confused when they saw nothing, with the result that they did not use the indicator handle or used it wrongly;
2. inability to understand the procedure;
3. nervousness on account of the isolated situation;
4. a combination of the above factors.

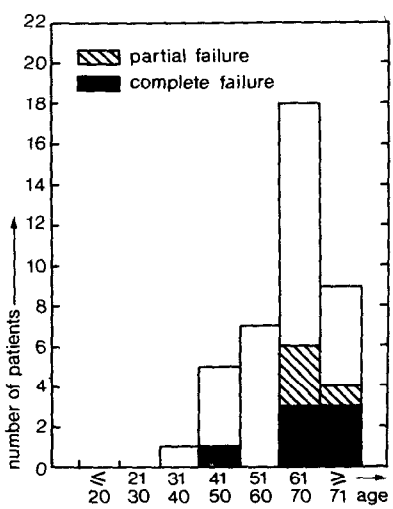


Fig. 2. Age-distribution of patients with glaucomatous defects.

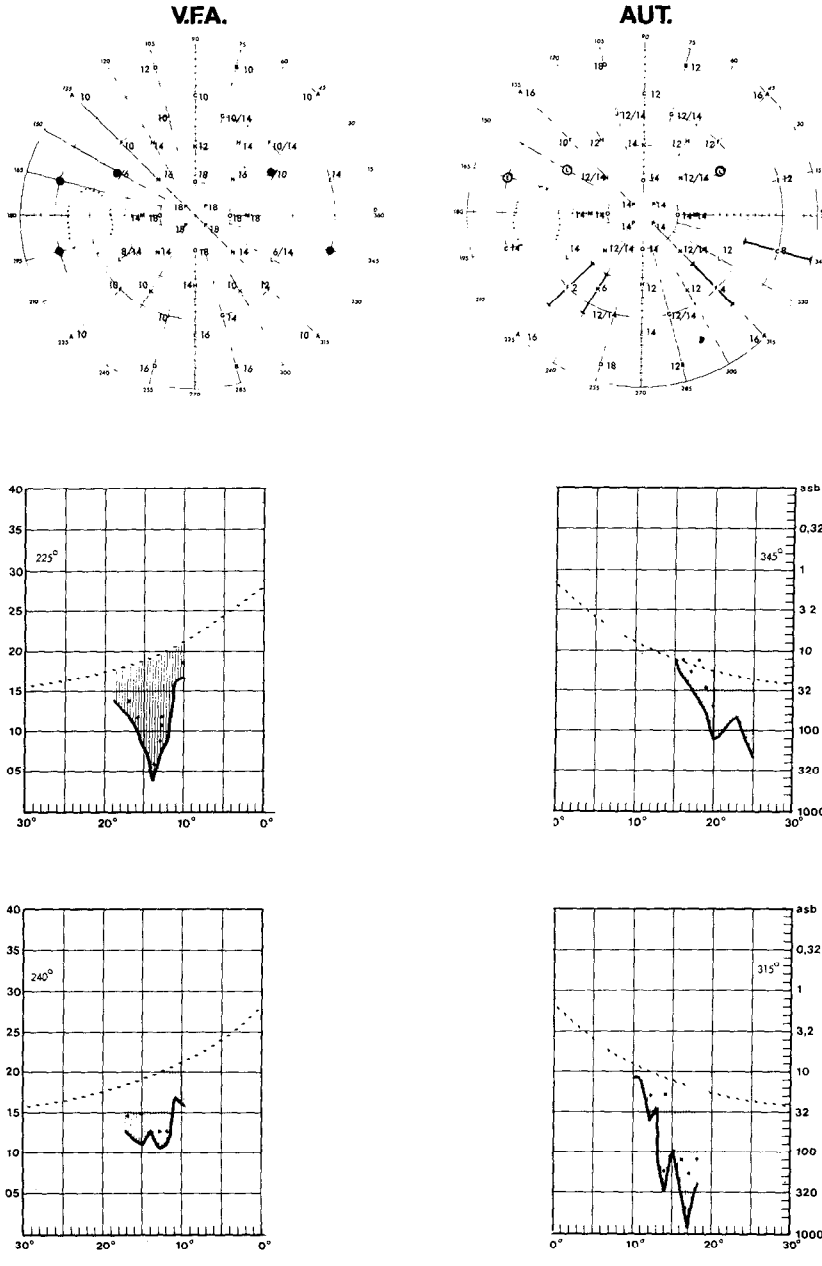
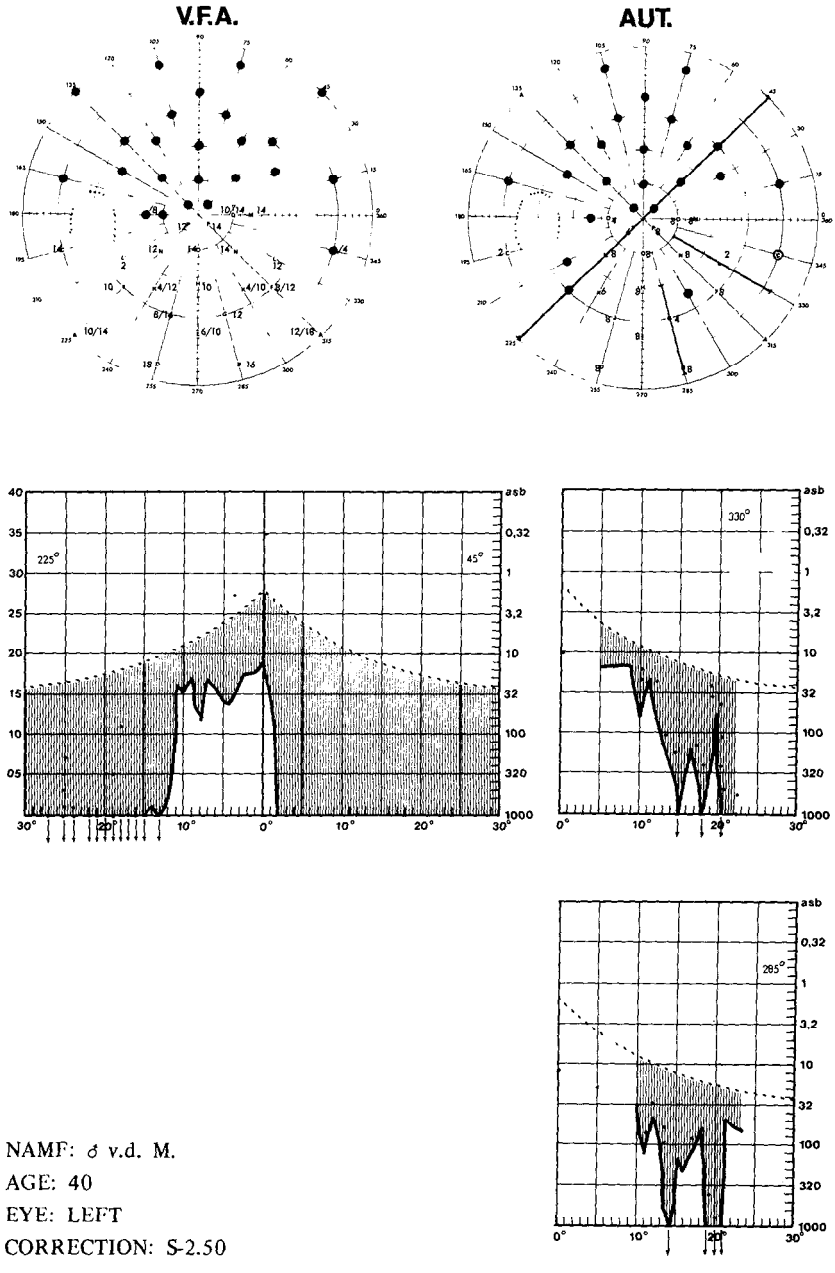


Fig 3 The Visual Field Analyser of this patient with myopia and glaucoma shows an enlargement of the blind spot (myopia) and defects for maximum luminance in the superonasal and inferonasal visual field. The semi-automat (AUT) reproduces these findings correctly as is also seen in the curves of the 345°, 315°, 240°, and 225° meridians



NAME: ♂ v.d. M.
AGE: 40
EYE: LEFT
CORRECTION: S-2.50

Fig 4. The VFA shows a large bundle defect for maximal luminance in the upper half of the visual field In the lower half is a defect that is in part for maximal luminance and in part relative The semi-automat (Aut) reproduces these findings. The whole level of sensitivity is lower with the semi-automat. This is due to differences in general stimulus intensity level

Re II In 3 cases there were obvious false positive results. This can be a question of different stimulation methods. Considering the problems with the apparatus this is a small number.

The results will be illustrated by means of 2 case histories (Fig. 3 & 4)

CONCLUSIONS

1. In 17.5% of the cases with glaucomatous defects the simulated automatic visual field examination was a total failure. This percentage is higher in the group above 60 years of age.
2. M.S.S.P. is suitable for automatic perimetry.
3. An oscilloscope is a suitable stimulation apparatus for automatic perimetry.

SUMMARY

A remote control oscilloscope was used for simulated automatic perimetry.

With this instrument, 79 normal subjects were examined and 40 glaucoma patients. 9% of the examination of normal subjects were a total failure, 7.5% a partial failure. 17.5% of the examination of the glaucoma patients were a total failure, 10% a partial failure.

Multiple Stimulus Static Perimetry is suitable for automatic perimetry. An oscilloscope is a suitable stimulation-apparature for automatic perimetry.

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See also Fankhauser et al., Aulhorn et al , Heijll et al., and Pashley et al in this volume, Session I

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COMPUTER SIMULATION OF EXAMINATION PROCEDURES FOR THE AUTOMATIC 'TÜBINGER PERIMETER'

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Since the beginning of 1975, the prototype of an automatic perimeter has been tested at the Eye Clinic at Tübingen. In the past, the tests were mainly concentrated on measurements along meridians, the results of which are commonly presented as profile curves. Thereby it was found out that both the manual method and the automatic method have their own specific advantages. To develop different examination procedures for an automatic perimeter a great deal of the experience and the decisions of a qualified perimetrist have to be implemented to adapt the examination programs to the special type of patient or to the expected visual field. To compare different examination procedures referring to objective or even subjective parameters, many time consuming measurement series with patients are usually necessary. As an alternative to such measurements the application of a computer simulation, a method which is applied to various domains in natural and technical science, is described in this paper.

PRINCIPLE OF SIMULATION OF EXAMINATION PROCEDURES

For the simulation of an examination procedure for the automatic perimetry the following idealization is made, namely that objectively measured profile curves exist as desired values for the light density threshold The examination strategy, which is to be tested, is now applied to a desired profile curve in such a way, that in a fixed coordinate the light density of the testpoint is changed until the threshold value is found. After the threshold values are determined at all points of latitude according to the tested strategy, the complete process of the examination is stored in the memory of the computer and it is now possible to analyse this process by computing the interesting statistical values. The following parameters are, for example, of interest for classification of a special examination procedure.

- total number of examination steps;
- ratio of the number of supra-threshold to the number of infra-threshold points;
- ratio of the number of supra-threshold to the number of infra-threshold approaches to the light density threshold,
- distributions for the number of successive recognized or unrecognized points.

Actually, the simulation is made with a record of many profile curve data, to which all interesting examination procedures are applied in successive simulation runs. If the data record is large and representative enough, these simulation runs yield various statistical parameters. To adapt examination procedures to special types of visual fields as, for example, to very small or broad total defects, the computer selects only such profile curves out of the complete data record which are of interest for the actucal simulation run.

In order to take into account the patient's subjective reactions on the presentation of the testpoints, the simulation model is extended in such a way that a transition region is defined on both sides of the objective threshold (Fig. 1). In the *supra-threshold region* all testpoints are certainly recognized, the testpoints which fall into the *transition region* are only recognized with a definite probability and in the *infra-threshold region* no testpoint is recognized.

The probability P(ΔLD) for recognizing a testpoint within the transition region is now determined as a function of the difference ΔLD between the light density of the testpoint and the objective threshold. For the simulation, this probability is assumed to be Gaussian distributed (Fig. 2). The width of the transition region is defined as $\Delta W = 4\sigma$. This model is able to simulate the different patient's reactions by variation of the width of the transition region.

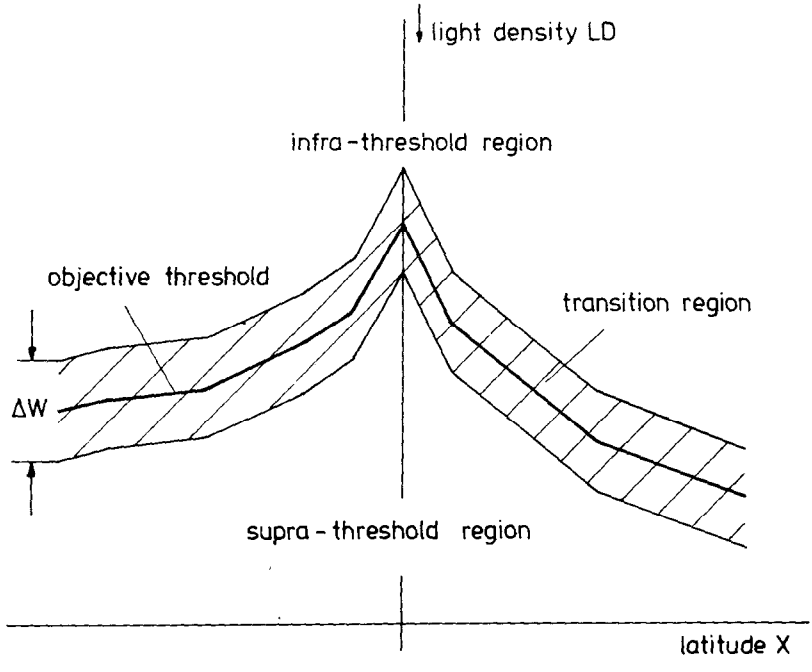

Fig. 1. Model with three regions for the light density sensitivity

SIMULATED EXAMINATION PROCEDURES

Up to now four different examination strategies have been developed for the profile curve perimetry. All these strategies have been tested by the described method of computer simulation with a data record of about 150 manually measured profile curves.

Fig. 3 shows on the left the process of an examination by strategy I. The examination proceeds in the direction of decreasing latitude from the periphery to the center of the visual field with only one threshold determina-

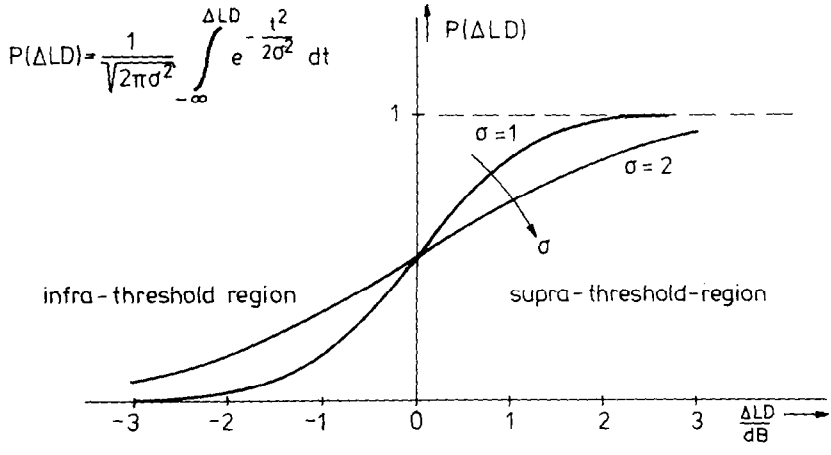

Fig. 2. Gaussian distributed probability for testpoint recognition within the transition region

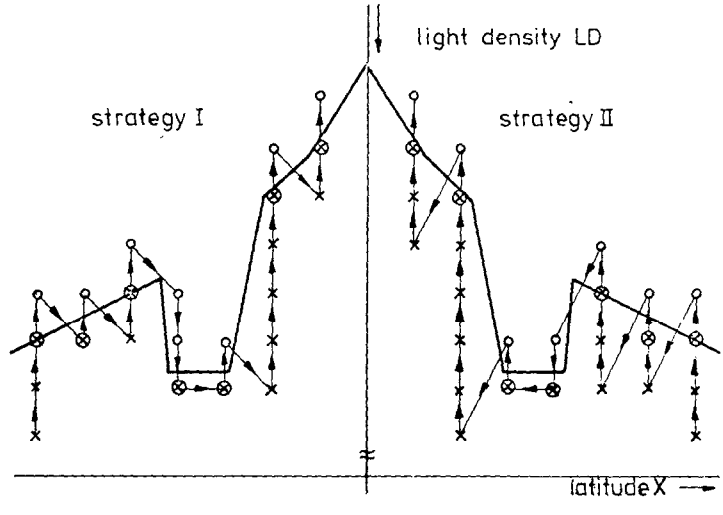

Fig 3. Principles of strategies I and II (x ≙ testpoint recognized, o ≙ testpoint not recognized, ⊗ ≙ threshold value).

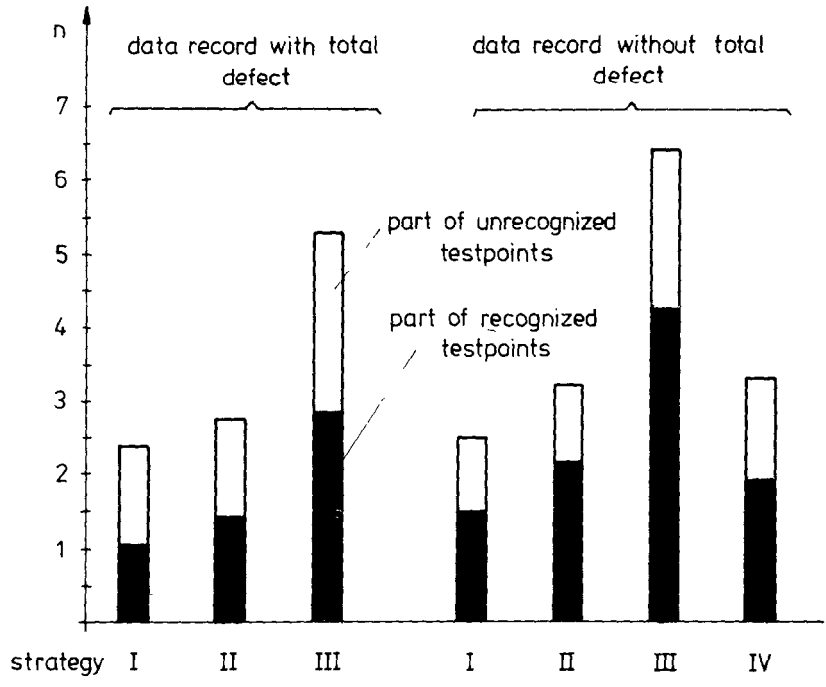

Fig. 4. Comparison of the average number n of examination steps for one threshold value (simulation with $\Delta W = 4\sigma$).

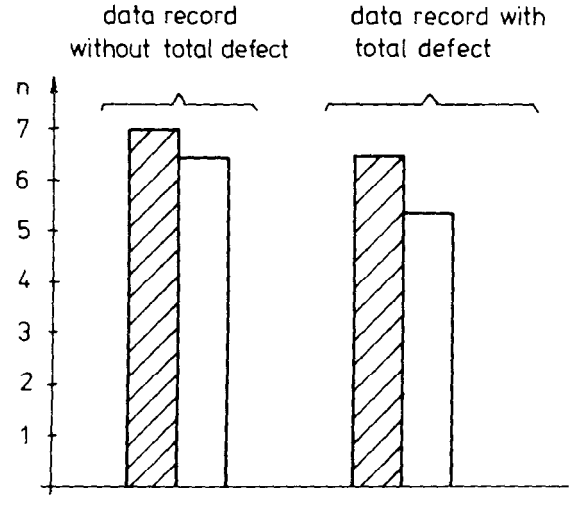

Fig 5 Comparison of simulation and examination results for the average number n of examination steps for one threshold value (examination results shaded)

tion in each coordinate. The strategy starts at successive points of latitude with the measured threshold value determined in the preceding point. In practice this strategy has the subjective disadvantage, that the light density of the testpoints always varies near the threshold, an effect which is not favourable for the patient. Strategy II, which is presented on the right side of Fig. 3 tries to avoid this effect by starting at a new point of latitude with a higher level for the light density. Nevertheless both strategies often show an unsatisfactory diffusion of the profile curve values. Therefore strategy III determines the threshold value twice for a fixed coordinate and only if these two values differ by more than one light density step, a third determination is made. A strategy IV was developed especially for the faster examination of normal curves. At the beginning of an examination, the threshold values in the center (0° latitude) and at the periphery points (+/-22° latitude) are determined. From these measurement results predictive values are calculated for the threshold at all intermediate coordinates. A repeated determination of the threshold value is carried out only, if the first measured value and the prediction value differ by more than one light density step.

SIMULATION AND MEASUREMENT RESULTS

As an example for the various simulation results, Fig. 4 shows a comparison of the number of examination steps for the strategies I-IV. By splitting into the two groups it can be seen that, on the average, the examination of profile curves without total defects needs more examination steps than the examination of curves containing total defects, but that the number of recognized testpoints increases at the same time. Remarkable is also the small number of examination steps for strategy IV, a result which is verified by pratical examinations.

Fig. 5 compares simulation results with the results of practical series of examinations for strategy III. For profile curves without total defects the simulation and the examination result are quite equal, while in the other case the simulation result differs by about one step. By varying the simulation parameters or by dividing the data record into special types of total defects, corresponding results can be obtained.

Our first simulation results have shown that computer simulation is a useful help for developing and testing examination procedures for the automatic perimetry.

SUMMARY

For the examination of patients with an automatic perimeter a number of different procedures are possible. In order to select the procedures that are most suitable for the different kinds of visual fields and different types of patients, many time consuming measuring tests would be necessary. Since the patients usually do not like to take the trouble of repeated examinations, we try to simulate the examination procedures and the related patient reactions on the computer. Thus the results of the various procedures are produced by varying the corresponding simulation parameters Statistical

methods may then be applied to these results

This paper describes the method of this type of computer simulation, especially the simulation of the patient's subjective reactions. The results of the simulation on the computer are compared with results obtained with patients measured by the automatic 'Tübinger perimeter'.

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BIPAS – BINOCULAR INSTANTLY PROGRAMMABLE AUTOMATIC SCREENER

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The objectives of screening and automation together with the problems and solutions specific to their combination are considered. BIPAS, an attempt to realise a practical instrument for clinical use, is described in the context of these considerations.

Two patient groups may be submitted to a visual field screening test. those referred for a field test as a result of clinical indications, or a sample of the population on whom no information is provided. It might be argued that referrals require more thorough examination but they will generally be rescreened within 6 months compared with intervals of several years for mass population screening. A false negative from the latter group will be at highest risk of unchecked progression Patients from both groups have no previous experience of the test which must determine whether or not further investigation is required. Provision of a screening test where there is at present an inadequate procedure or none at all can only be advantageous if the level of false positives is low and does not overload follow-up facilities.

Automation in visual field investigation may be employed to gain greater information and provide in depth analysis of an individual examination, or to achieve an increase in the number of examinations possible. Both these aims have the common advantage that automation reduces the time required from clerical and skilled technical staff, but in terms of the equipment necessary they are not readily compatible. The design and development of BIPAS is an attempt to fulfill a need for more widespread first phase examination (Greve, 1973). However, all users may not have a satisfactory follow-up procedure or referral system and BIPAS has been designed to offer reasonable performance for full assessment and patient management. It is possible to programme the machine for partial investigation of one or both eyes, eliminate redundant stimuli and increase resolution in selected areas.

Harrington (1975) puts the case that perimetry should still be considered an art, and there is strong argument for creating a rapport and interaction between the patient and examiner. This highlights the problem faced in a fully automated test. As one of its objectives BIPAS is to evaluate the possibility of screening without operator intervention. The range of psychological variables involved in such a situation of patient-machine interaction must therefore be considered. These fall into three categories, the stable

long term personality traits such as intelligence, curiosity, extraversion and anxiety; the medium term behaviour factors such as the current emotional state of the patient, level of fatigue and cyclic variations; and the short term phenomena such as attention, habituation, expectancy and arousal. For a patient in a test situation these variables interact to determine such characteristics as motivation, performance potential and susceptibility to feedback from the test. Some patients may need extrinsic encouragement, some may be intrinsically rewarded by their performance and some may try too hard to do well in the test. A good perimetrist will automatically compensate for differences in patients but a machine is not so perceptive or flexible. At best the system is designed so that the maximum percentage of patients can accomodate to it.

Experience with the Globuck Screen (Gloster & Buchanan, 1965) and the modified Goldmann Perimeter (Gloster, 1970) has demonstrated success with a broad based patient sample using a single point, randomly positioned stimulus to examine the central field. A simple push button response is required from the patient. A short trial on a modified Globuck Screen indicated that a considerable number of patients were unhappy with two independent response mechanisms. However, trials with a fully automated system (Pashley, 1974) have stressed the need for patient control. BIPAS therefore provides a push button which has two modes of operation, 'press' or 'hold'. With this single button, the patient can step and recycle the instructions, stop and start the machine and respond to the test stimuli. An easy communication with the machine is set up and the 'language' rules are explained carefully in the initial instructions. The sequence of a BIPAS examination session is illustrated in Figure 1. An important consideration in patient-machine interaction is to put the patient at ease and in a condition of maximum comfort. A friendly participatory instruction routine is coupled with a large black tangent screen with crossed polaroids to eliminate need for monocular occlusion (Fig. 2). Most importantly the level of performance must be maintained as high as possible to avoid self depressing effects on the patient.

The distribution of stimuli must be arranged to maximise the detection

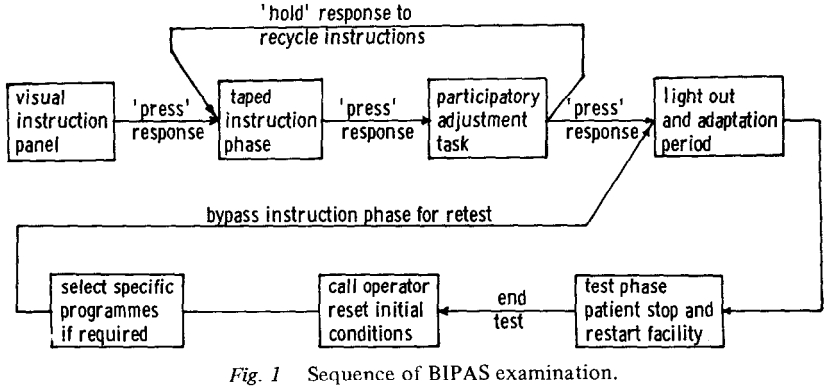


Fig. 1 Sequence of BIPAS examination.

of pathological abnormality in the field whilst minimising collection of unwanted information. Half of the examination points of BIPAS are devoted to searching for arcuate defects. Figure 3 shows a computer printout produced by averaging the results from all glaucoma patients tested on the static Goldmann test (Gloster, 1970) over several years. From such com-

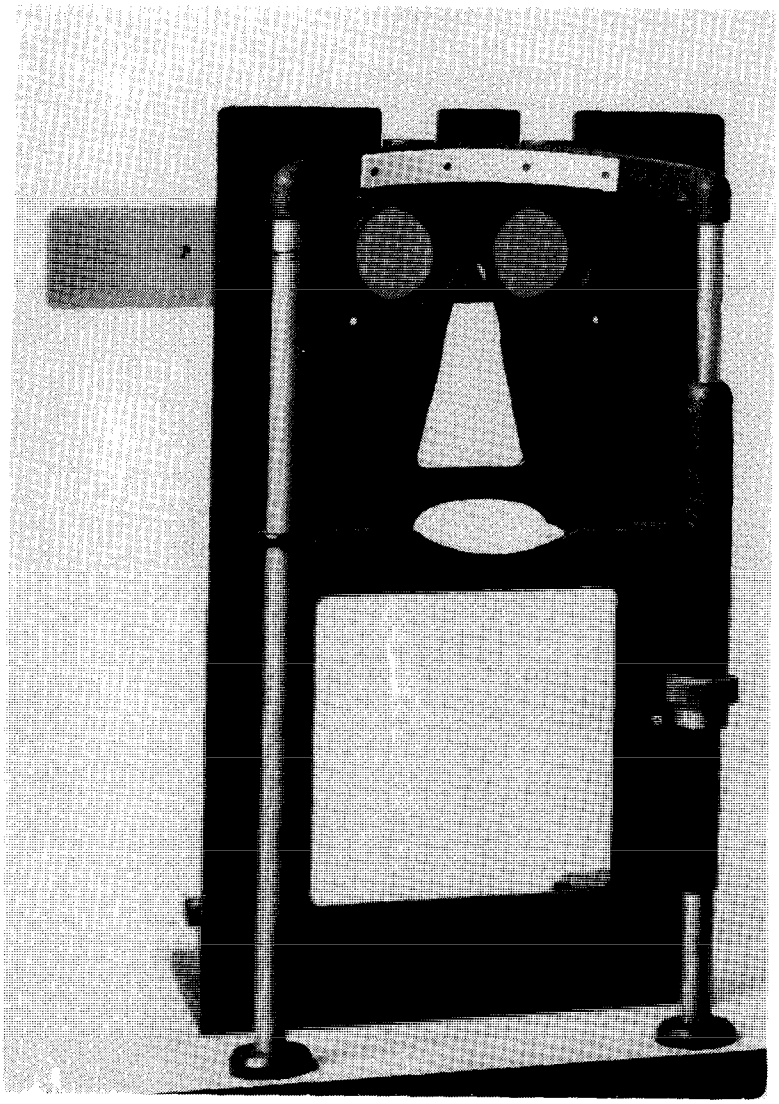


Fig 2 Head rest for BIPAS A Haag-Streit chin rest with vertical adjustment is mounted on a table Crossed polaroids are fixed in front of the eyes and a sliding carriage permits occlusion of either eye together with insertion of circular filters The eyes are located centrally in front of the screen and 1 metre from it.

posite patterns areas of highest likihood of defect were deduced and a 32 point programme evolved. A further 32 points were added based on clinical consultation, to examine either side of the physiological midlines for disturbances in the optic pathways and the centro-caecal area for toxic conditions. To this main programme of 64 points per eye were added 64 auxilliary points to increase the resolution of coverage. Figure 4 illustrates the arrangement of the 256 points on the screen and figures 5 and 6 are samples of subroutines which can be programmed for each eye. Stimuli are in pairs, the outer visible to the right eye and the inner to the left. In addition to the main, auxilliary, arcuate and neurological programmes it is possible to switch in and out any combination of quadrants for each eye.

After instructions and a final adaptation phase in test lighting, the test procedure is initiated. Background luminance of the 1 metre square black tangent screen is variable in the mesopic to low photopic range. Mid range spectral sources (light emitting diodes radiating at 560 nm) are used for stimuli. Tests are underway to establish whether sufficiently uniform thresh-

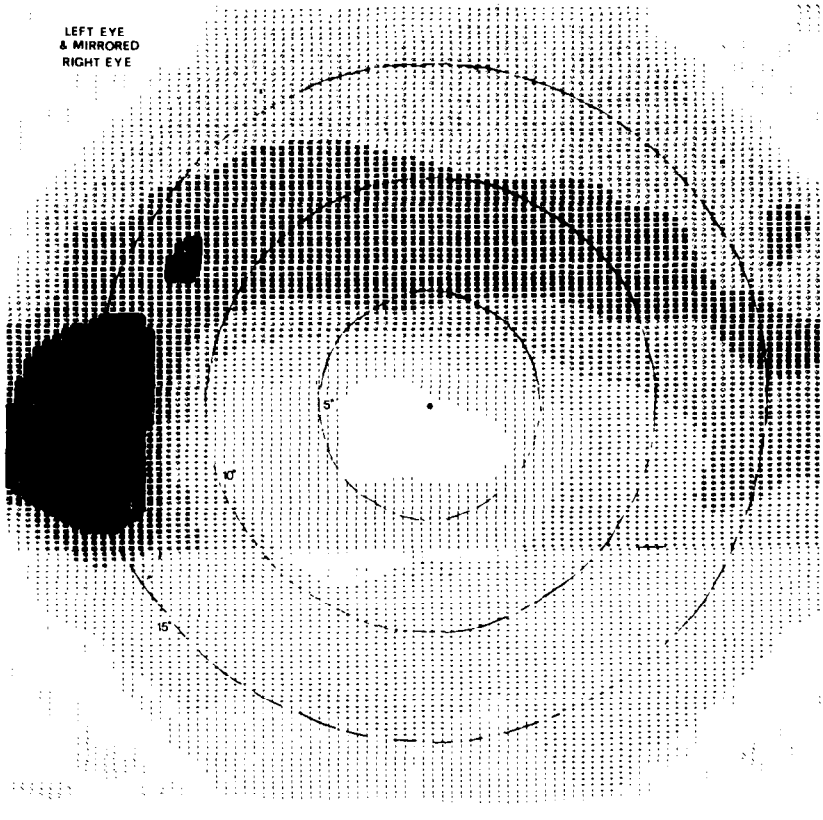


Fig 3. Computer print-out of average glaucomatous field defect

olds over the area to be tested can be obtained by manipulating the background lighting. This would avoid individual adjustment of the light sources. The aim is to examine all points at 0.5 l.u ± 0.2 l.u. above normal threshold and again at 2.5 l.u. above threshold providing tests for 'relative' and 'absolute' loss of vision. Even if this technique proves satisfactory it will be necessary to determine threshold for some patients and an automatic pretest routine for this is to be implemented.

The test is illustrated in Figure 7 and comprises a selection routine which skips over points not programmed followed by a stimulus and response sequence. Arousal is sustained and distraction minimised by playing a recording of white noise during the test phase. A random delay precedes each stimulus to reduce the possibility of psychological blocks (Bills, 1931), and habituation (Mackworth, 1969). Two aspects of attention are relevant in the test phase. Attention is broadened to the whole of the test field by instruction. Temporal peaking of attention possibly occurs in the Globuck screen which inherently produces a click before each stimulus, thereby signalling

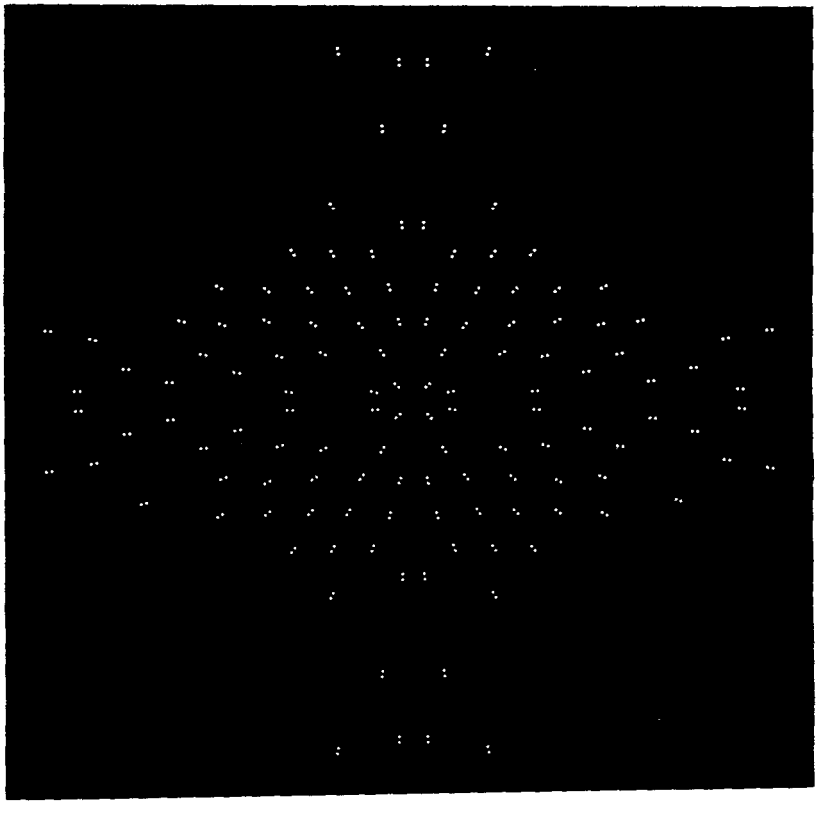
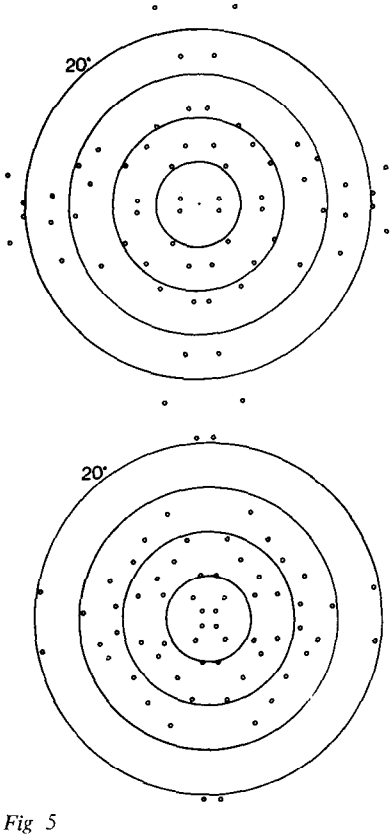


Fig 4 View of back-lit BIPAS screen showing the total array of stimulus holes

its imminence. It is the clinical impression that this helps to sustain performance possibly by setting up a neural expectancy wave (Tecce, 1972). Facility to cue the stimulus in this fashion is incorporated in BIPAS. The directing of attention to the stimulus may enhance perception and reduce delay in response. With na cue, response latencies can reach 1.5 seconds (Pashley, 1974), even at the commencement of the test. This duration is allowed for post stimulus response in BIPAS and is also the time required to establish a 'hold' response on the button. For convenience the two luminance levels of stimulus are presented sequentially at the same location in the current design, the bright stimulus energised only if the dim is not registered. Heijl & Krakau (1975) agree that randomisation is necessary with repeated stimuli and the test may have to be divided to avoid patient anticipation of a brighter stimulus following the first presentation.



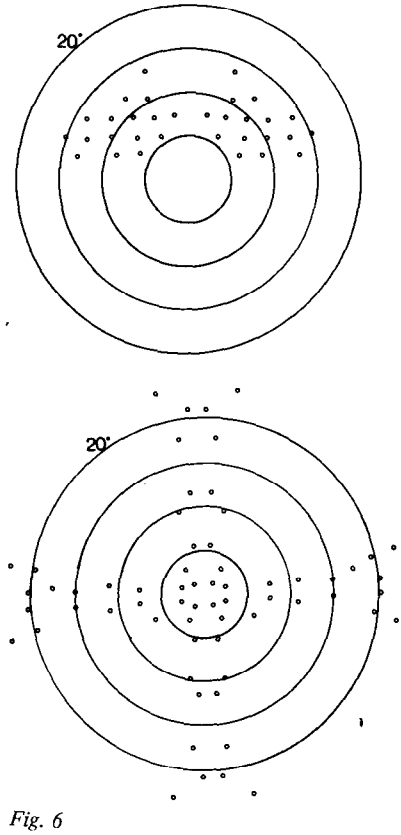


Fig 5

Fig. 6

Fig. 5. Distribution of points for the main programme (above) and auxilliary programme (below).

Fig. 6. Subroutines for upper arcuate (above) and non-glaucomatous defects (below).

Recording of results is simple, figure 8, consisting of a side by side plot of each eye. An XY recorder circles only presented positions and places a diagonal through the circle for each response failure. The control logic sends a binary code (between 1 and 128) together with a left/right signal to the recorder control. A programmed read only memory decodes this numerical address through digitally coded co-ordinates to analogue data for the X and

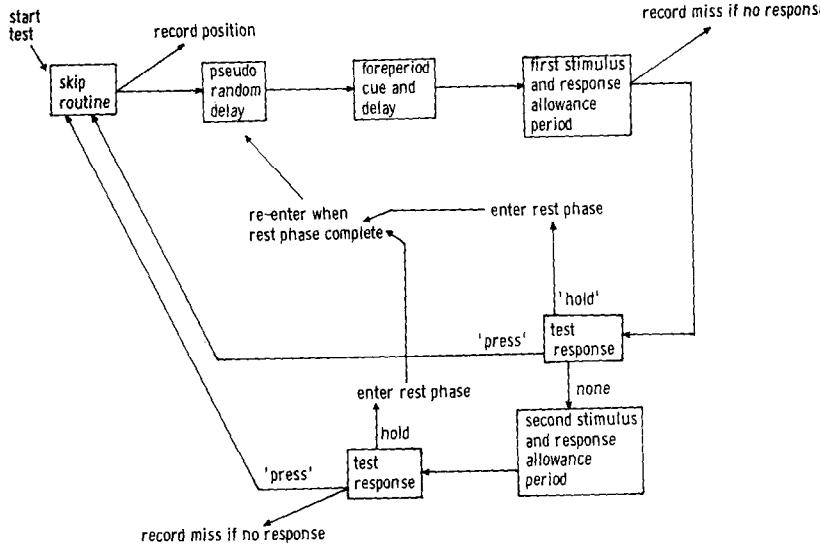


Fig. 7. Sequence of test point selection, presentation and patient response

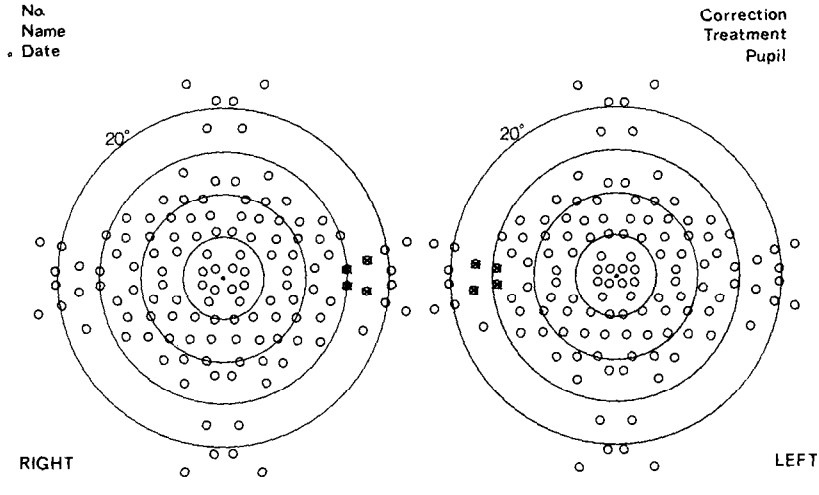


Fig 8. Chart of fullest possible examination

Y inputs to the recorder. The switched signals for the recorder marks are added to the position voltages and the pen is controlled remotely from the logic.

The co-ordinate addresses are available in 10 bit digital form or as analogue voltages and could therefore drive any XY display, but the screen employed is simply a large commutator with each of the 128 lamp pairs electronically demultiplexed from a numerical address. The lamp pairs are diodes wired back to back so that opposite polarity supplies energise the left and right lamps. The lamps are exposed through screened holes (15′ arc) on a secret-til-lit panel. Polaroid filters on the rear of the screen cover the holes such that all the inner holes are crossed at 90° with all the outer holes. Patients viewing through appropriately crossed polaroids see only one set of stimuli with each eye.

Full clinical trials are to commence shortly but a small trial has been accomplished using a programme of 2 presentations at each of 4 points in both eyes. The points were selected as being most vulnerable to loss in glaucoma and are located at approximately 12° eccentricity on the 45°, 135°, 225° and 315° meridii. The static Goldmann 14 test was used as a standard. 84 eyes were tested. 30 eyes showed full fields on BIPAS and all Goldmann fields for these patients were full with the exception of 3 possible enlargements of the blind spot into areas not covered by the BIPAS examination. 7 of the 54 eyes showing defects on BIPAS showed no defect on the Goldmann test representing a false positive rate of 8% and a further 7 fields showed inconsistencies between the two tests. Many of the defective eyes indicated greater defects on this short test and although all eyes had vision for at least one of the four locations some patients with miosis failed to respond.

All eyes will be retested with a full examination. A questionnaire produced favourable comments from patients and will be extended for the full clinical trial to seek comments and suggestions for system improvement.

All the logic and control in BIPAS uses CMOS low voltage circuits. If an immediate record is not required the equipment may be run from low voltage (e.g., car) batteries to generate magnetic tape records for later transcription.

SUMMARY

A system for examining the visual field is described with special reference to problems involved in use as a rapid automated screening test with minimum operator supervision Green solid-state light sources, a 1 metre square screen and mesopic adaptation are employed. By an arrangement of crossed polaroids, both eyes are tested with a random sequence of single point presentations. Facilities for programming extra stimuli make the apparatus useful for management and following up of diseased eyes with defective central fields.

ACKNOWLEDGEMENT

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COMPUTERIZED GLAUCOMA VISUAL FIELD SCREENING

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Several automatic perimeters have been presented during the last few years. Until recently, however, there have been no systematic clinical studies, using such perimeters. In the present study the computerized fully automatic perimeter is used, primarily intended for glaucoma visual field screening and control and described in 1975 by Heijl & Krakau. In addition a special glaucoma screening test logic has been utilized. The aim of this paper is to compare this computerized screening with manual selective screening (a variant of that proposed by Armaly (1972)).

MATERIAL

181 eyes in 100 patients from a glaucoma out-patient clinic were tested. The median age of the patients was 64 years Eyes with documented large visual field defects were excluded.

EXPERIMENT

Automatic perimetry

The perimeter set-up described by Heijl & Krakau (1975) has 64 static test points concentrated in the central visual field. The intensity variation of the stimuli ranges over 16 intensity steps, the ratio between two consecutive intensity levels always being 1:2. The perimeter is fully automatic – the test is controlled by a minicomputer and the results are presented on teletype and a graphic plotter (Fig. 1).

The test logic for glaucoma visual field screening must allow for completing a test session in a short time, since a fairly rapid deterioration of the patient's achievements often takes place in automatic perimetry (unpublished results). The test logic must also be constructed in such a way that a moderate amount of patient blunders does not jeopardize the result of the test. Our glaucoma screening computer test logic has been based on a supraliminal type of stimulus presentation (like that used in Armaly's selective perimetry). The test logic is described in Fig. 2.

The testing at each point follows fixed rules, but the stimuli are presented in random order during the test. The patient therefore cannot anti-

cipate the location of the next stimulus. A laboratory assistant instructs the patient and starts the perimeter. The testing is completely automatic and there is no interference by the laboratory assistant during the test. In most cases the test time is less than 4 minutes per eye, in the case of visual field defects it is somewhat longer.

Manual perimetry

All eyes were examined with a slightly modified version of Armaly's selective perimetry (Armaly 1972). All details are given in 'Automatic Perimetry in Glaucoma Visual Field Screening' (Heijl 1976).

Procedure

All patients were primarily tested with both the automatic and the manual selective perimetry. If these screenings were both normal the visual field in

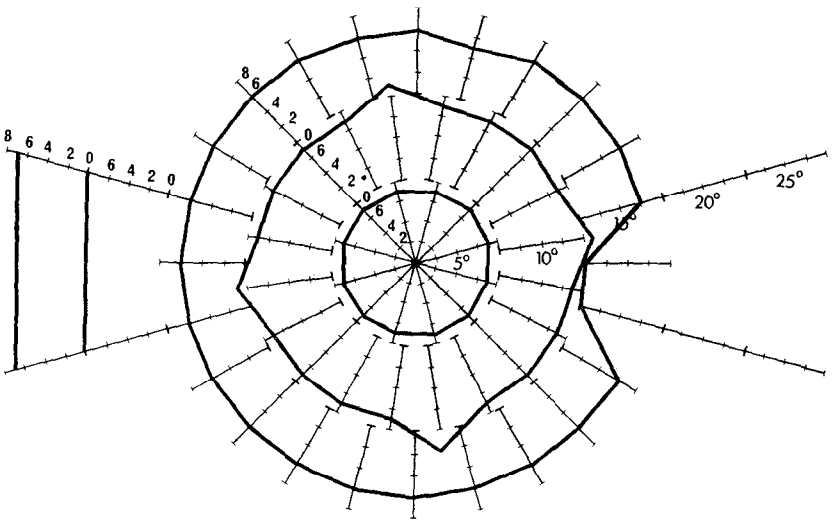

Fig 1 . Normal automatic visual field chart (right eye). Results are plotted as polar coordinates and *not* as isopters. Intensity level (i) of the n:th test point (i_n) is represented by a point on the radius from origo through the n:th test point. Its distance from origo is determined by the intensity level as follows:

i units for the first circle (5°) of 12 points;
i+8 units for the 2nd (10°) circle (20 points);
i+16 units for the 3rd (15°) circle (24 points);
i+24 units for the points at 20° eccentricity (2 points);
i+32 units for the points at 25° eccentricity (2 points).

Another four temporal points are not tested Points belonging to the same circle are connected In this diagram intensity level numbers (0 denting no response to the highest intensity and 8 a low threshold) are marked along the 135° and 165° meridians

question was accepted as normal. If only one of the screenings was pathologic the visual field was rescreened by both methods. One abnormal point was enough to assess a visual field as pathologic. When the screenings were complete all detected field defects were confirmed by conventional kinetic and static profile perimetry. All doubtful cases were examined by the same methods.

RESULTS

47 out of the 181 eyes examined were found to have pathologic visual fields when all examinations were completed. All these pathologic visual fields were spotted with the computerized perimeter, while one pathologic visual field was falsely interpreted as normal when the manual selective perimetry was used. There were 16.0% false positives at the first examination with the automatic perimeter, while the manual selective perimetry gave 11.0% false positives (on condition that the patient was given a second chance in all initially missed paracentral points).

By rescreening the numer of false positives could be greatly reduced – to 4.4% with the computerized method and 3.3% with the manual method. (The exact procedure is described in 'Automatic Perimetry in Glaucoma Visual Field Screening', Heijl 1976). The test logic was constructed with the aim of keeping the false positives low. In this respect it was fairly effective. Thus, if no re-exposure of initially missed paracentral points had been made,

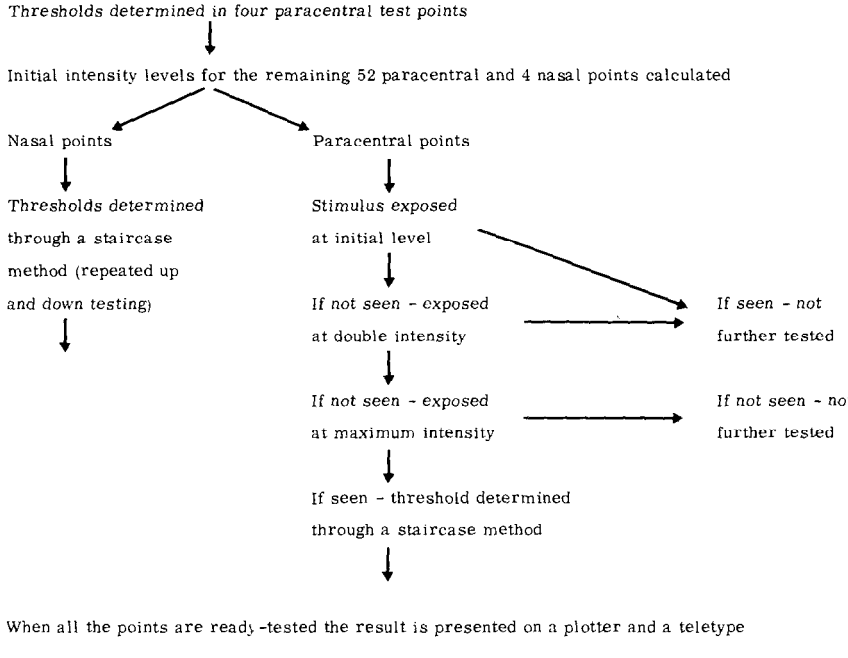

Fig. 2 Test logic (simplified).

the number of false positives risen to roughly 80% of the normal fields.

An interesting phenomenon must be mentioned here. The automatic perimeter often indicates larger and/or deeper defects than those found in conventional perimetry. We have also seen defects, detected by the automatic perimeter, which have been impossible to confirm with conventional perimetry, though detected several months later even with conventional perimetry. One such case at least is included in this study. It was a small scotoma which appeared in the same position both at automatic screening and rescreening, but could not be detected with kinetic perimetry or static profile perimetry, nor with manual selective perimetry. Half a year later, however, the scotoma could be confirmed by conventional methods. It is thus erroneously registered as a false positive in this study. Possibly, other false positives may develop in a similar way in the future.

DISCUSSION

It is clear from the results that the sensitivity of the method is good. (Armaly's method has a documented high sensitivity (Rock et al. 1973)). The specificity is not excellent, any more than it is in manual selective perimetry, but the specificity after a second screening (95.6%) is acceptable.

It should be realized, however, that the figures mentioned, providing roughly equal sensitivity and specificity for the manual and the computerized perimetry, have little bearing on conventional clinical work. Thus, out of the 47 pathological visual fields of this study 20 had falsely been labelled normal on previous controls, although all the patients had been subject to repeated perimetry and most of the patients also to selective perimetry. The explanation must be the conditions under which the fields were plotted. The ophthalmic assistant responsible for the selective perimetry in this study worked under optimal conditions. Thus he had almost unlimited time at his disposal and knew that all his results would be compared with results obtained by other methods. Such favourable conditions are usually not met with in clinical work.

It may thus be concluded that automatic computerized perimetry with

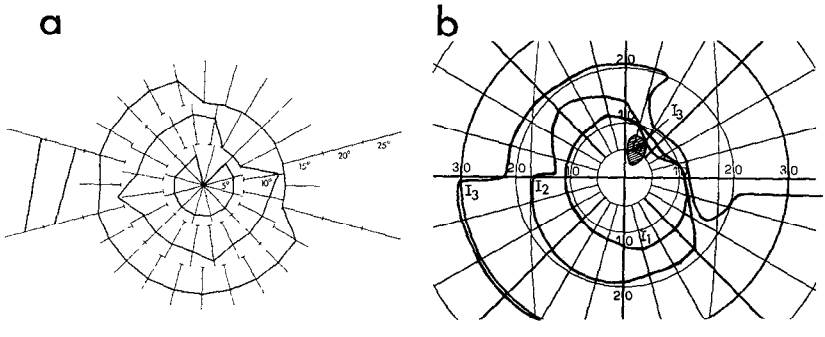

Fig. 3. Glaucomatous visual field. a) Automatic field b) Central kinetic Goldmann field

the present equipment could give results just as good as those obtained with very careful manual selective perimetry. Compared with routine clinical perimetry the automatic screening would in most instances turn out to be superior.

SUMMARY

The automatic computerized perimeter described by Heijl & Krakau (1975) was used for glaucoma visual field screening. It was compared with carefully performed manual selective perimetry in 181 eyes of 100 patients from a glaucoma open-care unit. The results of the two methods were very similar. All defect visual fields found were identified by the automatic screening procedure and only one pathologic visual field was falsely classified as normal with manual selective perimetry. The false positives were 16.0% in the automatic perimetry and 11.0% in the manual perimetry. The false positives could be greatly reduced (to 4.4% and 3.3%) by re-screening. The automatic perimetry was shown to be superior to 'routine perimetry'.

It is now possible and permissible to use a computerized perimeter for glaucoma visual field screening. A necessary prerequisite, however, is that the computer is programmed in such a way that a moderate number of patient blunders does not jeopardize the test result.

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THRESHOLD NOISE AND VARIABILITY OF FIELD DEFECTS IN DETERMINATIONS BY MANUAL AND AUTOMATIC PERIMETRY*

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The variation of perimetric results may be enormous, depending on many factors including technique, subject, examiner and pathology. If one wants to compare two techniques such as manual and automatic perimetry in regard of the detection rate of field defects and possibly their approximate shape it seems justified to rely on single measurements of a large number of subjects (Heijl, 1976, Aulhorn & Durst 1976).

We followed a completely different approach namely the quantitative assessment of the variation by repeated topographic mappings of single pathological fields by manual and automatic perimetry. Our present experience is based on the evaluation of numerous manual and more than 200 'Octopus' field measurements of 12 diseased and 5 control eyes. As will immediately become apparent, valid and meaningful comparisons are very difficult to make due to the threshold noise (Niesel 1970) and to systematic differences between various methods. We will demonstrate this by one representative case.

We thought that threshold determinations performed on one eye of a patient with irregularly shaped, possibly variable bitemporal scotomata would be particularly suitable for such a comparative study using the Goldmann apparatus, the Tuebingen perimeter and the 'Octopus'. Bitemporal field defects in cases of chiasmal processes may vary considerably with time in a single subject (Walsh & Hoyt 1969, Duke-Elder 1971, Kennedy & Smith 1975). In these cases, close follow-ups are needed in order to differentiate between variation and true progression of defects. In such follow-ups, an automatic perimeter should provide at least as much quantitative information on the exact extension of scotomata as well as data for quantitative assessments of their variability as would be expected from manual perimetry done by a well-trained examiner. The various modes of data display offered by the 'Octopus' (i.e. half-tone displays, selected static profiles, figure tables) which are described in detail elsewhere (Spahr 1975, Fankhauser et al. 1976) were all evaluated and shown to be of great help in such statistical evaluations. In a number of control subjects, the automatic representation

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of normal fields by 'Octopus' was found to be entirely equivalent to convential methods.

In the work with 'Octopus', the following advantages turned out to be to the credit of automatic perimetry·

(1) With the automaton, the quality of a precise mapping in regard to spatial extent and sensitivity loss of localized field defects is equal or superior to that obtained by conventional methods.

(2) The variability of the results of repeated field examinations with the automaton is very nearly equal to that of the static manual technique. In kinetic perimetry, the intrasubject variability was lower for one single examiner but higher when the visual fields of the same eye obtained by different examiners were compared.

(3) An interesting effect that has not yet been satisfactorily explained, has consistently been observed during our studies: The gradient of sensitivity depressions found in disturbed areas of a field appears steeper and the visual loss more severe with the automaton than with conventional techniques. In contrast, the sensitivity gradients of normal fields towards the field periphery were found to be the same by both techniques.

These three statements shall be illustrated by some concrete data·

Figure 1 shows the fields taken at the first admission of a 67 years old lady who consulted her ophthalmologist because of presbyopic complaints and who presented an unexplained acuity loss of her left eye. Only after a follow-up of several months, including additional field examinations, a strong suspicion of bitemporal hemianopia finally led to the detection of a suprasellar tumor. For a further representative illustration we shall concentrate on the right eye only.

Figure 2 presents two fields of the right eye taken by two different examiners of the same institute. These two fields are very similar to the first two stages in a set of 8 fields published in 1914 by Cushing & Walker as a demonstration of a steady progression of bitemporal field defects in a case of 'pituitary disease'. However, in our patient no real significant progression could be verified after a follow-up of one year.

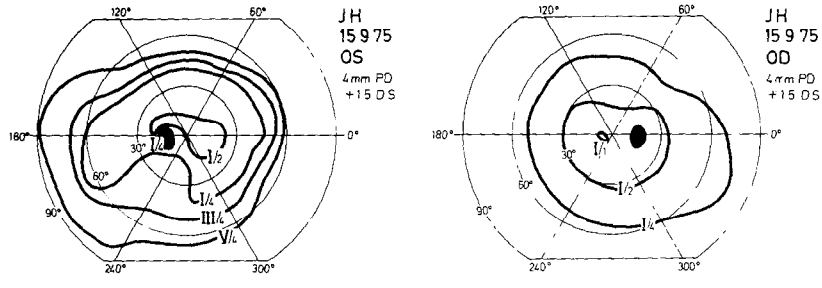

Fig 1. First visual fields taken from a 67 years old patient with a suprasellar tumor diagnosed only several months later. Kinetic perimetry. Goldmann apparatus. Background luminance 31.5 asb Meridional mean scanning density: 1 determination point/15°

In Figure 3 the averaged kinetic results obtained by examiners A and B from 5 and 6 sessions, respectively, are shown. In three quadrants the correspondence of the results is almost perfect. In the disturbed upper temporal quadrant, however, examiner B found a more marked loss of sensitivity for all isopters than examiner A. The standard deviation is 2.0 and 2.7 dB, respectively, in the disturbed quadrant and 1.0 dB in the remaining

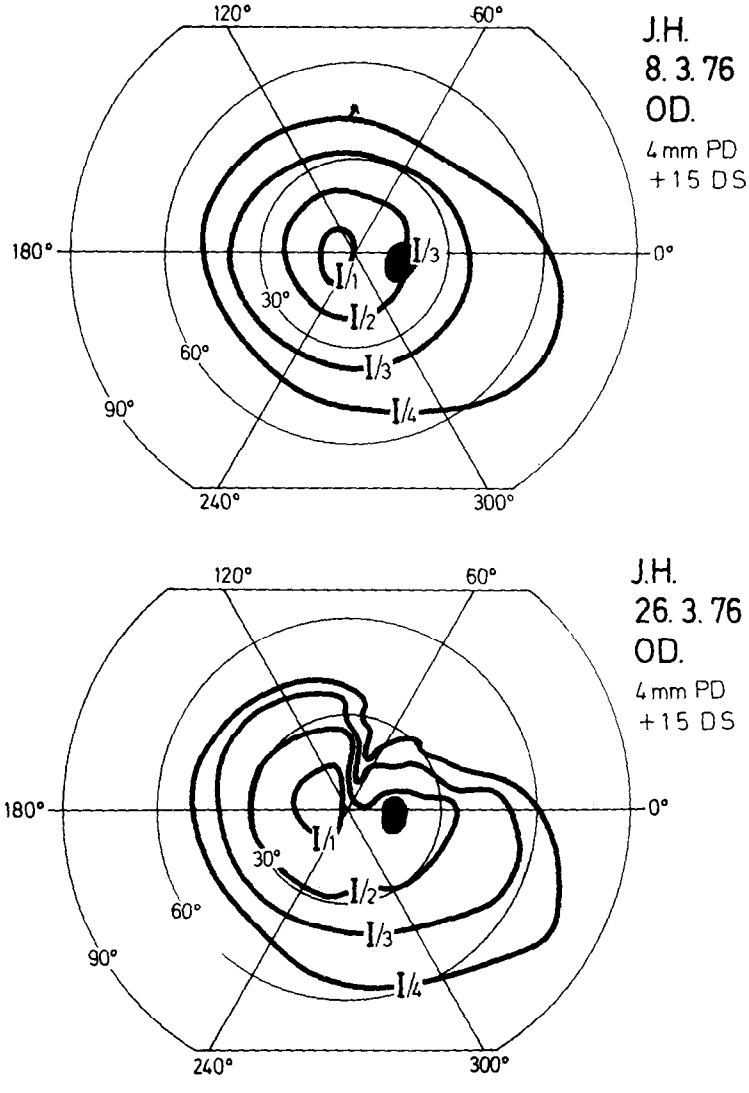

Fig. 2. Visual fields of the same eye taken by two different examiners Goldmann perimeter. Background luminance 31.5 asb Meridional mean scanning density: 1 determination point/15°.

three quadrants. The half-tone display (C) below was obtained by a single screening test with the 'Octopus', the examination taking about 15 minutes. In spite of the rather small scanning density with an interstimulus distance of 15°, the comprehensive detection of the field defects is entirely satisfactory.

Figure 4 shows an arbitrarily chosen series of kinetic determinations (central fields up to 25° eccentricity) taken by different or the same examiners indicating the large scatter of results obtained for the same field. Examiner C, for instance, discovered the relative defect below the blind spot only after repeated examinations. The half-tone displays below show two consecutive 'Octopus' fields, the third display presenting the average of test 1 and test 2.

The detection of relative defects in the temporal half-field appears most comprehensive with one single determination by the automaton. In other cases too, the qualitative reproducibility of complex pathological fields proved to be fully satisfactory.

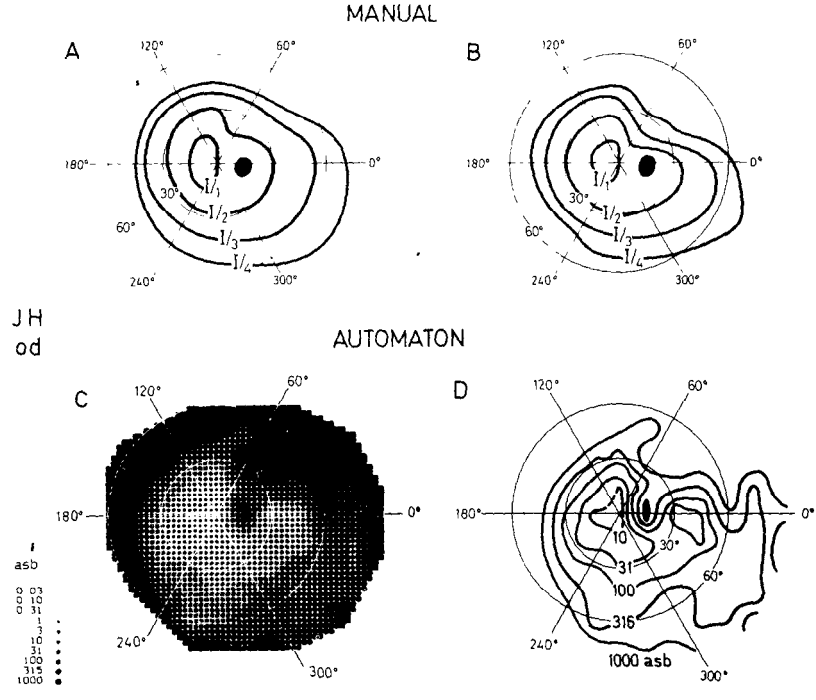

Fig 3

Above: Averaged isopters from kinetic perimetry (examiner A: 5 tests, examiner B: 6 tests) Standard deviations see text. Goldmann perimeter. Background luminance 31.5 asb.

Below: One automatic static screening test (C), interstimulus distance 15° (square lattice), remaining data interpolated. Isopter display (D) derived from C. Background luminance 4 asb

In our patient, 20 extensive examinations by manual static perimetry and 22 tests by automatic perimetry were performed within 8 months. Comparing, for instance, the most disturbed threshold levels on the 45° meridian, we found a high degree of variation with both techniques only in the defective part of the field. The left hand graph on Figure 5 shows mean profiles obtained by averaging the results of 4 static manual measurements as compared to 4 'Octopus' measurements on two meridians. For the disturbed meridian the standard deviations amount to 4.1 dB for the data obtained with manual and 3.0 dB for the data originating from automatic perimetry. In contrast, the corresponding values amount to only 1.1 dB (manual) and 0 9 dB (machine) on the undisturbed meridian. The right hand graph presents the corresponding regression lines demonstrating the average level and the slope of sensitivity loss on the two meridians with manual as compared to the automatic technique.

As stated above, in cases of chiasmal lesions tremendous fluctuations have been observed in repeated threshold determinations. In our case the fluctuation appeared considerable but did not differ from pathological fields due to glaucoma or receptor defects in cases which were analyzed in the same way during our present studies.

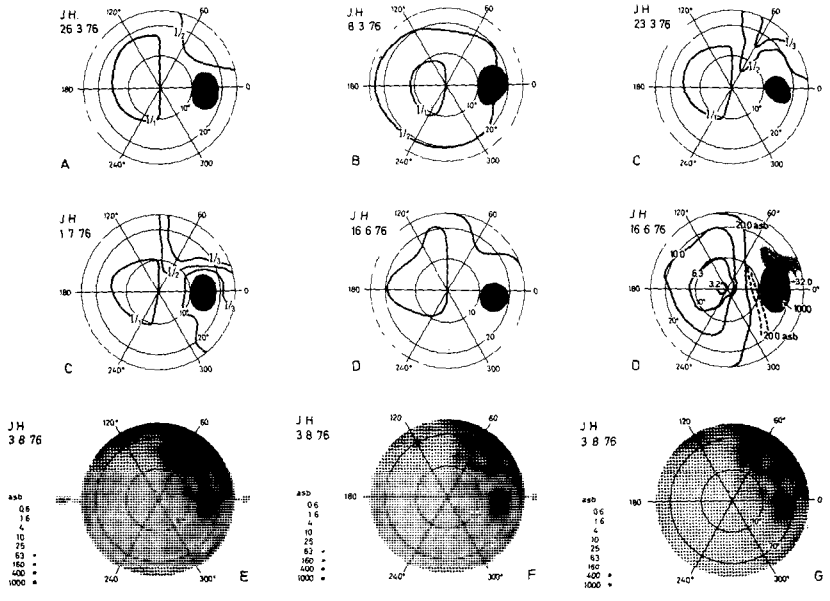

Fig 4

Above: 6 central fields of the same eye. Kinetic perimetry A-D different examiners. Goldmann perimeter Background luminance 31.5 asb Meridional mean scanning density: 1 determination point/15°. D: fields obtained with a Tuebingen perimeter. Background luminance 10 asb Other stimulus parameters indicated as far as available. *Below*: Central field half-tone displays from automatic perimeter 'Octopus' E, F: test 1 and 2 G: average of test 1 and 2. Interstimulus distance 2.5° on 24 meridians at 15° intervals, remaining data interpolated Background luminance 4 asb.

Furthermore, the results of our analysis excluded any progression which could easily be suspected by comparing selected single fields of the presented case. The various origins of the threshold fluctuation, particularly prominent over pathologically disturbed field areas, are still to be investigated. The same holds for the possibly important phenomenon that visual loss in pathological fields was consistently recorded with higher sensitivity by machine than by hand perimetry. Similar observations were reported by Heijl & Krakau (1975).

We may conclude that with the automatic perimeter 'Octopus' the analysis of complex defective visual fields is highly reliable. The variability of the results of repeated examinations equals that of conventional perimetry.

At the same time, our comparative studies stressed two other points convincingly, namely the limited significance of a single field determination (Niesel et al. 1970) as well as the urgent need for noise diminution by averaging techniques which is, in fact, a justification of machine perimetry.

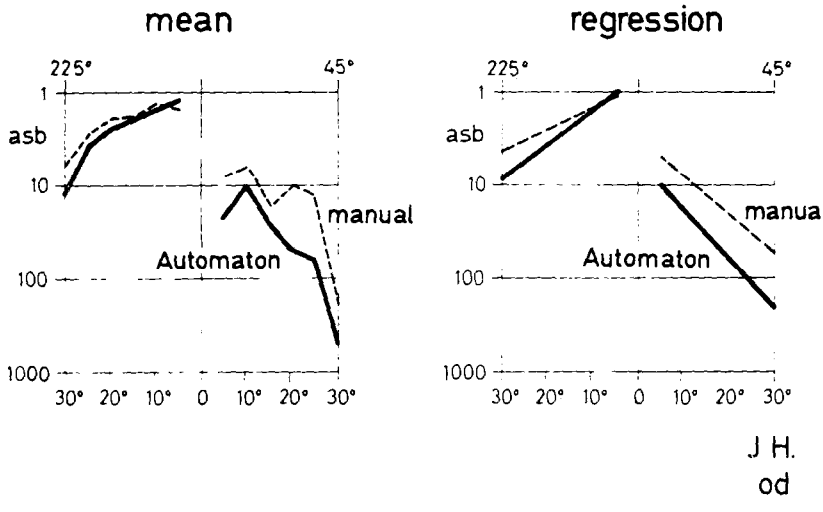

Fig. 5.
Left: Averaged static profiles from 4 manual and 4 automatic tests across a defective (45° meridian) and normal area (225° meridian) of field J H. Standard deviations see text. Background luminance 4 asb. Spot size 1/2°. Interstimulus distance 5°.
Right: Regression lines calculated from the averaged sensitivity profiles.

SUMMARY

Repeated visual field examinations were performed in a case of bitemporal field defects using manual techniques as compared to the fully automated perimeter 'Octopus'. The qualitative detection of scotomata was excellent with the automaton. With both techniques, an equally high amount of threshold fluctuation was found in defective areas of the field. The automaton recorded a higher density of field defects than manual techniques.

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DISCUSSION

OF THE SESSION ON AUTOMATION OF PERIMETRY

Leydhecker to Aulhorn and Fankhauser: I did not quite get how Aulhorn directs the attention of the patient. The other point of my question was, why Fankhauser's procedure lasts three times as long as a manual procedure while Heijl reported that he does it in four minutes. What is the essential difference?

Aulhorn to Leydhecker: We give extensive information to the patient before the investigation, but not during the investigation. We have seen that in most cases fixation is better in automatic perimetry because the stimuli follow each other so rapidly that the patient realizes that it is useless to deviate from correct fixation. Perhaps he may do so during the first moments but then he becomes aware that fixation devations are not helpful during the detection task. During manual perimetry he more often looks to the stimulus because he thinks it helps, and, in fact, he may detect better. In contrast, in automatic perimetry, the exposures are much too short so that the patient has no other choice than to look at the fixation point.

Fankhauser to Leydhecker. The answer is: what you are comparing is not comparable. The speed of any procedure critically depends on the amount of questions you are asking, the precision which is wanted, on the resolution in space and contrast you are aiming at. Obviously, it also greatly matters whether you are examining the whole visual field or only a smaller or larger part of it. The Octopus, as other automata, may be programmed to work slow with high precision or to work fast but then precision suffers.

The speed of operation of computer perimetry using the Octopus is 3 times as fast as by conventional static hand perimetry. Longer session durations when using the Octopus are caused by the fact that in the results presented at this symposium a high degree of definition in regard to the spatial coordinates and the sensitivity resolution was aimed at. Since the information obtained is related to the number of questions put (i.e. answers received), the more time one spends, the more one will know about a disturbed visual field. Programs for short examination durations exist, which are as short as may ever be desired, speed of examination presenting no problem to the Octopus computer system.

One must realise, however, that in all screening methods, examination duration is traded against information obtained.

Leydhecker to Fankhauser Are Heijls procedures also quite exact? That is the point.

Fankhauser to Leydhecker: Dr. Heijl's experiment was a screening experiment while our investigations were concerned with a very far reaching detail analysis. This is the essential difference with all its consequences. Is it not so, Dr. Heijl?

Heijl to Leydhecker The intention of my paper was only to compare the results of my clinical study with the results of another possible technique. This programme was a screening programme for defects. Therefore, I needed only a little less than four minutes. Of course, it would have taken me much more time for a detailed examination.

At the same time I would like to stress that I do not think that we could do too lengthy examinations. We have made quite a lot of experiments which have not yet been published which show that a very rapid deterioration of the patient's achievement takes place in automatic perimetry and that deterioration is much faster for patients than for normal subjects.

Greve to Leydhecker I think there is a great difference as Fankhauser pointed out in using automation for detection or screening or else using automation for a complete examination. In most normal people, as we have shown, automation is very effective and goes very well. In our cases the problem started when defects were found. Then it becomes really much more difficult. This may explain the differences one finds in different procedures.

Weale to Gauger. I like to ask Gauger about his programme. He indicated that one of the systematic factors that he introduced is the assumption that the visibility or rather the probability of detecting the target follows a Gaussian distribution, but I think that most workers found that the distribution followed is Poisson. Could you tell if this is likely or unlikely to produce an artificial bias into your program?

Gauger to Weale We can program the model according to Poisson distributions also. This is no problem for the program.

Bebie to Gauger I should like to make a comment on Dr. Gauger's paper and ask a few questions. You use a cumulative normal distribution for the frequency-of-seeing curve. We have used the same function for the description of the transition region in our simulations, which have been published two years ago in the Marseille proceedings. What is the numerical value which you used for the standard deviation sigma of your cumulative normal distribution? According to our experience with about fourty normal and pathological visual fields, values between 0.1 and 0.4 log units should be inserted.

The second question concerns the accuracy of your threshold determinations, which, apart from the number of stimuli used for one single

threshold determination, is the most important criterion in order to choose the best strategy among many strategies. We believe that we have settled this question and we have made our decision for the repetitive up- and down-method in steps of 4, 2 and 1 decibel. What are typical accuracies, that is to say typical root mean square fluctuations which you encounter in repeated threshold determinations, carried out according to the rules of your different strategies?

Gauger to Bebie. To your first question: a sigma of 0.1 log units has been assumed. To your second question I may say, that we are at the beginning of our simulation runs and the simulations with the transition region are not finished yet. I cannot give you the values which you want to hear from me.

SUMMARY OF SESSION 1: AUTOMATION OF PERIMETRY

F. FANKHAUSER

Pressure of time and the complexity of the subject force me into making somewhat broad generalisations and it appears to me an impossible task to describe adequately the numerous technological refinements achieved during the past two years.

The speed of evolution of the research group on automation, perhaps more than any other, is influenced by and depends on the progress in the technological disciplines and the rapidly growing facilities provided by the computer sciences. The growing abundance of such facilities has made possible quite a large spectrum of solutions of the automation problem, solutions both in regard to strategies, finding expression in the refinement of computer programs, as well as in regard to the pure apparatus component.

Thus, the probability of being led into identical apparatus solutions within research group 7 is very low. This, is fortunate of course, since otherwise various members would find themselves in competitive positions.

The other, possibly greater, advantage of this diversification is the growing probability that the customer finds the apparatus of his choice. I hope that the number of customers – that is, the opthalmologists who have decided to delegate the difficult, time and energy consuming task of manual visual field analysis to a partner without flesh and blood, a partner who is never tired, never angry, never misbehaves and who never refuses any unpleasant work – will rapidly increase.

We have been told that the era of computers, artificial intellects and automata has arrived. This is good for Research Group 7.

In the history of mankind it has never been possible to stop or to escape from the strong shifts and trends caused by a new invention or a new fundamental principle such as are induced by the computer sciences. Computers will slowly or rapidly invade almost all spheres of human activity and perimetry will not be the last conquest. So, to state the same fact in a different way, whether you like it or not, all of you will be our customers one day and we shall be your salesmen.

The customers-salesman relationship has always been a lucky one, because the salesman will do whatever is in his power to satisfy the customers wishes. He will try to find out exactly the individual problems

of his client and approach him in as fiendly and positive a manner as he can in order not to keep him from loosing interest. Thus it is easily seen that the research group 7 members, children of the large IPS family, will be its most pleasing members. They are simply forced to behave in this way, whether it is natural to them or not.

So there are mechanisms built into the research group 7 structure having having as result that the IPS will be happy with us.

THE EFFECT OF TRABECULECTOMY ON THE PROGRESSION OF GLAUCOMATOUS VISUAL FIELD DEFECTS*

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A variety of surgical procedures have been devised to lower intraocular pressure in patients with chronic open angle glaucoma (Kronfeld, 1972; Smith, 1974). Most of them create a fistula between the anterior chamber and the subconjunctival space which allows aqueous to drain.

The effectiveness of these operations has traditionally been judged by their ability to lower intraocular pressure. All the operations commonly employed have been fairly successful when judged in this way (Scheie, 1962; Leydhecker, 1966, Drance & Vargas, 1973; Spaeth, Joseph & Fernandes, 1975).

Little attention has been paid to the ultimate effectiveness of surgical pressure reduction in halting or slowing down progression of visual field loss.

In 1939 Burke found that despite successful filtering surgery, a sizeable proportion of patients showed further progression of their visual field defects. He did not find any difference between pressures of the group which did progress from the group which did not.

In 1955 Boyd reported a high incidence of visual field progression following surgery when compared with medical therapy. He did not relate this to pressures attained following therapy.

In 1966 Leydhecker presented a series of patients showing significantly less visual field progression when pressure was normalized following surgery.

In 1972 Smith showed that there was less visual field progression following surgery than there had been before surgery. The clinical data relating field progression to postoperative control of pressure of individual patients was not presented.

We studied retrospectively the visual fields of open angle glaucoma patients who had filtering surgery performed, and analysed the relationship between the effect of the operation in reducing pressure and the postoperative changes in visual field defects.

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SUBJECTS AND METHODS

All visual fields of chronic open angle glaucoma patients who had a trabeculectomy by one of us during the years 1969 through 1974 were reviewed. Fields of a number of non-surgical patients were included to make sure the observer did not know which fields belonged to the operated group.

All visual field examinations had been performed by experienced technicians on either the Goldmann or Oculus perimeters utilizing both kinetic and static techniques.

All field defects were described, and the observer noted which fields showed evidence of progression over previous examinations.

Progression of the visual field defects was said to occur when the following changes were present:

1. Deepening of a scotoma on static perimetry by 0.5 log units or more, or a deepening of a scotoma from being relative to absolute.
2. Widening of a scotoma on static perimetry by 3° or more.
3. Widening of a nasal step or other peripheral defect on kinetic perimetry by more than 5°.

The rest of the clinical data, including the date of operation, were subsequently examined and suitable patients were selected for further study. All patients who met the following criteria were included in the study:

1. At least 3 preoperative fields showing well documented progression of defects had to be available.
2. Visual acuity had to be maintained for reasonable appraisal of the fields.
3. There had to be no other pathology which would affect the visual field.

The 12 preoperative months were used to evaluate pressures preceding surgery. The postoperative assessment excluded the first 6 weeks following surgery.

RESULTS

A. Patient group

Twenty eyes of 16 patients (7 male, 9 female) were studied. Fifteen patients had chronic simple glaucoma, while one had chronic glaucoma associated with a contusion angle deformity.

The median age at the time of operation was 65 years, with a range of 35 to 79 years.

The number of visual field examinations done prior to surgery ranged from 3 to 17 (median 7), and in the postoperative period from 2 to 14 (median 5).

B. Effects on surgery on the intraocular pressure

The distribution of mean preoperative and postoperative pressures of the individual eyes is shown in Figure 1. There was a significant shift to lower pressure levels following surgery. The means for the group were 25.4 mm.Hg. preoperatively and 16.7 postoperatively ($p < .001$).

The distribution of the amount of pressure reduction from the preoperative pressure means to the postoperative pressure means for the 20 eyes is shown in Table 1. The mean pressure reduction for the entire group was 8.7 mm.Hg.

The percentage of pressure readings over 21 mm.Hg. was used to assess the quality of pressure control. The distribution of the percentage of pressure readings over 21 mm.Hg. for the preoperative and postoperative periods is shown in Figure 2. There was a significant improvement in the quality of pressure control following surgery ($p < .001$).

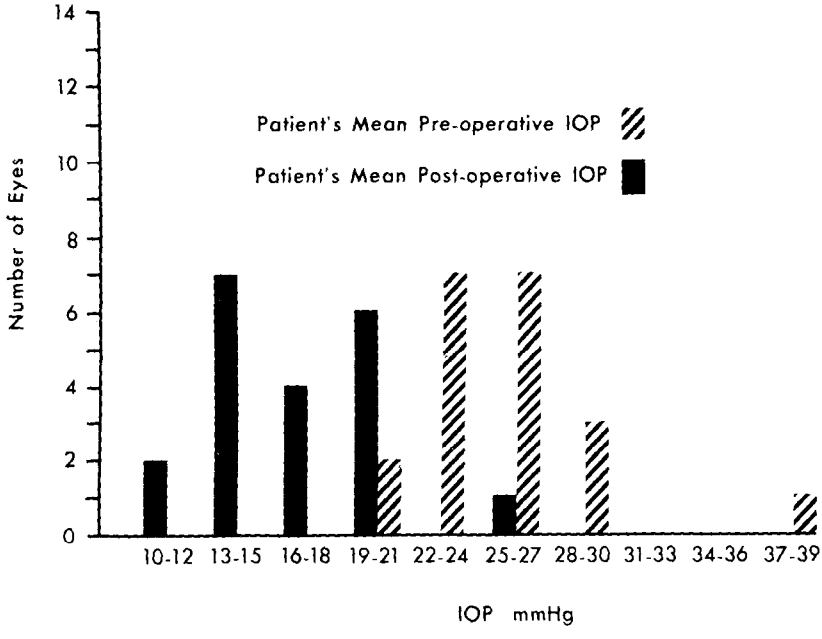

Fig. 1 Frequency distribution of mean intraocular pressures for the preoperative and postoperative periods of the 20 eyes showing shift to lower pressure levels following surgery.

Table I Frequency distribution of pressure reduction following surgery

Pressure reduction (mm Hg)	Number of eyes
≤ 2	2
3 – 5	2
6 – 8	6
9 – 11	4
12 – 14	5
15 – 17	1

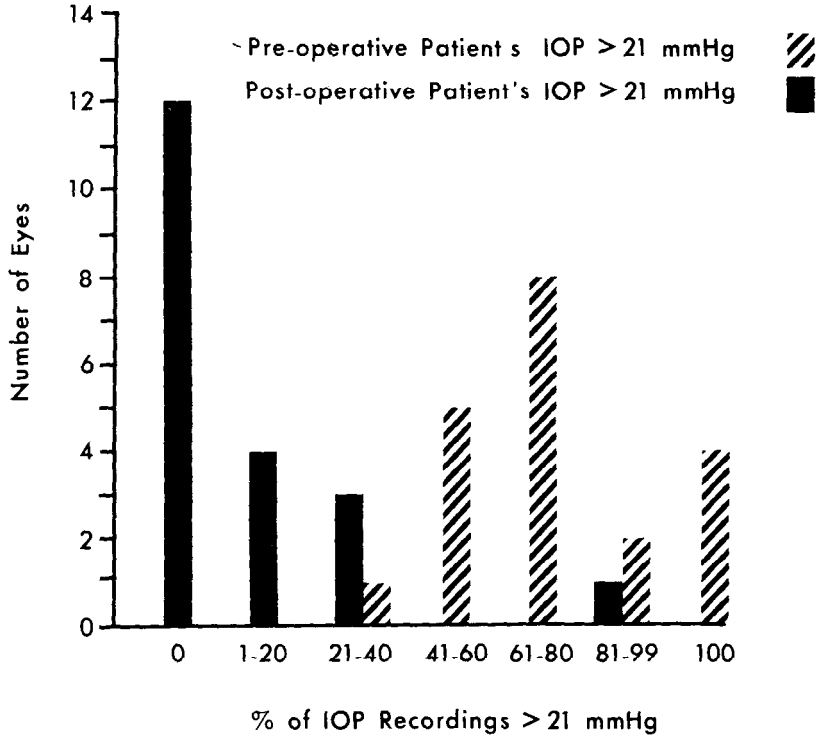

Fig. 2 Frequency distribution of percentage of intraocular pressure readings greater than 21 mm.Hg. for the preoperative and postoperative periods of the 20 eyes showing improvement in quality of pressure control following surgery.

Table II Comparison of pressure reduction and quality of pressure control following surgery in eyes showing progression versus those not progressing

	Postoperative progression	Postoperative non-progression	
No. of eyes	8	12	
Mean Preop 10P	25 8 mm. Hg	25.1 mm. Hg.	$p < 0.8$
Mean Postop 10P	17 6 mm. Hg	16.1 mm. Hg.	$p < 0.2$
Mean Pressure Reduction	9 00 mm. Hg	8.1 mm. Hg	$p < 0.7$
Mean % of Postop Pressures > 21 mm Hg.	11 3%	12 4%	$p < 0.9$

C. Behaviour of the visual field following trabeculectomy

In all 20 eyes, progression of visual field defects occurred preoperatively in spite of medication and was the indication for surgery.

Postoperatively, 12 of the eyes showed no further change in their visual field, while in 8 eyes progression of defects occurred. In 6, extension or deepening of pre-existing defects took place, while 2 developed fresh scotomata.

A comparison of the mean pressures before and after surgery, the amount of pressure reduction, and the quality of pressure control of those eyes showing further postoperative field progression and those without further progression (Table 2) shows no significant pressure differences in the 2 groups.

The 2 groups were also compared for age, family history, blood pressure, other systemic medical illnesses, the appearance of a disc hemorrhage, and the requirement after surgery for antiglaucoma medication. None of these parameters was significantly different in the 2 groups.

Table 3 compares the eyes with 8 mm.Hg. or less of pressure reduction following surgery with those with 9 mm.Hg. or more pressure reduction. There is a slightly higher incidence of progression of field in the group with less pressure reduction, but the difference is not statistically significant.

Table 4 compares those eyes with no postoperative pressure recordings over 21 mm.Hg. with those where at least one postoperative pressure over 21 mm.Hg. was recorded. There is a higher incidence of progression in the group with the poorer pressure control (62.5% versus 25%). The difference, however, is not significant at the 5% level of significance.

DISCUSSION

The rationale of the medical and surgical treatment of glaucoma is based on the belief that lowering an elevated intraocular pressure will protect the visual field (Armaly, 1969). If this is true, one would predict there should be evidence of less visual field progression following surgical pressure reduction in a group of patients whose fields had been progressing. One would further predict that those eyes with the greatest pressure reduction and best control of pressure would show less field progression than those eyes where pressure was less reduced or less well controlled.

The results of this study fulfilled the first prediction. Of the 20 eyes studied, all showed progression before surgery, but only 8, or 40%, showed evidence of further progression following surgery.

However, eyes with the greatest pressure reduction or the best pressure control did not necessarily do better. When the eyes which progressed were compared with the eyes which did not, no significant difference in pressure or quality of control was found. When the eyes with the greatest pressure reduction or be quality of control were compared with the eyes with the least pressure reduction or poorest quality of control, there was no significant difference in the proportion of eyes which progressed.

In this study one cannot relate prognosis following surgery to the pres-

sure level achieved. Other authors have also noted this lack of a direct relationship between the pressure level and field progression both in surgical (Leydhecker, 1966; Smith, 1972) and non-surgical patients (Armaly, 1969; Harbin et al. 1976).

One major problem in this study is the lack of controls. There is no way of knowing which patients would have progressed if surgery had not been performed. To learn this one would have to refrain from operating on a control group of patients showing field progression and elevated pressures despite medical therapy. Such an approach would be ethically unacceptable at the present time.

Table 3. Comparison of eyes showing ⩽ 8 mm Hg. pressure reduction with those showing ⩾ 9 mm Hg. pressure reduction

Amount of pressure reduction	Eyes showing post-operative progression	Eyes showing no postoperative progression	No of eyes
⩽ 8 mm Hg	5	5	10
⩾ 9 mm Hg	3	7	10

Table 4 Comparison of eyes never having postoperative pressure recording over 21 mm Hg with eyes having some pressure recordings over 21 mm Hg postoperatively

Highest postoperative pressure	Eyes showing post-operative progression	Eyes showing no postoperative progression	No of eyes
⩽ 21 mm. Hg	3	9	12
> 21 mm Hg	5	3	8

SUMMARY

The visual fields of 20 eyes (16 patients) who had trabeculectomy were reviewed. All 20 eyes showed progression of defects preoperatively. Postoperatively, 8 eyes showed further progression, and 12 showed no change. There was no significant difference in the amount of pressure reduction or the quality of pressure control achieved after surgery in the eyes which progressed or the eyes which did not. When the eyes with the greatest pressure reduction or the best quality of control postoperatively were compared with the eyes with the least pressure reduction or the poorest quality of control, there was no difference in the proportion of eyes which progressed. The conclusion is that one cannot predict the behaviour of the visual field after glaucoma surgery based on the effect of the surgery on pressure alone.

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FREQUENCY DISTRIBUTION IN EARLY GLAUCOMATOUS VISUAL FIELD DEFECTS

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For the investigation of the emergence and further development of glaucomatous visual field defects, it seems advantageous to classify the defects found according to their respective stages of development. To find a useful division into stages, we looked through the visual field findings of approximately 6,000 patients with a definite or suspect glaucoma, one third of these patients had glaucomatous field defects. The regularity, which we found during our study of these defects, makes a division into five stages appropriate

1. exclusively relative defects;
2 spot-like, stroke-like, or arcuate absolute defects, still without connection to the blind spot;
3. arcuate absolute defects already connected to the blind spot, and with or without a nasal break-through into the periphery;
4. extensive ring-shaped or halfring-shaped defects, keeping a central island of sensitivity;
5. central island collapsed, and only the peripheral temporal visual field rest is left.

Fig. 1 shows a sketch of the stages of defect using the example of a defect in the lower half of the visual field.

In our opinion, the second stage seems to be especially important and informative for the elucidation of the emergence of visual field damage, as it concerns pronounced early defects, which are nevertheless absolute already and, in our experience, no longer have much chance of remission. With the relative defects of stage I, on the other hand, we found great deviations, but we should not like to consider these proved before it has been established for certain in the individual case that the deterioration and improvement of light difference sensitivity, respectively, lie outside the deviation of response in the visual field area.

Field defects in the second stage were found in a little over 400 patients. Since a simple observation of the visual fields could not give us sufficient information concerning the predilection points of these small absolute early defects, we ascertained the frequency distribution of the scotomas in the visual fields in this stage statistically. 400 visual fields were placed – each individually – on a radial 'net' and the 'meshes' touched by the absolute scotomas were marked (Fig. 2) A counting of these markings gave a fre-

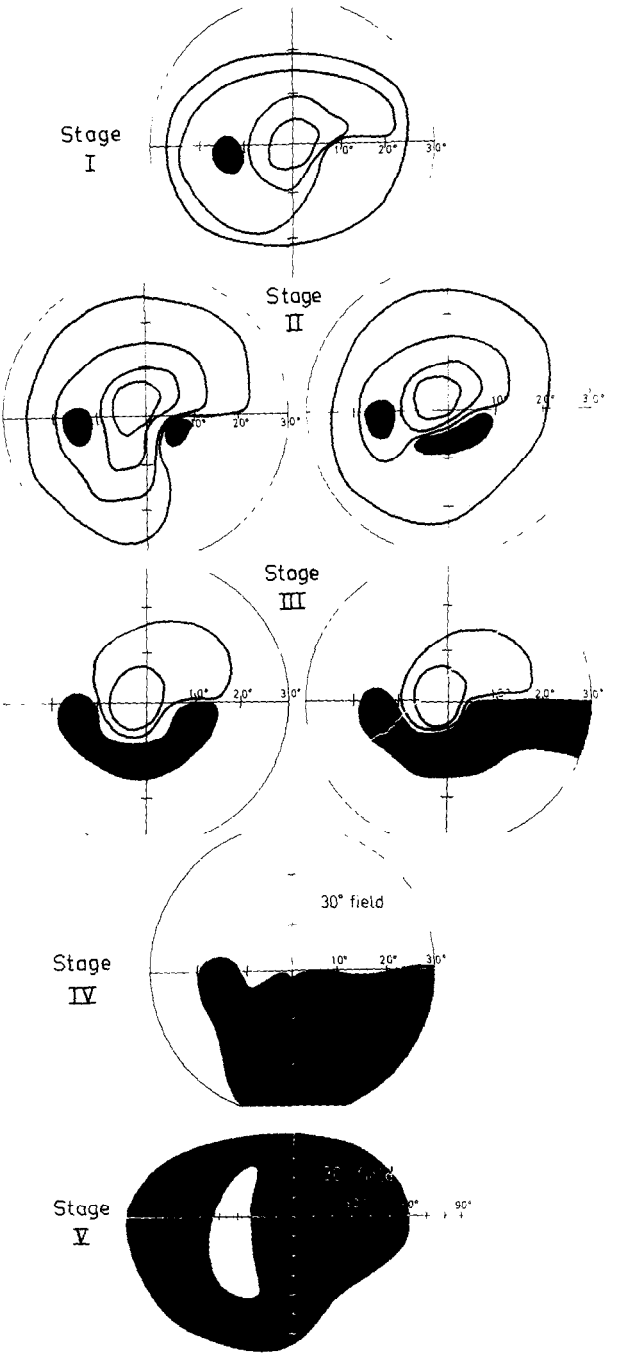

Fig 1. Sketch of the 5 stages of development of glaucomatous visual field defects using the example of a defect beginning in the lower half of the visual field. In stage II and III two different possibilities of defects are shown for each stage.

quency-distribution of defects over all meshes (Fig. 3).

A counting of this nature had already been carried out one year before with 200 visual field defects in stage 2 (Fig. 4). At that time a fairly wide-meshed net had been used, which could of course have blurred the exact location and form of the defects. Consequently a much finer net was used this time. Whilst the number of meshes in the old counting came to 76, it was 3 times as big in the new one with 228 meshes. As can be seen from a comparison of Fig. 3 and Fig. 4, the frequency-distribution does not differ very much from the first counting. The position of the scotoma location seems very similar in both countings. The limitation of the areas most frequently damaged corresponds better to the nerve fibre pathway with the finer net than it does with the wider one; the form of the scotoma, however, still appears unnaturally angular. In order to obtain information going beyond the characteristics of the predilection points of early defects and concerning the form of the defects, a very much finer net would have to be used. The best information would of course be gained by drawing all defects on top of each other. We are at the moment in the process of developing a device for such evaluations.

Since the result of each visual field examination was also determined substantially by the method of examination, the conduct and ability of the examiner, and by the type of instrument used, it was assumed that the results of our study concerning frequency distribution would be influenced decisively, too. In order to eliminate this influence on the examination as far as possible, we not only made a frequency distribution for all 400 patients together, but in addition made evaluations of four individual groups of one hundred visual fields, giving four corresponding frequency distributions (Fig. 5). The cases were classified chronologically. The frequency distributions 1 and 2 are from examinations during the years

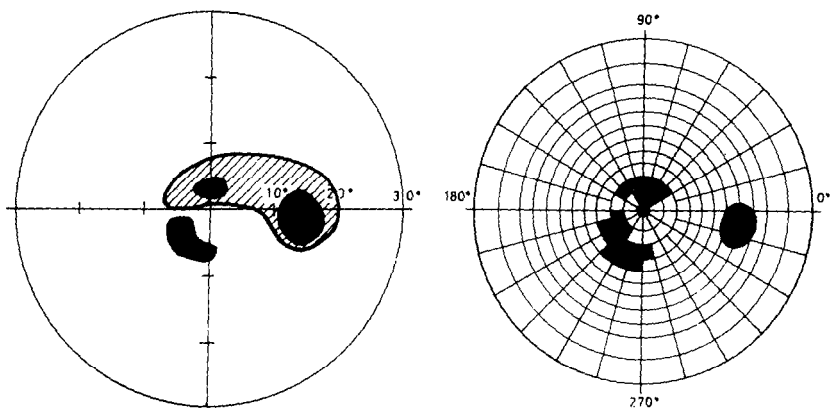

Fig 2 Typical glaucomatous early defect (left) and its representation on the radial net for statistical purposes (right). Only the absolute defects were plotted. The circles of the net lie at 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 22 and 26 degrees eccentricity. Each 'mesh' of the net touched by the absolute defect was marked

1953-1968, the third frequency distribution from the years 1968-1974, and the fourth from the time between 1974 and now.

During these periods the examiners in our perimetry department changed several times, new instruments were bought, and the number of examinations per day was increased. As the four different frequency distributions show, however, there still is a big similarity in the appearance of these four distributions, in spite of the changes on the examination side. We are quite aware of the fact that, as a result of this chronological evaluation, an influence of the examiner cannot be fully eliminated, but it is apparent that it does not play a big part as regards the position of the early defects.

Some surprising information is provided by the frequency-distribution graph, which could not have been obtained from the observation of individual cases:

1. The frequency of scotomas is approximately the same in the upper and

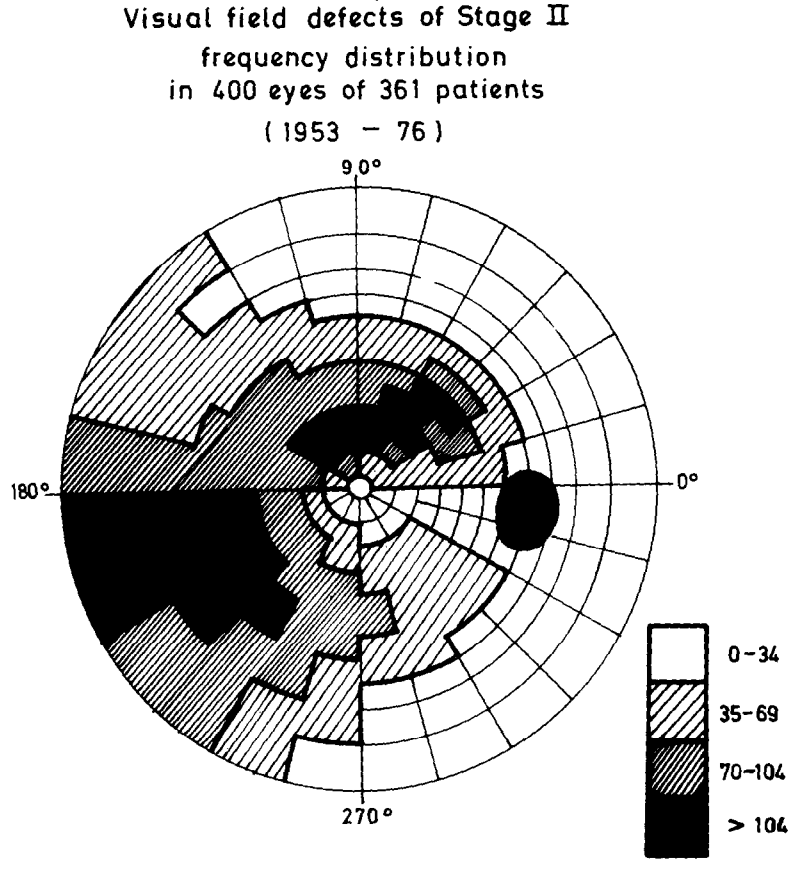

Fig 3. Frequency-distribution of the absolute scotomas of stage II in the visual fields of 400 eyes

lower halves of the visual field, but scotoma location varies considerably.
2. In the upper half of the visual field, they are fairly equally distributed, lying arcuate around the centre; in the lower half they lie predominantly in the nasal quadrant.
3. In the upper half of the visual field, the defects lie much closer to the visual field centre than in the lower half.

From the location of the defects, it must be concluded that the primary nerve fibre damage at the edge of the optic disc is not symmetrical in the upper and lower halves of the disc, but that it lies closer to the vertical meridian in the upper half and closer to the horizontal meridian in the lower half. If the nerve fibre grouping at the edge of the disc is the same as illustrated in Fig. 6 by HARRINGTON, then the damage must lie asymmetrically as marked in the figure at the edge of the disc. The reason why the position of glaucomatous atrophy differs so much in the upper and lower halves of the disc cannot be found out from our study. This fact, however, should be the point of departure for further pathogenetic considerations.

If one was to measure the cup disc ratio in a good many disc meridians,

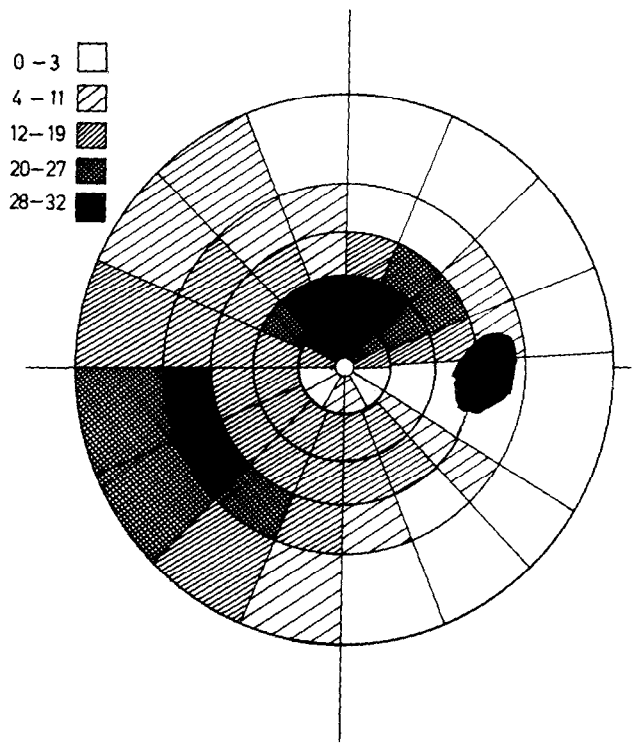

Fig 4 Frequency-distribution as in Fig 3 with 200 eyes, but with very much larger fields on the radial net.

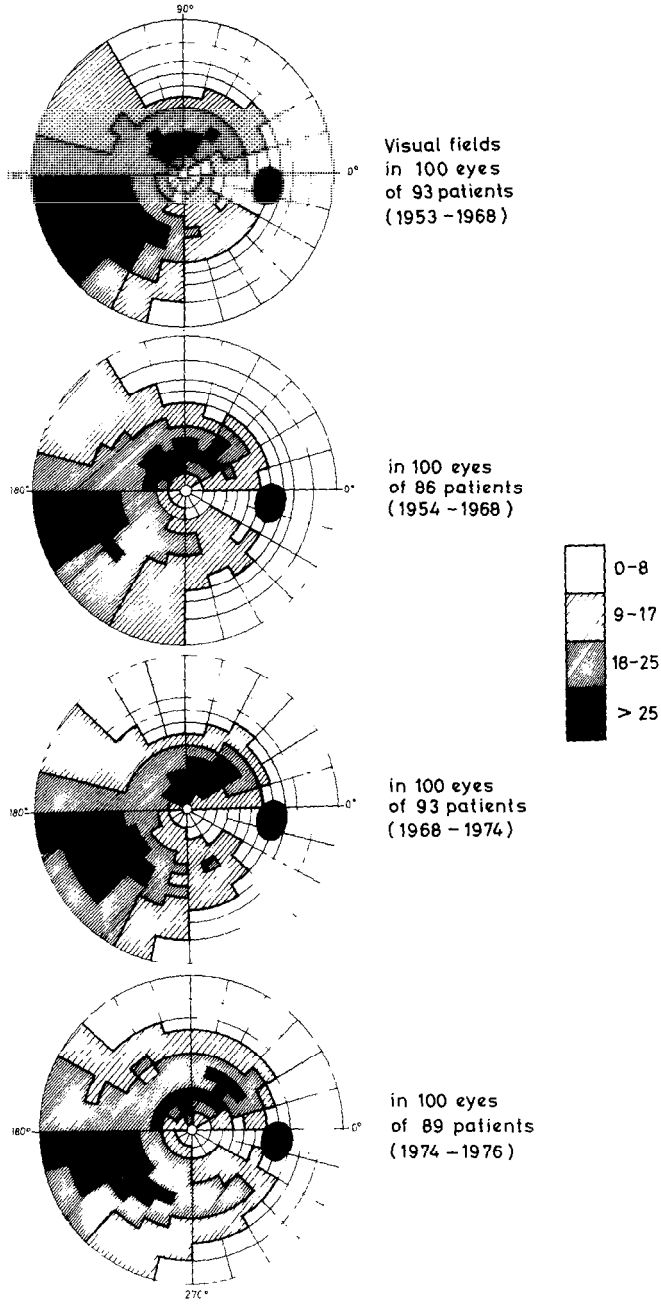

Fig 5. Frequency-distribution as in Fig. 3, classified chronologically

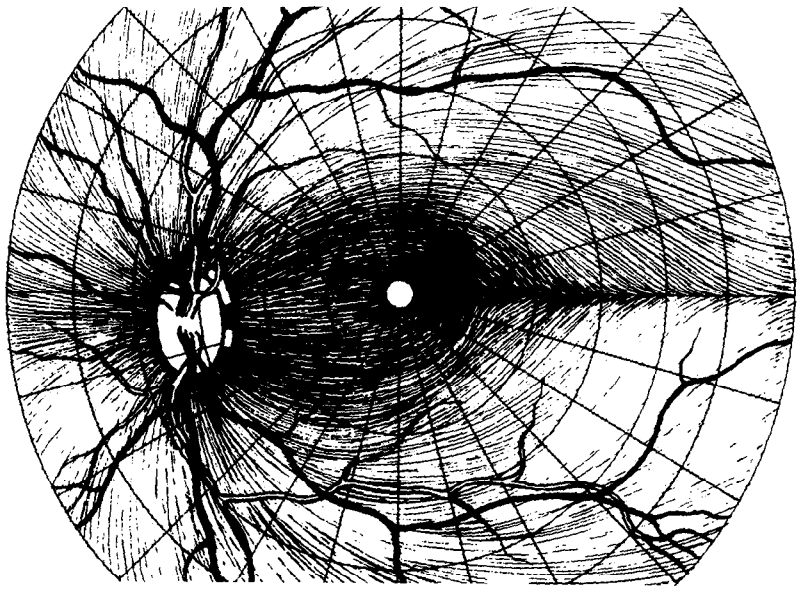

Fig 6. Nerve fibre pathway in the retina according to Harrington At the temporal edge of the disc the nerve fibre bundles are marked where, according to the frequency-distribution of glaucomatous field defects, the first damage is expected to be

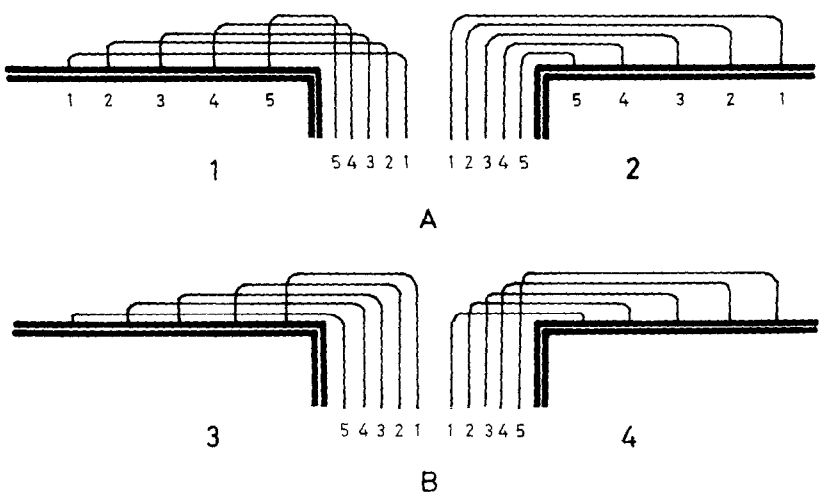

Fig. 7 Sketch of the different possibilities of the nerve-fibre course at the edge of the disc according to Traquair.

one would expect the differing location of damage in the upper and lower halves of the disc to be shown in the measurement as well. The cup disc ratio, however, is usually only measured along one or two meridians by most authors.

Since approx. one million nerve fibres must pass into the small area of the disc at its edge, it is obvious that the fibres must be tightly packed on top of each other. As long as the structure of this packing cannot be determined for certain, we cannot ascertain from our visual field defects whether the layers nearer the sclera or nearer the vitreous body are damaged first at the edge of the disc either. Theoretically, four possibilities of layering exist, as shown in the sketch (Fig. 7) by Traquair. As far as we know, it is still not clear today which of these four possibilities is the right one.

According to the study of perimetric and ophthalmological findings in a few individual cases, it seems most probable to us that grouping 2 or 4 in the sketch of Fig. 7 is the right one. As shown in Fig. 8, damage of the upper layer of the nerve fibres leads to visual field defects lying very far from the blind spot, whereas chorioidal lesions, as for example in chorioretinitis juxtapapillaris, can lead to arcuate scotomas lying close to the blind spot, if focus at the edge of the disc lies temporally rather than nasally – as is usually the case – in the area of the bow-shaped fibres. Whether there is any justification in concluding from such individual observations that the upper fibres have their receptive fields more in the temporal half of the retina, and the lower-lying fibres more in the nasal half, i.e. close to the blind spot, remains to be seen. In our opinion, however, this is an important question which must be answered if the pressure-induced lesion mechanism of the papilla is to be understood exactly.

If we now make the hypothesis for our work that, within a nerve fibre bundle, the receptive fields of the temporal paracentral retinal areas have their neuritis lying more superficial than the corresponding nasal areas at the edge of the optic disc, we would have to conclude from our results that the

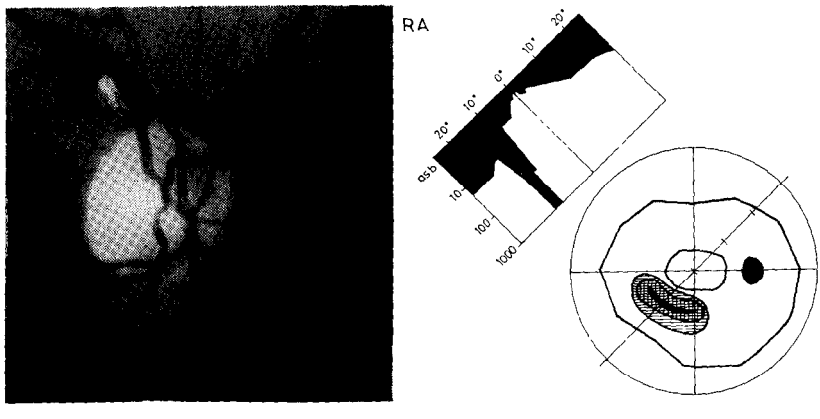

Fig. 8. Damage of the upper layer of the nerve fibres near the disc (left) and the corresponding field defect (right).

disc lesions affect the superficial nerve fibres more in the upper half of the disc and the lower lying fibres more in the lower half.

One other fact can be gathered from the evaluation of the visual field defects of stage II the scotomas in the upper as well as in the lower halves of the visual field lie at first at a fairly big distance from the blind spot and only start increasing in size in the direction of the blind spot during the growth of lesion. The scotoma grows, therefore, in exactly the opposite direction to that described in earlier literature; here, the so-called enlargement of the blind spot was always cited as the first sign of visual field lesion.

The study of the regularities in glaucomatous field defects in the second stage seems especially important for two reasons. The first concerns the fate of the individual patient. The small absolute defects do not yet cause serious orientation difficulties, on the other hand, however, this stage shows the ophthalmologist unmistakably that the existing intraocular pressure is too high for the individual eye. The determination of this is of the greatest importance for the patient because a suitable therapy must be urgently applied at this point.

To determine this reliably, however, it is essential for the perimetrist to look for the defects in those areas, where they are most likely to appear, and our frequency distributions are, in our opinion, important for this. The second reason is of a purely scientific nature: a refined study on the relation between the type and extent of optic disc lesion on the one hand and visual field damage on the other is only possible in a stage of development, in which the defects are still very small and not very numerous. It can be expected that such studies will be able to improve our knowledge concerning the pathophysiological process in glaucoma.

SUMMARY

For this study the visual fields of 300 patients with early glaucomatous visual field defects have been evaluated. Only those visual fields were considered in which the scotomas were still without connection to the blind spot, because this seems to be a characteristic for the early defect. In a diagram of the frequency distribution the typical site of the early defects is clearly demonstrated. As a very interesting result it is shown that the defects in the upper half of the visual field are placed closer to the centre than those in the lower half of the visual field.

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THE REPRODUCIBILITY OF STATIC PERIMETRY IN GLAUCOMA*

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(London, England)

ABSTRACT

10 Glaucoma patients with scotomata were compared with normal coevals on four separate occasions. Log. plots were obtained of the error of each measurement as a function of retinal illumination. A linear relationship was found and only at low thresholds was it possible to assess change in the visual function and to call it statistically significant

The results will be published in detail elsewhere

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* Abstract of paper to be submitted to *Br J Ophthal*

EXPERIENCES WITH A PROTOTYPE 100 HOLE FRONT PLATE FOR THE VISUAL FIELD ANALYSER IN GLAUCOMA

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(London, England)

The engineers were given a brief to make up a front plate for the analyser with 100 holes within the 25° perimetric angle. They were asked to put as many holes on or within the 5° perimetric angle as was practical. They found it easier to place the stimuli in a radial disposition. Figure 1 shows the distribution, as well as the 32 patterns. Each pattern has the stimuli arranged in an irregular disposition.

The number of stimuli provided by this plate is considerably greater than those provided by both the Standard 46 hole plate and the Glaucoma plate, which Lavergne used together to show the accuracy of the analyser using this technique to detect glaucoma. It must be pointed out here that in the production plate which only has 98 holes, the distribution of the stimuli are not in this radial manner.

The chart also shows that for recording a large number of stimuli the central 5° area and 5°-10° area have been expanded.

Figures 2 and 3 show the visual fields of a proved case of early open angle glaucoma. In the left eye the 46 hole plate showed a questionable field defect, whilst the 100 hole plate shows an early but unquestionable arcuate defect. In the right eye the 46 hole plate shows a probable early defect, whilst the 100 hole shows a definite field defect.

Figure 4 shows an early glaucoma defect on the 100 hole chart along the 337.5° meridian between 7° and 12°. The Goldmann Static perimeter profile along the 330° meridian shows an almost exact correspondence.

I would like to mention briefly a technique which will allow us to 'pattern bomb' to coin a phrase from photocoagulation, the whole or any part of the central field with stimuli. Employing the 100 hole plate first normally and then with the eccentric fixation target, virtually any number of stimuli can be proved

This technique is employed in screening laser works only for the last 5 patterns of the 100 hole plate. This provides 80 stimuli within about 6° from fixation. The eccentric fixation is used up, down, right and left.

Figure 5 shows the coverage that could theoretically be obtained using the eccentric fixation within 10° from fixation.

I believe that this 'pattern bombing' technique using the 98 hole plate might provide the simplest and most rapid manner to detect very early field defects of any origin.

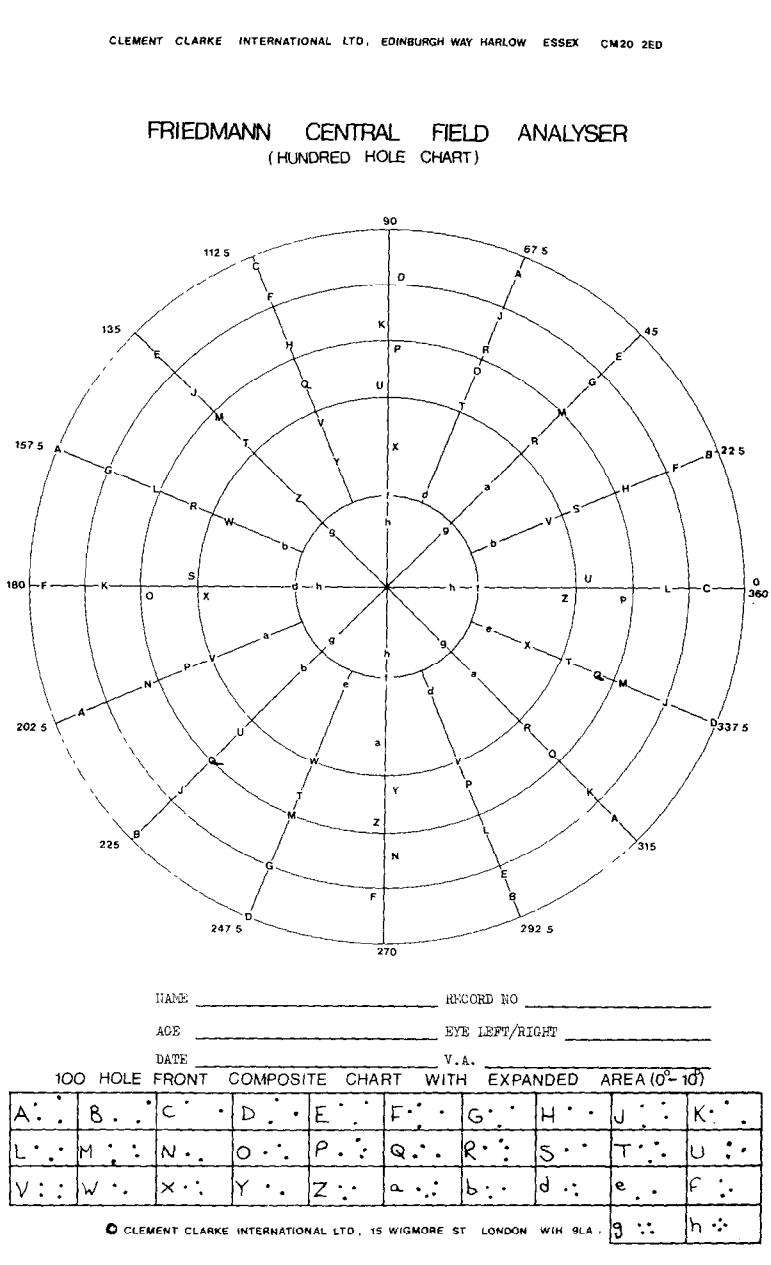


Fig. 1 100 hole 'Engineering' prototype stimuli distribution in the central field (see text).

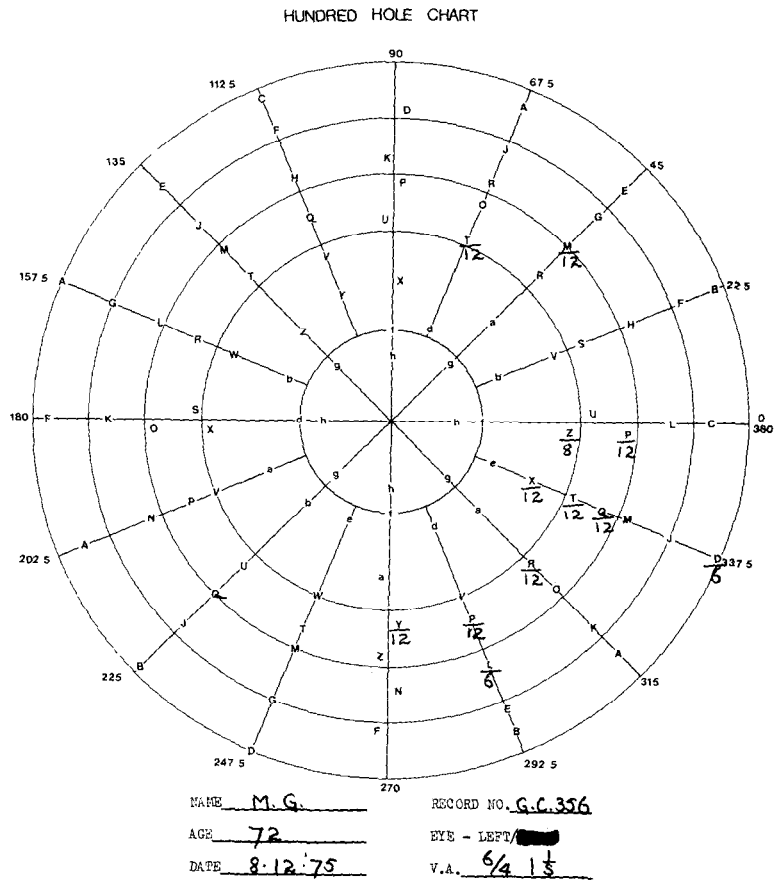


Fig. 2 M.G Left eye. 100 hole chart. Early glaucoma. 46 hole examination showed a probably normal field.

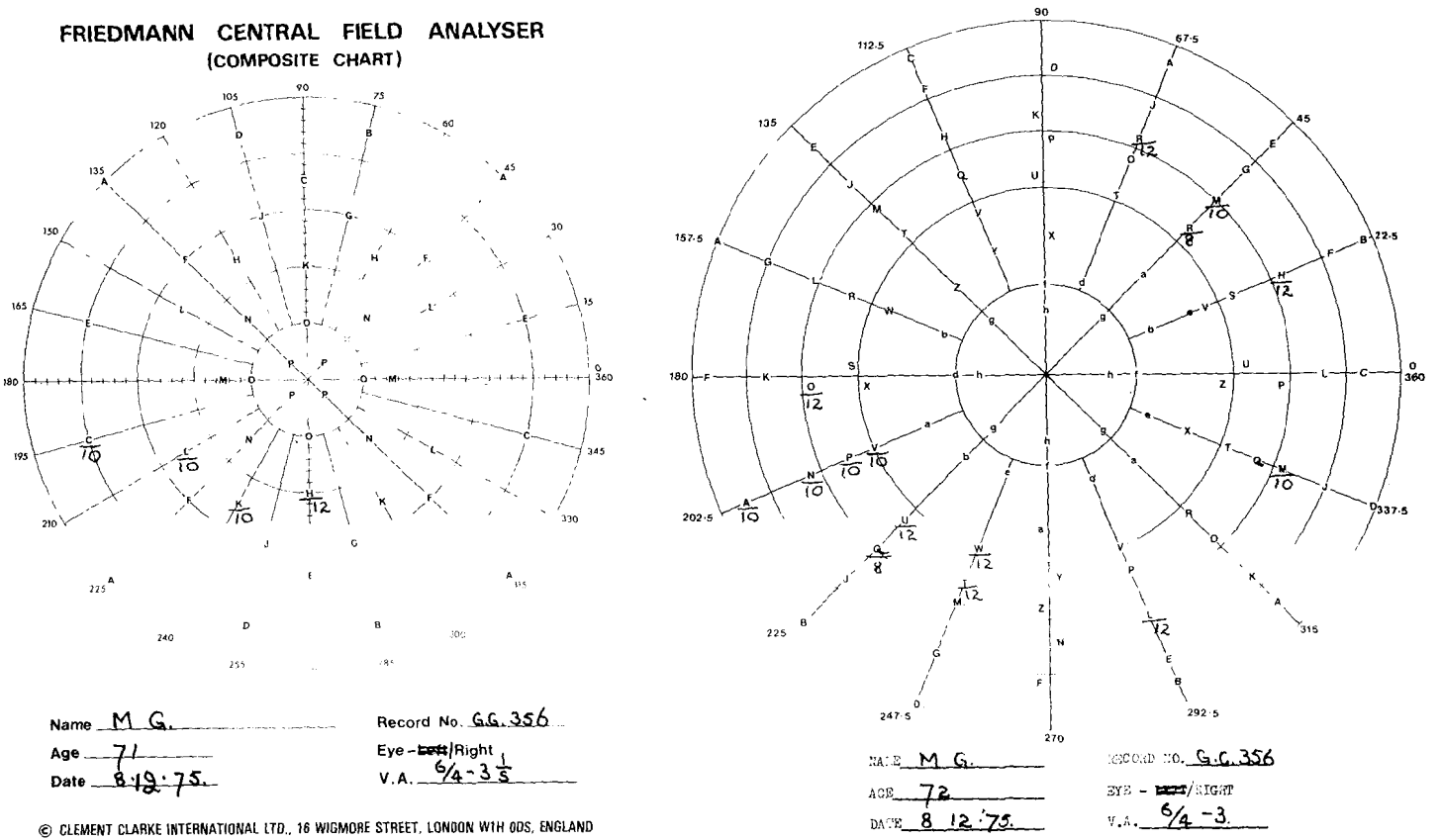
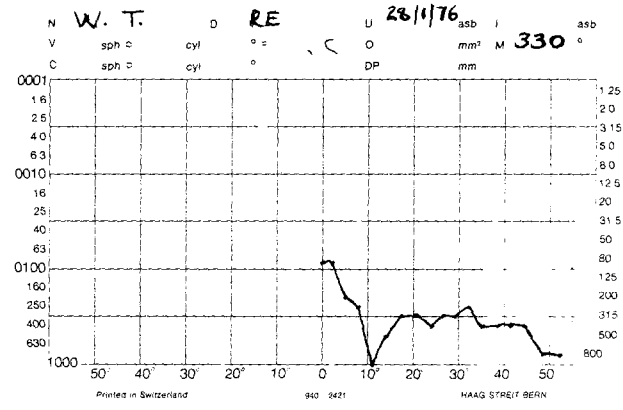
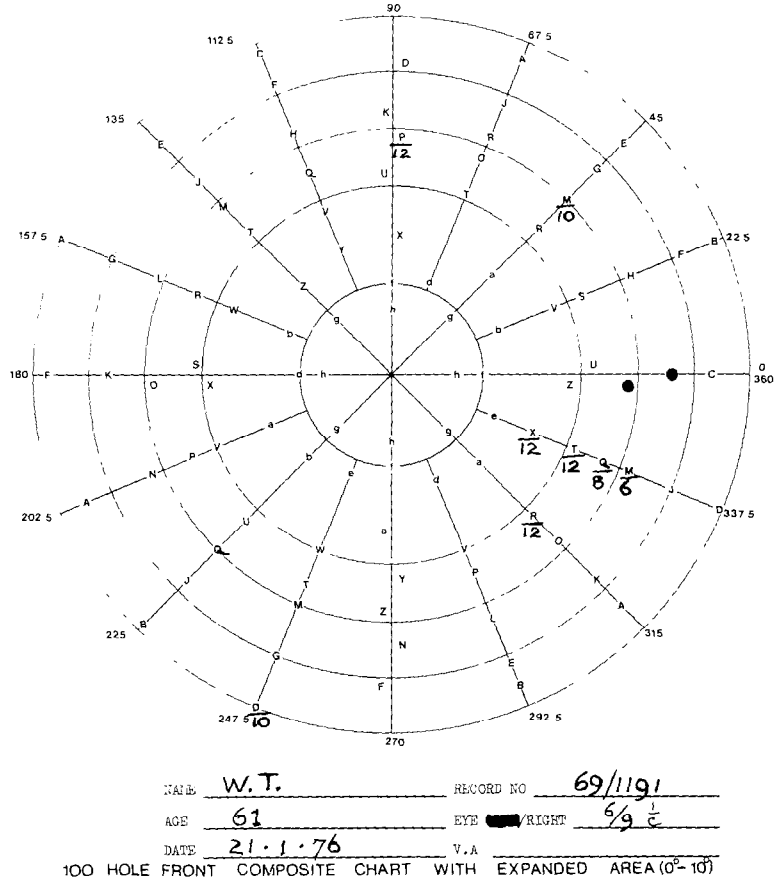


Fig. 3 M.G. Right eye 46 hole plate shows a probable early glaucoma field defect 100 hole plate shows a definite arcuate scotoma.



FRIEDMANN CENTRAL FIELD ANALYSER
(HUNDRED HOLE CHART)



NAME W. T. RECORD NO 69/1191
AGE 61 EYE ■/RIGHT 6/9 1/2
DATE 21·1·76 V.A
100 HOLE FRONT COMPOSITE CHART WITH EXPANDED AREA (0°-10°)

Fig. 4 Goldmann profile Static perimetry and analyser 100 hole front which shows a defect on the 337 5° meridian. The Goldmann static profile is along the 330° meridian Both show depressed function between 7° and 15°. The two black spots on the 100 hole chart fall on the blind spot

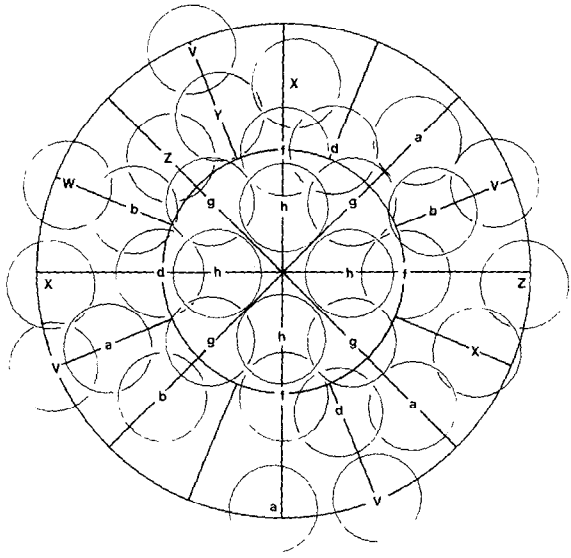


Fig. 5 This shows the coverage that could theoretically be obtained using the eccentric fixation within 10° from fixation..

I wish to acknowledge the help given by my technicians Miss Graham, Miss Glock and Mrs. Speed.

SUMMARY

The paper deals with the results obtained with a 100 hole plate in cases of glaucoma and compares the results with those obtained with the 46 hole plate.

REFERENCE

Lavergne, G. Extrait du *Bulletin de la Societe Belge d'Ophthalmologie* 167: *611-621* (1974).

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THE CENTRAL VISUAL FIELD CHANGES IN GLAUCOMA USING GOLDMANN PERIMETER AND FRIEDMANN VISUAL FIELD ANALYSER

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(Tokyo, Japan)

INTRODUCTION

The visual field examination is one of the essential methods for the diagnosis of glaucoma. In order to find out the frequency distribution of early glaucomatous visual field changes, in the central visual field (30°), we have analyzed the data of visual field examination with the Goldmann perimeter and Friedmann's visual field analyzer.

213 eyes were examined with the Goldmann perimeter and 67 eyes with Friedmann's visual field analyzer. Greve's topographical units were used to analyze our data (Fig. 1).

RESULTS

Table 1 shows the frequency distribution of visual field changes as found with the Goldmann perimeter. Especially, the depression by I/4 isopter is most often found in the nasal and Bjerrum area. The visual field changes in

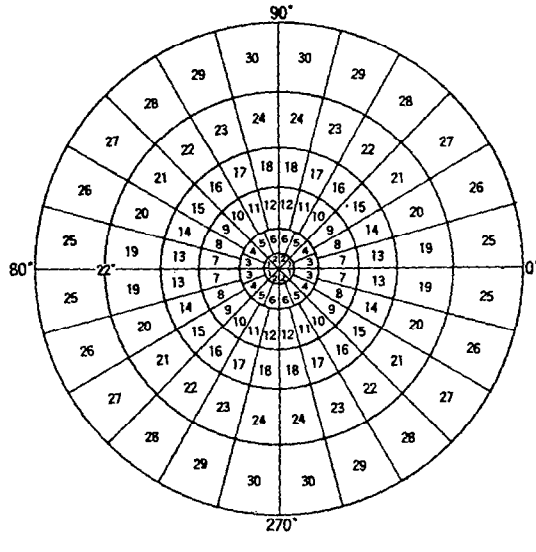

Fig. 1 Greve's topographical units.

unit No	superior nasal				superior temporal				inferior temporal				inferior nasal			
	1/4		1/3		1/4		1/3		1/4		1/3		1/4		1/3	
	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%
1	65	30.3	86	40.1	60	28.0	79	36.9	58	27.1	74	34.5	73	34.1	90	42.0
2	61	28.5	82	38.3	70	32.7	87	40.6	60	28.0	79	36.9	73	34.1	92	42.9
3	95	44.3	124	57.9	91	42.5	118	55.1	86	40.1	108	50.4	102	47.6	124	57.9
4	101	47.1	131	61.2	100	46.7	125	58.4	88	41.1	113	52.8	99	46.2	127	59.3
5	103	48.1	138	64.4	99	46.2	128	59.8	88	41.1	117	54.6	102	47.6	131	61.2
6	103	48.1	139	64.9	105	49.0	140	65.4	100	46.7	118	55.1	100	46.7	129	60.2
7	127	57.4	162	75.7	122	57.0	162	75.7	120	56.0	158	73.8	120	56.0	151	70.5
8	121	56.5	167	78.0	129	60.2	166	77.5	116	54.2	154	71.9	114	53.2	149	69.6
9	122	57.0	166	77.5	129	60.2	165	77.1	112	52.3	145	67.7	110	51.4	148	69.1
10	124	57.9	168	78.5	130	60.7	165	77.1	110	51.4	141	65.8	120	56.0	146	68.2
11	130	60.7	166	77.5	131	61.2	164	76.6	109	50.9	140	65.4	108	50.4	141	65.8
12	125	58.4	175	81.7	129	60.2	167	78.0	106	49.5	139	64.9	104	48.5	139	64.9
13	139	64.9	186	86.9									129	60.2	164	76.6
14	137	64.0	157	73.3	146	68.2	180	84.1					124	57.9	163	76.1
15	132	61.6	184	85.9	147	68.6	176	82.2	124	57.9	162	75.7	119	55.6	156	72.8
16	129	60.2	182	85.0	141	65.8	174	81.3	117	54.6	154	71.9	117	54.6	154	71.9
17	136	63.5	183	85.5	143	66.8	175	81.7	110	51.4	154	71.9	116	54.2	150	70.7
18	134	62.6	181	84.5	142	66.3	177	82.7	110	51.4	149	69.6	112	52.3	150	70.7
19	145	67.7	196	91.5									133	62.1	179	83.6
20	142	57.9	196	91.5	148	69.1	185	86.4					128	59.8	172	80.3
21	138	64.4	185	80.4	147	68.6	187	87.3	128	59.8	173	80.8	121	56.5	169	78.9
22	138	64.4	187	87.3	146	68.2	185	86.4	120	56.0	165	77.1	121	56.5	162	75.7
23	141	65.8	196	91.5	147	68.6	185	86.4	113	52.8	164	76.6	119	55.6	161	75.2
24	138	64.4	193	90.1	146	68.2	185	86.4	113	52.8	163	76.1	117	54.6	164	76.6
25	145	67.7	195	91.1	139	64.9	186	86.9	137	64.0	173	80.8	133	62.1	185	86.4
26	140	65.4	201	93.9	142	66.3	188	87.8	128	59.8	174	81.3	124	57.9	184	85.9
27	143	66.8	206	96.2	142	66.3	196	91.5	120	56.0	171	79.9	124	57.9	185	86.4
28	146	68.2	208	97.1	149	69.6	203	94.8	120	56.0	174	81.3	119	55.6	182	85.0
29	156	72.8	211	98.5	158	73.8	208	97.1	121	56.5	173	80.8	124	57.9	180	84.1
30	159	74.2	216	100.0	158	73.8	206	96.2	121	56.5	172	80.8	126	58.8	181	84.5
		59.3		80.4		60.7		77.8		48.9		65.5		53.4		71.7

Table 1. Frequency distribution of glaucomatous visual field changes as found with the Goldmann perimeter (213 eyes).

unit number	superior nasal						superior temporal						inferior temporal						inferior nasal					
	1.8		1.6		1.4		1.8		1.6		1.4		1.8		1.6		1.4		1.8		1.6		1.4	
	stimulus points	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%	number of eyes	%
1	P	5	7.5	3	4.5	2	3.0	P	4	6.0	3	4.5	1	1.5	P	4	6.0	4	6.0	3	4.5	P	2	3.0	2	3.0	1	1.5
2	P	5	7.5	3	4.5	2	3.0	P	4	6.0	3	4.5	1	1.5	P	4	6.0	4	6.0	3	4.5	P	2	3.0	2	3.0	1	1.5
3	O	2	3.0	2	3.0	2	3.0	O	3	4.5	3	4.5	2	3.0	O	3	4.5	2	3.0	2	3.0	O	2	3.0	2	3.0	2	3.0
4	P	5	7.5	3	4.5	2	3.0	P	4	6.0	3	4.5	1	1.5	P	4	6.0	4	6.0	3	4.5	P	2	3.0	2	3.0	1	1.5
5	P	5	7.5	3	4.5	2	3.0	P	4	6.0	3	4.5	1	1.5	P	4	6.0	4	6.0	3	4.5	P	2	3.0	2	3.0	1	1.5
6	O	4	6.0	4	6.0	4	6.0	O	5	7.5	5	7.5	4	6.0	O	2	3.0	1	1.5	1	1.5	O	2	3.0	1	1.5	1	1.5
7	M	4	6.0	4	6.0	3	4.5	M	7	10.4	7	10.4	6	9.0	M	7	10.4	6	9.0	6	9.0	M	4	6.0	4	6.0	3	4.5
8	O	2	3.0	2	3.0	2	3.0	O	3	4.5	3	4.5	2	3.0	O	3	4.5	2	3.0	2	3.0	O	2	3.0	2	3.0	2	3.0
9																												
9	N	8	11.9	5	7.5	3	4.5	N	5	7.5	4	6.0	3	4.5	N	2	3.0	2	3.0	2	3.0	N	2	3.0	2	3.0	2	3.0
10	N	8	11.9	5	7.5	3	4.5	N	5	7.5	4	6.0	3	4.5	N	2	3.0	2	3.0	2	3.0	N	2	3.0	2	3.0	2	3.0
11																												
12	K	15	22.4	11	16.4	7	10.4	K	15	22.4	11	16.4	7	10.4	H	2	3.0	2	3.0	2	3.0	H	2	3.0	2	3.0	2	3.0
12	O	4	6.0	4	6.0	4	6.0	O	5	7.5	5	7.5	4	6.0	O	2	3.0	1	1.5	1	1.5	O	2	3.0	1	1.5	1	1.5
13																												
14	L	16	23.9	15	22.4	12	17.9	L	16	23.9	12	17.9	8	11.9	L	14	20.9	8	11.9	8	11.9	L	9	13.4	9	13.4	5	7.5
15	L	16	23.9	15	22.4	12	17.9	L	16	23.9	12	17.9	8	11.9	L	14	20.9	8	11.9	8	11.9	L	9	13.4	9	13.4	5	7.5
15	F	13	19.4	12	17.9	5	7.5	F	21	31.3	14	20.9	5	7.5	F	15	22.4	13	19.4	9	13.4	F	10	14.9	10	14.9	8	11.9
16	N	19	28.4	15	22.4	8	11.9	N	18	26.9	14	20.9	6	9.0	K	11	16.4	12	17.9	7	10.4	K	8	11.9	8	11.9	6	9.0
16	Y	13	19.4	12	17.9	5	7.5	F	21	31.3	14	20.9	5	7.5	F	15	22.4	13	19.4	9	13.4	F	10	14.9	10	14.9	8	11.9
17	N	19	28.4	15	22.4	8	11.9	N	18	26.9	14	20.9	6	9.0	K	11	16.4	12	17.9	7	10.4	K	8	11.9	8	11.9	6	9.0
17	J	14	20.9	13	19.4	8	11.9	G	22	32.8	19	28.4	10	14.9	G	7	10.4	7	10.4	7	10.4	J	11	16.4	10	14.9	7	10.4
18	K	15	22.4	11	16.4	7	10.4	K	15	22.4	11	16.4	7	10.4	H	2	3.0	2	3.0	2	3.0	H	2	3.0	2	3.0	2	3.0
19	J	16	23.9	13	19.4	8	11.9	G	22	32.3	19	28.4	10	14.9	G	7	10.4	7	10.4	7	10.4	J	11	16.4	10	14.9	7	10.4
19	E	11	16.4	8	11.9	8	11.9	E	14	20.9	9	13.4	9	13.4	C	10	14.9	8	13.4	6	9.0	C	10	14.9	10	14.9	8	11.9
20	E	11	16.4	8	11.9	8	11.9	E	14	20.9	9	13.4	9	13.4	C	10	14.9	9	13.4	6	9.0	C	10	14.9	10	14.9	8	11.9
21	F	13	19.4	12	17.9	5	7.5	F	21	31.3	14	20.9	5	7.5	F	15	22.4	13	19.4	9	13.4	F	10	14.9	10	14.9	8	11.9
22	F	19	28.4	12	17.9	5	7.5	F	21	31.3	14	20.9	5	7.5	F	15	22.4	13	19.4	9	13.4	F	10	14.9	10	14.9	8	11.9
23	J	16	23.9	16	23.9	8	11.9	G	22	32.3	19	28.4	10	14.9	G	7	10.4	7	10.4	7	10.4	J	11	16.4	10	14.9	7	10.4
24	C	19	28.4	16	23.9	7	10.4	C	19	28.4	16	23.9	7	10.4	C	10	14.9	9	13.4	6	9.0	C	10	14.9	10	14.9	8	11.9
24	J	16	23.9	16	23.9	8	11.9	G	22	32.3	19	28.4	10	14.9	G	7	10.4	7	10.4	7	10.4	J	11	16.4	10	14.9	7	10.4
25																												
26																												
27	A	16	23.9	16	23.9	10	14.9	A	14	20.9	10	14.9	6	9.0	A	6	9.0	2	3.0	3	4.5	A	7	10.4	7	10.4	4	6.0
28	A	16	23.9	16	23.9	10	14.9	A	14	20.9	10	14.9	6	9.0	A	6	9.0	2	3.0	3	4.5	A	7	10.4	7	10.4	4	6.0
29	D	16	23.9	16	23.9	10	14.9	D	19	28.4	15	22.4	10	14.9	D	5	7.5	4	6.0	4	6.0	D	8	11.9	8	11.9	6	9.0
30	D	16	23.9	16	23.9	10	14.9	D	19	28.4	15	22.4	10	14.9	D	5	7.5	4	6.0	4	6.0	D	8	11.9	8	11.9	6	9.0
			19.4		16.4		14.9			19.4		14.9		9.0			11.2		9.9		7.9			9.9		9.7		7.0

Table 2. Frequency distribution of glaucomatous visual field changes as found with the Friedmann's visual field analyzer (67 eyes).

both isopter I/4 and I/3 are more frequently found in the upper half than the lower half. There is no great difference between nasal side and temporal side in both upper and lower half of the visual field. That is, the frequency distribution by I/4 is 59.3% in superior nasal side, 60.7% in superior temporal side, 48,9% in inferior temporal side and 53.3% in inferior nasal side The frequency distribution by I/3 is 80.4% in superior nasal side, 77.8% in superior temporal side, 65.5% in inferior temporal side and 71.0% in inferior nasal side.

Fourteen out of 213 eyes with glaucomatous visual yield changes were thought to have early defects. Fig. 2 shows the distribution of the visual field changes of these 14 eyes on the topographical units. Table 2 shows the frequency distribution of early visual field changes detected by Friedmann's visual field analyzer. Fig. 3 shows the frequency distribution of all positions that were not seen at a luminance corresponding to the 1.8 log unit filter. Depressions are most frequently found in the unit numbers 14 to 18 and from 21 to 24. These positions correspond to the Bjerrum area. Visual field changes were more frequently found in the upper half than in the lower half. In the upper half and lower half there are no differences in frequency distribution between the nasal side and the temporal side. There was a low frequency within ten degrees.

Fig. 4 shows the frequency distribution of all positions that were not seen at a luminance corresponding to the 1.4 log unit filter. The results are similar to those of Fig. 2.

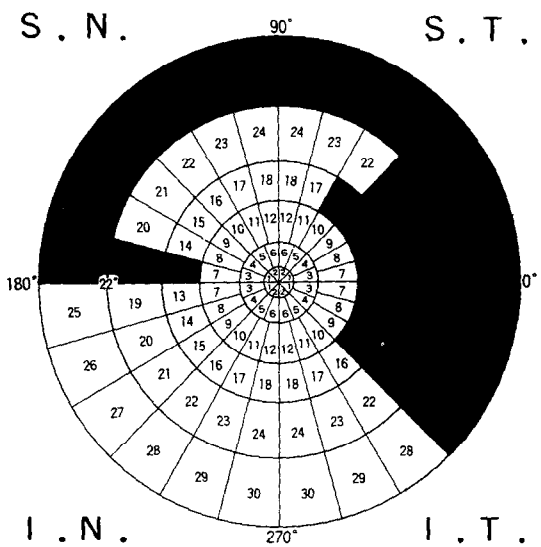

Fig. 2. Distribution of early glaucomatous changes of 14 eyes.

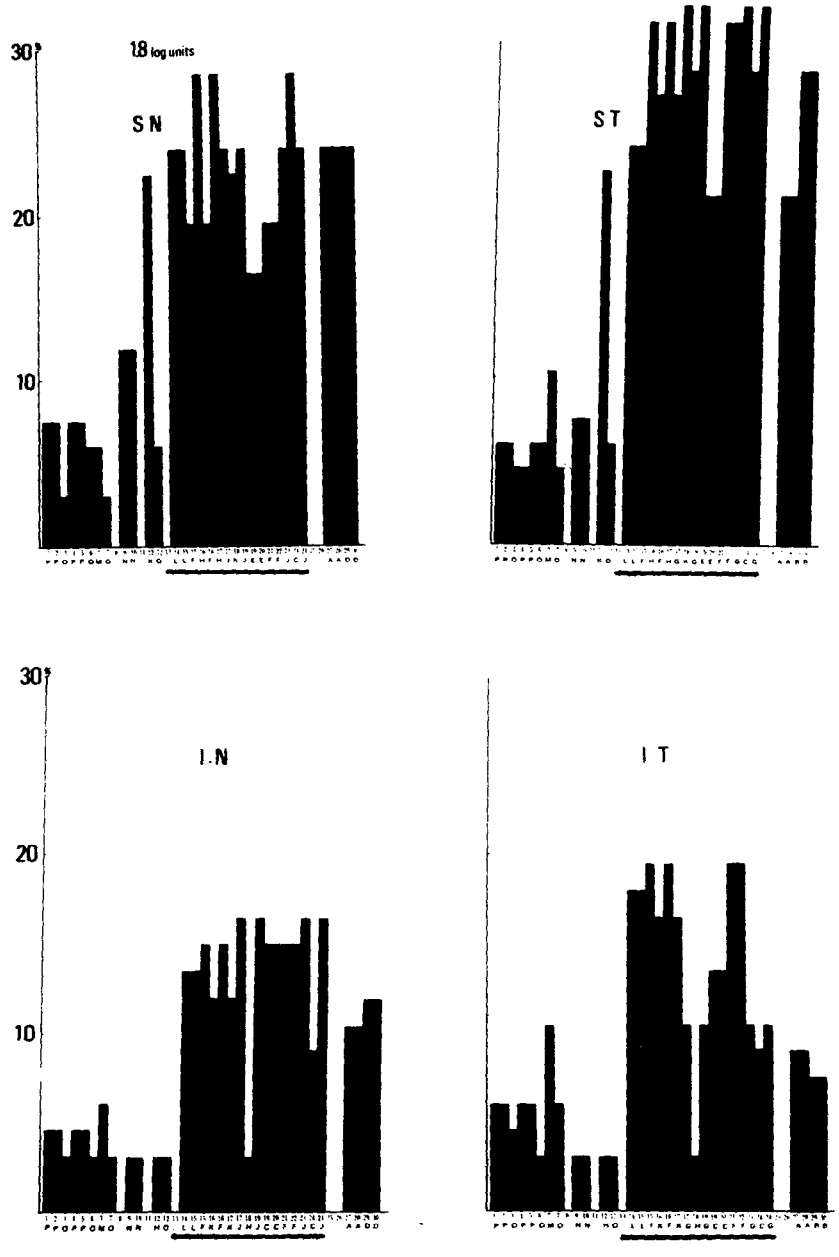

Fig. 3 Frequency distribution of all positions that were not seen at a luminance corresponding to the 1.8 log unit filter. Legends under columns should be read as follows:

1	2	3	4	5	6	7	7	8	9	10	11	12	12	13	14	15	15	16	16	17	17	18	19	20	21	22	23	24	25	26	27	28	29	30
P	P	O	P	P	O	M	O		N	N		K	O		L	L	F	H	F	H	J	K	J	E	F	J	C	J			A	A	D	D

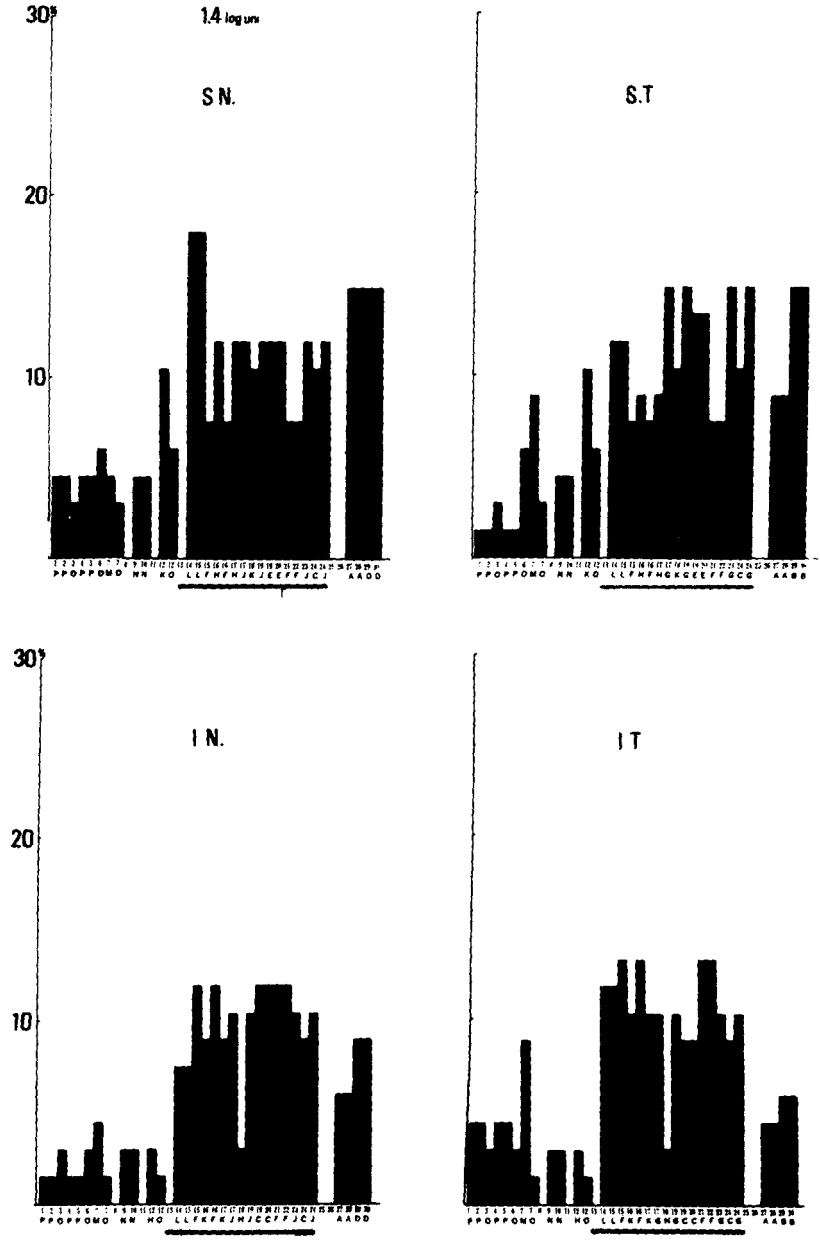

Fig 4. Frequency distribution of all positions that were not seen at a luminance Corresponding to the 1.4 log unit filter Legends under columns should be read as follows:

1	2	3	4	5	6	7	7	8	9	10	11	12	12	13	14	15	15	16	16	17	17	18	19	20	21	22	23	24	25	26	27	28	29	30
P	P	O	P	P	O	M	O		N	N		K	O		L	L	F	H	F	H	J	K	J	E	F	J	C	J			A	A	D	D

DISCUSSION

It is most important to know where early glaucomatous visual field changes appear An optimal detection procedure should have an even distribution of a very high number of stimuli But, it is impossible to use so many stimuli on routine examination. Therefore, we investigated the frequency distribu-

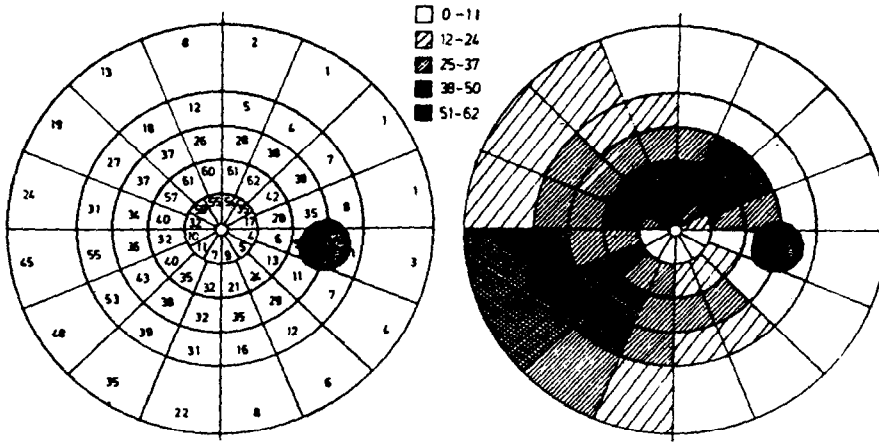

Fig 5. Professor Aulhorn's diagram of the distribution of early glaucomatous visual field changes (reprinted from *Folia ophthal. Jap* 27)

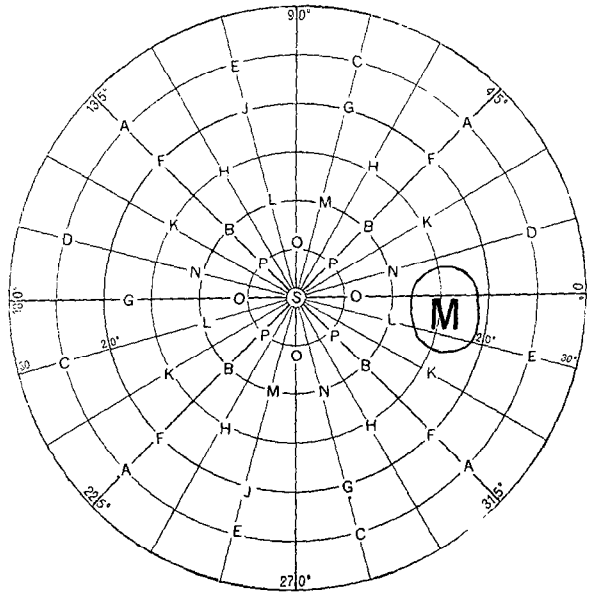

Fig 6 The distribution of the 51 points of our new front plate.

tion of glaucomatous visual field changes of 213 eyes examined with the Goldmann Perimeter and 67 eyes examined with the Friedmann Visual Field Analyser. From these data, we concluded that there is a high frequency in the nasal and Bjerrum area. We noticed few independently occurring defects within ten degrees eccentricity. Our results are different from those of Prof. Aulhorn (Fig. 5), who found a high frequency within ten degrees eccentricity in the superior half of the visual field.

From our distribution diagram, we selected suitable detection points. We distributed many detection points in the Bjerrum and nasal areas (Fig. 6) On the other hand, we distributed less detection points on the vertical meridian, the horizontal meridian and the central area within ten degrees eccentricity.

A new front plate for the visual field analyser was made. The number of stimuli is 51. Now, the background luminance is an important factor in visual field examination In order to improve the sensitivity of perimetry, the mesopic condition was selected (0.0315 asb) based on the experiences of Prof. Matsuo & Dr Endo ten years ago. Under mesopic conditions the

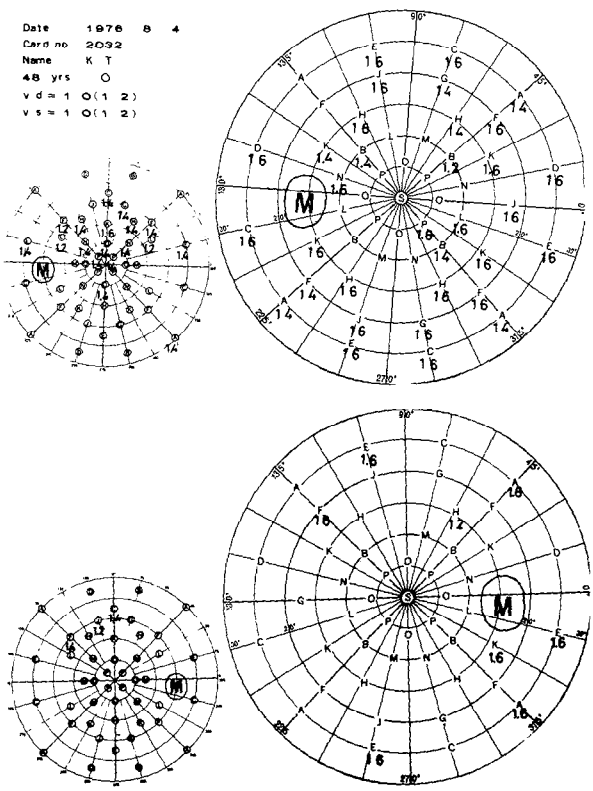

Fig 7 Results of the examination with Friedmann's visual field analyzer and our new front plate in case 1

sensitivity curve is flat. Therefore, the size of all stimuli in our case is ten minutes in angle, which can be compared with the standard stimulus size of the Tübingen Perimeter. The central visual field analyser with the new plate can quantitatively measure the sensitivity of the retina by changing neutral density filters with 0.1 log unit step.

CASE REPORTS

The usefulness of the new front plate will be illustrated by two case reports.

Case 1 (Fig. 7) shows the visual field changes of case 1. The small figure shows the results of Friedmann Visual Field Analyser and the large figure of the new plate.

A defect is indicated by 8 positions on the new plate and by 3 spots on the Friedmann Visual Field Analyser in the right eye. Similarly, 34 defect positions were detected on the new plate and 17 defect positions by Friedmann Visual Field Analyser in the left eye.

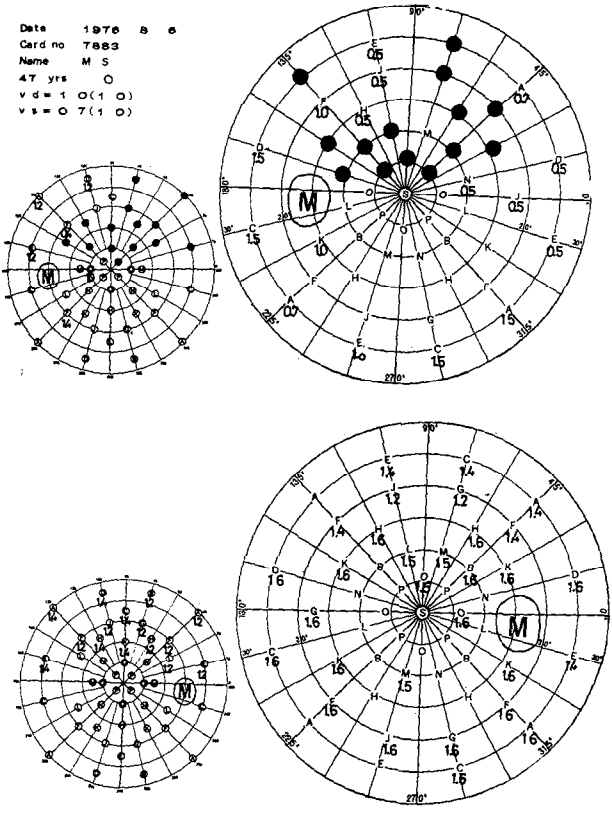

Fig 8. Results of the examination with Friedmann's Visual field analyzer and our new front plate in case 2.

Case 2 (Fig. 8) shows that at 30 positions a defect was detected by the new plate and 15 by the Friedmann Visual Field Analyser in the right eye. At 31 positions a defect was detected on the plate and 20 positions by Friedmann Visual Field Analyser in the left eye. Black spots indicate no perception.

SUMMARY

We investigated the frequency distribution of glaucomatous visual field changes as found with Goldmann Perimeter and Friedman Visual Field Analyser. Greve's topographical units were used for analysing our data. We developed a new plate for the Visual Field Analyser based on the new distribution of stimulus positions.

ACKNOWLEDGMENT

We wish to thank Professor Harutake Matsuo and Dr. Nariyoshi Endo of our department for their kind and helpful instructions. The assistance of Miss Kayoko Harasawa and Miss Keiko Kumasaka is also appreciated.

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DETECTION OF EARLY GLAUTOMATOUS DAMAGE
PART I. VISUAL FIELD EXAMINATION

E.L. GREVE & W.M. VERDUIN

(Amsterdam)

There are two examination methods possible for the detection of early glaucomatous damage visual field examination and ophthalmoscopy of the disc.

In this first section the detection sensitivities of 5 methods of visual field examination are compared·

1. Kinetic perimetry.
2. Armaly (Drance) method.
3. Multiple Stimulus Static Perimetry (M.S.S.P.) using the Friedmann Visual Field Analyser (modified front-plate).
4. Classical static perimetry (S.S.S.P., Aulhorn-Harms method).
5. A modification of the classical static perimetry method, i.e. continued stimulation (Verduin-Greve).

NORMAL VISUAL FIELD AND EARLY DETECTION

Before these methods are discussed the normal visual field and the early glaucomatous visual field must be defined.

The normal visual field has been described in a number of publications (see Greve, 1973). The most important fact is that the normal variation in S.P. measurements is in the 0 2-0.4 log unit range, depending upon the experience and accuracy of the patient. Angioscomata are also a feature of the normal visual field, these may have an intensity of 1.0 log unit but they are very narrow, i.e. 1-2 degrees. The size and intensity of the smallest (not necessarily earliest) visual field defect can be deduced from the particulars about the normal visual field. A loss of sensitivity of 0.5 log unit or more is certainly abnormal when the normal variation of measurements is 0.3 log unit, except where an angioscotoma is concerned. A defect with the maximum width of at least 3° can seldom be the effect of a vascular shadow.

Thus, when the variation is normal we may speak of a defect when the intensity is 0.5 log unit or more and the width 3° or more at the widest, upper part (Fig. 1). This type of defect was called a 'wedge-shaped defect' by us in 1972 (W.S.D). The maximum intensity for a W.S.D. was arbitrarily fixed at 1.0 log unit.

We suggested at that time that a W.S.D. can be one of the earliest forms of glaucomatous visual field damage·

1. A W.S.D. is a significant local reduction of sensitivity.
2. Typical deeper glaucomatous defects can develop from a W.S.D.,
3. A W.S.D. is often combined with a more extensive defect,
4. A W.S.D. is sometimes reversible

The fact that a W.S.D. can be an early glaucomatous defect does not necessarily imply that it is always associated with glaucoma. This is true for larger fibre bundle defects as well, which are also not specific for glaucoma. The specificity of the W.S.D. has not been sufficiently investigated as yet.

It is improbable that W.S.D. can be found in normal eyes but we have found them in association with eye diseases other than glaucoma. Nevertheless the discovery of a W.S.D. in glaucoma requires extra attention and a careful follow-up. It should be emphasized here that the W.S.D. is a typical product of S.S.S.P. The significance and the value of the discovery of such early defects in general ophthalmic practice and in the specialized visual field department are naturally different. The practical value of the W.S.D., to emphasize this once more, is in the suspicion aroused the position concerned is suspicious (see also Part II: Cupping).

This study is concerned with the earliest possible detection of defects, with the secondary object of comparing them with early defects in the optic disc.

METHODS

A short description of the examination methods used is unavoidable (for a more detailed description the reader is referred to Greve, 1973).

Kinetic perimetry was performed by the usual method i.e. 4 isopters with 0.5 log unit difference in luminance between them (I/4, I/3, I/2, I/1

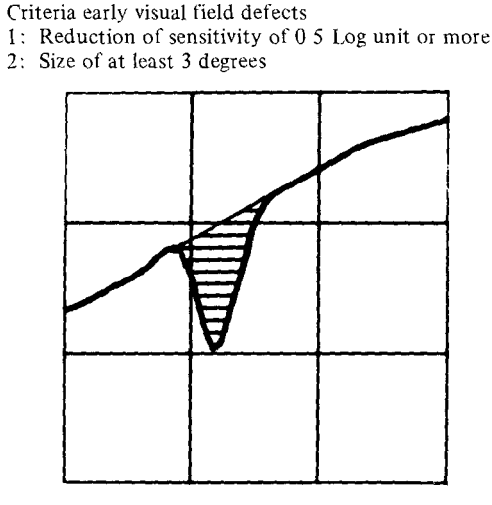

Fig 1 A wedge-shaped defect (W.S.D.) which has an intensity of 0.5 log units or more and a width of at least 3° in its upper part.

with the Goldmann perimeter) were examined, 16 measurements per isopter. The limitations of this form of kinetic perimetry are due to the small number of measurement positions within the 30° visual field and the speed of movement. When drawing comparisons with static perimetry one must realize that two fundamentally different methods are being compared.

The Armaly method (Armaly, 1969; modified by Drance, 1971, 1972) makes use of the Goldmann perimeter for a combination of kinetic and static measurements (Fig. 2). The supraliminal static measurements must be considered separately if the possibilities of this method are to be understood. To determine the stimulusluminance for the static measurements in the 15° area the threshold is first measured at 4 positions on the 25° parallel by means of S.S.S.P. The threshold luminance thus found is used for the examination of 76 positions on and within the 15° parallel. This means that the stimulus used is close to threshold level at 15° eccentricity and far above threshold level at 2.5° eccentricity. The 15° area is thus examined with a weak stimulus and the paracentral area with a stimulus which is too strong. The result is a risk of false positive results in the 15° area and a risk of false negative results in the pericentral area.

This is a fundamental objection to the Armaly method. A method which is equally supraliminal in the whole of the area under examination is to be

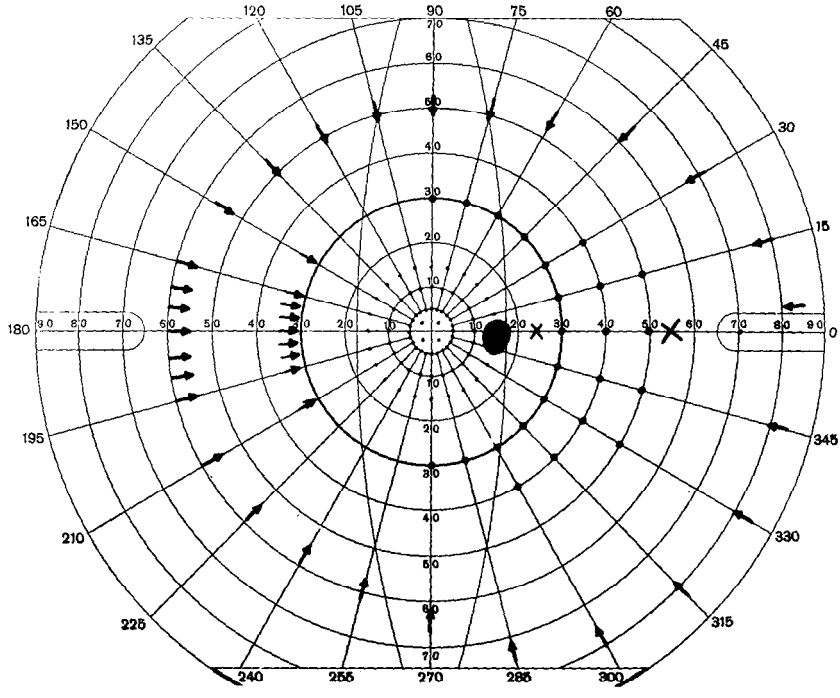

Fig. 2. Armaly-Drance screening method (see text)

preferred. In this study only the area within the 30° parallel was used for comparison.

M.S.S.P. by means of the *Visual Field Analyzer* was performed with a modified front-plate which allows the presentation of 150 stimuli in the 22° area (Fig. 3). In a first phase the threshold is measured at 50 positions. If necessary, if no defects have been found in the first phase, in a second phase measurements are made at an additional 100 positions 0.4 log unit above threshold level. Thus, in this method a combination of threshold and suprathreshold presentations is used. All the supraliminal presentations are equally far above threshold level.

In the *Aulhorn-Harms method*, the classical static perimetry method, the luminance of the stimulus is increased from the infraliminal area and presented with steps of 0.1 log unit. The first perception of the stimulus is noted. If necessary the measurement is repeated. Every measurement con-

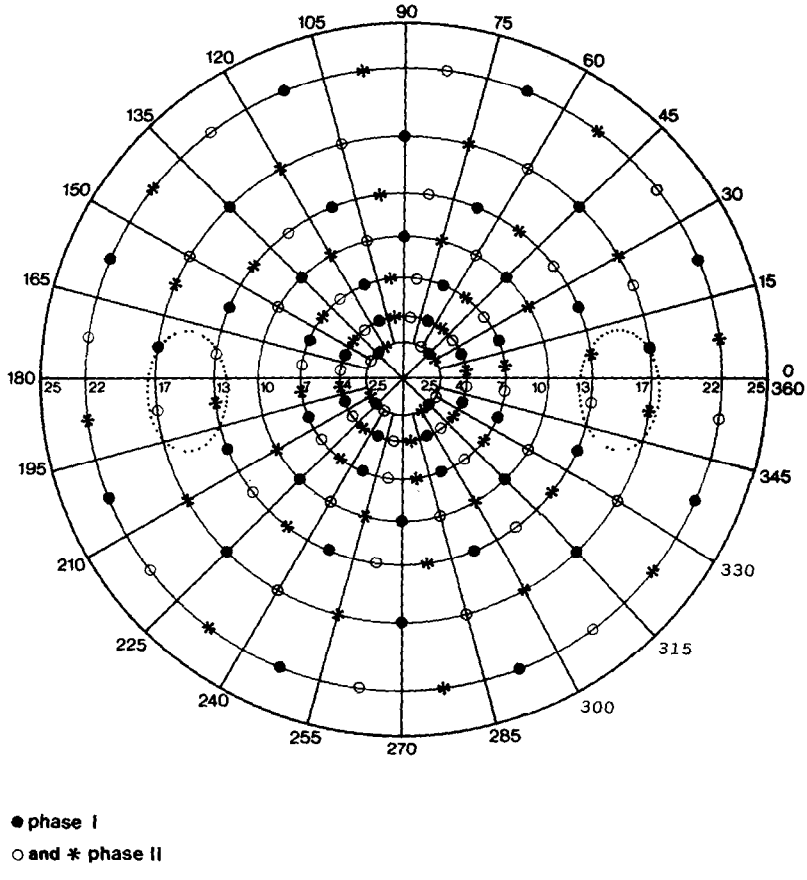

Fig. 3. Amsterdam Front Plate with the possibility of presenting 150 stimuli in 2 phases.

sists of an average of 4 presentations, in the absence of defects. 120 measurements are made in all on the 4 oblique meridians.

In *static perimetry with continued stimulation*, as performed by Verduin and Greve, after the first perception of a stimulus, this is repeatedly presented at increasing luminance levels until it is seen at each presentation (Fig. 4).

The effect of this modification is:

a) an increase in the number of presentations and thus in the chance of detection,

b) (as hypothesis) the measurement of a sort of fatigue phenomenon.

It appears that a greater intensity of defects is measured by this method than by the classical method, it is thus more sensitive.

There is an essential difference between the Armaly- and M.S.S.P. methods on the one hand and the Aulhorn-Harms and Verduin-Greve methods on the other. The most important difference is in the number and distribution of the stimuli. In the first two methods there is a more or less even distribution of the stimuli in the 15° or 22° area respectively. This means that in each given unit of surface area one stimulus is presented. In the Aulhorn-Harms and Verduin-Greve methods large areas are not examined, but on the 4 oblique meridians very precise measurements are made degree by degree. The same unit of surface area is examined with a much larger number of stimuli than in the Armaly- and M.S.S.P. methods. This has advantages for the detection of early defects. The disadvantage is clearly the duration of the examination. In Table 1 a number of features of the above S.P. methods

VERDUIN / GREVE METHOD OF CONTINUED STIMULATION

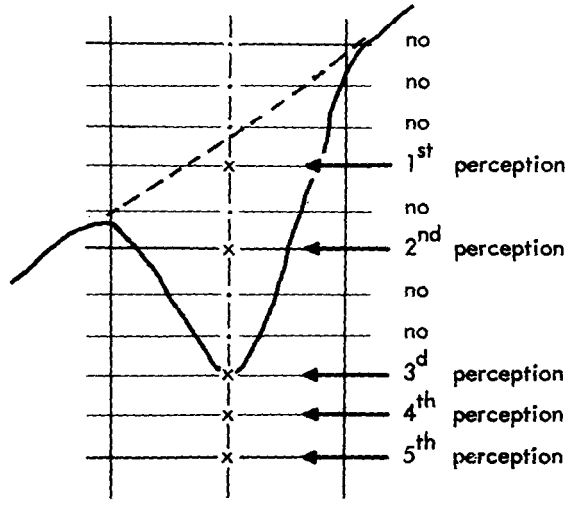

Fig 4 Static perimetry with continued stimulation after Verduin-Greve.

are summarized. When judging the results these points must be taken into consideration: whether the threshold is measured or not, the number and distribution of the stimuli and the time needed for the examination. These factors explain to a large extent the differences in detection sensitivity of the methods.

Finally, the assessment of the value of the detection methods has a practical aspect: is a given method, with regard to time and apparatus/personnel, a possibility for a given type of practice. This interesting aspect is not the subject of this article.

PATIENTS

Care is necessary when selecting patients. On which criteria for early damage must the selection be based? Visual field defect or suspected pathological cupping? And if it is based on visual field defects, the question arises which method should be used for the selection.

In our case all 5 detection methods were used on 32 eyes from 25 patients, who all had a chronic wide- or narrow-angle glaucoma or suspected glaucoma. They were selected on the basis of visual field defects and in a few on suspected cupping. (Note: in another study, to be published later, the patients were selected solely on the grounds of suspected cupping). 12 Patients were 60 years old or younger and 13 patients were older than 60. In 7 of the 25 patients both eyes were assessed. In all cases a general ophthalmological examination was carried out and in addition gonioscopy, examination of the lens in mydriasis and examination of the blood vessels, the disc and the retina in mydriasis. In all cases a diurnal I.O.P. curve without therapy was made.

RESULTS AND COMMENTS

The assessment of the visual fields was based on the results of the method of continued stimulation (Verduin-Greve). Seven visual fields had no defects,

Table 1. Comparison of 3 methods of visual field examination and the duration of the examination

		number of positions		duration of pure examination
		threshold	supra	
Armaly	15° area	0	76	6′ – 10′
M.S.S P.	22° area	50	100	5′ – 15′
A.H./V.G.	30° area	120	0	30′ – 45′

Armaly method time exclusive periphery.
A.H /V.G. method time only static perimetry.

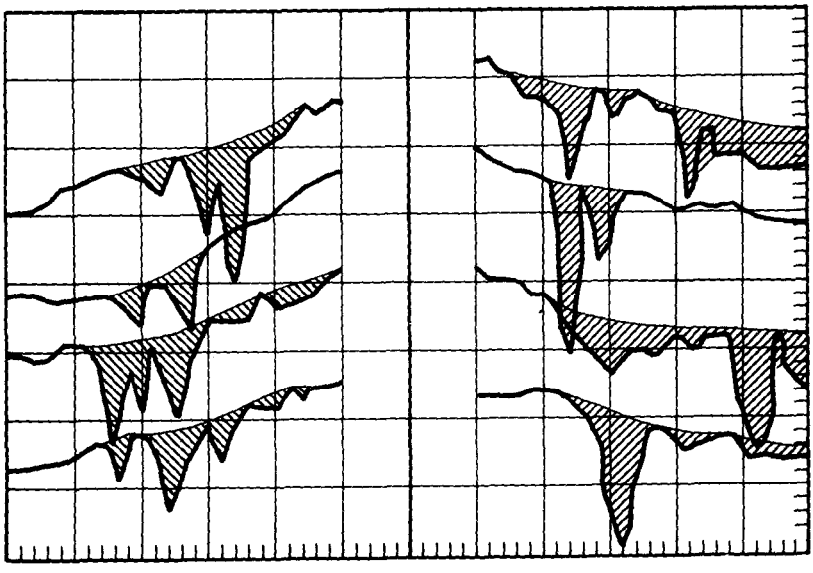

Fig. 5. Example of some of the w.s.d. found in this study

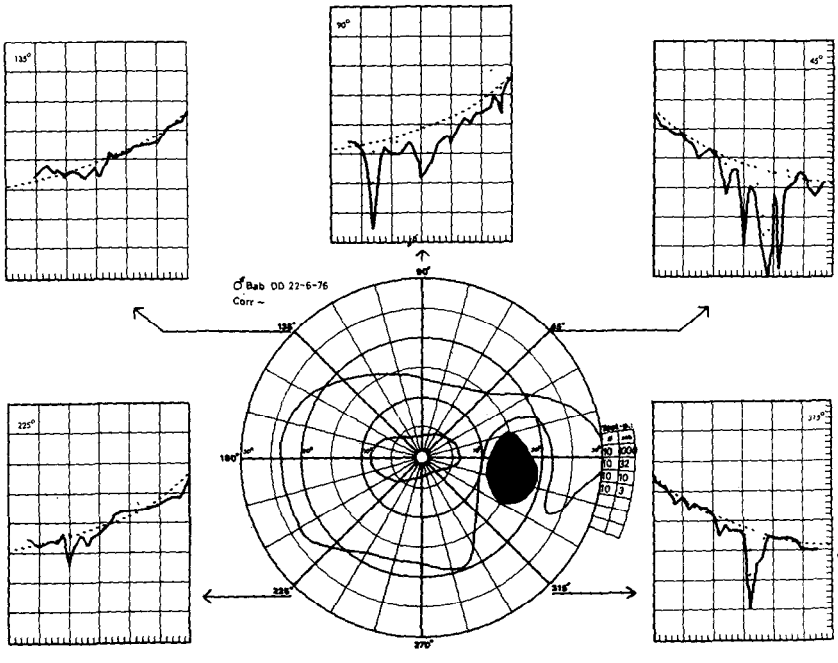

Fig. 6. Example of an early glaucomatous defect in a later stage than a W.S.D

eleven had a W.S.D. and fourteen had an early defect at a more advanced stage than a W S.D.

Fig. 5 shows a number of the W.S.D. found. In Fig. 6 an example is given of an early glaucomatous defect with an intensity of more than 1 log unit.

Kinetic perimetry

The results of kinetic perimetry are considered first. A defect was found by kinetic perimetry in only 8 of the 25 eyes in which either a W.S.D. or a larger early defect was present. In 17 cases (68%) the defect was missed. W.S.D. were not detected at all and the other defects were only indicated in just over half of the cases. This means that all former publications on the results of glaucoma study, in which only the usual kinetic perimetry was used, give an incorrect picture of the presence or absence of early glaucomatous defects. In particular, all publications on comparisons between the disc and the visual field, as charted by kinetic perimetry alone, have their limitations (see Part II).

It would be advisable for future studies, in which glaucomatous visual fields are assessed, that they should not be examined by means of kinetic perimetry alone. As a critical side-light we may add that, theoretically, kinetic perimetric can be performed much better, but the advantages of speed and easy operation are then often lost.

Static perimetry

The assessment of the 4 S.P. methods is divided into three parts. In the first place we wanted to know whether the detection method in question gave any indication of a certain defect. This was determined per half visual field.

The results of the first assessment are given in Table 2. The Aulhorn-

Table 2. The results of detection by Aulhorn-Harms (A H.) method, M S S.P with the Visual Field Analyzer, and Armaly method
In this evaluation each visual field half was interpreted separately and as an entity i.e whether the detection method indicated the presence of a defect in that visual field half.

	No. of	Aulhorn-Harms		M.S.S.P.		Armaly	
	VF – halfs	right-	wrong	right-	wrong	right-	wrong
Normal	27	27 (100%)	0	22 (82%)	5	23 (85%)	6
W.S.D.	19	18 (95%)	1	14 (74%)	5	9 (47%)	10
DEFECT	15	15 (100%)	0	13 (87%)	2	10 (67%)	5

Harms method revealed everything, with one exception. The M.S.S.P. and Armaly methods gave 18% and 15% false-positive results, respectively. Five of the 19 cases of W.S.D. (26%) were missed by M.S.S.P. and ten by the Armaly method (53%). Two of the 15 other defects (13%) were missed by M.S.S.P. and five (33%) by the Armaly method.

In the second place only those positions were compared where there was at least one measurement with all methods. This second method of assessment was chosen in order to exclude as far as possible the influence of the distribution of the stimuli and to concentrate on the method of measurement. Nevertheless this comparison always goes in favour of the Aulhorn-Harms and Verduin-Greve methods because these, as has already been pointed out, have more stimulus positions in a given area (usually 5x as many) and more measurements per position than the Armaly-Drance and M.S.S.P. methods. This gives an indication of how difficult it is to compare different methods of examination.

From Table 3 it can be seen that the 3 detection methods have only a few measurements in common in areas where there is a defect with an intensity of 1.0 log unit or more. This stresses again the fact that we are dealing with different methods. The Aulhorn-Harms method only shows false negatives (16 out of 56) in the W.S.D. group (0.5-0.9 log unit). This illustrates the greater sensitivity of continued stimulation. The M.S.S.P. and Armaly methods show a small percentage of false-positives (8% and 5% respectively).

The number of false negatives in this type of evaluation is very high for both the M.S.S.P. and the Armaly method (± 55% and 70%, respectively). It is also much higher than in the general evaluations (Table 2 and 4), as is to be expected because of the small number of measurements per area in the M.S.S.P. and Armaly methods as compared with the Aulhorn-Harms and Verduin-Greve methods. This illustrates the simple fact that an increase in

Table 3. Evaluation of detection sensitivity of Aulhorn-Harms method, M.S.S P. with the Visual Field Analyzer, and Armaly method In this evaluation only those areas were compared in which all 3 methods had at least one stimulus.

Intensity of defect	No. of measurements	Armaly-Harms		M S.S.P.		Armaly	
		right	wrong	right	wrong	right	wrong
Normal ≤ 0 4	384	384	0	353	31 (8%)	367	17 (5%)
0.5–0.9	56	40	16 (28%)	24	32 (57%)	16	40 (72%)
1.0–1.4	17	15	2 (12%)	8	9 (53%)	5	12 (71%)
≥ 1.5	8	8	0	5	3	5	3

the number of positions and the number of measurements increases the chance of detection of early defects.

In the third place the results have been evaluated again in a different way (Table 4). Now the only question was whether one of two detection methods (M.S.S.P. and Armaly) did indeed detect the most important defect. Other defects even when they were in the other visual field half were not included in the evaluation.

The clinical significance of this evaluation is that if a defect (and not all defects) has been detected the examiner will proceed in any case to the second phase of visual field examination. Using this type of evaluation both detection methods have not given any false-positive results. The M.S.S.P. missed only 1 out of 11 w.s.d. and the Armaly method 4 out of 11 W.S.D. In the Defect group the results are even better i.e. M.S.S.P. missed 1 out of 13 and Armaly 3 out of 11).

It is clear that the type of evaluation of the visual field is an important factor in the ultimate conclusions concerning the sensitivity of a detection method.

As noted in the introduction, when judging the results of a comparative investigation, one must realize the reasons why differences in sensitivity between detection methods occur. The differences found by us can be explained by:

1. the size of the defect;
2. the intensity of the defect;
3. the number and distribution of the positions examined;
4. the number of measurements per position; threshold, suprathreshold or continued stimulation;
5. the method of presentation (clockwise along a parallel, meridian, multiple stimulus);
6. the type of evaluation.

Intentionally, the only defects considered in this study are small defects or defects of slight intensity. The discovery of these defects is the result of a

Table 4.

		M.S.S P.		Armaly	
		right	wrong	right	wrong
NORMAL	7	7 (100%)	0	7 (100%)	0
W.S.D.	11	10 (91%)	1	7 (64%)	4
DEFECT	14	13 (93%)	1	11 (79%)	3

very sensitive but time-consuming method of examination. Rapid detection methods like M.S.S.P, and the Armaly-Drance method will miss a number of these early defects because various concessions are made to the speed of the examination. Perimetry can give a very sensitive measurement of early damage, but rapid perimetry results in loss of sensitivity.

If larger defects are included in a study of this sort the percentages of false-negative results will be much smaller. If the study is limited to complete fibre bundle defects (arcuate scotomata) the percentage of false-negative results with the M.S.S.P. and Armaly methods is practically zero. The final result of such a study therefore is dependent on the proportion of early (small) and advanced defects. We have found no account in the literature of a study in which only early defects were considered.

If the choice is to be made between the M.S.S.P. and the Armaly-Drance method, in our opinion the M.S.S.P. is to be preferred. The theoretical reasons have already been given in the introduction, the practical reasons follow from the results of this study. The high degree of detection sensitivity of the Aulhorn-Harms and Verduin-Greve methods is probably not a practical possibility for general ophthalmic practice because of the length of the examination time, it is, however, essential for a fundamental comparative study of the detection sensitivities of visual field examination and ophthalmoscopy.

SUMMARY

In this study the detection sensitivities of 5 methods of visual field examination are compared in 32 eyes from 25 patients with established or suspected glaucoma.

The methods were: kinetic perimetry, the Armaly-Drance method, multiple stimulus static perimetry (M.S.S.P.-Visual Field Analyzer with modified frontplate-), classical static perimetry – the Aulhorn-Harms method –, and static perimetry with continued stimulation (– as performed by Verduin and Greve –). The investigation only covered early visual field defects. In 7 cases there was no defect, in 11 cases there was a wedge-shaped defect (W.S.D.) and in 14 cases there was a slightly more advanced defect. A W.S.D. was defined as a defect with a minimum intensity of 0.5 log unit and a maximum intensity of 0.9 log unit. The other defects had an intensity of 1.0 log unit or more; none were complete fibre bundle defects.

The W.S.D. were not revealed by kinetic perimetry. Only 8 of the 14 other early defects were found.

It was shown that the appreciation of M.S S.P. and Armaly-method depended very much upon the type of evaluation. If only the question was asked whether *a* defect was found and not *all* defects, there were no false-positive results. The M.S.S.P. gave false-negative results in 9% of W.S.D. and 7% of other early defects. The Armaly method gave 36% false-negative results in W.S.D. and 21% in other early defects.

However, the percentages of false-negative results were much higher if a careful comparison was made concerning all defects present. Classical static perimetry only gave poorer results than the method of continued stimulation in the W.S.D. group (as was to be expected).

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DETECTION OF EARLY GLAUCOMATOUS DAMAGE
PART II. CUPPING AND VISUAL FIELD

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In the first part of the description of our investigation into the detection of early glaucomatous damage, various methods of visual field examination were considered. In this second part the glaucomatous changes in the optic disc will be considered and compared with the results of visual field examination.

At the present time the prevention of glaucomatous damage occupies a position of steadily increasing importance. When deciding whether a patient with raised I.O.P. should be treated or not, the presence of glaucomatous damage is an important factor. It therefore seems well-advised to concentrate on the early signs of glaucomatous damage.

It is generally accepted that the correlation between glaucomatous cupping and visual field defects is good. If no glaucomatous cupping is seen a visual field defect is thought to be unlikely and vice versa. Studies on the relationship between glaucomatous visual field defects and pathological cupping are numerous (Armaly, 1969a, Armaly, 1969b; Aulhorn & Harms, 1960, Douglas & Drance, 1974; Drance, 1974; Hitching & Spaeth, 1976; Kirsch & Anderson, 1973, Lavergne & Joachim, 1967, Shutt & Boyd, 1967). These studies include all stages of glaucomatous damage. It then appears that the correlation between visual field defects and pathological cupping is good in 70-85% of cases. However, we know of no studies in which early visual field defects are compared with early glaucomatous damage.

The correlation between glaucomatous cupping and glaucomatous visual field defects is dependent on the *method of examination* and the *criteria* for the existence of early damage In the first part of this paper the criteria for early glaucomatous visual field defects were discussed.

For the assessment of the optic disc we used direct and indirect ophthalmoscopy (mono) and stereo-biomicroscopy using a contact lens. The state of the optic disc was recorded by means of a drawing and stereo-photography The excavation was assessed by one of us (ELG) using the contact lens.

In addition to the first observer (ELG) the stereo-photographs were assessed by two independent, experienced observers, who knew nothing about the visual field defects or any other particulars about the patients; they only studied the stereo-photographs. The best picture of the optic disc, as was to be expected, was obtained by means of biomicroscopy.

CRITERIA FOR EARLY GLAUCOMATOUS CUPPING

Important factors in the assessment of glaucomatous cupping were (Armaly, 1969, Fishman, 1970; Hitching & Spaeth, 1976; Kirsch & Anderson, 1973; Schwartz, 1973, Snydacker, 1964; Tomlinson, 1969; Witusik, 1966):

1. The form of the rim tissue. temporal unfolding as indicated by a sharpened rim with bayonetting of the vessels; saucerization; local signs such as notching and laminar dot; vertical ovalness as such is a dubious sign.
2. The colour of the rim tissue.

Asymetry of the cups in the two eyes of one patient is suspicious but does not necessarily indicate the presence of a visual field defect. The same is true for the cup-disc ratio and nasal displacement of the blood vessels. A large cup-disc ratio is suspect and a reason for examining the edge of the cup carefully; but a large cup-disc ratio was not in itself considered an indication of damage. It is well known that large physiological cups regularly occur.

PATIENTS

The group of 25 patients (32 eyes) was described in the first part. The horizontal cup/disc ratios were: 2 c/d ratios of 0.1-0.3; 9 c/d ratios of 0.4-0.5; 14 c/d ratios of 0.6-0.7; 7 c/d ratios of 0.8. There were no excavations up to the edge of the disc.

RESULTS

Horizontal C/D ratio and visual field

The distribution of the C/D ratios over the various types of visual field is shown in Table 1.

From this table no conclusions can be drawn about the reliability of the C/D ratio as an indicator of visual field defects. The majority of the cases were selected on the basis of the presence of defects. If patients are selected

Table 1. Distribution of the C/D ratios over the various types of visual field. (M = myopic)

C/D	total	N	WSD	DEF
0.1 – 0.3	2	1	0	1 (M)
0.4 – 0.5	9	3	3	3
0.6 – 0.7	14	2	7	5
0.8	7	1	1	5
	32	7	11	14

on the basis of the C/D ratio alone no visual field defects will be found in a large number of cases. On the other hand it appears that early defects can occur in association with all C/D ratios and that in the same group of C/D ratios both normal visual fields and defects are found.

Suspected pathological cupping and visual fields

The relationship between the assessment of the excavation and the visual field is given in Table 2.

In the normal visual fields (there were only 7) a defect was expected on the basis of the condition of the disc in a few cases. This is in agreement with accounts in the literature (Drance 1974). The W.S.D. were predicted in about 40% (19 of the 44 assessments). The other early defects were predicted in an average of 52% of the cases (29 of the 56 assessments), with extremes of 36% (5/14) and 70% (10/14).

Table 2 also shows the differences in interpretation between different observers. Compare observers 3 and 4, for instance There are also differences in the assessments made by the same observer (1 and 2) at different times and using different methods (1· contact glass and drawing, 2 stereophotographs).

In view of the lapse of time between the two assessments and the possibility of a slight alteration in the interpretation of the disc, no opinion can be given, based on these data (columns 1 and 2), on the comparative accuracy of the assessment by means of a contact glass or using stereo-photographs.

In any case the image of the disc obtained with the contact lens is much clearer than the stereo-photographs. The photographs have the advantage that they are permanent and can be assessed by more than one person.

The figures given above refer to the correlation between the excavation and visual field defects found by the method of continued stimulation (Verduin-Greve). A completely different result is obtained when the excavation is compared with the results of the Armaly method (Table 3, ob-

Table 2 The relationship between the assessment of the excavation and the visual field as found by the method of continued stimulation For instance, 7/11 means that in 7 cases out of 11 WSD a defect was predicted

	EXAMINATOR					
	1	2	3	4	TOTAL	%
NORMAL	0/7	2/7	2/7	1/7	5/28	18
W.S.D	4/11	7/11	3/11	5/11	19/44	43
DEFECT	5/14	8/14	6/14	10/14	29/56	52

server ELG, stereo-photographs). The correlation with suspected pathological cupping is now much better (8/11, 73%). As far as W.S.D. are concerned the correlation is about the same for both methods, although better for the Armaly method if this is compared with the average of the 4 assessments (43%, Table 2). The results of this better correlation with defects is naturally that the number of wrong assessments in the group if normal visual fields increases (5/14 positively assessed, 36%).

COMMENT

The importance of the routine assessment of the optic disc in ophthalmological practice lies chiefly in the detection of glaucomatous damage.

Each assessment concerns an individual case. Has the patient a pathological cup or not? In practice it is essential to know how reliable disc assessment is and when this assessment must be followed by a visual field examination. The initial assumption is that a normal excavation (e.g. cup/disc 0.2) becomes slowly larger under the influence of raised I.O.P. At the stage when the C/D is 0.6, for example, it is assumed that visual field defects have not yet appeared if the rim of the cup is normal. After this the so-called temporal unfolding occurs, which gives rise to visual field defects, especially if the poles of the disc are involved (Read & Spaeth, 1974).

This hypothesis about the development does not provide a rule of thumb for the detection of early glaucomatous damage. The only significance of the C/D ratio is its relationship to the chance of a visual field defect. A low C/D ratio means that the chance that a visual field defect is present is slight, but not that it is zero; a large C/D ratio corresponds to a larger chance but gives no certainty. Visual field defects are found associated with C/D ratios of 0.3 and 0.4 With a C/D ratio of 0.7 or 0.8 visual field defects need not necessarily be present. Selection by means of the C/D ratio is thus not sufficient, as Armaly (1969) has already stated. The assessment of the C/D ratio is a first step a large cup arouses suspicion and is a reason for examining the rim of the cup with extra care.

Table 3 The relationship between the assessment of the excavation and the visual field as found by the Armaly-method and the method of continued stimulation. Percentages between brackets For instance, out of 14 normal visual fields (Armaly-method) 5 i.e 36% had a suspicious disc

	Armaly		Cont Stim	
	VF	disc	VF	disc
NORMAL	14	5 (36)	7	2 (29)
W.S D	7	4 (57)	11	7 (64)
DEFECT	11	8 (73)	14	8 (57)

What other criteria must be considered in the assessment?

A visual field defect probably arises when the rim tissue is gradually destroyed. Either a wide or a narrow rim can be affected, depending on the pre-existing disc features. The assessment of the rim is of primary importance. It is important whether the rim is still round and the colour good, or whether there are small local defects or more generalized lesions in the rim.

These lesions in the rim tissue are more often seen associated with medium and large C/D ratios than with small ones. Problems in assessing the rim usually occur in the medium group, i.e. C/D ratios from 0.4-0.7. In this group the ability to predict early visual field defects appears to be limited (43% for W.S.D., 52% for other early defects). *The assessment of the disc in this group of early defects is characterized by uncertainty*

The correlation between excavation and visual field defect is clearly dependent upon the examination method used. When a sensitive method of visual field examination is used the ability to predict visual field defects on the basis of the excavation is seen to be much lower than when one of the more usual detection methods is used.

The various observers came repeatedly to different conclusions. The true value of the assessment of the disc in the individual case lies in the suspicion aroused. Every suspect disc should be followed up by means of a visual field examination. On the basis of the assessment of the disc it is not possible to exclude the existence of a visual field defect with certainty (see also Armaly, 1969), not even when the criteria given by Spaeth are used. In addition, it is well known that the assessment of the disc in the presence of cataract, a narrow pupil and myopia is difficult.

When we compare the assessment of the disc with the assessment of the visual field it appears that the visual field gives more certainty than the disc for the management of the patient.

A W.S.D. gives grounds for suspicion. A series of W.S.D. in the course of the fibre bundles is even more suspicious. A defect of more than 1.0 log unit in the course of the fibre bundles raises no problems of interpretation. We had far fewer problems with the interpretation of the visual field examination than with the interpretation of the anomalies of the disc. We also think that it is simpler for everyone who is conversant with visual field examination to base his conclusions on the visual field examination than on the assessment of the excavation. The function of the assessment of the disc is in our opinion to reveal cases in which visual field examination is necessary and that were not picked up by routine I.O.P. measurements.

It is very important that the assessment of the disc should not be overemphasized by glaucoma experts. The impression can easily be given that the practising ophthalmologist can rely upon disc assessment instead of visual field examination.

It should be stressed that.

a) When the I.O.P is raised visual field examination must always be performed (comparison with the excavation gives important information),

b) When the I.O.P. is not raised and a suspicious excavation is seen, visual field examination must always be performed, because the presence of a visual field defect cannot be excluded by disc assessment.

SUMMARY

The correlation between assessment of the excavation and early visual field defects is not as good as in more advanced visual field defects.

The correlation depends on the method of visual field examination. In the individual case it is difficult to reliably predict the pressence of an early visual field defect from the assessment of the excavation. The results of visual field examination are easier to interprete than the assessment of the excavation in cases with early damage.

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TOPOGRAPHICAL STUDIES OF FIELD DEFECTS IN VARIOUS STAGES OF PRIMARY CHRONIC GLAUCOMA

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Field defects in primary chronic glaucomas are characterized by arcuate scotomas in the Bjerrum area, nasal step, persistent retention of the central field and a small temporal island of vision. However, no topographical studies have been made of the glaucoma field defects based on the stages of glaucoma.

A NEW CLASSIFICATION OF STAGES OF PRIMARY CHRONIC GLAUCOMAS

We studied the visual fields of 266 eyes of 137 patients with chronic glaucomas of various types using a Goldmann perimeter, and we classified the stages of chronic glaucomas based on the visual field loss as follows:

Stage 1: The earliest stage of glaucoma without any field changes by kinetic Goldmann perimetry (Fig. 1).

I-a: Normal field.

I-b: Abnormal field detected only when more precise method is used.

Stage, II· The early stage of glaucoma with abnormal field for isopters I-4, I-3, I-2 and I-1, but without abnormalities for an isopter V-4 (Fig. 1).

II-a: Normal for an isopter I-4, but abnormal for isopters I-3, I-2 and I-1.

II-b: Abnormal for all I isopters.

Stage III: The middle stage of glaucoma, with abnormal field for an isopter V-4, but with field loss not exceeding a half of the normal field for V-4 target (We called it V-4 field) (Fig. 2).

III-a: Field loss or contraction is not exceeding a quarter of V-4 field.

III-b: Field loss is more than a quarter but less than a half of V-4 field.

Stage IV The late stage of glaucoma, with field loss exceeding a half of V-4 field but with preserved macular field (markedly contracted field) (Fig. 2).

IV-a: Field loss exceeds a half of V-4 field with preserved macular field.

IV-b Macular field only is preserved.

Stage V: The very late stage of glaucoma without macular field but with preserved field outside the macular field (Fig. 2).

Stage VI The end stage of glaucoma with loss of V-4 field.

Analyses were also made of relationships between C/D ratio, vision, critical fusion frequency in a central field and modes of therapy and the above

mentioned stages of glaucoma in a different group consisting of 263 eyes of 135 cases with primary chronic glaucomas.

It seemed reasonable to assume that the stages of glaucoma based on our classification of field defects were in good agreement with the deterioration of the above parameters or modes of therapy.

TOPOGRAPHICAL STUDIES OF FIELD DEFECTS IN VARIOUS STAGES OF PRIMARY CHRONIC GLAUCOMA

We studied the topographical field defects in 658 eyes of 399 cases with primary chronic glaucomas consisting of 191 male cases and 208 female

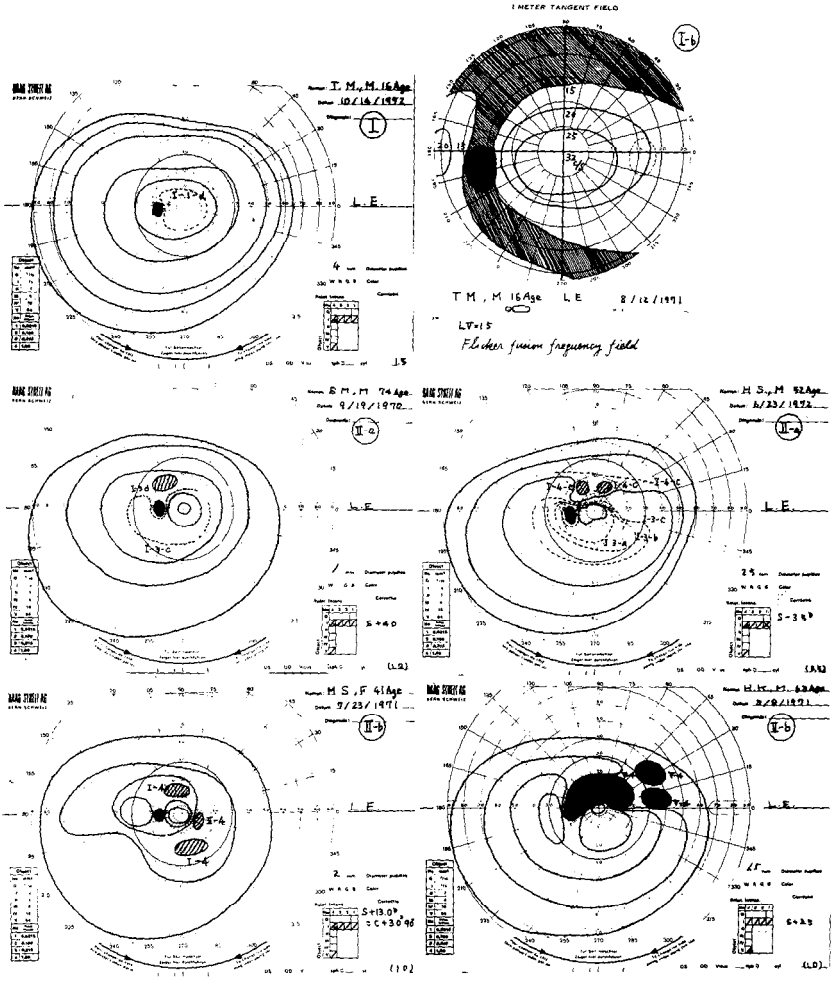


Fig. 1 Kosaki's classification of stages in chronic glaucoma

cases. Age distribution is shown in Table 1. Five isopters V-4, I-4, I-3, I-2, I-1 were routinely determined on all cases and contraction of isopters exceeding 10 degrees on each meridian in comparison with the average normal isopters of Dr. Furuse was assumed to be abnormal and was subject to statistical analyses. All data of the left eye were expressed as field changes of the right eye. Statistical analyses were made of incidence of abnormal field for all five isopters in all stages of glaucoma.

Figures show incidence of abnormal contraction of isopters in various stages of glaucomas. The abscissae is the direction of each meridian and the ordinate is incidence of abnormal contraction of isopters.

In 163 eyes of stage II-a, as shown in Fig. 3, I-2 isopter shows the highest incidence of abnormal contraction in the 30° meridian (that is temporo-superior area) in 75% of the cases. V-4 and I-4 isopters are normal at this stage.

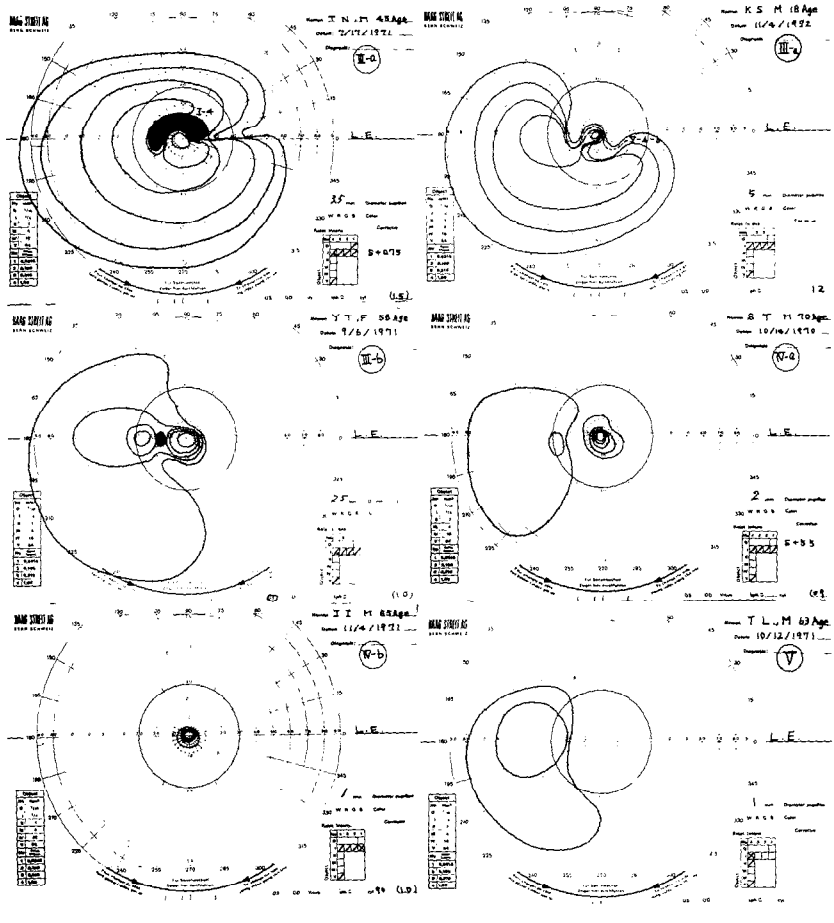


Fig. 2 Kosaki's classification of stages in chronic glaucoma.

In 108 eyes of stage II-b, as shown in Fig. 4, contraction of I-3 isopter of 180° meridian (i.e. nasal field) was observed in 84% of the cases. V-4 isopter is normal at this stage.

In 104 eyes of stage III-a, in which V-4 isopter shows abnormal contraction, as shown in Fig. 5, contraction of isopters is observed in the nasal field parallel with the progression of the stages of glaucoma.

In 121 eyes of stage III-b, in which the field loss is more than a quarter, as shown in Fig. 6, contraction of isopters is more pronounced in the nasal-upper quadrant than in any other quadrant.

When viewed from the standpoint of isopters, the highest incidence of glaucoma field defects were found, as shown in Figs. 7 and 8, in the temporosuperior area (30°-60°) of I-2 field at the stage of II-a and the highest incidence of contraction of field was found in the nasal area (135°-195°) of I-2 field and in the nasal area (165°-195°) of I-3 field at the stage of II-b. As shown in Figs. 9 and 10, the highest incidence of contraction was observed in the nasal area (165°-195°) of I-4 field at the stage of III-a, and in the nasal area (150°-180°) of V-4 field at the stage of III-b. The temporoinferior field (330°-15°) was found to remain in the highest percentage of the cases studied at the latest stage (Stage V).

Table 1

399 Cases (M-191, F-208) —— 658 Eyes (R-338, L-320)

Age	Cases
< 10	3
11 - 20	18
21 - 30	27
31 - 40	29
41 - 50	55
51 - 60	80
61 - 70	117
71 - 80	61
81 <	9

Open Angle	476
Closed Angle	182
KOSAKI'S STAGE	
Ia	0
Ib	32
IIa	163
IIb	108
IIIa	104
IIIb	121
IVa	89
IVb	16
V	25
VI	0

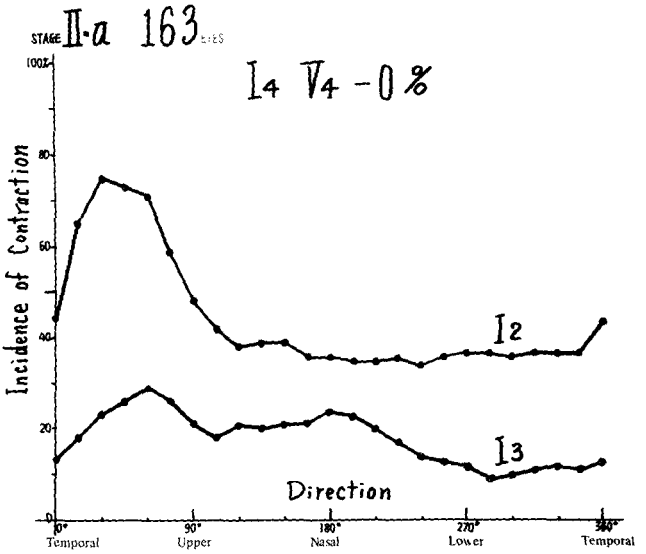

STAGE II-a 163 EYES
I4 V4 - 0 %
Incidence of Contraction
100%
80
60
40
20
0
I2
I3
Direction
0°
Temporal
90°
Upper
180°
Nasal
270°
Lower
360°
Temporal

Fig. 3

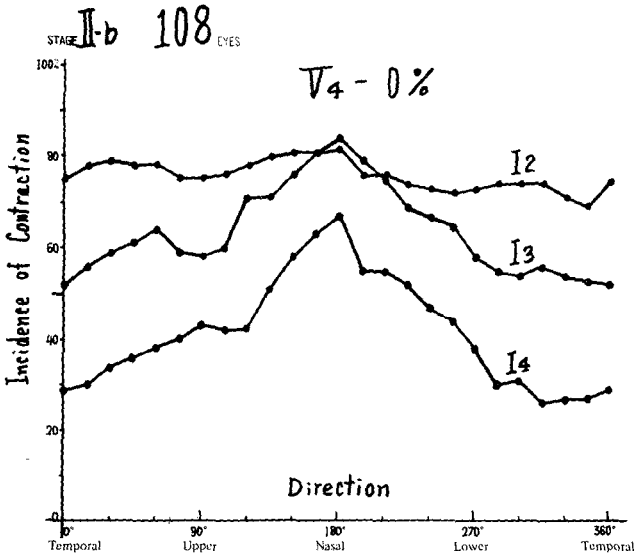

STAGE II-b 108 EYES
V4 - 0 %
Incidence of Contraction
100%
80
60
40
20
0
I2
I3
I4
Direction
0°
Temporal
90°
Upper
180°
Nasal
270°
Lower
360°
Temporal

Fig 4.

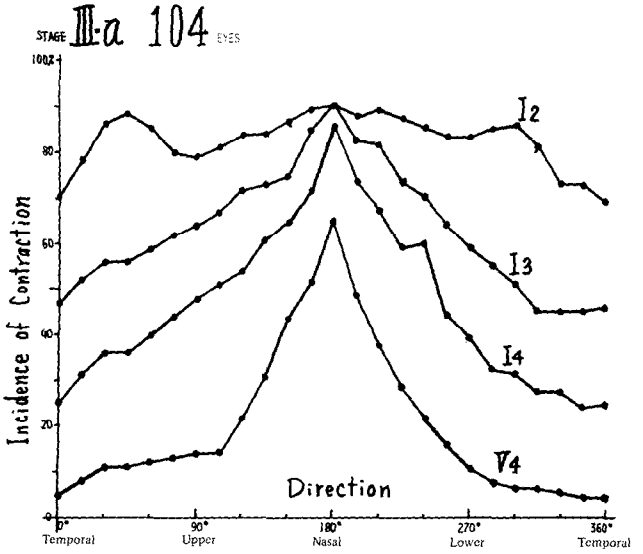

STAGE Ⅲ-a 104 EYES
100%
80
60
40
20
0
Incidence of Contraction
I2
I3
I4
V4
Direction
0°
Temporal
90°
Upper
180°
Nasal
270°
Lower
360°
Temporal

Fig. 5.

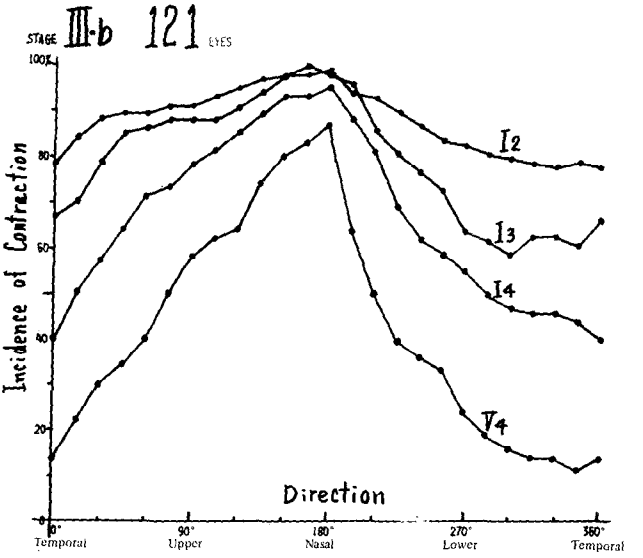

STAGE Ⅲ-b 121 EYES
100%
80
60
40
20
0
Incidence of Contraction
I2
I3
I4
V4
Direction
0°
Temporal
90°
Upper
180°
Nasal
270°
Lower
360°
Temporal

Fig. 6.

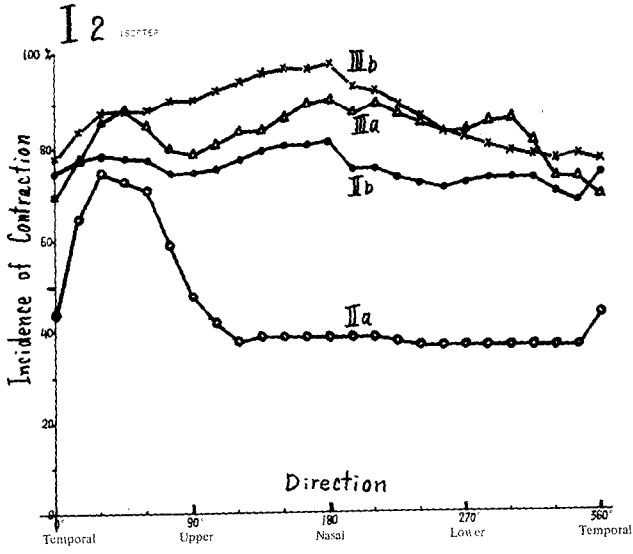
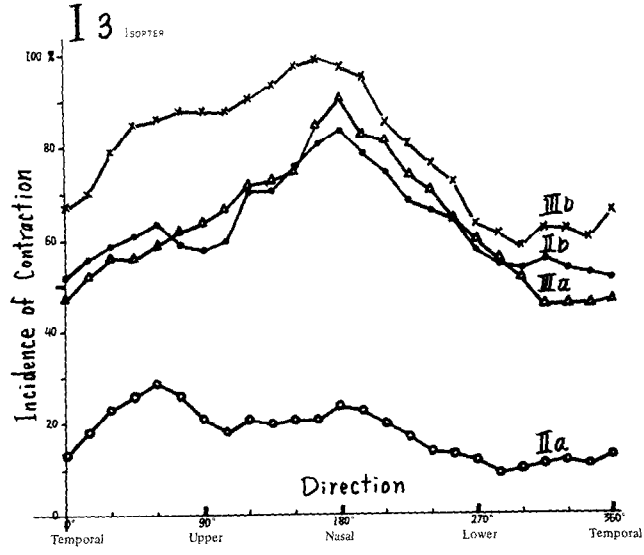

I 2
ISOPTER
100 %
80
60
40
20
0
Incidence of Contraction
IIIb
IIIa
IIb
IIa
Direction
0°
Temporal
90°
Upper
180°
Nasal
270°
Lower
360°
Temporal

Fig. 7.


I 3
ISOPTER
100 %
80
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40
20
0
Incidence of Contraction
IIIb
IIb
IIIa
IIa
Direction
0°
Temporal
90°
Upper
180°
Nasal
270°
Lower
360°
Temporal

Fig. 8

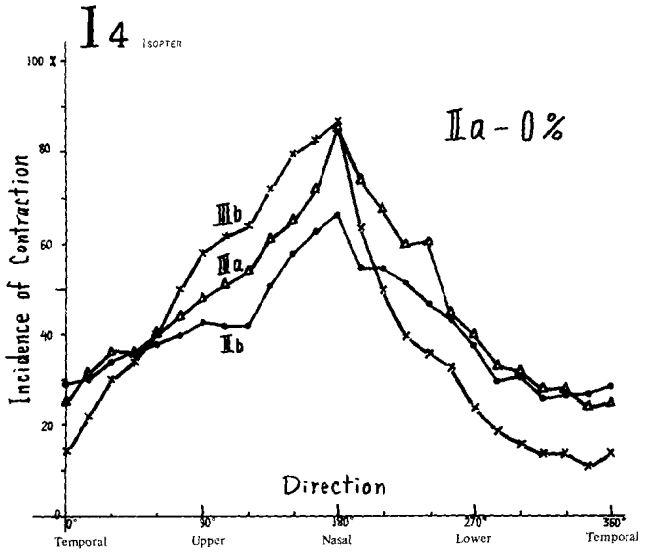
I 4 ISOPTER
100 %
80
60
40
20
0
Incidence of Contraction
IIa - 0 %
IIb
IIa
Ib
Direction
0°
Temporal
90°
Upper
180°
Nasal
270°
Lower
360°
Temporal

Fig. 9.

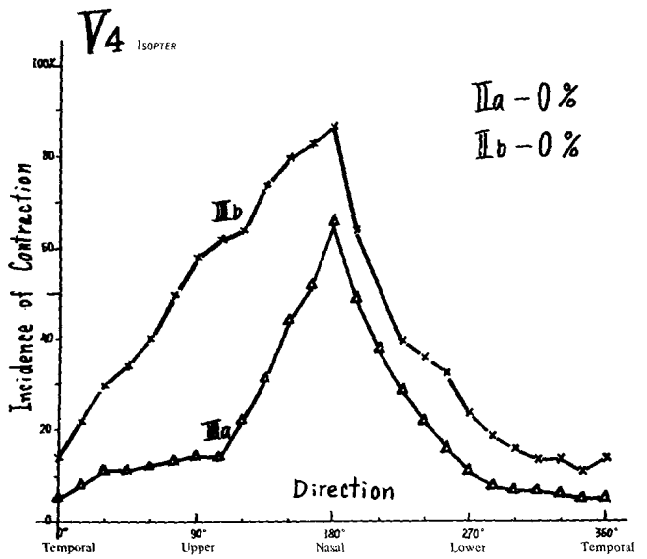
V4 ISOPTER
100%
80
50
40
20
0
Incidence of Contraction
IIa - 0 %
IIb - 0 %
IIb
IIa
Direction
0°
Temporal
90°
Upper
180°
Nasal
270°
Lower
360°
Temporal

Fig. 10.

CONCLUSION

It is thus concluded that the initial field change is observed in the temporo-superior area of I-2 field, followed by the contraction of I-3 and I-4 field in the nasal area, and then by the contraction of V-4 field in the nasal and naso-superior area, and that the temporo-inferior field remains until the very late stage.

SUMMARY

Field defects in primary chronic glaucomas are characterized by arcurate scotomas in the Bjerrum area, nasal step, persistent retention of the central field and a small temporal island of vision. However, no topographical studies have been made of the glaucoma field defects based on the stages of glaucoma.

Field defects were studied topographically in 658 eyes of 399 cases with primary chronic glaucomas using a Goldmann perimeter and classified according to Kosaki's classification of stages of glaucomas using perimetric data.

Highest incidence of glaucoma field defects were found in the following areas of the visual field: (1) temporosuperior area (30°-60°) of 1-2 field at the stage of IIa, (2) nasal area (135°-195°) of I-2 field and nasal area (165°-195°) of I-3 field at the stage of IIb, (3) nasal area (165°-195°) of I-4 field at the stage of IIIa, (4) nasal area (150°-180°) of V-4 field at the stage of IIIb. The temporal field (330°-15°) was found to remain in the highest percentage of the cases studied at the latest stage (stage V).

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PERIPHERAL NASAL FIELD DEFECTS

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The relative value of peripheral nasal field defects in assessing visual field loss in chronic open angle glaucoma, has varied considerably over the past one hundred years. Von Graefe & Bjerrum (1890) emphasized central field examination, whereas Rønne (1909) demonstrated unequivocally that well demarcated peripheral nasal field defects occur. Traquair (1931, 1940), Dubois-Poulsen (1952), Harrington (1964), and others, in widely read and quoted textbooks, paid little attention to the defect which was so well defined by Rønne.

The very meticulous central visual field studies reported by Aulhorn & Harms (1967), Armaly (1972), Drance (1969), and others, have further relegated the value of the nasal field defect to a secondary role. As a consequence of these publications, which reflect very sophisticated perimetric studies, many clinicians, using less sensitive techniques and equipment, have tended to ignore peripheral field areas when testing for glaucoma.

The purpose of this study was to assess the value of peripheral nasal field defects in glaucoma patients. A previously reported study (1971) had led us to believe in its important role as a marker of glaucoma damage.

MATERIAL AND METHODS

Selection of patients

Sixty four (64) consecutive patients with chronic open angle glaucoma and documented visual field loss, seen in consultation by the author, were selected for this study.

Methods

All patients had a complete ophthalmic examination which included medical, family and ocular history; visual acuity, refraction; tonometry; gonioscopy; ophthalmoscopy; contact lens examination of the optic nerve head; skull x-ray; medical assessment.

Perimetry was carried out using the Armaly screening procedure (as modified by Drance). All defects were confirmed with kinetic and static perimetry on the Goldmann perimeter.

RESULTS

In the 64 consecutive patients with glaucoma, there were 115 eyes with characteristic glaucomatous field loss. Of these eyes, 36 showed advanced field loss and were excluded from further consideration in this study.

In the seventy-nine (79) eyes with early field loss, 25 eyes (31.6%) showed the presence of a well defined peripheral nasal step (Table 1). Of these, 10 eyes (12.6%) demonstrated only the step defect with no evidence of a central defect.

DISCUSSION

Using a visual field testing technique which has been shown to have a high degree of sensitivity and specificity for glaucomatous field defects, this study shows a significant prevalence of peripheral nasal steps. This in in keeping with prior studies as reported by Aulhorn & Harms, Armaly, LeBlanc.

However, despite the sensitive testing of the central visual field which is part of this study, 12.6% of eyes FAILED to show changes in the central field while demonstrating a well marked peripheral nasal step defect. Using a comparably sensitive technique, the clinician would falsely diagnose as normal the visual field in 1 out of 8 eyes examined if he failed to explore the peripheral field area.

It appears to this observer that in those cases where the isolated step is the only field defect, the intra-ocular pressure may also prove to be an elusive marker for glaucoma. Furthermore, in a study (1975) correlating disc evaluation and field loss. Drance (1975) showed that those patients with isolated nasal field defects were the most likely to be called normal (therefore false negative) on disc evaluation.

CONCLUSION

In practical terms, this study reiterates the value of detecting peripheral nasal field defects in the assessment of the glaucoma patient. Clinicians can be guided as follows:

a) when using a well controlled sensitive technique to search the central visual field (i.e. Armaly-Drance modified Screener), the nasal step area assessment will detect 1 in 8 cases of glaucoma and therefore is of very significant diagnostic value;

b) when using less sophisticated and sensitive methods of screening the

Table 1. The occurrence of a nasal step in 79 eyes with early field loss

Early field loss	79 eyes	
Nasal step present	25 eyes	31.6%
Isolated nasal step	10 eyes	12.6%

central field (as many clinicians do), the peripheral nasal field area becomes even more important to screen and increases considerably the yield of field testing,

c) when using VERY VERY SENSITIVE techniques to search the central visual field (i.e. Tubinger perimetry, kinetic and static) the finding of a peripheral nasal step adds very little to the diagnostic value of the test.

SUMMARY

Sixty-four (64) consecutive patients with chronic open angle glaucoma presented characteristic early visual field loss in 79 eyes. Of these, 10 eyes (12.6%) showed an isolated peripheral nasal step as the only defect.

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MOIRÉ TOPOGRAPHIC METHOD FOR MEASURING THE DEPTH OF PAPILLARY EXCAVATION

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(Osaka, Japan)

INTRODUCTION

Although the quantitative evaluation of the papillary excavation with glaucomatous visual field has been studied intensively, there is no appropriate way of measuring the depth of the papillary excavation clinically. In some clinics, stereo pictures and other methods are used, but these methods are too complicated to apply in routine examination.

On the other hand, the moiré method recently developed (1970) by Takasaki is a new, simple technique for taking three dimensional measurements. In this technique, the three dimensional coordinate values x, y and z are obtained on the photograph and the volume and surface area can be calculated accurately. We developed an apparatus based on this principle and applied it to measure the depth of papillary excavation.

METHOD

The depth measurement of papillary excavation is made by the moiré patterns originated from superposed images of two gratings (Fig. 1). Arrows show the direction of the grating image projection. Crossed points of the two grating images on a curved surface form the higher contrast. The optical system of the apparatus is shown in Fig. 2. S_1 and S_2 are light sources, G_1 and G_2 are gratings, L_1 and L_2 are collimating lenses, P is a parallel plate to give the movement of image of G_1 and E is test eye. Contrast of grating images is observed through lens L_3. In order to make the images of gratings and the discrimination of moiré fringes from fine structures of papillary surface, an adding type moiré system is employed and the grating constant is selected to 400 μ. To avoid the decrease of sensitivity caused by the larger grating constant, the superposed position of two grating images is varied stepwisely by parallel plate rotation. One pitch movement of the grating images is made by six division rotations of parallel plate dials and this movement corresponds to 800 μ depth difference. Therefore, one division of the dial gauge corresponds to 130 μ depth difference.

In clinical use, the grating images are formed on the photo-cathode of an ITV-camera after direct observation of the grating images on the papillary and retinal surface. After that, seven pictures of ITV-images corresponding to each division movement (from -3 to $+3$) of the parallel plate dial gauge are taken successively.

RESULT OF CLINICAL USE

1) Normal eyes (Eyes with normal papilla ophthalmoscopically and normal visual field according to Goldmann isopter perimetry)

Case 1. 74 years, male. Superposed grating images on the papillary and retinal surface are shown in Fig. 3. The maximum contrast point of the superposed grating images is the picture −1. This is the reading of the parallel plate dial gauge. Therefore, the papillary and retinal surfaces are on the same plane.

Case 2. 46 years, male. Fig. 4 shows superposed grating images on the papillary and retinal surfaces. The maximum contrast point of superposed grating images is −1. The level difference between peripheral surface of

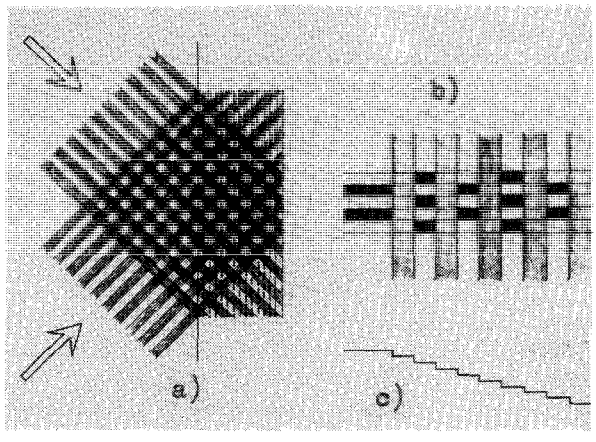

Fig. 1. Moiré fringes on concave surface. a) Arrows show the direction of the grating image projection. b) Moiré fringes observed on concave surface c) Concave surface

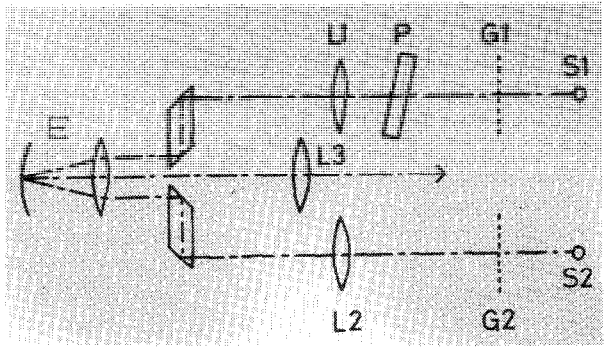

Fig 2. Optical system of apparatus.

papilla and retinal surface cannot be found. On the central area of the papilla, however, the maximum contrast of grating images can be found at point 0. Therefore, there is about 130 μ excavation limited in the central area of this papilla.

2) Glaucomatous eyes (Eyes with disc pallor ophthalmoscopically and glaucomatous visual field defect according to Goldman isopter perimetry)

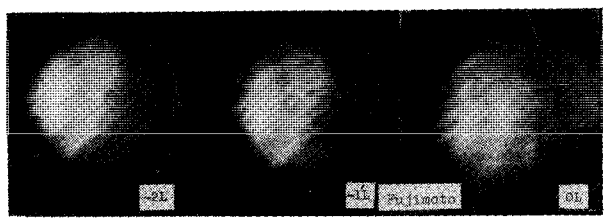

Fig. 3. Superposed grating images on the retinal and papillary surface of case 1 (normal left eye).

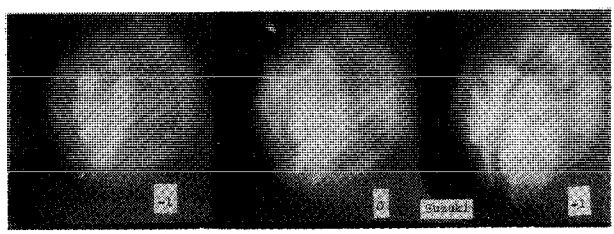

Fig 4 Superposed grating images on the retinal and papillary surface of case 2 (normal left eye)

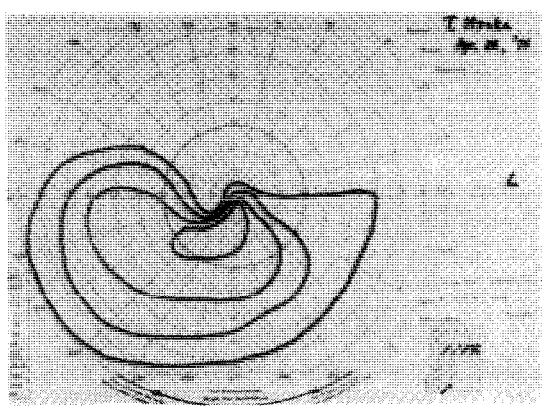

Fig 5 Visual field of case 3.

Case 3. 53 years, male. This case has been observed in our clinic for about ten years. Fig. 5 shows the left visual field and Fig. 6 shows superposed grating images on the papillary and retinal surfaces. The maximum contrast point of superposed grating images on the papillary surface is picture +2 and that of retinal surface is picture 0. Therefore, the level difference is about 260 μ. On the peripheral area of papilla, however, the maximum contrast images is at picture 0. Therefore, the excavation area with 260 μ is in the central greater area of the papilla.

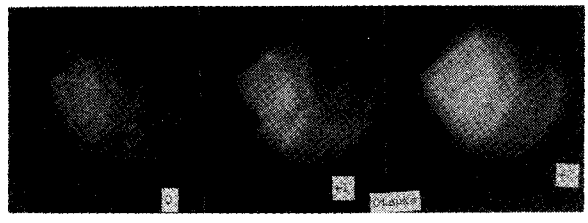

Fig. 6. Superposed grating images on the retinal and papillary surface of case 3 (glaucomatous left eye).

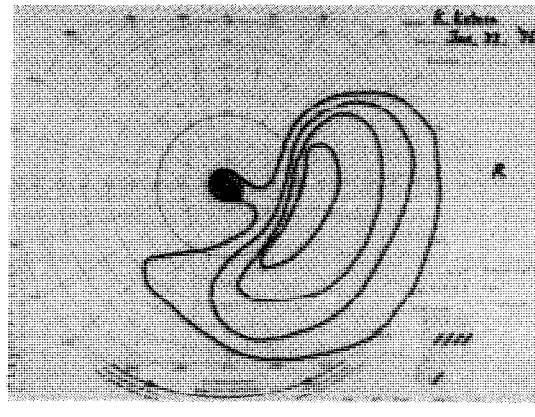

Fig. 7 Visual field of case 4.

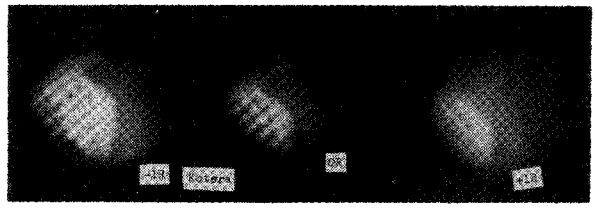

Fig 8. Superposed grating images on the retinal and papillary surface of case 4 (glaucomatous right eye).

Case 4. 40 years, female. This case has also been observed in our clinic for about ten years. Fig. 7 shows the right visual field and Fig. 8 illustrates the superposed grating images on the papillary and retinal surfaces. The maximum contrast point is picture 0 on both the papillary and retinal surfaces. But the phase of grating images on the papillary and retinal surfaces is inverted, i.e., the white lines on the retinal surface invert the black lines on the papillary surface and the black lines on the retinal surface invert the white lines on the papillary surface. Therefore, the level difference between papillary and retinal surface is estimated at about 800 μ. The left eye findings of this case are equal to the right eye findings.

COMMENTS

The apparatus

In this work, it is pointed out as a defect that the observed grating images are not too clear and that the sensitivity of this apparatus is not too high (about 130 μ). We are trying to use a more sensitive ITV-system to obtain clearer images and a smaller grating constant to increase the sensitivity of depth measurement.

Clinical results

In normal eyes, the level difference between the papillary and retinal surfaces is 130 μ or less at the most. In eyes with progressed glaucomatous visual field defects, oberserved for ten years in our clinic, the level difference between the papillary and retinal surfaces is 260 μ or more and in case 4 it is about 800 μ. We intend to measure the depths of papillary excavation of many cases with the improved apparatus and to investigate the correlation between the optic cup topography and visual field defect of glaucoma.

SUMMARY

An apparatus to measure the depth of papillary excavation, clinically based on the principle of moiré topography, has been developed. The depths of papillae with normal and glaucomatous visual field can be measured by this apparatus.

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LONG TERM STUDY OF VISUAL CAPABILITY IN RELATION TO INTRA-OCULAR PRESSURE IN CHRONIC OPEN ANGLE GLAUCOMA
First results and perspectives

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The aim of this study was to determine a reliable control index related to the effectiveness of medical treatment on functional data among glaucomatous subjects. The difficulties were found in the great number of measures to be performed on each subject, and in summarizing the overall information contained in successive examinations.

MATERIAL AND METHODS

Population

The present study includes 87 patients (159 eyes) with chronic open angle glaucoma, 19 of them having pigmentary glaucoma or myopia. All but two of the eyes studied had visual field defects in static perimetry (Friedmann) at the first examination. Subjects with aphakic glaucoma, dense cataract or psychosocial conditions incompatible with long term follow-up were previously excluded.

Planning of survey

The subjects were followed-up twice a year in an out-patient department and submitted to medical treatment in order to keep their intra-ocular pressure in the normal range.

Each examination involved

- the measurement of far and near visual acuity with eventual correction;
- kinetic perimetry with the Goldmann apparatus and static perimetry with the Friedmann analyser (1),
- intra-ocular pressure by Goldmann applanation only stable values after successive measurements were utilized;
- lens opacity, papilla atrophy and macular degeneration were classified into four degrees according to their severity,
- cup/disc ratio was evaluated in terms of areas.

Statistical analysis

The Friedmann data were standardized over the patient's age (Demailly

1973). Let Ni be the number of the filter with which the test is detected by the patient at the point i, and R the reference corresponding to his age, the new variable.

$$VC = \frac{Ni + 2}{R + 2}$$

(Ni = −2 for a black point) defines the 'visual capability' of the subject at point i, whatever his age, and varies from zero (black point) to 1 (normal point).

The 'total visual capability' is the sum over the 47 points of different visual capabilities of one eye.

Statistical analysis was made according to the usual tests, (Schwarts 1972), especially Pearson's r correlation coefficient and analysis of variance on the INSERM UNIVAC 1107 using the PASTIS programme (Philippe 1970).

RESULTS

Baseline characteristics of the studied group are shown in Table 1. Statistical analysis showed that for one eye the changes of intraocular pressure were not sufficient to explain the variability of total visual capability a poor correlation is observed between these two parameters. The progressive damage to the visual field was also a function of time. So, the linear regression of Total VC/OP versus time

$$\frac{\text{Total VC}}{\text{OP}} = at + b$$

Table 1. Baseline characteristics

	NUMBER	MEAN	STANDARD MEAN ERROR	RANGE
AGE (YEARS)	87 SUBJECTS	61	1.1	17 - 80
DURATION OF SURVEY (YEARS)	159 EYES *	4.0	.25	2 - 7
OCULAR PRESSURE (MMHG)	159 EYES	22	4.8	6 - 41
TOTAL VC	159 EYES	41	.9	3 - 47
CUP/DISC	81 EYES	.43	.03	.10 - .95

* 15 UNILATERAL GLAUCOMATOUS SUBJECTS = 15 EYES AND
72 BILATERAL GLAUCOMATOUS SUBJECTS = 144 EYES

where t is the time of survey, was computed for each eye. The coefficients 'a' and 'b' being highly correlated ($r = -0.71$, $p < 0.001$), it was possible to consider the slope 'a' alone as a rough summary of the information contained in successive examinations (e.g., Fig. 1). A larger negative 'a' indicates more severe functional damage.

The observed distribution of 'a' (Fig. 2) exhibited a slight excess of

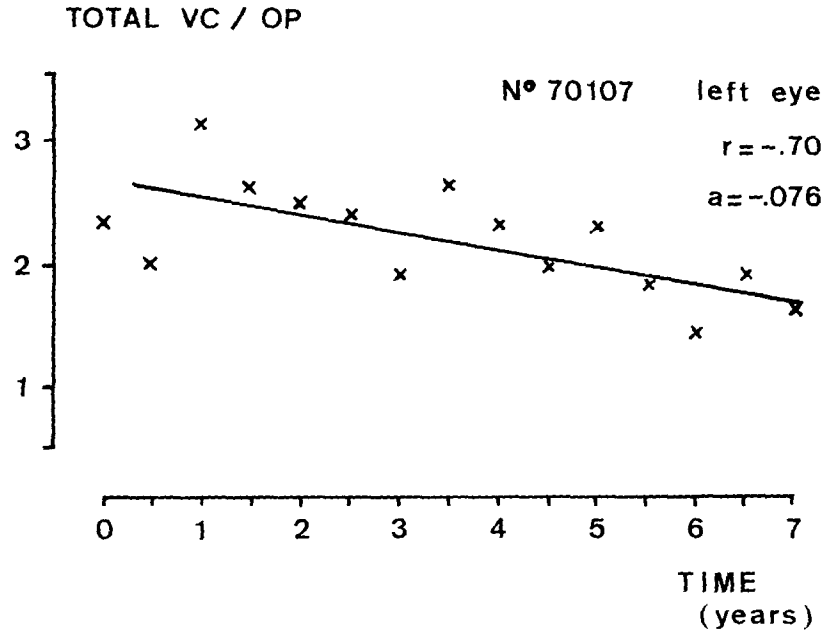

Fig 1. Example of a slope for one eye. The first examination was eliminated to compute the regression to avoid a bias because some subjects have been previously treated and others not.

Table 2. Relations between the slope 'A' and clinical data

		MACULAR DEGENERATION NO	YES	P VALUE	LENS OPACITY NO	YES	P VALUE
1ST EXAM.	NUMBER	148	11		135	24	
	MEAN A	-.006	-.086	<.06	.002	-.096	<.01
LAST EXAM.	NUMBER	143	16		128	31	
	MEAN A	-.013	-.070	<.05	.005	-.079	<.05

negative values corresponding to more severe cases. In fact, significant relations were found between 'a' and the presence of either macular degeneration or lens opacity (Table 2). However, slope 'a' was not significantly correlated with the age of the patient, the cup/disc-ratio or papilla atrophy.

It can be concluded that it is necessary to extend this study thoroughly with more subjects in order to establish the ability of this new parameter to characterize visual impairment.

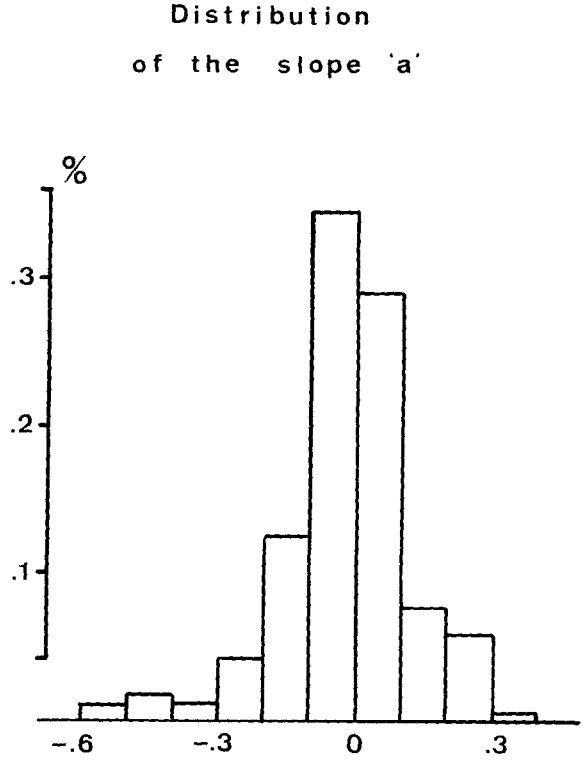

Fig. 2. Distribution of the slope 'A' for the 159 eyes.

SUMMARY

90 subjects (164 eyes) have been treated with follow-up twice a year in an out-patients department (mean duration of survey: 5 years, range 2-7 years).

The following data were systematically recorded: intra-ocular pressure, cup/disc ratio, degree of optic disc atrophy, visual acuity and visual capability in Friedmann perimetry. The statistical analysis shows highly significant correlations between cup/disc ratio and visual acuity on the one hand,

($r = -0.18$, $p < 0.001$) and the total visual capability (VC) on the other hand ($r = -0.60$, $p < 0\ 001$).

Moreover, the study of the visual capability changes in relation with ocular pressure (OP) shows a linear regression of the VC/OP ratio, according to the duration of survey, this evolution being different from one subject to another. This result suggests the calculation for each eye of a 'visual control index', i.e. the slope of the VC/OP v.s. time regression line. This new parameter would be an approach of a quantitative estimation of the efficacy of medical treatment on perimetric data It would be interesting to investigate the relations of this index with other parameters like age, cup/disc ratio, optic disc atrophy and different forms of chronic simple glaucoma, in order to determine the most predictive of them.

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THE INFLUENCE OF SHORT-TERM IOP ELEVATION AND HYPOXIA ON THE IMPULSE CONDUCTION IN THE NERVE FIBRE LAYER OF THE CAT RETINA*

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The present neurophysiological study was carried out to quantify changes in the impulse conduction along the unmyelinated ganglion cell axon of the cat retina during elevated IOP and graded hypoxia.

Antidromic action potentials were elicited by electrical stimulation of the optic tract. The field potentials of these antidromic impulses could be directly recorded from the retinal surface by a varnished tungsten electrode of low resistance (Fig. 1). In this way, the function of the unmyelinated ganglion cell axon could be tested separately from influences of retinal input during elevated intraocular pressure. Changes in these field potentials during IOP elevation directly reflected the impairment of the impulse conduction along the ganglion cell axon between the lamina cribrosa and the electrode. The IOP was elevated by infusion of heparinized Ringer solution into the anterior chamber during continuous pressure control. Hypoxia was obtained by ventilation with gas mixtures of low oxygen concentrations.

This direct access to a test of the function of the unmyelinated ganglion cell axon under pathological conditions led to the following results

1. Impulse conduction along the axon was influenced only when the IOP reached the mean arterial blood pressure of the aorta (perfusion pressure = 0) (Fig. 2). Axonal impulse conduction, therefore, proved to be much less sensitive to IOP elevations than the synaptic processes within the retina (Grehn et al., in press).
2. Slow-conducting fibres were influenced somewhat earlier than the fast-conducting fibres.
3. During complete retinal ischaemia, the impulse conduction was blocked after 700-1000 action potentials had passed the ischaemic nerve fibre, irrespective of stimulus frequency (Fig. 2). This corresponds well with the amount of intra-axonal potassium required to maintain the membrane potential without ion pump activity in retinal unmyelinated nerve fibres (Katz, 1966). It therefore could be assumed that ion pump activity was stopped by complete retinal ischaemia.

* Supported by the Deutsche Forschungsgemeinschaft (Gr. 161 & Gr 538).

4. This hypothesis was further supported by an experiment in which the ion pump activity of the axon membrane was inhibited by local administration of ouabain at the optic disk.
5. A short-term total asphyxia led to an impairment in impulse conduction similar to that caused by pressure ischaemia.
6. A direct comparison between the conduction of action potentials in the nerve fibre layer of the retina and potentials related to synaptic processes (ERG, EEG, evoked cortical potentials) could be obtained by simultaneous

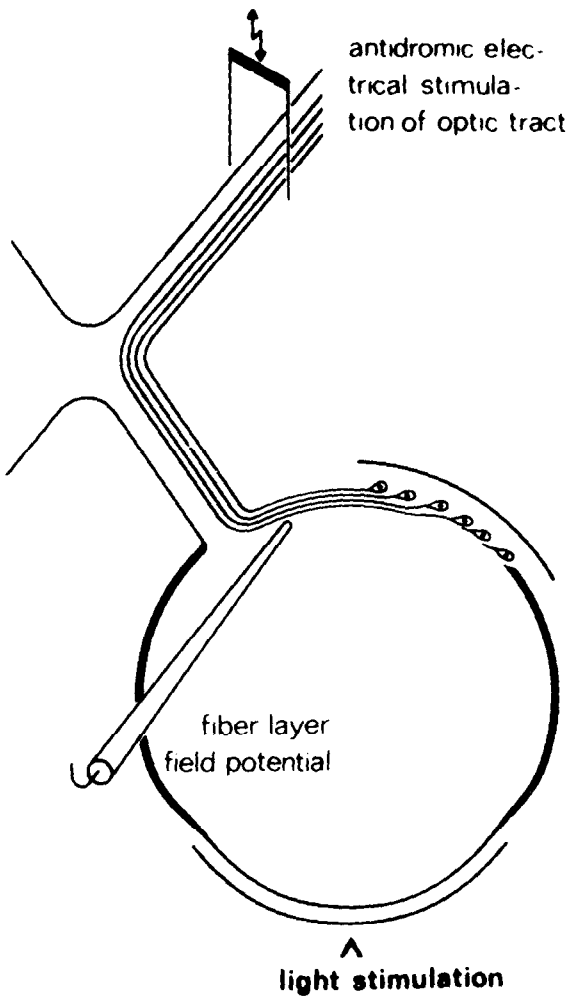

Fig 1 Schematic drawing of the experimental procedure: Electrical stimulation of the optic tract elicited action potentials conducted antidromically to the ganglion cells Stimulation of ipsilateral optic tract provided pure fibre potentials between the optic disk and the area centralis

recordings during graded hypoxia. It became evident that all potentials related to synaptic processes were extinguished completely while the impulse conduction along the ganglion cell axon remained unchanged (Fig. 3).

These experiments in the cat demonstrate that a considerable ischaemia is tolerated by the axonal impulse conduction of the retinal nerve fibre layer as long as a residual blood flow is maintained. Nevertheless, degeneration occurs first in the ganglion cell layer even after short-term IOP elevation (Anderson & Davis, 1975). Evidently, we must distinguish between a retinal perfusion necessary to maintain the structure of the nerve fibre layer and a much less critical perfusion for impulse conduction. While functionally the nerve fibres seem to be the most resistant part of the retina, their morphology is likely to be more labile even in short-term ischaemia.

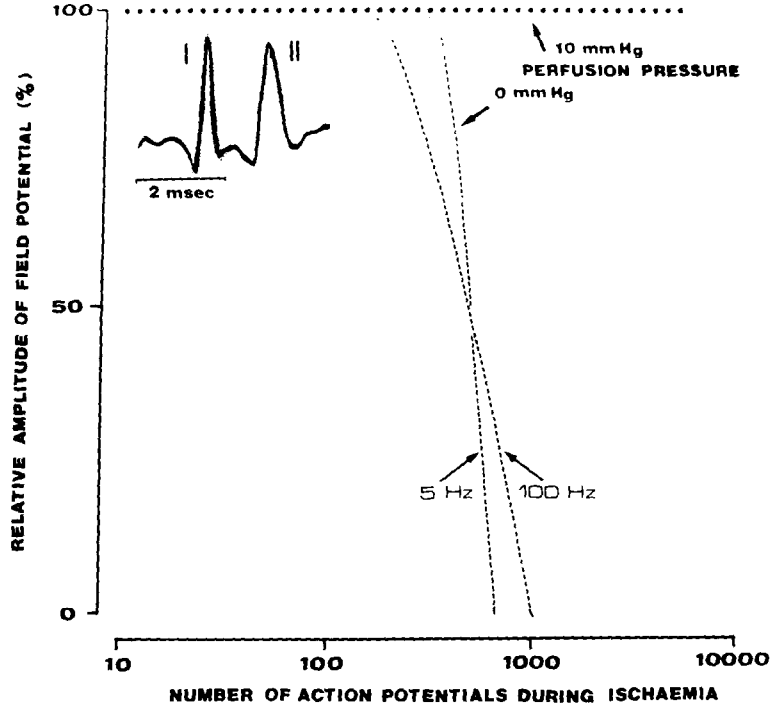

Fig. 2 Behaviour of nerve fibre field potentials at critical perfusion pressures (PP): No change in impulse conduction at PP = 10 mm Hg after 6000 action potentials; blockage of impulse conduction at PP = 0 mm Hg after 700-1000 action potentials. Upper left: Original registration of fibre potentials during antidromic electrical stimulation. I: fast conducting fibre group, II: slow conducting fibre group

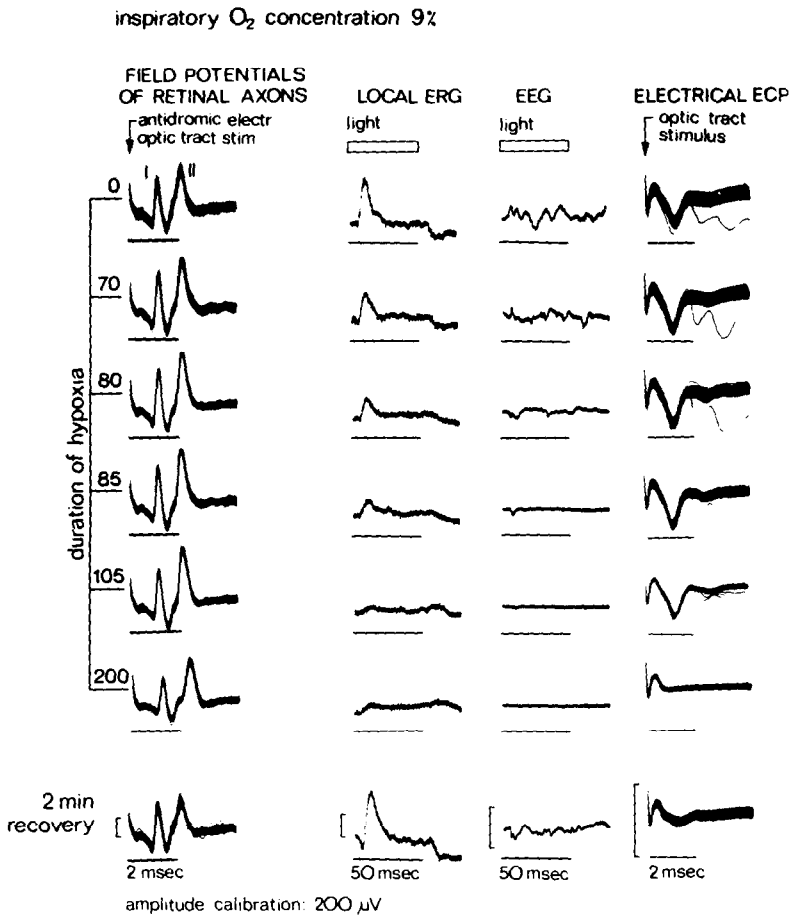

Fig. 3 Progressing influence of graded hypoxia (9% 0_2-respiration) on the impulse conduction of the nerve fibre layer, ERG, EEG and electrical evoked cortical potential during simultaneous recording. Field potentials and local ERG were obtained alternately by the same electrode

SUMMARY

The present neurophysiological study deals with changes in the impulse conduction along the unmyelinated nerve fibres of the retina during short-term IOP elevation and graded hypoxia.

No change in antidromically elicited fibre potentials was found as long as the intraocular pressure was below the mean arterial blood pressure. When the perfusion pressure (mean arterial blood pressure minus IOP) was set to 0, a rapid decrease in potential amplitude occurred. About 700-1000 action potentials could be conducted after the onset of total ischaemia. Simultaneous recordings of the ERG b-wave and the fibre potential were performed

during graded hypoxia. According to these experiments and to previous ganglion cell recordings it became evident that the synaptic signal transmission within the retina is more sensitive to *short-term ischaemia* than the impulse conduction along the unmyelinated nerve fibre.

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THE EFFECTS OF SURGICAL PRESSURE REDUCTION ON THE GLAUCOMATOUS FIELD*

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(Vancouver, Canada)

The reversibility of glaucomatous visual field defects as the result of pressure reduction has been described by Sameljoff (1922), Seidel (1914), Sloan (1931), and many others. Most of the patients they reported suffered from angle closure glaucoma and the changes in the visual field occurred as the result of precipitous pressure reduction which was often pharmacologically induced Armaly (1969) was probably the first to show the reversibility of the glaucomatous visual field in chronic open angle glaucoma and described a number of patients whose visual field defects improved or disappeared entirely. Some of his patients improved after pressure reduction but some improved without pressure change while others progressed with normal intraocular pressure. He suggested that factors other than intraocular pressure must be identified. As there are some patients in whom field reversibility seems to be related to a reduction in intraocular pressure, one should reduce pressure in all eyes so as to find those eyes in which visual field defects are, in fact, pressure-dependent. Heilmann (1973) studied the effects on the visual field of pressure reduction produced by Diamox and compared them with the effects of pressure reduction produced by Clonidine, which also reduces ocular pressure but produces a synchronous blood pressure reduction. An improvement in the visual fields could be shown in patients treated with Diamox but none occured with Clonidine. The implication was that intraocular pressure reduction produced the improvement whereas intraocular pressure reduction accompanied by blood pressure reduction failed to do so.

The phenomenon of reversibility of visual field defects in chronic open angle glaucoma may be important. If it is a common occurrence and if factors other than the intraocular pressure reduction can be shown to play a part, the prognosis of the disease and the indications for medical therapy would have to be redefined.

The establishment of pressure dependence of visual field defects at a reliably reversible stage would be exciting. The present study, in chronic open-angle glaucoma patients, was undertaken to examine the effects of surgical pressure reduction on reproducible but relative nerve fibre bundle defects examined by profile (static) and kinetic perimetry.

* Supported in part by MRC Grant No MT 1578

METHODS

All patients with chronic open angle glaucoma, whose visual field defects progressed and whose intraocular pressure control was inadequate so that surgery was advised, were studied provided that their visual acuity was adequate for accurate plotting of visual fields. Two baseline examinations were carried out preoperatively and included an assessment of visual acuity, pupil size, applanation intraocular pressure, systemic blood pressure, estimation of foveal differential thresholds and accurate study of a number of points in the visual field with moving and stationary stimuli. The isopter was tested 4-5° above and below the nasal horizontal (Fig. 1). Each differential threshold was measured ten times. Three intensities (10, 100, 1000 apostilbs) with a 10 minute target size were used in order to measure the isopter peripherally, 30-40° from fixation and more centrally. The temporal peripheral isopters just above and below the horizontal were similarly measured. Differential thresholds of the foveal area to a 10 minute stimulus were also

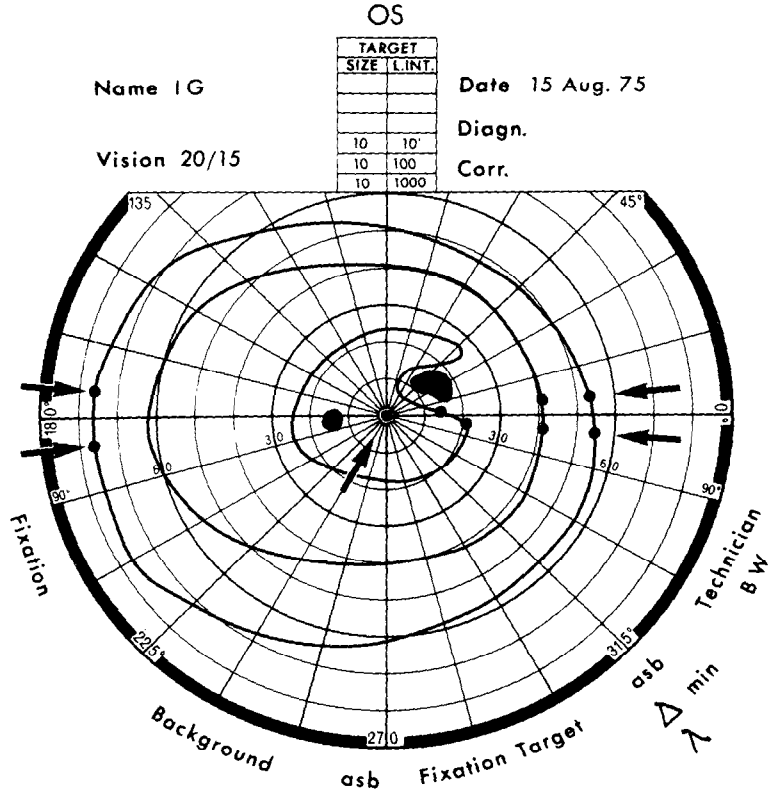

Fig. 1 Visual field of patient with dense scotoma illustrating the points measured to kinetic stimuli and macular sensitivity. Static perimetry not shown.

obtained ten times. Meridional static perimetry was then performed through a scotoma. A point in a relative part of the scotoma was selected and its threshold determined ten times. The same parameters were measured in the postoperative assessment usually six to twenty weeks after surgery when the eye and its pressure had stabilized. In order to achieve comparable pupil sizes Pilocarpine was used for the postoperative examination. The pressure reduction achieved by the surgery was calculated for each patient from the pressure readings at the time of the examination. The mean of the ten static threshold determinations was calculated for each patient and the change in the mean from the immediate preoperative to the postoperative value was determined. The statistical significance of the change in pressure and the mean change in the thresholds was ascertained and the regression of the intraocular pressure changes on the threshold changes was calculated.

Five parameters were used in the kinetic isopter measurements. The means of the pre and postoperative thresholds of the inferior nasal periphery (4-5° below the horizontal), superior nasal periphery (4-5° above the horizontal), inferior nasal central isopters (4-5° below the horizontal), nasal superior central (4-5° above the horizontal) and macular thresholds were calculated. A multiple regression of the change of intraocular pressure on the change in these thresholds was calculated. A stepwise backward regression was also undertaken and finally the individual threshold changes were considered separately and related to the reductions of intraocular pressure.

Nineteen eyes of eighteen patients were studied. Their ages ranged from fourteen to seventy-seven years with a median of fifty-eight years. Fourteen eyes had profile perimetry carried out, whereas all nineteen eyes had kinetic thresholds determined.

RESULTS

A. Profile Perimetry

The mean pressure reduction in the fourteen was 14.8 mm. Hg with a standard deviation of 10.1 mm. Hg. The pressure reduction attained the 0.1% level of statistical significance. The difference between means of the pre- and postoperative thresholds was −0.125 log units (S.D. 0.45) which was not statistically significant. The regression of intraocular pressure change on static threshold change showed the regression to be Δ IOP = 13.62-0.986 Δ threshold The regression coefficient was not significantly different from zero. Of the fourteen static profiles, ten appeared no better on inspection and four seemed to show improvement.

B. Kinetic Perimetry

The mean pressure reduction of the nineteen eyes was 14.0 mm. Hg (S.D. 8.54 mm. Hg)

The mean changes preoperative-postoperative kinetic and foveal thresholds are shown in Table 1.

Multiple regression of Δ IOP on Δ thresholds showed no joint regression.

Stepwise backward regression indicated one highly correlated variable ($r = -0.53$)namely the change in the inferior nasal central threshold. The regression was calculated as $\Delta IOP = 13.53\text{-}1.1970\ \Delta$ inferior nasal central threshold. The regression coefficient was statistically significant (P = 2%). Due to high correlations between some of the independent variables, no other threshold changes correlated significantly with changes in intraocular pressure when considered jointly. When considered separately, it can be seen again in Table 2, only the inferior nasal central thresholds showed a significant regression coefficient while the superior central and inferior nasal peripheral coefficients barely reached a 5% level of statistical significance. In all the regressions the addition of quadratic terms did not increase r^2 to any extent Seven of the nineteen eyes showed a greater than 5° widening (? improvement) of the peripheral nasal isopters. In three of them, both the superior and inferior isopters widened while in the other four the change occured only in either the superior or inferior isopters. Five of the nineteen eyes showed a widening in the central isopter above or below the horizontal of more than 2.5°.

Using the chi square the improvement was not significantly more frequent among the under 57-year-olds compared with those over 58 years and not more frequent in early relative defective fields than in the relative parts of advanced field defects.

Table 1 Mean changes of kinetic and macular thresholds before and after operation

	Mean Preop-Postop..Threshold	S.D
Superior Nasal Periphery	-2 86°	4 55
Inferior Nasal Periphery	-1 61°	5.43
Superior Nasal Central	1 46°	4.74
Inferior Nasal Central	-0 39°	3 79
Macular Sensitivity	0 04 log units	0 47

Table 2 Regression coefficients Δ thresholds on Δ IOP

	Regression Coefficient	Sifnificance
Superior Nasal Periphery	-0 050	N S
Inferior Nasal Periphery	-0 63	P ≈ 0 05
Superior Nasal Central	-0.74	P ≈ 0 05
Inferior Nasal Central	-1 20	P ≈ 0 01
Macular Sensitivity	-0 27	N S.

DISCUSSION

The concepts of improvement of visual field defects in chronic open-angle glaucoma brought about by pressure reduction are fairly new. The academic and practical implications are, however, very important. The errors arising from subjective responses, from lack of reproducibility, interpatient variability, difference in the refraction, pupil size and the variety of pharmacological agents are considerable. Serious attempts should be made to design experiments which minimize them. The present study attempted, in prospective manner, to deal only with operative pressure reduction, to maintain reasonably constant pupillary size, to reduce variability by using a single skilled technician and patients familiar with the technique. Yet there were many pitfalls. It seems, however, that changes in the visual field can result from pressure reduction. The phenomenon should now be studied more carefully in order to learn the conditions under which improvement can occur and can be reliably predicted to occur. It will take a few years to understand the significance and ultimate course of the improvements. We could be in an exciting era in our understanding of the glaucoma patient but currently we must continue to think of glaucoma as a progressive disease.

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DISCUSSION

OF THE SESSION ON VISUAL FIELD IN GLAUCOMA

Friedmann to Werner Have you correlated the rate at which your cases deteriorated before operation and your postoperative changes in fields?

Werner to Friedmann We thought that over, but we had a lot of trouble deciding how to assess the rate of deterioration because the fields that we had in this retrospective study would have been done at different time intervals, and I found it very difficult to get any sort of consistent measurement of rate with the techniques we are using.

Leydhecker to Werner Can you see whether those which progressed after the operation were late cases as regards the progress of field, which means did they have a considerable field loss before operation? Or, did they include also early cases with a slight field loss, and an other question: can you say anything about whether the speed of field loss was in any way diminished or not?

Werner to Leydhecker With regards to the severity most patients had quite severe defects at the time they were operated although there were some who had relatively early defects. There did not seem to be any correlation between the severity of defects preoperatively and whether or not they progressed. With regards to the rate of progression: we did not develop a satisfactory technique for assessing the rate of progression of the field defects.

Matsuo to Grehn. Where is the location of the stimulated area in the fundus: not in the optic disc, I suppose? Is it near the optic disc or where else?

Grehn to Matsuo: There are two types of experiments. One with electrical stimulation, and the one used here had antidromic stimulation. There was an electrical stimulus within the optic tract; the other one was the light stimulus. The electrode was in position in the surface of the retina. The electrode was positioned between the optic disc and the area centralis of the cat-fundus. It was in between, and this was the trick of the experiment to get pure fibre potentials. If you stimulate the ipsilateral optic tract you elicit potential with the ganglion cells too. So, if you get an area before the fibre potentials reach the

ganglion cells, you are sure to get pure fibre potentials and this was the very important thing for this study.

Dannheim to Drance There are two problems which we should try to discuss today:

1. What is the earliest change in the glaucomatous field. Unless we have the knowledge what is likely to occur early, all our techniques, no matter how good the instruments are, some early visual field defects will be missed.

2. What are the implications for perimetry and glaucoma management of the reversibility of field defects. I would suggest to you that we concentrate on the earliest change in the glaucomatous visual field.

The visual fields of 2 patients are demonstrated to elucidate some characteristics of early glaucomatous field damage

Fig. 1 shows the left field of the first patient corresponding to a widely cupped disc. The peripheral (left) and central kinetic field (right) present a discrete nasal step in the mid-periphery. This circumscript alteration is confirmed by repeated testing just above and below the horizontal meridian. A large white or colored supraliminal target moving evenly in a circular direction appeared as pale, blurred and faded in a small nasal and temporal sector marked as hatched. The same assessment a few weeks earlier had resulted in identical findings. The circular-static profil crossing the horizontal meridian 15° paracentral (top right) has no significant changes in the area just below the nasal horizontal except for some increase in variation of single responses. Supraliminal white and colored stimuli appeared subjectively altered in the range recorded as hatched on the lower scale.

Fig. 2 demonstrates the left field of the second patient taken two days apart. The isopters have again been evaluated very carefully where they cross the nasal horizontal meridian. They indicate a disturbance in the nasal peripheral field extending centrally 7° in the first, 10° to 15° in the second test. The region in which the sensation of supraliminal white and colored stimuli appeared defective (marked as hatched) extends in

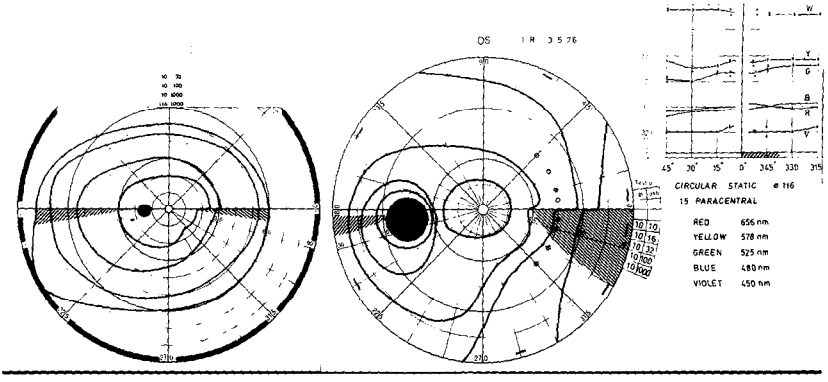

Fig 1

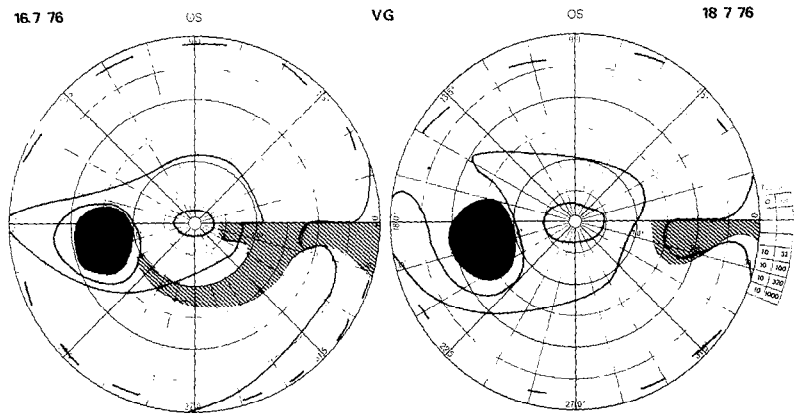

Fig 2

the first plot way over into the Bjerrum area towards the bind spot. In the second test two days later the extent of the sensoric disturbance is much less without any arcuate characteristics.

One may derive from these two cases·

1. Nasal steps may be early sign of glaucomatous damage. 10% of about 200 fields with early glaucomatous changes where reported to have circumscript alterations adjacent to the nasal horizontal without arcuate extension into the Bjerrum area (Dannheim, 1974). This is a considerably higher frequency than that of an earlier communication (Aulhorn & Harms, 1967).
2. The temporal field is worth being accurately tested in glaucoma (Brais & Drance 1972).
3. Static perimetry – even if optimally applied – does not necessarily contribute to the information already gained by kinetic perimetry. The earliest glaucomatous change in static perimetry seems to be an increase in variation of responses as compared with the unaffected surrounding field.
4. Disturbance of sensation of supraliminal stimuli may reveal definite additional information about the presence and extent of glaucomatous damage.
5. The disturbance of sensation of supraliminal stimuli may vary in extent considerably as opposed to the disturbance of kinetic threshold perimetry, which shows little reversibility.

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Fankhauser on Dannheim: Caution should be observed when deducing the existence of glaucoma from the observation of a nasal step. The reasoning to be followed may well be generalized for other early field changes, considered symptomatic of glaucoma.

Nasal steps may be artifacts due to instrumental and procedural errors or to random threshold fluctuations which cancel out when averaged over a number of determinations. Apart from this category of pseudo nasal steps, it ought to be emphasized that *reproducible, statistically significant* nasal steps may be observed in eyes which may never produce the other pathological field changes typical for glaucoma. In addition, other distinct diseases of the neuro-visual apparatus may produce nasal steps as has been emphasized by Magis during the session.

The conditional probability (forward probability) that Glaucoma (G) will produce a nasal step (S) may be denoted by P (S | G), the forward probability that other states or conditions ($\bar{G}$) will produce a nasal step by P (S | $\bar{G}$). and the corresponding probabilities of no nasal step ($\bar{S}$) being produced by P ($\bar{S}$ | G) and P ($\bar{S}$| $\bar{G}$). To my knowledge, these transition prohabilities have not yet been determined numerically. However, for the conclucions to be drawn below, very rough estimates are sufficient.

What we are interested in, is the backward probability, P (G | S), i.e. the probability of an observed nasal step being due to glaucoma. Applying Bayes' wellknown theorem, this probability is given by

$$P(G \mid S) = P(G) \cdot P(S \mid G) \;/\; P(G) \cdot P(S \mid G) + P(\bar{G}) \cdot P(S \mid \bar{G})$$

It can be seen that the required backward probability can only be found if, in addition to the forward probability, P (G), i.e. the a priori probability for the occurrence of glaucoma is also known. The latter may differ for various populations.

The following numerical examples serve only to illustrate the strong influence of the relevant variables upon our conclusions, choosing the figures *arbitrarily*.

1) $P(G) = 0.02$ N(number of individuals examined) = 1000
$P(S \mid G) = 0.5$ $P(S \mid \bar{G}) = 0.05$
$P(\bar{S} \mid G) = 0.5$ $P(\bar{S} \mid \bar{G}) = 0.95$

From these figures it follows that out of the total number of nasal steps detected (59) – due to the relatively low occurrence of glaucoma – only 10 can be attributed to glaucoma, whereas 49 are due to other causes. Doubling P (G) up to 0.04 would bring the number of glaucoma-induced nasal steps from 10 to 20.

2) $P(G) = 0.02$ $N = 1000$
$P(S \mid G) = 0.5$ $P(S \mid \bar{G}) = 0.01$
$P(\bar{S} \mid G) = 0.5$ $P(\bar{S} \mid \bar{G}) = 0.99$

Now, although the assumed probability of non-glaucoma conditioned nasal steps has been lowered to one percent, apart from 10 nasal steps, which are due to glaucoma, still 10 nasal steps, not due to glaucoma will be found, i.e the predictability of the presence of glaucoma is still poor.

3) $P(G) = 0.02$ $N = 1000$
$P(S \mid G) = 0.5$ $P(S \mid \bar{G}) = 0.001$
$P(\bar{S} \mid G) = 0.5$ $P(\bar{S} \mid \bar{G}) = 0.999$

Here now, because of the very low probability of non-glaucoma conditioned nasal steps, out of a total of 11 nasal steps found, 10 have to be attributed to glaucoma and only one to other causes.

From this it may be seen, that we vitally depend upon exact figures for the forward probabilities of glaucomatous and non-glaucomatous eyes to produce nasal steps. Also, a decrease of pseudo nasal steps, due to insufficient apparatus or methods or to noise in the neuro-visual system, which can be suppressed by noise-attenuating methods as provided by computer-perimetry, notably increases the specifity of a nasal step being due to glaucoma. Independent information indicative of glaucoma, such as a paracentral scotoma may greatly increase one's certainty concerning the existence of glaucoma and should be looked for carefully.

Greve: As I said in my paper the wedge-shaped defects are one of the earliest manifestations if glaucomatous visual field damage (see figures in Greve & Verduin this volume). Of course, the earliest manifestations depend on the method of examination used. If one uses static perimetry in several meridians, degree by degree, as a routine for detection of early defects one will find a high number of wedge-shaped defects. The specifity of these defects is not yet known. It is important to prove that a relative defect like the wedge-shaped defect follows the course of the nerve-fibre bundles. What we need now is an investigation of visual fields of normal subjects and of patients with several types of eye disease (diabetes, venous trombosis etc) to get information about the specifity of wedge-shaped defects.

Another interesting point is the reproducibility of wedge-shaped defects, especially in relation to reversibility. In conclusion: wedge-shaped defects occur without doubt in glaucoma patients. They are of slight intensity, small and probably early signs of damage. Their specifity has to be investigated. Their possible role in evaluaing therapeutic response could be interesting.

Drance to Greve Before dealing with Dr Greve's interesting paper in detail, one has to decide first what a particular method of perimetry is designed for In glaucoma screening, for which the Friedmann and Armaly methods were specifically designed, one fundamentally asks only one question, 'Is there a visual field defect present or not?'. If a defect is present, the visual field has to be accurately plotted in detail. A screening method has to be practical for it has to be applied to all those at risk. It must therefore be fast and simple for the patient to perform, easy for technicians to learn and it has to screen those areas of the visual field which will give the maximal return for the time. In glaucoma suspects this includes the central 25°, the nasal portions of the field all the way to the periphery and an exclusion of unusually placed sector defects. In order to be practical in the management of the glaucomas it must look for proven nerve fiber bundle defects, early and late, small and extensive, absolute and relative. A practical screening method

is not designed to look for the earliest glaucomatous damage for research purposes. When earlier and small visual field disturbances are shown to be important and progressive, then new screening methods have to be designed in order to encompass the new knowledge.

Dr Greve asks some irrelevant questions, as neither the Aulhorn/Harms static perimetry or his own modification of it, and he admits this in his paper, are practical for a general ophthalmic practice because of the length of the examination. We do not know what the wedge-shaped defects which are to be found mean, what their natural history is, how often they ultimately develop into classical scotomata, how often they are combined with more severe field defects, and whether when so combined, their natural history is different. The visual field defects were found by means of the continued stimulation performed according to his method and by classical static perimetry both on the Oculus perimeter. One must obviously not be surprised when those methods are found to have few false negatives. To do a comparison the tests have to be random in order, the technicians must have no knowledge of the visual fields, all examinations should be done by the same person who is familiar with all of the tested methods of perimetry.

Dr Greve therefore shows that there are some wedge-shaped defects whose natural history has to be studied in detail, which have a relationship to nerve fibre bundle defects and for which a practical screening method will have to be designed when these defects are validated as significant defects. It is not my intention to discuss the relative merits of the Friedmann and Armaly screening methods in detail. The Friedmann Analyser is a good method for screening the central 25° of the field but misses the peripheral visual field defects which the Armaly method, as modified by us, will not miss. Kinetic perimetry, well done, with the selection of the appropriate stimuli which concentrates on the inner 25° will also have a much higher yield of positives except in the wedge-shaped as yet unproven scotomata. The Armaly method is likely to find false positives at the periphery of the central field and false negatives near the centre as pointed out by Greve and so the method has now been altered as a result of Greve's suggestion in order to avoid these pitfalls.

It is important to study the small scotomata which Greve describes, and I agree with him that the Aulhorn/Harms method, with modifications to include a static/kinetic examination with suprathreshold targets of those areas which the meridians do not plot, is the most sensitive method for their detection. Aulhorn has pointed out the importance of the paracentral scotomata but only those that are dense and reproducible. She has not addressed herself in detail to the relative paracentral wedge-shaped scotomata which Greve described and which we should now be studying.

With reservations as to the philosophical shortcomings and the experimental design described in Greve's paper, I congratulate him for pointing out some of the possibly significant early glaucomatous changes.

Greve to Drance This study has been set up to compare early damage as detected by visual field examination on the one hand and ophthalmoscopy on the other hand. It was not intended to give guidelines for general ophthal-

mic practice, but to point out that our present methods of detection are not the most sensitive way of finding early defects. For any *research-project* which attempts to study early glaucomatous damage the present detection methods with limited sensitivity are not sufficient. Specially when comparing disc-evaluations with visual field examination it is necessary to use a highly sensitive method of visual field examination in combination with the well-known methods of detection. I completely agree with Dr Drance that it has to be proved that it is worthwhile to increase the sensitivity of our present routine – detection methods in order to include a larger number of W S D. However, for the clinical management of glaucoma patients it makes a difference whether a visual field defect is present or not. It cannot be denied that a W.S.D is a defect Therefore it is necessary to study its practical significance in more detail.

Finally it was pointed out that the out-comes of disc-visual field comparative studies are highly dependent on method of examination and type of evaluation. For that purpose too it was necessary to compare different methods of visual field examination.

Leydhecker There has been a lot of consideration of the nasal step and other early signs of field defects I have, however, been shocked by the first paper from Drance's group and also by the last paper from his group, which signify, if I understood corretly, that glaucoma is a disease which progresses whatever we do. Thus, surgery does not stop the field progression and field defects are not reversible either. Maybe I am exaggerating a bit but I am sorry to hear that because, if you remember, Duke-Elder said as early as 1925 that glaucoma progresses whatever you do'. Since then the words of some of the people at this symposium suggests that we cannot stop the deterioration of the field and that we cannot do anything useful to slow down the disease.

Drance Dr Leydhecker has raised some very important points that have to be cleared up satisfactorily, otherwise I will have left the wrong impression. I would like to concentrate on the statistical side first so as to clear up any wrong impressions.

I would, first, like to deal with reversibility A number of people have presented evidence of reversibility by showing the disappearance usually of small relative scotomata but occasionally even fairly advanced visual field defects and Dr. Heilmann has shown the improvement in fairly advanced visual field defects, although obviously not their disappearance. The problem is that in psychovisual phenomena there is a day-to-day scatter in responses and such scatter also varies from one patient to the next. One has to be able to identify phenomena that can be recognized over the background noise in the system In the paper, which I have presented, there was an improvement postoperatively in visual function of the relative areas of the glaucomatous fields which could be statistically secured. The fact that it was statistically secure does not make the change biologically significant but merely indicates that it was unlikely to have occurred due the chance alone. Much more sophisticated work now has to be done in order to try learn the

conditions under which reversibility occurs. If one can recognize those conditions one might have a better understanding of the pathogenesis of visual field defects in glaucoma and also one may have a more rational way of managing the disease.

With regards to Dr. Leydhecker's point about the postoperative deterioration of the visual field, I think Dr. Werner's paper did in fact show that the majority of patients who had a good pressure reduction did not show further progression of the visual field. The point that he made, however, was that in spite of the fact that in some patients excellent pressure reduction was obtained postoperatively the visual field progressed. Because we are surgically conservative, the relatively small sample which we had available for such a study made it impossible to secure statistically the correlation between lack of progression of the visual field and pressure control. We believe that there may be such a correlation, but it could not be statistically secured and we may have to look at a larger sample before it becomes statistically significant. Biologically, however, the pressure reduction is very important and we are convinced that operative pressure reduction does in fact provide a good chance of arresting the deterioration of the visual field, but not in all patients.

SUMMARY OF SESSION II. VISUAL FIELD IN GLAUCOMA

S.M. DRANCE

The Glaucoma Research Group wishes to thank Professor Aulhorn and Dr. Greve as well as the Local Organizing Committee for the excellence of the Symposium.

The Glaucoma Research Group has so far attracted 36 members from all over the world. One of its first actions was to carry out a survey of current perimetric procedures to which 21 of the 36 members replied. The survey showed wide divergence on some basic points of technique and understanding of the glaucomatous field defect. There was overwhelming agreement, however, that in order that perimetry for glaucoma detection and management be carefully carried out, well-trained technical help is necessary and already widely employed. There is also agreement that for screening of the visual field, single stimulus or multiple stimulus static perimetry is the method of choice in conjunction with kinetic isopter perimetry. The majority of those responding had enough confidence in their perimetry to make important patient management decisions based on it.

There is major agreement that small paracentral scotomata and small arcuate scotomata are early defects of glaucoma, though they are not specific to this disease. Opinion is evenly divided that nasal steps and relative paracentral scotomata are early defects and there is now only minimal support for the position that enlargement of the blind spot and enlargement of angioscotomata are early perimetric changes in chronic simple glaucoma which are specific enough to be of value.

At the Second Visual Field Symposium the twelve glaucoma papers were of high quality and showed, among other things, that the arcuate scotomata in the upper field were nearer fixation than the lower ones, but neither the upper nor lower linked up with the blind spot early; that the peripheral nasal step should be looked for as an isolated field defect, that static perimetry is less reproducible, particularly away from the centre, than we would like to believe; that the relative paracentral disturbances may be an early change and may be reversible, and our screening methods must, if necessary, be redesigned not to miss them. Efforts must be increased to follow such patients in case they develop definitive glaucomatous field changes; that pressure reduction surgically produced can result in visual function improvement and can also arrest the progression of the visual field in the majority but not by any means all patients

The discussion was lively and accentuated the difference in views and our gaps of knowledge as to what constitutes the earliest detectable field defect in chronic simple glaucoma. Any isolated nasal step reproducibly found has to be examined carefully to confirm its presence by means of circular static perimetry, repeated kinetic examination, and when confirmed indicates nerve fibre damage. The central field must then be examined with extra vigilance and other causes of nerve fibre bundle damage must be excluded. The patient must be meticulously followed until the defect is established as being reproducible and significant when the appropriate further management of the patient should be undertaken.

Isolated relative paracentral scotomata which all of us find with varying frequency, depending on the perimetric method used, is also an early disturbance of the visual field in chronic simple glaucoma. Like the nasal step, however, it requires perimetric confirmation, perimetric reproducibility, before it can be accepted by all of us as a specific disturbance of nerve fibres. The presence of other features of glaucoma and the exclusion of local retinal causes, as well as the exclusion of the non-glaucomatous causes of nerve fibre bundle damage make it more significant. Only longitudinal studies which have to include non-glaucomatous subjects, will ultimately produce the necessary epidemiological confirmation that these changes are truly early features of the disease. There are as yet very few meaningful studies of this kind. They are badly needed.

It was a pleasure, as always, to have Professor Goldmann participating in our discussion and he raised the question of a silent period between the onset of pressure and visual field defects which requires serious attention. Meticulous perimetry and careful binocular examination of the disc with good magnification are now more necessary than ever because of the large group of people with no damage, elevated introacular pressure, who are obviously at greater risk but whose ophthalmologists have now latched onto the term 'ocular hypertension' and are using it clinically in a way in which it was never intended. The direct or indirect implication that this is a benign state is quite unjustified and may do harm to many people unless this is clearly recognized. Nobody can belong to this group without the most careful exclusion of early field defect and our perimetric responsibility becomes greater than ever.

The Glaucoma Research Group hopes that its enthusiastic members will provide some answers to these intriguing questions during future meetings.

PERIMETRY AND ELECTROPHYSIOLOGY

G.H.M. VAN LITH

(Rotterdam, The Netherlands)

For an objective perimetry by means of electrophysiological methods the electroretinogram (ERG) and the visually evoked cortical potentials (VECPs) are at our disposal. Concerning this topic a lot of work has been done by various research groups (Brindley, 1965; Beinhocker, 1966; Hache, 1972; Henkes & Van Lith, 1973; Van Lith & Henkes, 1973). The results are disappointing at this very moment, though hopeful for the future. I will deal with both aspects: the hopeful results we got and the disappointments we went through.

Before averaging computers were available, ERG signals from localised retinal areas were too small to be visualised amidst a noise level. If the entire retina is illuminated, potentials of about 500 μV can be obtained. They are a summation potential of both the rod system and the cone system. If, however, the two systems are separated carefully, the rod system appears to produce not more than 400 μV, the cone system less than 200 μV. Potentials of that order can easily be recorded with ordinary amplification techniques, such as EEG-machines. The smallest potentials, on the other hand, which can be registered with such apparatus, are approximately 20 μV, smaller potentials being masked by random background noise.

In order to obtain a potential of that magnitude under photopic conditions, 20° of the retina have to be illuminated, at least in the posterior pole In the retinal periphery, where cone density is lower, even larger test fields have to be used. But then, it is a fallacy to speak about perimetry. It was clear to us that for a successful electroperimetry much smaller potentials than 20 μV must become distinguishable. In other words the signal-to-noise ratio had to be improved. This became a reality with averaging techniques. The smallest response, which now could be recorded, became 5 μV, in noise-free circumstances and from quiet subjects even as low as 1 μV.

Using averaging techniques, it appeared that under photopic conditions the height of the ERG correlated with the number of cones stimulated (Armington, 1968, Van Lith & Henkes, 1968, Jacobson, 1969). This was a hopeful result, bringing an electroperimetry within our reach. However, stimulating areas outside the fovea, we saw how favoured the fovea with its high cone density was in delivering a reasonable local response. Outside the fovea, only very small responses could be obtained.

Concerning the VECPs, the situation was even more hopeless. Even when

outside the fovea test fields were enlarged to such a degree that ERGs of about the same height were obtained as compared to those of the fovea, the VECPs remained too small to be of any use for a perimetry (Van Hof, 1966; Jacobson, 1969; Van Lith & Henkes, 1970).

A very logical idea was to use the rod system for testing retinal sensitivity in the periphery, since the rod density, opposite to the cone density, does not decrease so much towards the periphery. It worked out to be an idle idea, since the electrical responses obtained under scotopic conditions remained of the same height, irrespective of the place of stimulation on the retina. Most probably, stray light effects obscured the results (Van Lith & Henkes, 1972).

There was, and still is, another problem, which limited the feasibility of the method. This was the factor 'time'. With averaging techniques it lasted too long to measure sensitivity of a reasonable number of places of the retina, since measurement at one place lasted at least half a minute and examination time could not be much longer than half an hour, the patient being exposed to the discomfort of a large corneo-scleral contactlens electrode. For these reasons stimulus conditions had to favour the electrical responses as much as possible, the recording system had to be the fastest available.

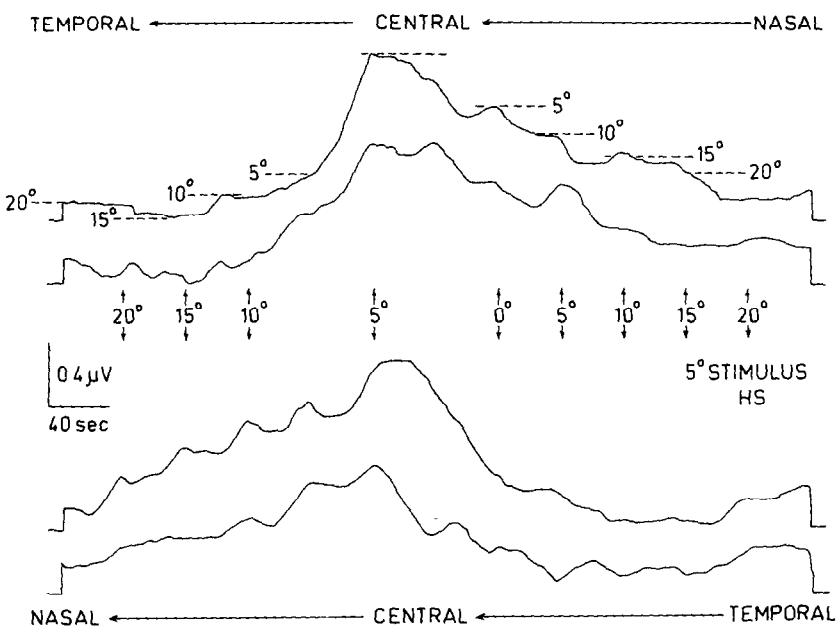

Fig 1 Electrical activity of a 20° central retinal area, obtained with a 5° stimulus spot and recorded with a phase-detector. The recordings have to be read from right to left The two upper curves have been made from nasal to temporal in the horizontal meridian, the two lower curves from temporal to nasal. The vertical bars indicate the moment the stimulus spot is moved, the horizontal bars the level of the electrical activity at the place stimulated.

The first aim is fulfilled with a blue adaptation light, which prevents stray light responses and suppresses the rods, but saves the cone sensitivity, used in combination with a white test light, which triggers all three cone systems. Furthermore, a stimulus frequency of 40 Hz is preferable, since lower frequencies lengthen the examination time and higher frequencies lower the responses too much.

Much faster recording systems as compared to the conventional averagers are the phase-detectors. They do not record the actual responses, but only their height. This implies that using phase-detectors we loose information viz. the waveform, but we gain time. Another advantage is that they are very sensitive.

With such apparatus we made the recordings shown in Fig. 1. It is a kind of static perimetry, but rather crude since it is made with a 5° stimulus. Nevertheless, this result encouraged us to examine a group of normal subjects and some patients. But again, it was a failure. variability was too large and the responses outside the fovea too small, to get clear differences between normal subjects and patients.

We stopped our experiments in this field, but only temporary, waiting for still better equipment to start again, also waiting on results of other groups, who had or will have better ideas than we.

SUMMARY

Though the amplitudes of local photopic ERGs are correlated with the number of cones stimulated, determination of local sensitivity of the retina by means of the ERG is still problematic, especially outside the foveal area. Here responses are rather small, on the other hand examination time rather long. Scotopic ERGs and VECPs seem to have even less chance to be fruitfully used for a real perimetry.

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QUANTITATIVE PERIMETRY AND LOCAL ERG IN THE DISEASES OF MACULAR AREA AND BJERRUM AREA

SUSUMU HAMAZAKI & HARUTAKE MATSUO

(Tokyo, Japan)

We have investigated the relationship between the results of quantitative perimetry as subjective examination and of local ERG as objective examination.

For a long time, reports have been made to acquire the local ERG clinically. Many of these were successful in local ERG from the macular area. Using one of the bleaching methods, local ERG was obtained from the macular area and also from the so-called Bjerrum area, which is surrounded

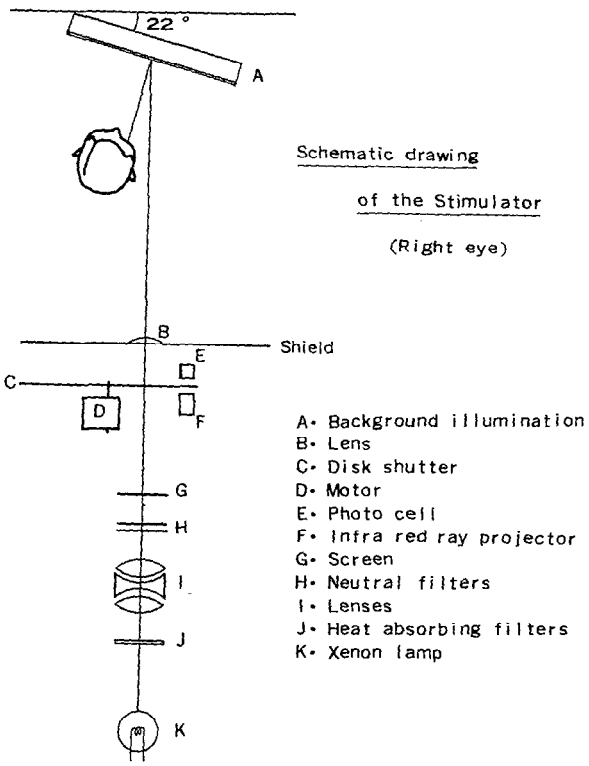

Fig. 1.

by the area of between 10 to 20 degrees eccentricity In several cases of macular degeneration, localised retino-choroidal atrophy, obstruction of the retinal artery branch and open angle glaucoma, the results of quantitative perimetry and local ERG were then compared.

METHODS

Kinetic perimetry using the Goldmann perimeter by the usual method, and static perimetry on the adequate meridian using the Tübinger perimeter were done, and some cases were also examined by the Friedmann Visual Field Analyser (FVFA).

The method of local electroretinography

Figure 1 shows a schematic drawing of the stimulation. The stimulator has a Xenon lamp as light source and a disk shutter. A in Figure 1 is the back-

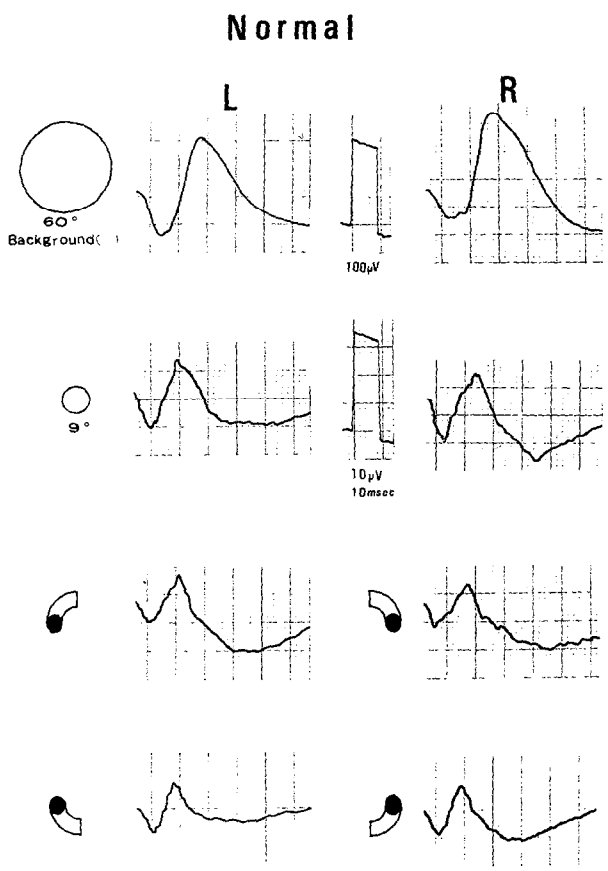

Fig. 2.

Case (T (68 y ♂ B) Macular degeneration

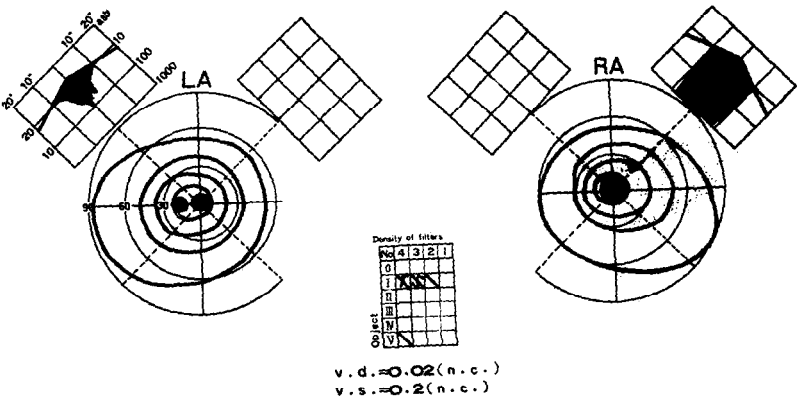

Fig. 3.

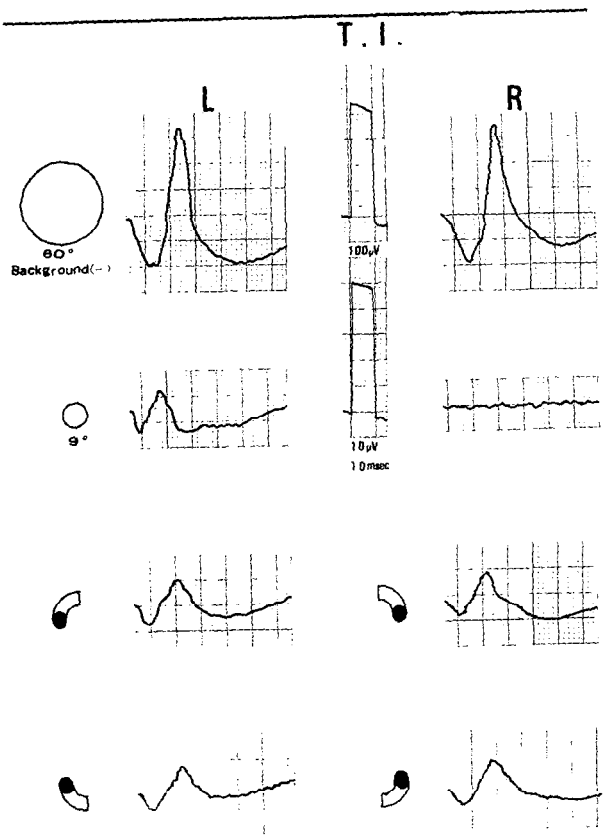

Fig. 4.

Case II N.F. 24y □ L) Macular degeneration

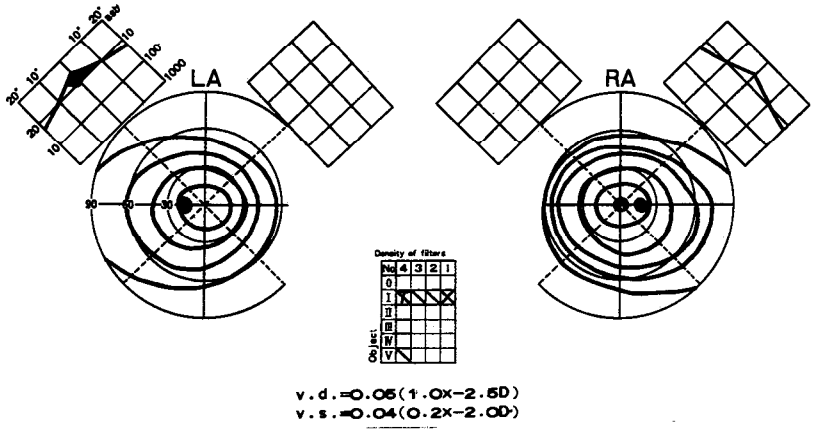

Fig. 5.

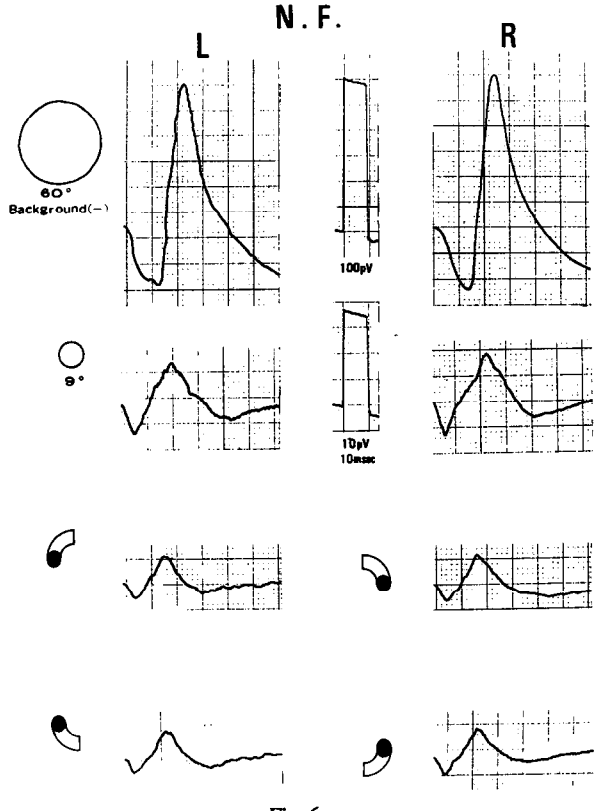

Fig. 6.

Case III S.S 45 y ○ R) Retino-choroidal atrophy

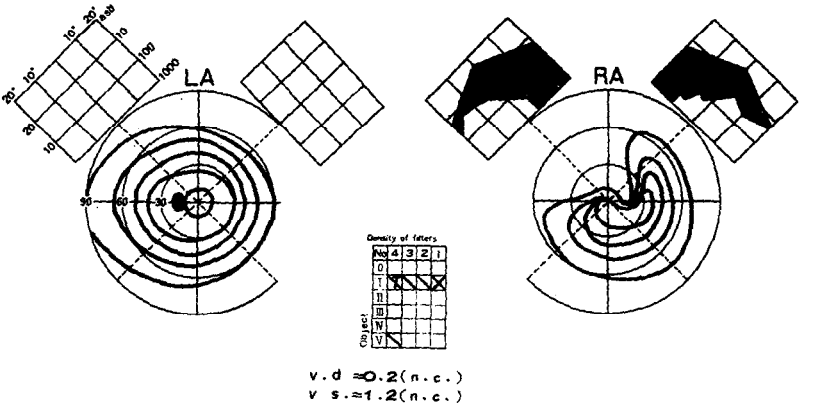

Fig. 7.

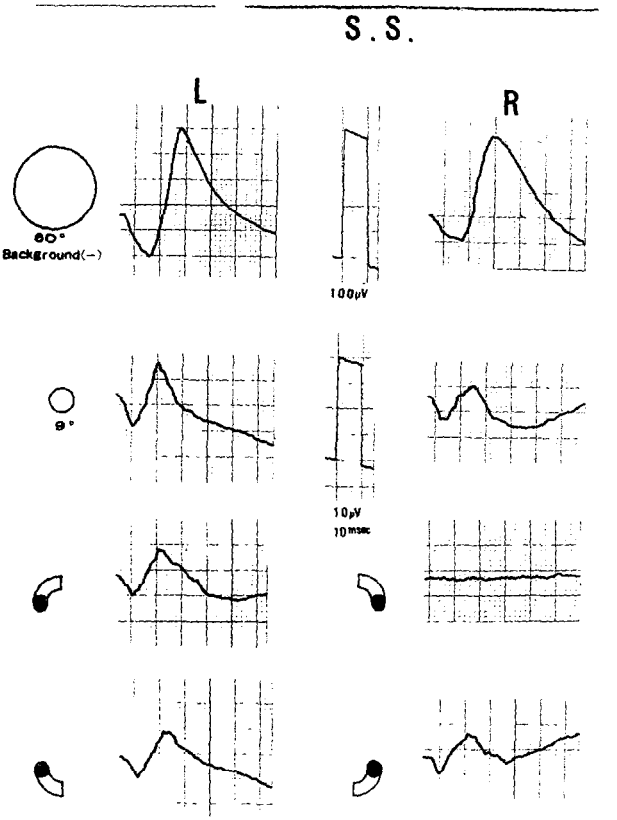

Fig. 8.

ground illumination in a shield box. An area of 60° of the retina can be bleached with this illumination.

By preliminary experiments, the difference between the stimulus intensity and background luminance was chosen; 0.5 apostilb logarithm units. This condition is in rod saturation. The duration of stimulus was 100 msec. and frequency was 4 c/s. Time constant was 0.3 sec.. The responses to two hundred stimuli were averaged by computer. To avoid the hum, a transfer circuit was used. The data was registered by the XY recorder.

Figure 2 shows stimulus patterns, background conditions and the results of normal subjects. Four kinds of stimulus patterns were used. The top diagram of this figure gives the ERG stimulated to the whole retina. The second diagram shows the wave which was stimulated with 9 degrees central stimulus, and blue background illumination. The third and fourth diagrams show the electroretinograms of upper and lower 1/4 circular parts from the blindspot in the Bjerrum area. At this point, 7 degrees of the white background illumination at central part was added to get good local response, and the remaining background was blue.

Case I. This case has macular degeneration in both eyes. In figure 3, kinetic perimetry by I/3 target shows 10 degrees central scotoma in the right eye and 8 degrees in the left. Also by static perimetry, high degrees of depression were found in right eye and low degrees in left. Local ERG are indicated in Figure 4. The ERG from the right macular area is extinguished. In the left eye, a and b waves are depressed.

Case II. This case has also macular degeneration. In findings of visual fields (Fig. 5), kinetic perimetry shows almost normal, but I/O isopter is not detected. Slight depression is given at the central part by static perimetry. Evident abnormality of local ERG (Fig. 6) cannot be indicated.

Case III. Case III has a large retinochoroidal atrophy due to the light coagulation of the thrombosis of inferotemporal retinal vein. With kinetic

Table 1

	Visual acuity	C value (Tonography)	Gonioscopy	I.O.P. (mmHg)	Glaucomatous excavation
Case VI	R 1.0(n.c.)	0.10	Open angle	18	+
47y O	L 1.0(n.c.)	0.15	〃	18	+
Case VII	R 0.3(0.8)	0.12	〃	10	++
15y □	L 0.1(0.5)	0.08	〃	22	+++
Case VIII	R 0.3(0.9)	0.14	〃	18	+
60y O	L 0.3(0.9)	0.16	〃	20	++
Case IX	R 0.4(0.7)	0.24	〃	12	+
68y □	L 0.2(0.4)	0.26	〃	12	++
Case X	R 0.08(n.c.)	0.10	〃	17	+++
60y □	L 0.4(n.c.)	0.15	〃	19	++

Case IV K.N. 38y ☐ R) Embolism of infero-temporal artery

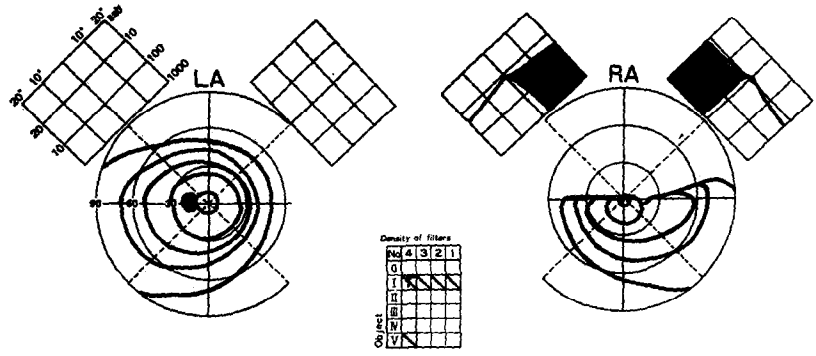

Fig. 9.

K.N.

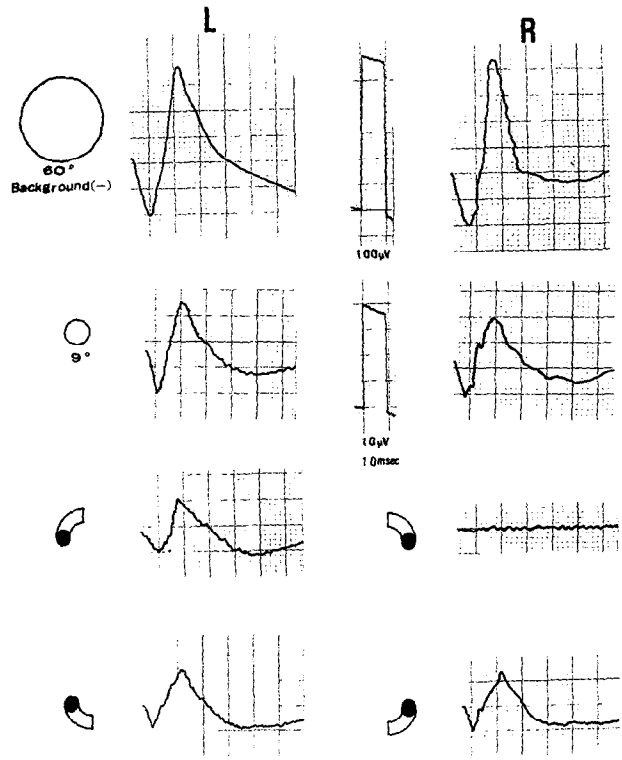

Fig. 10.

Case V I I 34 y O R) Embolism of superotemporal artery

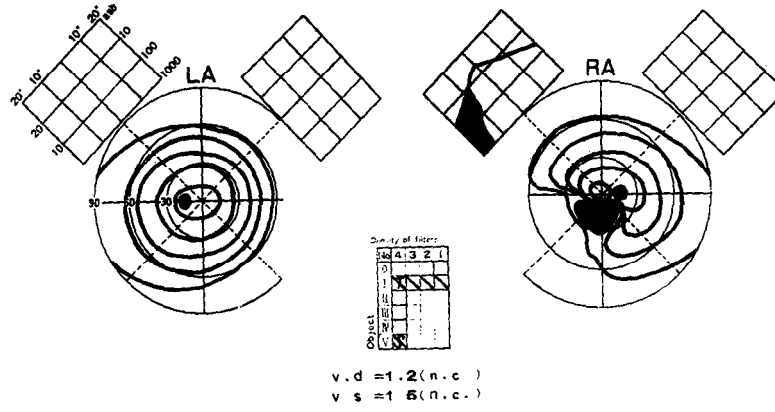

Fig. 11.

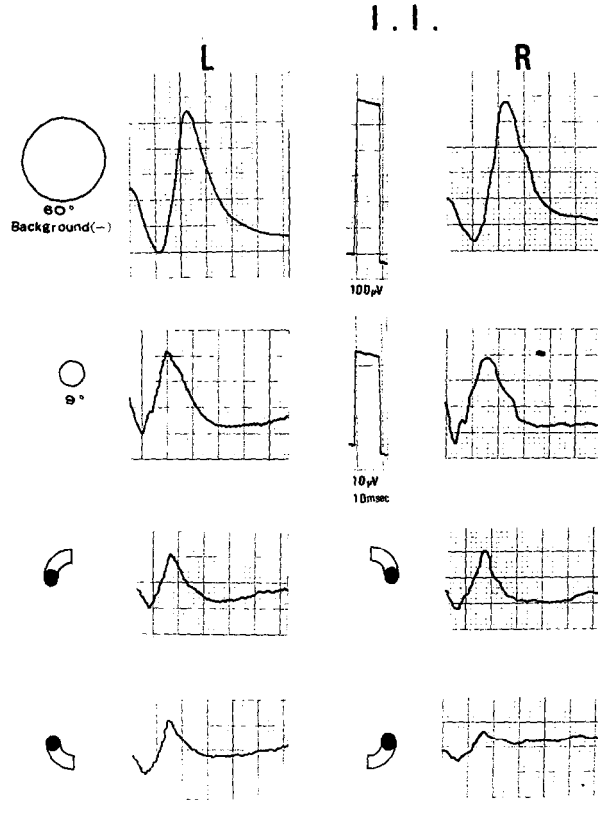

Fig. 12.

and static perimetry (Fig. 7), a large deficit is shown in the nasal upper quadrant, and some depression in the macular area. The ERG (Fig. 8) of the macular area is diminished in a and b waves corresponding to the visual field defect, and the ERG of the upper part of the Bjerrum area is extinguished.

Case IV. In this case, an obstruction occurred in the inferior retinal artery 4 months before the examination. When the visual field and ERG were tested, grayish cloudiness could still be seen, in the lower part of retina Kinetic and static perimetry gave high degrees of depression in the area supplied with inferior retinal artery (Fig. 9). The ERG of the upper part of the Bjerrum area was absolutely extinguished (Fig. 10).

Case V. This case has also an obstruction of superotemporal retinal artery. After one month of onset, grayish cloudiness of the retina disappeared. In Figure 11, high degrees of depression in the lower Bjerrum area can be seen by both methods of perimetry. Figure 12 shows the subnormal ERG of the lower part of the Bjerrum area.

In this report, only two out of five cases of open angle glaucoma were discussed in detail, since similar results were obtained in all five cases. Diagnosis is decided by the tests which are described in the Table 1.

Case VI. The result of kinetic perimetry shows the scotoma of the Bjerrum area in the left eye and a baring blind spot in right eye. By static perimetry and FVFA, the scotomas are found in the same places (Fig. 13). It is sup-

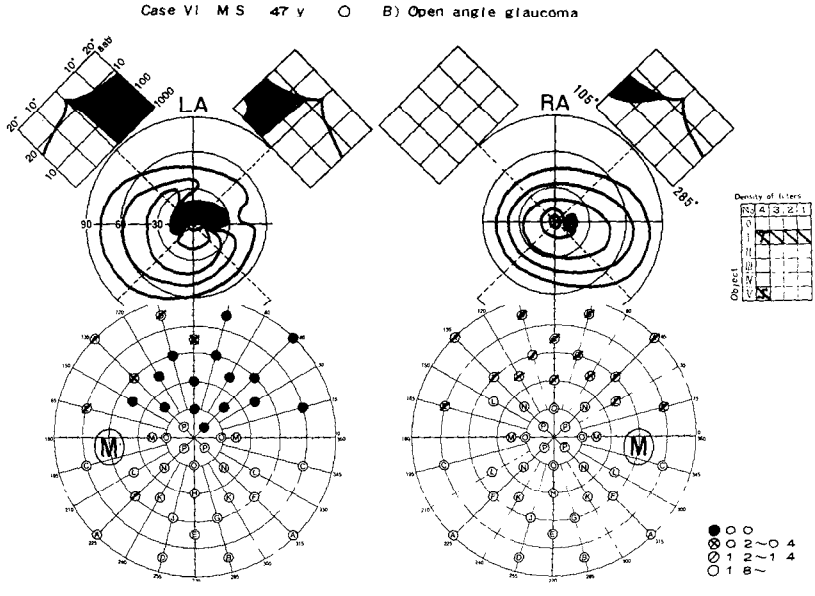

Fig. 13.

posed that this features the early stage of glaucoma. In the finding of the local ERG, the corresponding section in the Bjerrum area, no special abnormality is shown (Fig. 14).

Case VII. This case also has an open angle glaucoma. Visual fields of boht kinetic perimetry and FVFA indicate progressed changes which are seen at the middle stage of glaucoma (Fig. 15). In the ERG no abnormality is recognised either (Fig. 16).

DISCUSSION AND CONCLUSION

In order to obtain the local ERG, a certain condition has to be fulfilled, i.e., if the background luminance is not high enough, the effects of the stray light cannot be suppressed, and if the stimulus intensity is too strong, the effects of stray light cannot be suppressed either. The small difference of contrast between the background luminance and stimulus intensity would

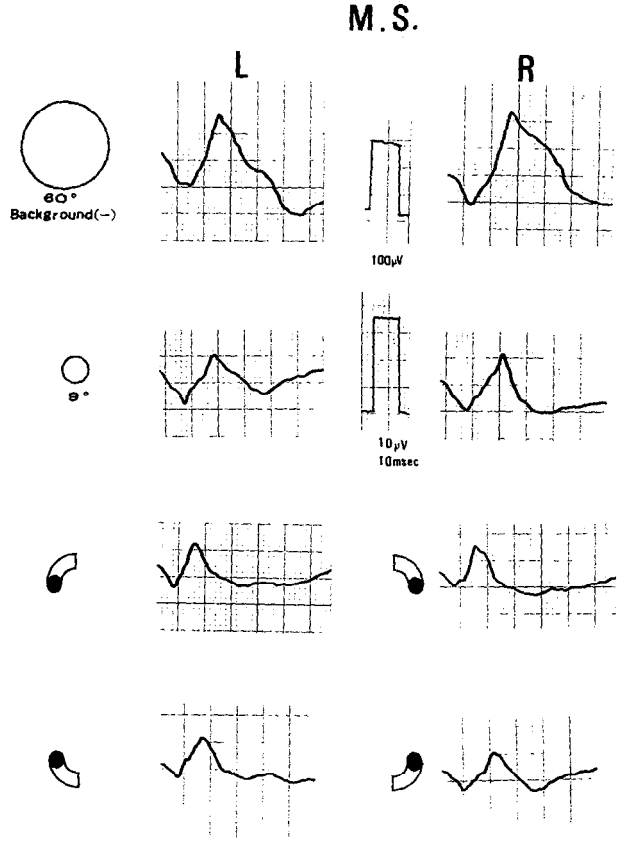

Fig. 14.

not produce the electroretinogram. With conditions as mentioned above, the local ERG was obtained at the macular area by Gouras (1962), Brindley (1965), Arden (1966), Aiba (1967), Bankes (1967), van Lith (1968), Jacobson (1969), Nagata (1970). We tried to obtain the local ERG from the macular area and from the Bjerrum area with a relatively weak stimulus intensity and a high background luminance. Therefore, the stimulus field should have been enlarged.

The relation of the three factors: fields, luminance of stimulus and background luminance is shown in Figures 17 and 18. The vertical scale indicates the intensity of luminance with apostilb log. units, the horizontal scale gives the eccentricity in degrees. It will be seen that when the Bjerrum area was stimulated, the macular area would be bleached. As mentioned before, the difference between the stimulus light and the background luminance is 0.5 asb. in log. units.

Case I, macular degeneration has a visual field with little difference in both eyes by kinetic perimetry, but evident difference is shown in static perimetry and local ERG. In case II, there is little difference in kinetic and static perimetry, and local ERG. Therefore, the amplitude of local ERG of the macular area was concerned with the degrees of depression by the static perimetry.

In the case of open angle glaucoma, since Karpe (1945) many investigators have reported that the ERG in glaucoma was either normal or subnormal. We tried to examine the ERG of the Bjerrum area in cases with Bjerrum scotoma. In these cases of glaucoma we obtained the same results.

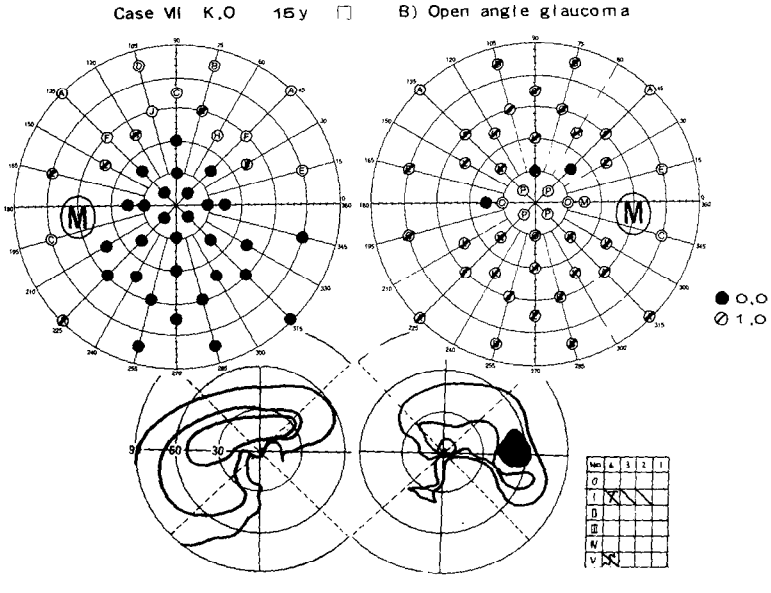

Fig 15

In spite of a high degrees of Bjerrum scotoma in kinetic and static perimetry, the local ERG of the Bjerrum area was always normal. In order to explain the origin of Bjerrum scotoma, many investigators have reported on the neurogenous or retinogenous origins. From our results, its origin is not in the least based on the disturbance of receptor cells layer and bipolar cells layer. Therefore, we suppose that its origin may be due to the third neuron.

In a case with large atrophic retina after the light coagulation (case III) serious visual field loss and extinguished ERG of the corresponding area were recognized. In spite of normal ERG by the usual method, local ERG of the corresponding area was extinguished. Therefore, it was reconfirmed that our local ERG was obtained from local region of the retina.

In the cases of obstruction of the artery branch with typical absolute field defects, case IV showed an extinguished local ERG, but, on the other hand, case V gave a subnormal result. Henkes (1954) reported that ERG in embolism of central artery was subnormal or negative typed, but only one case with occlusion of the ciliar artery had an extinguished ERG. In case IV,

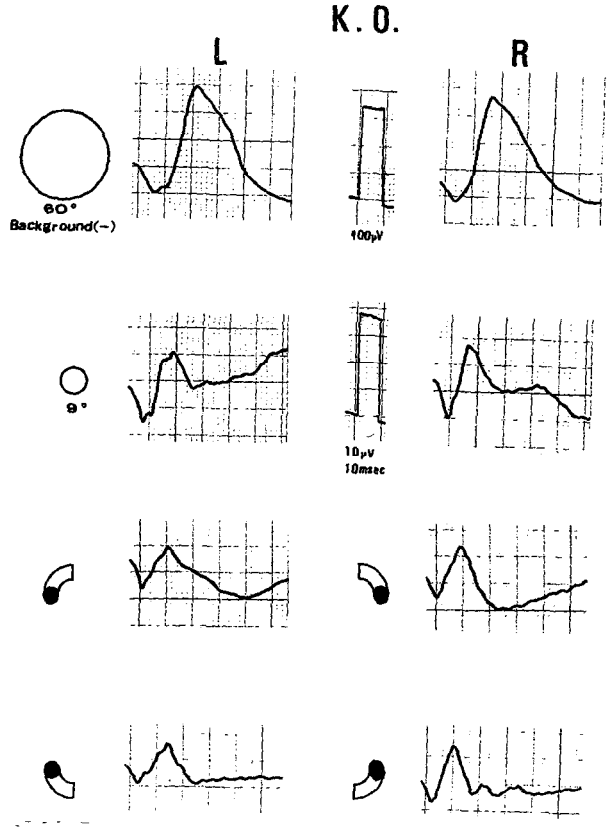

Fig. 16.

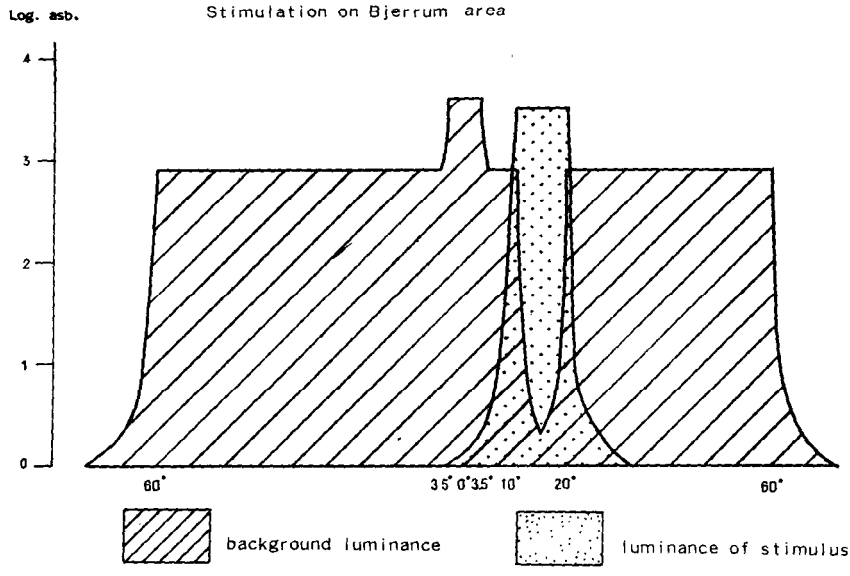
Log. asb.
Stimulation on Bjerrum area
4
3
2
1
0
60°
35° 0° 35° 10°
20°
60°
background luminance
luminance of stimulus

Fig 17

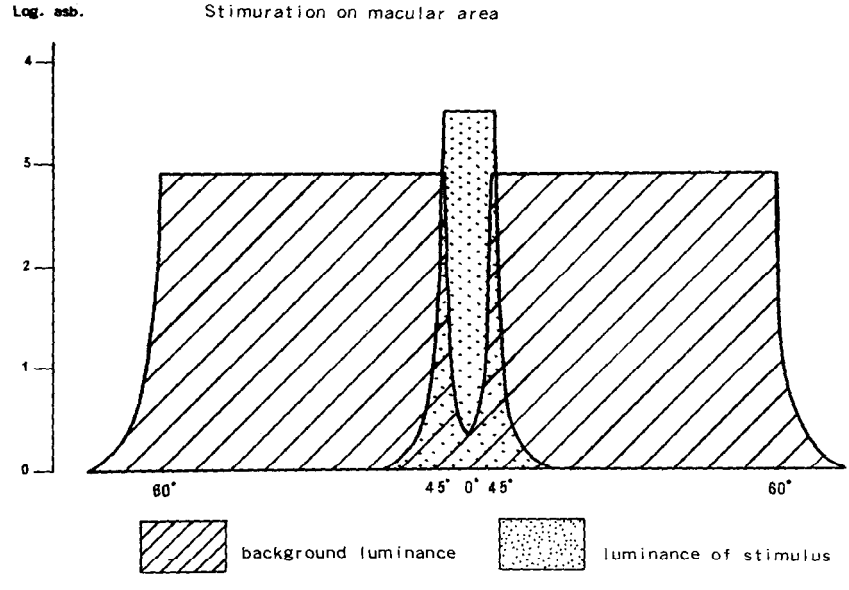
Log. asb.
Stimuration on macular area
4
5
2
1
0
60°
45° 0° 45°
60°
background luminance
luminance of stimulus

Fig 18.

when the tests were ready, it was recognized that grayish cloudiness of the retina was left after 4 months. Therefore, we supposed that this difference in local ERG was due to the duration and the limit of recovery by embolism. But in the visual field, both cases show the absolute scotoma in the Bjerrum area, there is no differnce in the quality, but in the first case the deficit is larger than in the latter.

SUMMARY

Quantitative changes of visual field and of local ERG were dicussed to detect the relations between both of them. In the cases of macular or Bjerrum areas' disorders, kinetic perimetry with the Goldmann perimeter and static perimetry with the Tübinger perimeter on the adequate meridian were done.

A significant local ERG was obtained using relatively weak stimulus intensity and high background luminance. When the macular area was stimulated with a 9 degrees central stimulus, a blue background luminance was used. When the Bjerrum area was stimulated with a I/4 circular stimulus on the upper or lower parts of blind spot, the background luminance of white at the central part, 7 degrees in diameter, and the other surrounding blue background was used.

In the cases of macular degeneration, the amplitude of local ERG of macular area was concerned with the degree of depression by static perimetry.

In case of large degeneration after the treatment of light coagulation in infero-temporal vein thrombosis, and the case of retino-choroidal atrophy after injury, both with serious corresponding visual field loss, it was recognized that the local ERG was not recorded, while the ERG by ordinary method was obtained in usual form.

In the several cases of embolism of artery blanch with typical absolute bundle form field defect, one case showed extinguished local ERG, and the others, subnormal ERG. This difference in local ERG would be due to the duration and the limit of recovery by embolism, but in the visual field did not find the equivalent differences.

Open angle glaucoma with Bjerrum's scotoma or deficit of upper part of central visual field shows the normal ERG by ordinary method and also by local stimulation at Bjerrum area.

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THE RECORDING OF THE SCOTOPIC AND PHOTOPIC DC-ERG BY MEANS OF LOCAL STIMULATION WITH WHITE LIGHT AND COLOURED BACKGROUND

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Earlier electroretinographic experiments, aiming to record responses to local light stimulation within the intact eye, are quite numerous. Because of severe technical problems, i.e. especially with straylight-problems, different techniques evolved.

Gouras et al. (1962) were the first to show spatial differences in the human ERG. They found a high sensitivity for red stimuli within the area of 15 degrees of the central visual field. Jacobson et al. (1969) received local responses with stimuli 1 log unit above background illumination. In these setups the effect of straylight based on Ulbricht's principle was very small. The amplitudes recorded in the central visual field were in the range of 2-3 microvolts. The number of responses to be averaged was fairly high, namely 250 responses.

Armington (1968) investigated the area-luminance relationship by means of alternating stripe patterns within the central 12 degrees and found a linear relationship. Brindley & Westheimer (1965) produced local responses by means of fixed light stimuli and changing background illumination. This ratio had to be between one to six and one to ten.

A reverse approach was carried out by Bagolini et al. (1973) utilizing Ulbricht's principle. Two perfectly alternately timed light stimuli were switched on at different retinal locations in order to keep the amount of stray-light constant and to obtain two electrical reponses originating from the stimulated retinal points.

Henkes & van Lith (1974), finally, separated photopic responses using a bright blue background at a high stimulus frequency. They had to use a special amplifiersystem i.e. lock-in-amplifiers to separate the B-wave amplitude from the noise level. Nevertheless, they were able to draw retinal sensitivity profiles in the photopic state.

With high stimulus frequencies it is impossible to record ERG-subcomponents. Therefore we used a technique which enabled us to record the subcomponents when applying red and blue background illumination to separate scotopic and photopic responses. Using light stimuli of at least 500 msec instead of light flashes enables us further to record the DC-component and the B-wave.

Figure 1a shows a Ganzfeld-ERG with dark backgrounds on the left and light backgrounds on the right. Note that with increasing light intensities

from the upper to the lower records the DC-component becomes more and more negative. This is shown in Figure 1b diagramatically. Here we see an amplitude-intensity function of the DC-component. Filled symbols refer to dark backgrounds, open symbols to light backgrounds.

Like the B-wave, the DC-component shows a readaptation after bleaching from negative to positive. Figure 2 shows the adaptation of the B-wave, the DC-component and the Off-response after preadaptation to 1400 cd/m^2 with a stimulus of 2 log units above the B-wave threshold in the dark. The net-value of the B-wave and the DC-component adaptation runs a somewhat similar course, whereas the Off-response shows a different behaviour. The B-wave is very small in the light adapted state as compared to the dark adapted state. When aiming towards local stimulation one could expect to get quite easy measurable amplitudes in the dark, whereas in the light

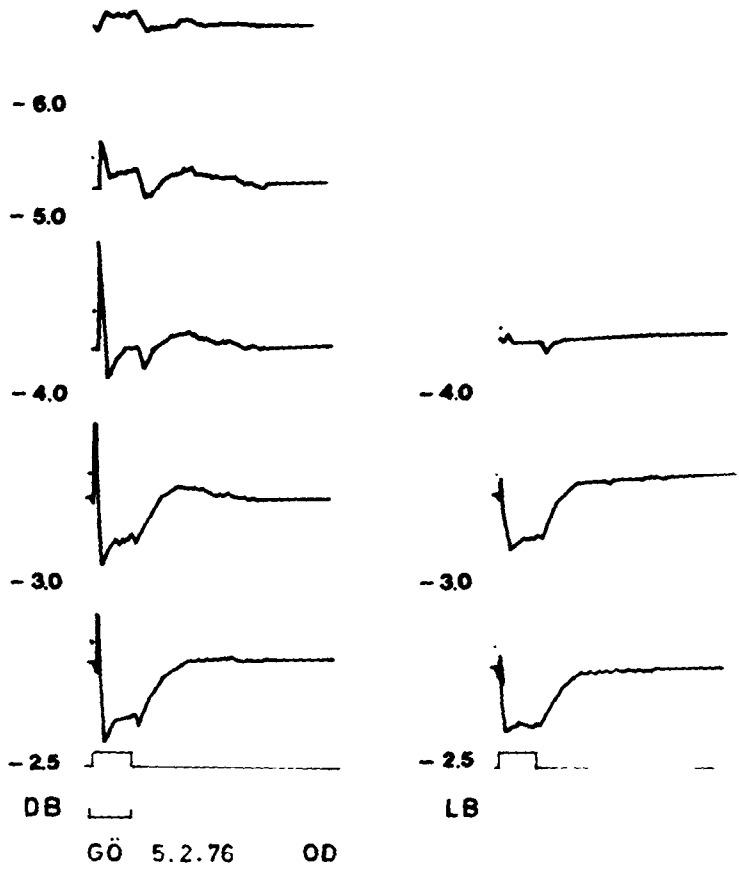

Fig. 1a. ERG of a normal human subject at different stimulus intensities with dark background, left, and light background, right. Calibration signal at the beginning of each sweep 100 microvolts Stimulus time 1 sec.

adapted state the signals to be recorded could be expected to be very small. In order to get responses from the rod and cone systems separately red and blue background illuminations in the lower photopic range were chosen. The light stimulus produced by a Xenon high pressure bulb passed an electromagnetic shutter and could be varied in steps of 0.2 log units over 5 log units. The stimuli were placed along the horizontal meridian in a sphere. The background illumination came from a projection system the light beam of which was passed through an Interference filter (Balzer 608 and 452). The subject placed into a shielded room was asked to fixate 4 points in the center each being 20 min in diameter at a distance of 2 degrees. After the contact lens had been placed onto the eye the blind spot was measured perimetrically and the light intensity of a test spot projected into the very center of the blind spot was decreased until no light sensation of the test spot was obtained. Measuring the reflection of light in fundus photographs at the optic disk and in the peripapillary area we found a ratio of roughly one to three. Therefore, the light stimulus was increased by half a log unit and this value was chosen to examine the horizontal meridian.

Figure 3 gives the amplitude-intensity relationship of a 2 degree stimulus in the fovea with a red background light. In the lower part of the figure we see the recordings at the different intensities used. The calibration at each

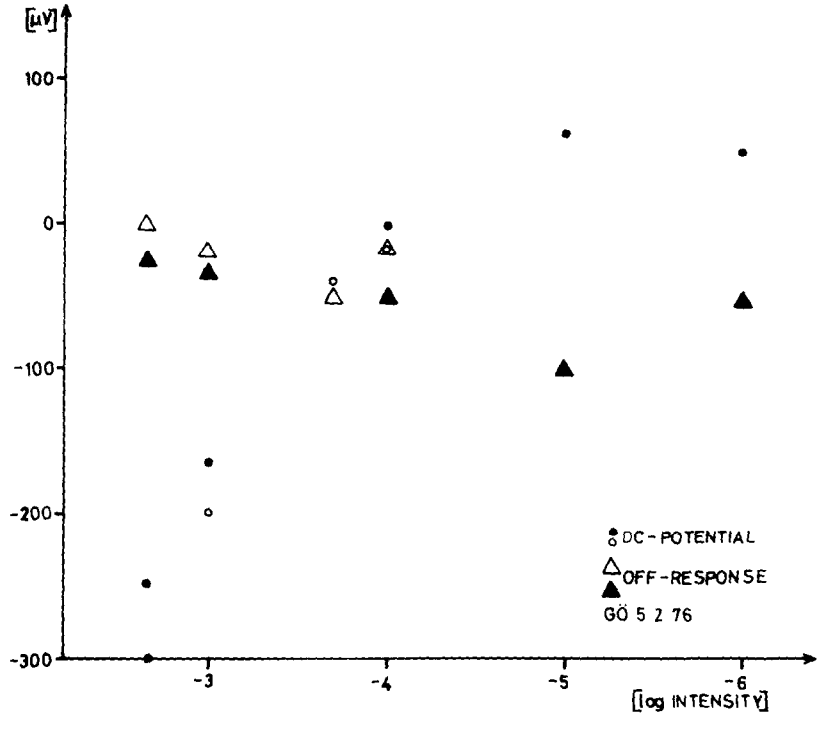

Fig. 1b Intensity function of the DC-component and the Off-response. Filled symbols at dark background illumination, open symbols at light background illumination.

starting sweep is 10 microvolts. The light stimulus is 1 sec long. Note that the B-wave, the DC-component and the Off-effect exhibit a somewhat linear relationship.

Figure 4 shows responses to local stimuli along the horizontal meridian with red and blue backgrounds. The upper curve has decreasing amplitudes of the B-wave from the center to the periphery at the temporal side more pronounced than on the nasal side. Nevertheless there is no great difference between 8 and 25 degrees nasally. This difference is even less, if we take the responses at blue background illumination. Here the B-wave amplitude changes between 3.5 and 6 microvolts.

Increasing the light stimuli to 1 log unit above the threshold within the peripapillary area at blue background illumination the amplitudes of the B-wave increase slightly (Figure 5). Nevertheless, they are still fairly small. Measuring the DC-component, which is negative in photopic or cone dominated conditions instead of the B-wave amplitude gives a clear sensitivity profile along the horizontal meridian.

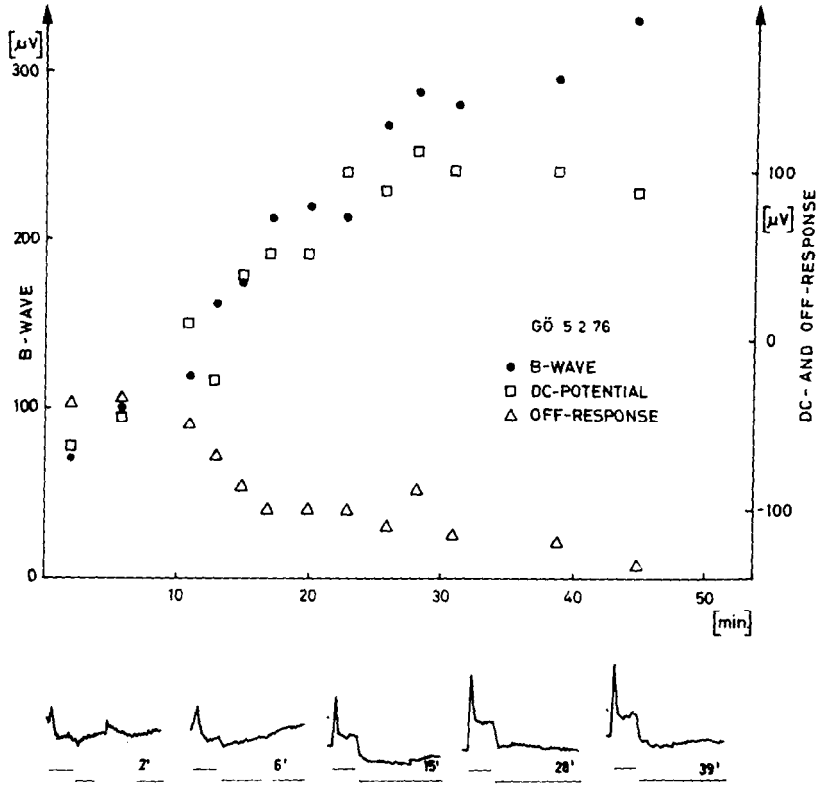

Fig 2. Time course of the readaptation of the B-wave, the DC-component and the Off-response after preadaptation to 1400 cd/m² In response to light stimuli of 1 sec duration 2 log. units above B-wave threshold. Note the difference in the slope of the DC-component and the Off-response.

Taking such profiles we notice that it can only be done in the central visual field. Towards the periphery, already at 9 degrees with red backgrounds, we find low B-wave amplitudes with almost no change. Measuring the DC-component the situation is somewhat better in photopic conditions. We probably face a methodological problem which arises from the measurement of the threshold at the blind spot. Instead of this, we should use a difference sensitivity threshold measurement to do threshold dependent measurements in different retinal locations as every perimetrist does in subjective perimetry.

It has been shown that under appropriate stimulus and background conditions it is possible to record scotopic and photopic dominated responses to local retinal stimulation. Because of the positive DC-component

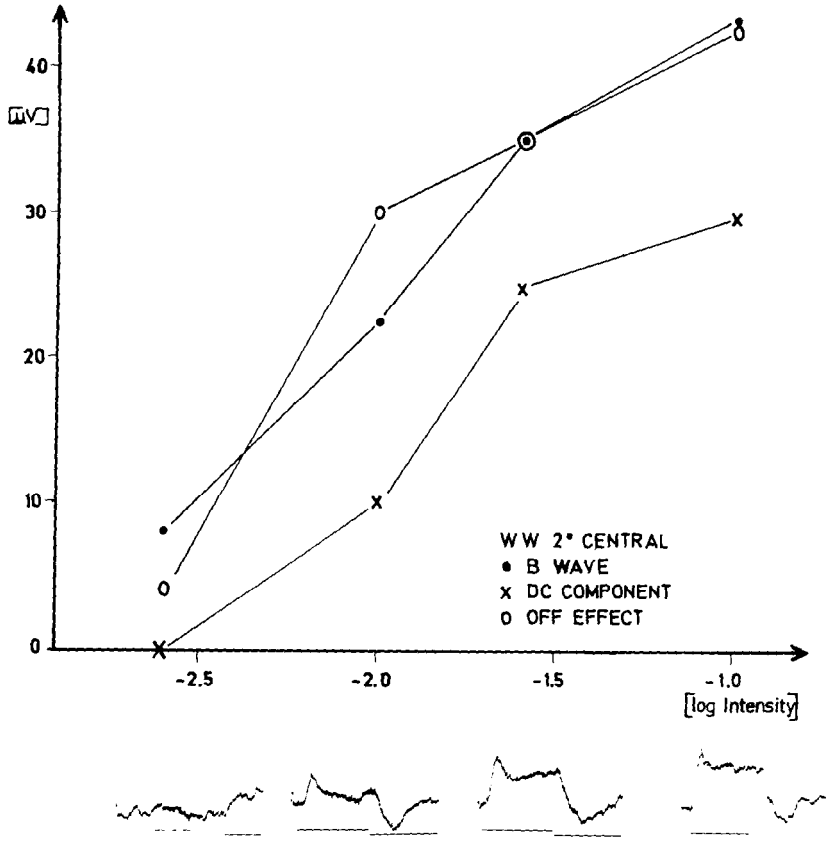

Fig 3. Amplitude-intensity relationship of a 2 degree stimulus in the fovea Average of 50 sweeps exhibiting linear increasing amplitudes Vertical scale in microvolts; horizontal scale relative intensity.

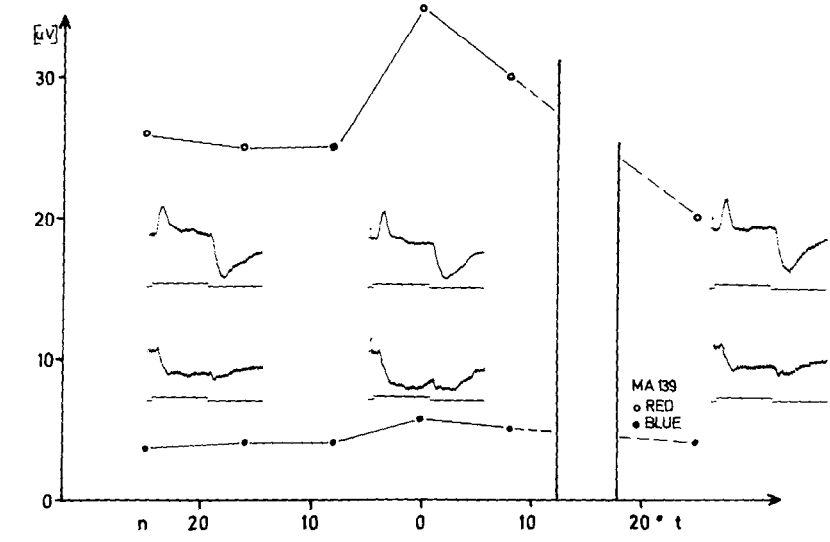

Fig. 4. Sensitivity profile of the local ERG in the horizontal meridian at red background (scotopic dominated) illumination upper records and blue background (photopic dominated) illumination lower records; light stimuli white 2 degrees Average of 50 sweeps upper records and 70 sweeps lower records

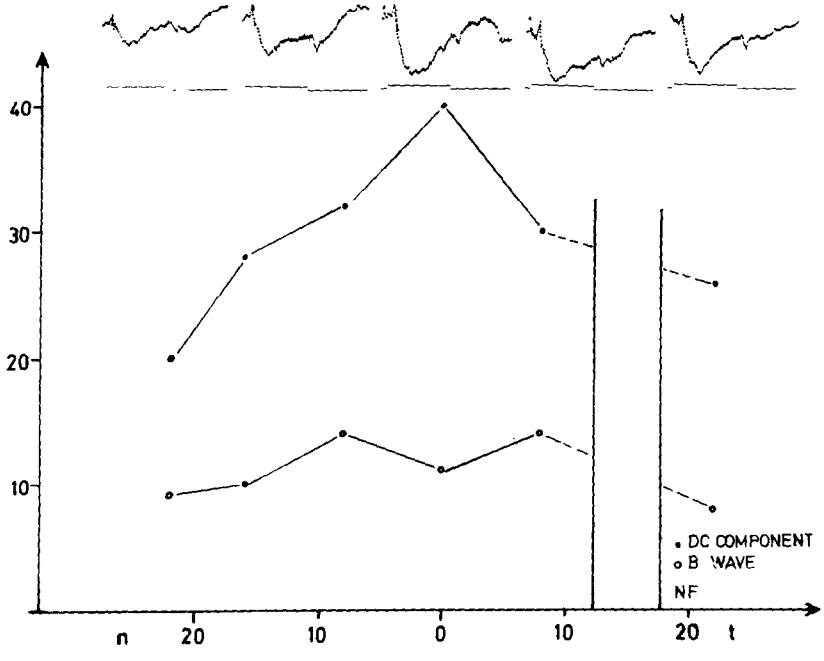

Fig 5 Sensitivity profile of the local ERG in the horizontal meridian at blue background illumination with white light stimuli. Vertical scale in microvolts. Horizontal scale in degrees The measurement of the DC-component shows contrary to the B-wave measurement an acceptable profile along the horizontal meridian. Average of 70 sweeps.

which is added to the B-wave under scotopic conditions we get fairly large amplitudes. Under photopic conditions, where we have a large negative DC-component with a small B-wave amplitude, the measurement of the DC-component allows us to record sensitivity profiles within the central visual field. If one wants to record outside of this area one has to use threshold adapted setups, which still do not have a significant amount of straylight.

SUMMARY

After reviewing the earlier experiments on local retinal stimulation, our results are presented using a DC-ERG method with light stimuli of one second Photopic and scotopic answers are recorded and assessed in the central visual field on the basis of B-wave and CD-component measurements

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PATTERNED EVOKED POTENTIALS IN OBJECTIVE PERIMETRY*

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INTRODUCTION

The application of evoked potential measurement techniques to visual field examinations is fairly common. Transient-state evoked potentials (EPs) (e.g. Ohba) or steady-state EPs (e.g. Regan) have been used to record the cortical response during macular and peripheral stimulation of the retina

This paper reports on steady-state EPs recorded during stimulation, at various eccentricities, of the vertical meridian of the visual field, by means of black and white alternating grating of variable size (Fig. 1).

We took as our starting point the findings of Campbell & Maffei regarding the connexion between psychophysical contrast threshold tests and EP amplitude measurements· they showed that the psychophysical threshold to contrast of a grating can be deduced by plotting the relationship between the amplitude of the EP and the logarithm of the contrast of the stimulus grating. This holds for the whole spatial-frequency spectrum of the visual system, and hence if the relationship between psychophysics and EPs still holds good in peripheral stimulations of the retina, it may afford a valuable assessment of cortical response on objective perimetry. We therefore set out to verify the validity of this affirmation on the basis of a clinical application of the spatial-frequency channels theory. Our preliminary findings are reported below.

MATERIAL AND METHODS

The experiments were carried out on two normal subjects, S.F. and E.C.. We used a 27″ television-stimulator which could display black and white circular gratings of different spatial frequencies. The VER's were recorded by means of an ORTEC averager (4623-4620) and plotted by an X-Y.

The spatial frequency of the grating had four values 4.38, 2.18, 1.64, 1.1. c/deg, its contrast corresponded to one third of the total contrast range of the instrument, which was approximately 40% of modulation depth.

Four degrees of stimulus were employed, namely 1°, 2°, 3° and 7°, while the eccentricity of the stimulus centre varied from 0° to 10° along the vertical meridian.

* This study was supported by C N R Grant 'Progetti finalizzati. Applicazione di tecnologie avanzate al sistema visivo'

RESULTS

The relationship between eccentricity and logarithm of the amplitude of VER's is reported in the plots of Figs. 2 and 3.

It can be seen from Fig. 2 that at a stimulus of 1° the VER is maximum at eccentricity 0°, but can no longer be detected at eccentricity 3°.

With stimuli of greater diameter the curves tend to flatten and extend, the same VER maximum value being recorded at a stimulus of 7° and up to an eccentricity of 3°. Not until an eccentricity of 8° is reached does the VER drop to zero.

At eccentricities of more than 1° and at a constant stimulus of 3°, one can see (as in Fig. 3, which shows two values of spatial frequency) an inverse relationship between spatial frequencies and VER amplitude. i.e., the smaller the spatial frequency in stimulation of the paramacular region, the higher the VER recorded.

Finally, if, in peripheral stimulation, one wishes to obtain a VER the amplitude of which is nearly the same as that recorded centrally for a fixed

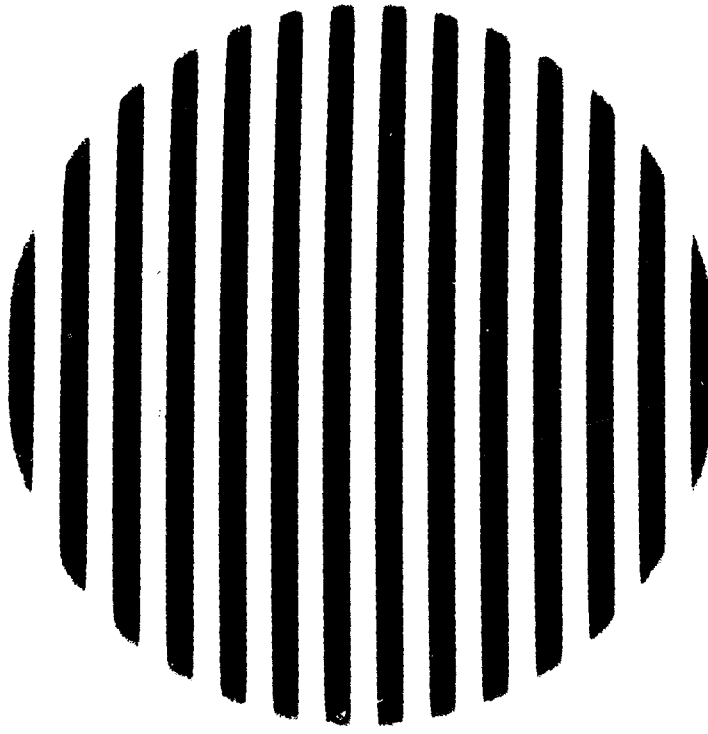

Fig 1 Black and white grating stimulus. The spatial period (or cycle) is defined as the distance (e g. in mm) between two consecutive stripes of the same colour. The number of spatial periods for every visual degree is defined as spatial frequency and is usually measured in cycles/degree

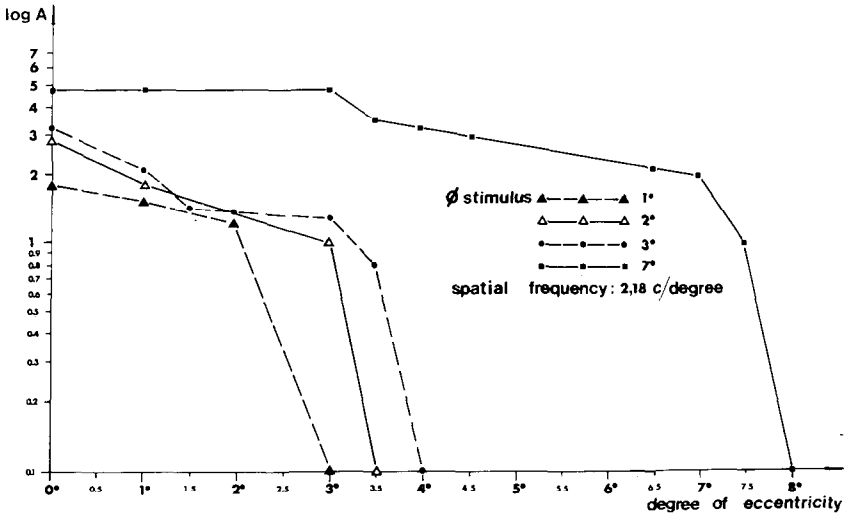

Fig. 2. Plots of the logarithm of the VER amplitude vs. eccentricity of the stimulus along the vertical meridian. The spatial frequency is the same for every degree of stimulus. Note that both the amplitude for zero eccentricity and the eccentricity for undetectable VER decrease at lower stimuli.

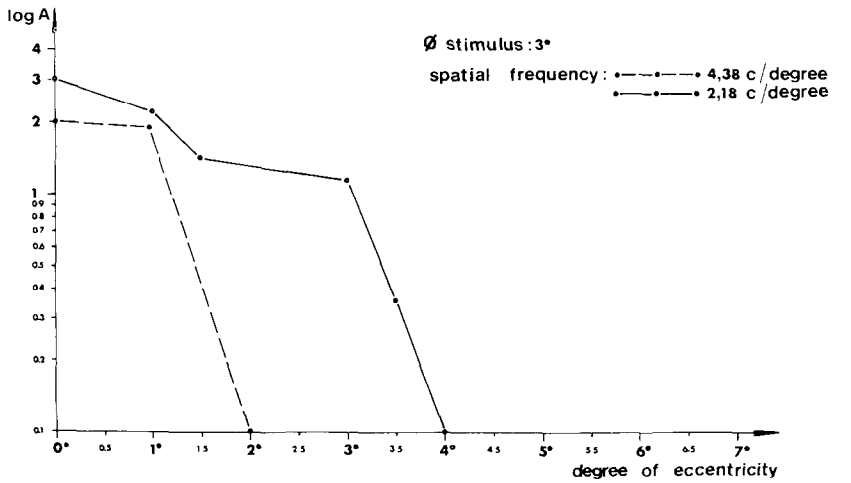

Fig 3. Abscissae and ordinates as in Fig. 2 The degree of stimulus is fixed. Note that the greatest VER amplitude is obtained with the smallest spatial frequency stimulus.

spatial frequency, the grating size has to be greatly increased. The relevant scheme is reported in Fig. 4.

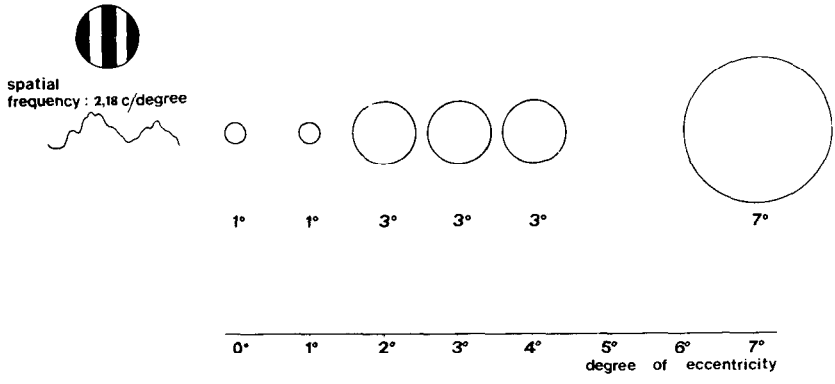

Fig. 4. This figure indicates the increase in stimulus necessary to obtain a peripherical VER of the same amplitude as that recorded in central stimulation

DISCUSSION

The following initial observations can be made:
1) The Campbell-Maffei technique in question enables one to carry out a perimetrical examination with a maximum eccentricity of 3° at a stimulus of about 1°, which is the value normally adopted in 'clinical perimetry'.
2) At a stimulus of 7° peripherical VER is zero, thus indicating that, at an eccentricity of more than 7°, an increased retinal area of stimulation is not sufficient to obtain a VER greater than zero.
3) We can infer that a VER greater than zero can be peripherically recorded only if the extreme marginal part of the stimulus occurs in a central or paramacular area.
4) There are two possible explanations for the drastic attenuation of the VER at increasing eccentricity the first is that the cortical area (projection of the macula) is much larger than that corresponding to the periphery, the second is that the macular cortical projection area is much nearer to the scalp surface than the peripheral area, so it may be easier for the electronic recording system to detect central activity.

In conclusion, the Campbell-Maffei technique would appear to be a good tool for the objective clinical evaluation of the foveal macular function in that it enables a kind of quantitative (e.g. static) perimetry to be satisfactorily performed in the above-mentioned region. Much work has yet to be done, however, on the relationship between psychophysics and VER measurements in questions of peripheral vision.

SUMMARY

The VER, obtained by means of an alternating-grating stimulus, is recorded perimetrically in normal and pathological subjects. Considering the results, it is possible to conclude that this method is useful for an objective study of a central area of the visual field, 10° in diameter.

ACKNOWLEDGEMENT

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QUANTITATIVE PERIMETRY AND VISUAL EVOKED POTENTIALS IN MULTIPLE SCLEROSIS*

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The value of the visually evoked potential (VEP) in diagnosis of multiple sclerosis (MS) has been well established (Ritchey, Kooi & Tourtellotte, 1971; Namerow & Enns, 1972; Feinsod, Abramsky & Auerbach, 1973; Halliday, McDonald & Mushin, 1973; Milner, Regan & Heron, 1974, Asselman, Chadwick & Marsden, 1975), but the superiority of this method over ordinary clinical methods is not yet supported by strong evidence. Some authors state that the VEP may be abnormal in the absence of visual symptoms or when psychophysical techniques do not disclose visual abnormalities. However, most have not measured vision completely. In some series, denial of past or present visual symptoms has been considered sufficient to exclude clinical evidence for lesions in the visual pathways. In others, only records of normal visual acuity support the statement that visual signs and symptoms were absent.

Burde & Galin (1975) found that static perimetry was the most sensitive method for detecting residual visual deficit after the resolution of symptoms of acute optic neuritis. We therefore compared the results of flash-evoked VEPs with those of quantitative static and kinetic perimetry in 49 patients with MS, with and without visual symptoms.

METHODS

Subjects

Forty-nine patients with well-documented MS (33 women and 16 men), ages 18 to 60 years, were studied. Twenty-four patients (group A) had a history of at least one attack of optic neuritis; twenty-five (group B) had never experienced symptoms suggesting past or present clinical involvement of the visual pathways. Six patients in a third group, group C, were examined during their first episode of acute monocular visual loss. A comparison group, D, consisted of nine patients with ischemic optic neuropathy. All patients were compared to 50 normal subjects matched to the patient population by age and sex.

* This work is reported in more extensive form in *Annals of Neurology*, June 1977, published by Little, Brown & Co.

VEP recording

The monocular flash-evoked VEP was measured on all patients and controls. The pupils were not dilated, the eye to be tested was slightly closed, and the opposite eye occluded by an opague patch. The Grass PS22 photostimulator was set at an intensity of 4 and flashes were delivered at a rate of one per second. Responses (128) were recorded (bandwidth 0.3 to 100 Hz) from active electrodes over the contralateral occipital cortex (O_1 or O_2) and referred to a common electrode at the vortex.

Visual acuity and kinetic visual fields were measured on all patients and control subjects. Static perimetry was performed on 38 patients and all controls. Visual fields were tested by methods described previously (Ellenberger, 1974).

RESULTS

The latency of the first major upward deflection was the most reliable index separating the VEPs of patients from those of normal subjects. Mean latency among the controls was 52.8 ± 4.0 msec. 60 msec was selected as the upper limit of normal latency; only 4% of normals fall above this level. Intraocular latency difference was less than 2.8 msec in 99% of the normal subjects; amplitudes did not differ by more than 10% between the two eyes.

Latency was abnormally delayed in 31 (97%) of 32 previously affected eyes in group A and in 13 (81%) of the 16 opposite (asymptomatic) eyes of these patients. The average latency of the VEP of affected eyes in this group was 80.5 ± 13.7 msec (abnormally prolonged, $p < .001$). In contrast, visual acuity was abnormal (20/30 or less) in only 53% of the previously affected eyes and in 25% of the unaffected eyes. Visual fields (either static, kinetic, or both) were abnormal (two or more test points below the mean) in 56% of the affected eyes and in 19% of the unaffected eyes. Static and kinetic perimetry were approximately equally effective in detecting residual visual deficit.

Among patients in group B, latency was delayed in 28 of 50 eyes (56%). Mean latency for all 50 VEPs was significantly prolonged (62.5 ± 11.5 msec, $p < .001$). In this group, visual acuity was abnormal in only 26% of the eyes. Kinetic perimetry was normal in all patients; static perimetry was abnormal in 5 of the 37 eyes tested (14%).

The six patients in group C were studied during an initial attack of acute optic neuritis and throughout its resolution. Amplitude of the VEP from the affected eye was reduced by 25 to 75% in 4 patients compared to that of their unaffected eye. Average latency of this group was not prolonged (58.0 ± 5.0) despite severe reduction of visual acuity. Among these patients (also among groups A and B) the duration of the prolonged latency did not correlate with visual acuity ($r = -0.148$); the delay remained constant or slowly increased during exacerbations and remissions of the visual deficit and then persisted indefinitely afterwards.

Nine patients with ischemic optic neuropathy were also studied. Amplitude was reduced in 8 of the 9 affected eyes that had a stable arcuate field

defect. Latency was prolonged in 5 of 9 affected eyes and, unexpectedly, in 3 opposite, i.e. unaffected, eyes.

DISCUSSION

We have shown that prolonged latency of the flash VEP is a more sensitive indication of demyelinating lesions in the visual pathways than quantitative perimetry, i.e. that an abnormality of the VEP may be present even when careful measurement of vision does not disclose abnormalities. The combination of normal vision and abnormal VEP thus strongly suggests MS.

Similar latency-amplitude abnormalities were seen in ischemic optic neuropathy, but then always accompanied a visual field deficit. The delayed VEP itself is therefore not pathognomonic of demyelination as suggested by Milner, Regan & Heron (1974), who compared demyelinative optic neuritis with retinal disease. The delayed VEP of three eyes with normal vision opposite eyes affected by ischemic lesions raises the possibility of additional, perhaps non-vascular, factors in the pathogenesis of this condition.

Our results are consistent with those of previous studies that demonstrated the abnormality in nearly 100% of eyes previously affected by optic neuritis and in approximately 60% of visually asymptomatic eyes of patients with MS. However, our high percentage of abnormal VEPs (81%) in asymptomatic eyes opposite affected eyes differs considerably from the combined results of Milner, Regan & Heron (1974) and Halliday, McDanald & Mushin (1972) who found normal VEPs in 32 of 32 such eyes. The results of Wildberger (1976) who also found abnormalities in opposite, asymptomatic eyes, are closer to ours.

The abnormality of the flash VEP, i.e. prolonged latency, does not correlate with visual acuity or visual fields, it is thus an independent phenomenon detected only electrically. Symptoms that may correlate with this abnormality most likely relate to the Pulfrich phenomenon, i.e. altered perception of moving images caused by inequal conduction velocities within the two optic nerves. The delay may not appear initially, possibly because acutely demyelinated fibers are non-functional; perhaps only remyelinated fibers conduct slowly. The pattern-evoked VEP, partly dependent on the clarity of the retinal image, correlates more closely with the measured visual deficit.

SUMMARY

We compared the visual evoked potentials (VEP) to flash with results of quantitative kinetic and static perimetry in 41 patients with multiple sclerosis. 21 patients (group A) had previously had one or more episodes of optic neuritis; 20 patients (group B) had not

In 95% of the group A patients, the latency of early wave components of the VEP was greater than 2 S.D. above the mean latency of 60 normal control subjects, 93% of the eyes previously affected by optic neuritis and 77% of the unaffected eyes showed this abnormal delay. In contrast, kinetic

perimetry was abnormal in only 45% of the affected eyes and 8% of the unaffected eyes. Static perimetry was abnormal in 48% of the affected eyes tested and in 22% of the unaffected eyes tested. In group B, 13 of the patients (65%) had an abnormal VEP, kinetic perimetry was abnormal in only one of these 13 and static perimetry was abnormal in only 4. In addition, only one group B patient had a normal VEP but abnormal visual function tests.

Thus, the VEP proved to be the most sensitive method of detecting past or present demyelinating lesions in the visual pathways. The magnitude of the VEP abnormality did not correlate with the presence or severity of a visual deficit, therefore, it may reflect a consequence of previous demyelination that does not necessarily impair vision as measured by quantitative perimetry. The abnormality is not specific for demyelination, but when found in patients with other types of optic neuropathy, it always accompanied a major, symptomatic defect in the visual field.

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PUPILLOGRAPHIC PERIMETRY

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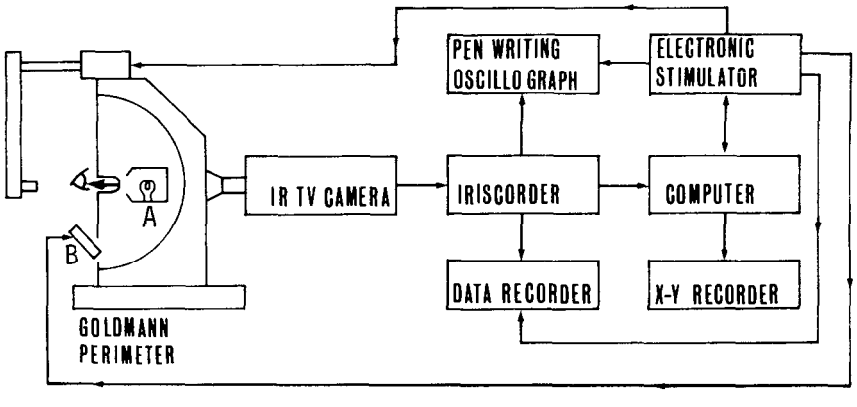
Up to now, we performed 'Pupillographic Perimetry' in several cases (1975a-d). In this paper, the authors would like to report on the relationship between functions of the rod or the cone, and the pupillary movements, using the infrared Videopupillographic apparatus (Iriscorder®) which can measure the absolute value of the pupillary area (Ishikawa, 1970).

The Iriscorder is used in combination with the Goldmann perimeter, signals from the Iriscorder are read and printed out by the X-Y recorder after being computed five times (Fig. 1). For the conditions of the experiment, see our previous paper (1975a).

Pupillograms under their respective adaptations are shown in Figures 3 and 4. In all these cases, when the test target is large and sufficiently bright, no definite prolongation of latency and no definite variation in the pattern of each pupillogram are observed. Therefore, it seems that no distinct changes in the patterns of pupillograms would be evoked by the rod and the cone.



A : INFRARED LIGHT SOURCE FOR IRIS ILLUMINATION

B' : DEVICE FOR BACKGROUND CORRECTION

Fig 1 Block diagram of experimental equipment

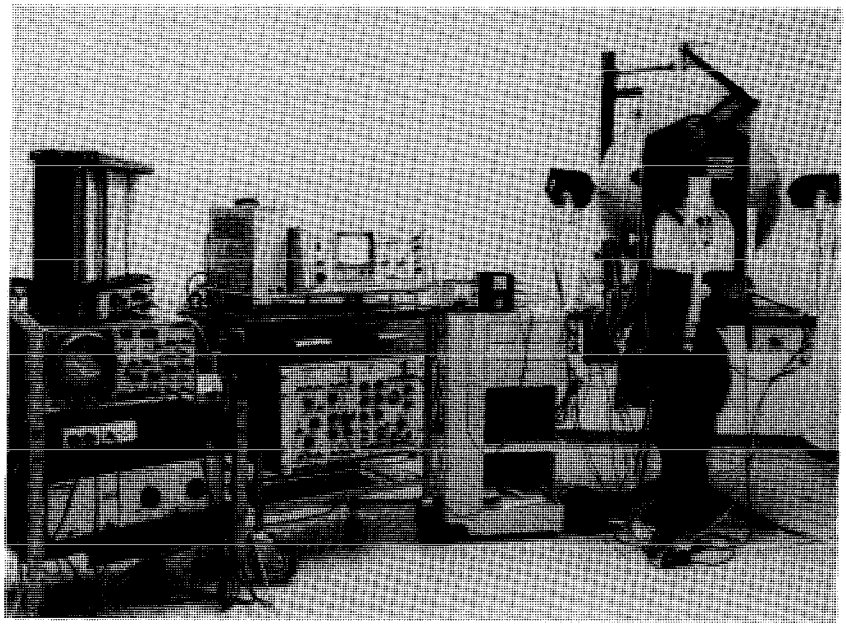


Fig. 2 Panoramic view of experimental equipment

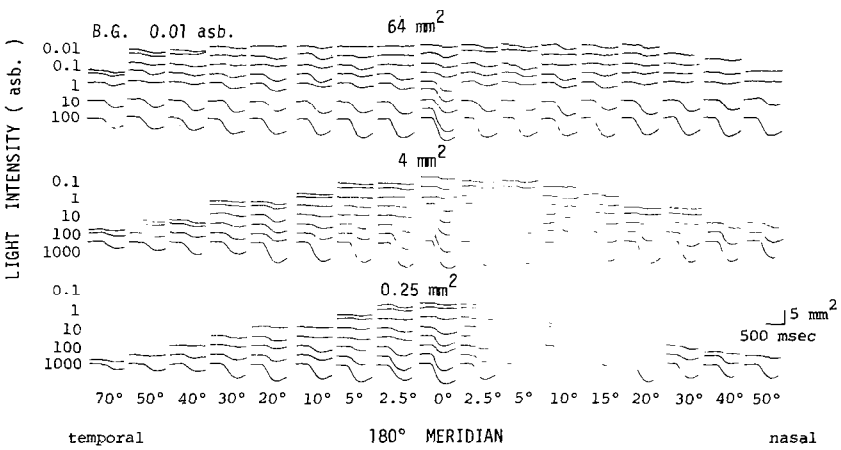


Fig. 3 Pupillogram under mesopic adaptation

Fig 4 Pupillogram under photopic and scotopic adaptation.

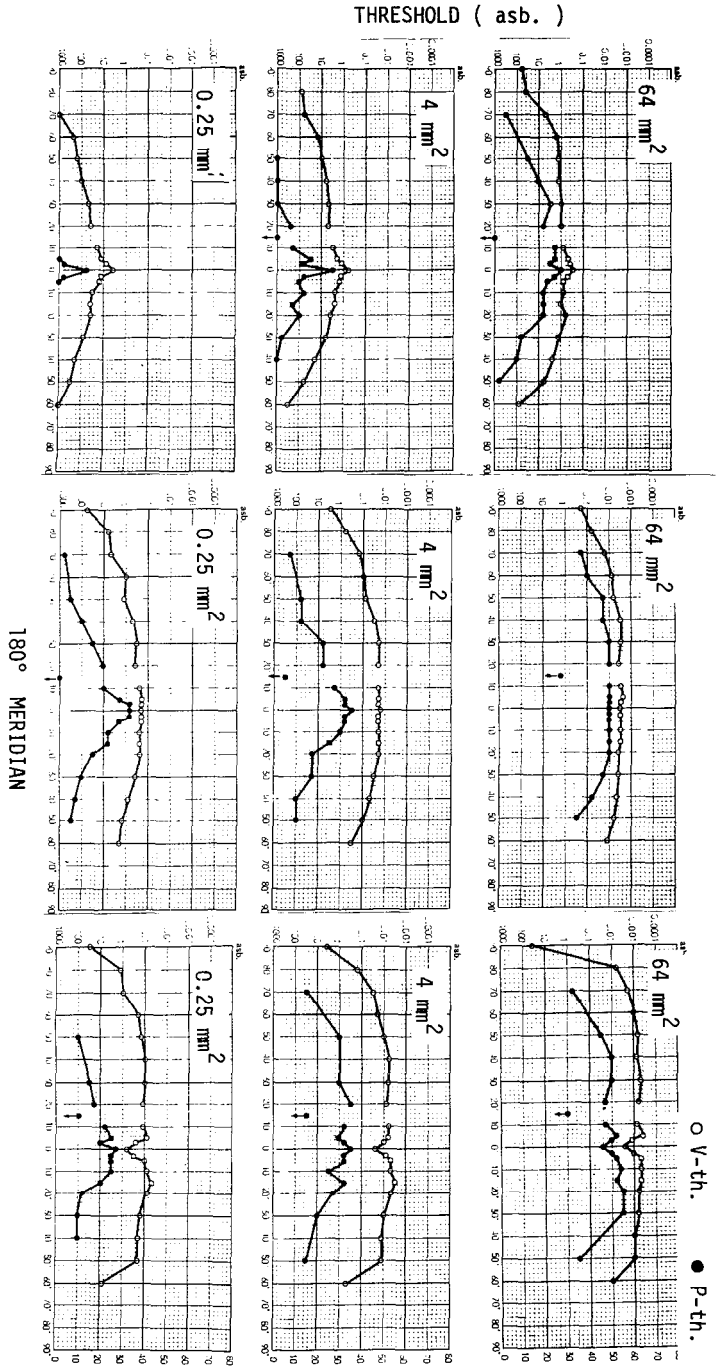


Fig. 5 Comparison of V-th. and P-th Variations under respective adaptations.

The subjective, static, visual threshold (V-th.) runs completely parallel with the pupillary threshold (P-th.) under each adaptation when the test target is large, as shown in Fig. 5 (Lowenstein, 1964). At the peripheral area, however, the smaller the target is the higher the P-th. will become. For example, if the target (1000 asb., 0.25 mm^2) is projected under the photopic adaptation, the pupil reacts at the central area only. Therefore, the cone is less sensitive than the rod, but shows a notable response in the

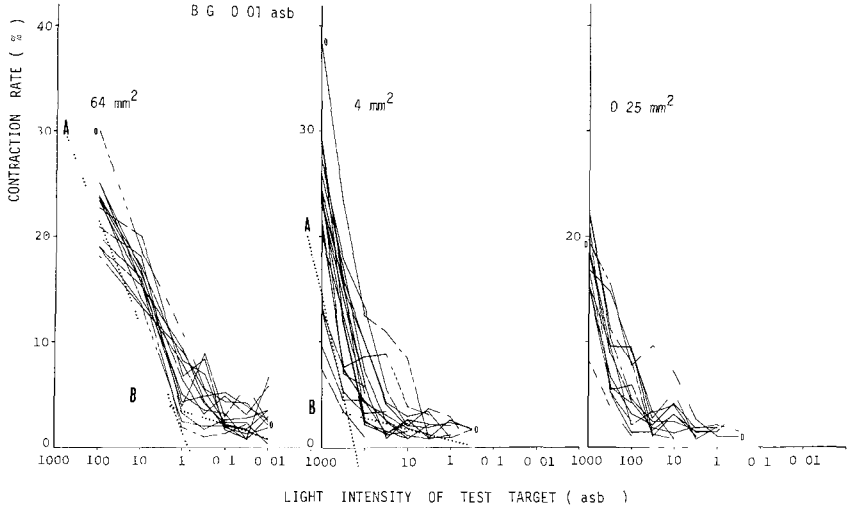


Fig. 6 Relation of contraction rate to target brightness under mesopic adaptation

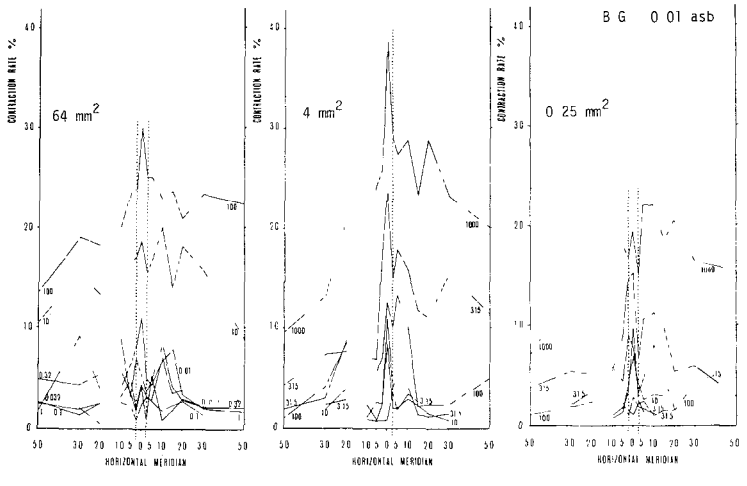


Fig 7 The contraction rate in each retinal area under mesopic adaptation.

central retina. On the other hand, the rod does not react unless a larger area of the peripheral retina is stimulated (Lowenstein, 1959, 1964).

The relation of the contraction rate to the target brightness under the mesopic adaptation is shown in Figure 6 by the two dotted lines A and B. Line A indicates the photopic component, line B indicates the scotopic component. These two components represent the cone function and the rod function, respectively (Lowenstein, 1959, 1964).

Concerning the contraction rate in each retinal area under the mesopic adaptation (Fig. 7), the rate becomes higher at the central area, but the low-sensitivity points are observed in all cases at point 2.5°.

We presume that these points are in the retinal areas where the proportion of the rod to the cone is 1 1, and that they correspond to the transitional points from the cone function to the rod function.

SUMMARY

Several characteristics of the pupillographic perimetry were investigated using a modified Goldmann perimeter, an infrared videopupillography (Iriscorder) and a computer. Threshold, latency and contraction rate of the pupillary area were measured under scotopic, mesopic and photopic conditions changing size, brightness, colour and exposing time of the test-object.

The threshold of pupillographic perimetry is compared with that of subjective perimetry. The contraction rate of the pupil in relation to the condition of test-object is discussed.

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OBJECTIVE PERIMETRIC MEASUREMENTS BY THE PUPIL BALANCE METHOD

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Sometimes the verbal information given by the patient is not satisfactory. That is why we searched for another source of information. After experiments with EEG and ERG we finally chose for the pupil diameter. This has the advantage of being the most convenient for the patient, because no electrodes have to be connected. The pupildiameter can be measured by means of an infrared T.V. system every twenty milliseconds.

Our statement is that every perceptable change in light distribution on the retina (although the total intensity does not change) causes a pupil contraction. We made use of this knowledge to measure the visual acuity. Our stimulus was an alternating checkerboard (See Fig. 1.). When the checks are large a pupil contraction is generated on every alternation. When the checks become smaller, the patient cannot resolve the picture and the pupil response vanishes. We found a proportional relation between the spatial frequency on which a just noticeable pupil contraction occurs and the visus obtained with the Snellen chart for patients having only refraction defects.

Not only changes in intensity distribution but also changes in color initiate pupil reactions (see Fig. 2.). When one alternates two colors in a homogeneous field, one cannot choose their intensities in such a way that the pupil contractions vanish, but for one intensity adjustment the pupil contraction on each alternation is the same.

This adjustment also gives an acceptable matched impression for the patient. Now we have a method to match the brightnesses of two colors: alternate them and adjust their intensities until a symmetrical pupil response (we call this an SPR) occurs.

When we change the relative intensities the pupil response behaves like a balance; that is why we call this the pupil balance method.

We can describe SPR as generated by a system of a few color selective channels, each containing an adaptation mechanism. After summation of the outputs of these channels we get an intensity channel which initiates the pupil responses. Measurements with variable alternation frequency show that all adaptation mechanisms have the same time constant (about 2.5 sec). This model accounts for the reactions on alternating homogeneous colored fields as well as those on alternating checkerboards.

With the criterion of SPR for matching colors we measured spectral sensitivity curves by taking one color as a reference (See Fig. 3.). The accuracy is 0.02 log units when a 6 degrees field is used.

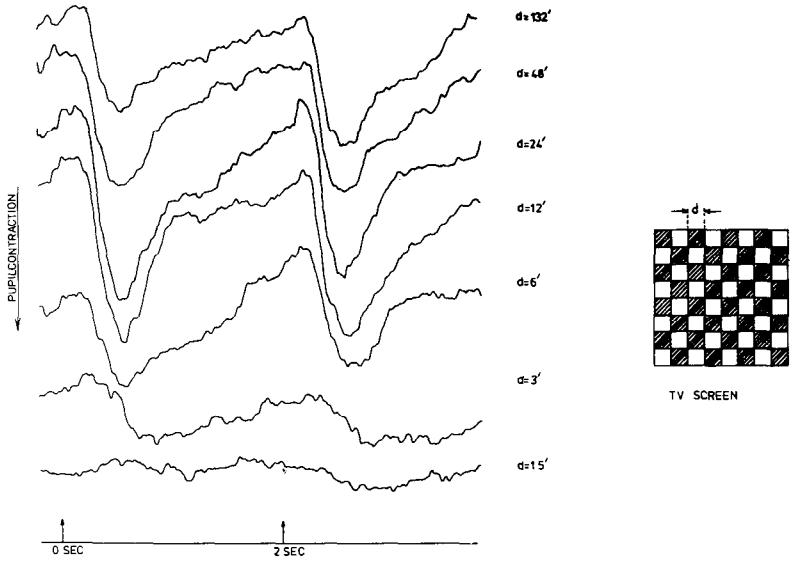

Fig. 1 Pupil responses of a person having average visual acuity on alternating checkerboards. d. stands for the visual angle. The moments of alternation are indicated by arrows. The responses are the average of twenty cycles. The checkerboards are generated by a T.V. system.

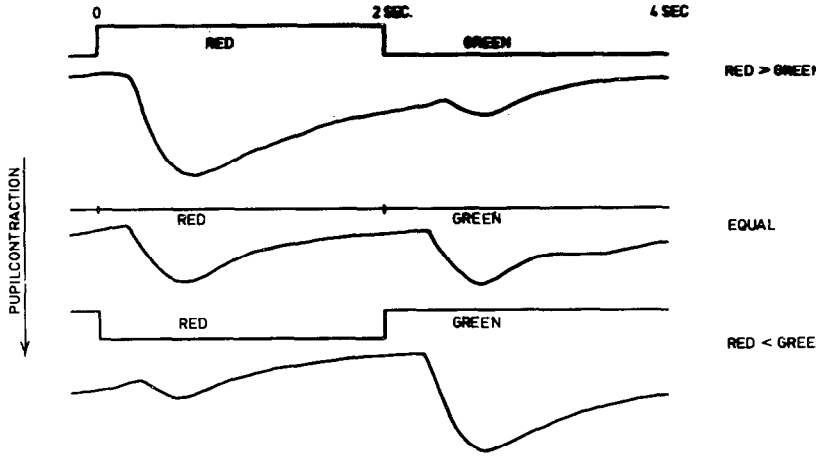

Fig 2 Pupil responses on a homogeneous field alternating between green and red. Above each response is indicated which color is present and at which relative brightness. The middle response is a SPR. The field size is about 5° foveally seen in maxwellian view.

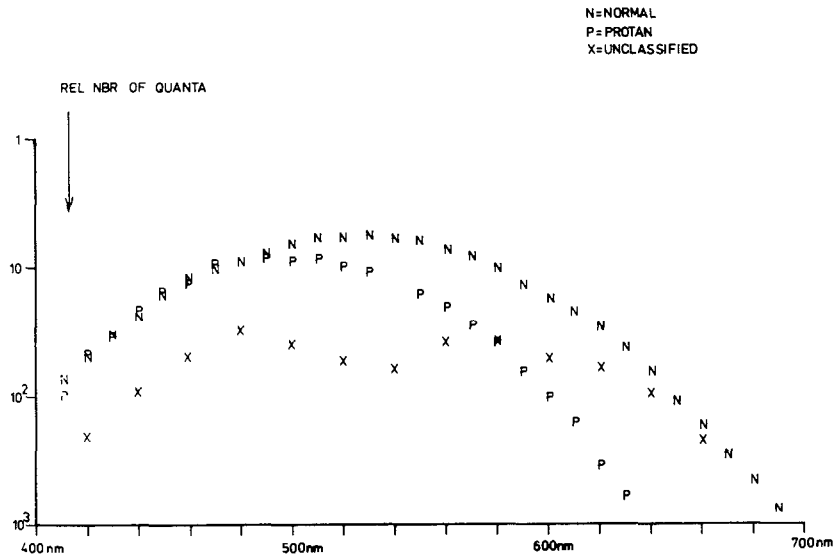

Fig. 3 Spectral sensitivity curves made by means of the pupil balance method. The curve of a person having normal color vision is indicated by N's, the curve of a protan by P's and the curve of a person having an unclassified defect by X's. The field size was 6°, the field was seen foveally in maxwellian view.

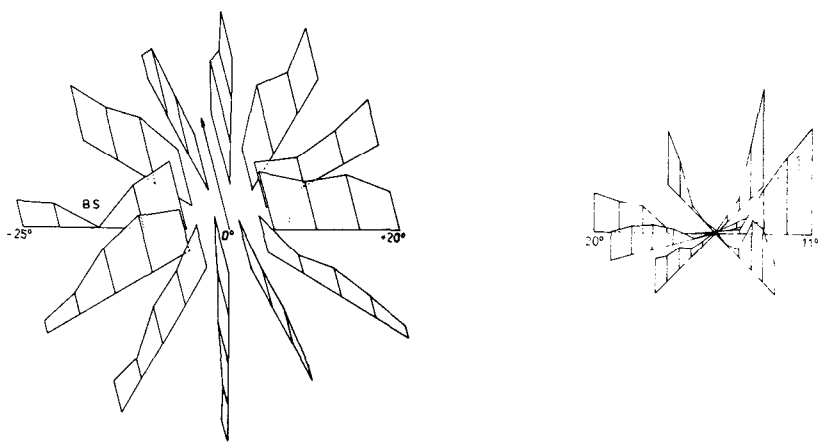

Fig. 4 Perimetrical plots. On the left the central part of the visual field, on the right a small area around the blind spot The lenght of the vertical lines indicates the amount of pupil contraction Retinal distance is measured from the fovea Stimulus is a flashing white point source on a white background

When one measures spectral sensitivity curves with stimuli decreasing in diameter, the curves shift gradually towards the rod sensitivity curve. This shift is explained by the occurrence of stray light in the eye: the contribution of the stray light increases with decreasing stimulus diameter and this stray light is mainly detected by the rods. The importance of stray light is indicated by the following experiment: when we project a flashing point source on the blind spot we measure the same responses as just outside the blind spot.

A common method to suppress stray light effects is the addition of a background. In this way we made perimetric plots, using as a measure for the local sensitivity the amount of pupil contraction on a flashing point source. (See Fig. 4).

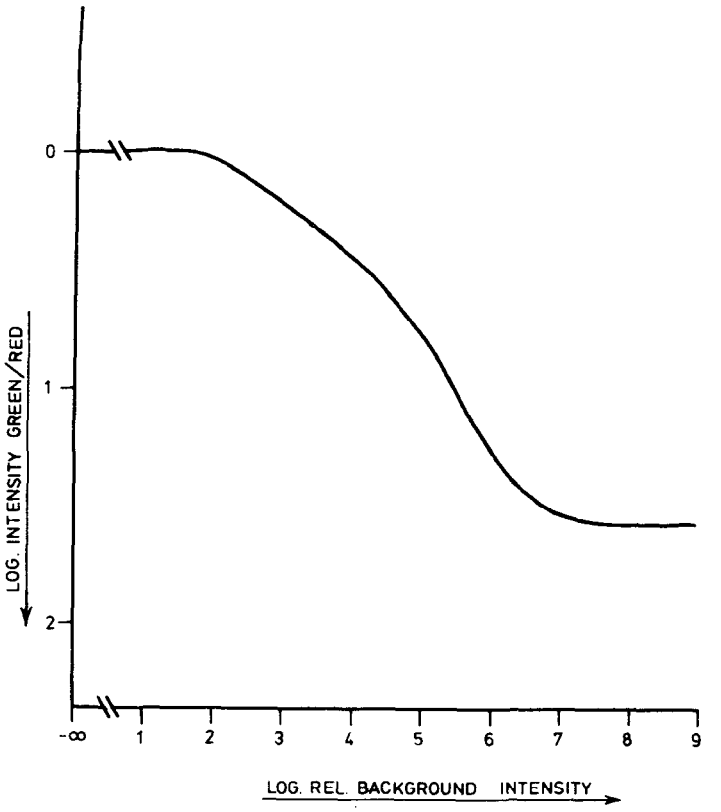

Fig 5. Shift of sensitivity for green light with respect to red light under influence of a white background. The vertical scale indicates the logarithmic ratio of the green and red intensities for which SPR is measured. The ratio found in absence of a background is supposed to be one The reference for the measurement was the red color. Stimulus was a 1° field, seen about 5° temporal in maxwellian view.

The more background illumination is added, the more sure one can be that the response is a local one. However, the response tends to decrease giving rise to long measuring times. It would be an advantage to know the stray light distribution of a point source. one could measure with lower stray light suppressing fields and afterwards correct the results.

So we set up an experiment based on the following considerations: an annulus glare source causes a high stray light level in its center; with a given stray light distribution one can compute the intensity in the center of the annulus. The reverse is also true when one can measure the intensities in the centers of several annuli, one can compute the stray light distribution. In the actual experiment we varied the intensities of the annuli in such a way that a constant intensity was obtained in the center. The problem is now how to keep the center intensity constant for several annuli.

A stimulus which is strongly dependent on the local background intensity is a spot (1° diameter) alternating between red and green. (This reflects the local Purkinje shift.) (See Fig. 5.) This stimulus is presented

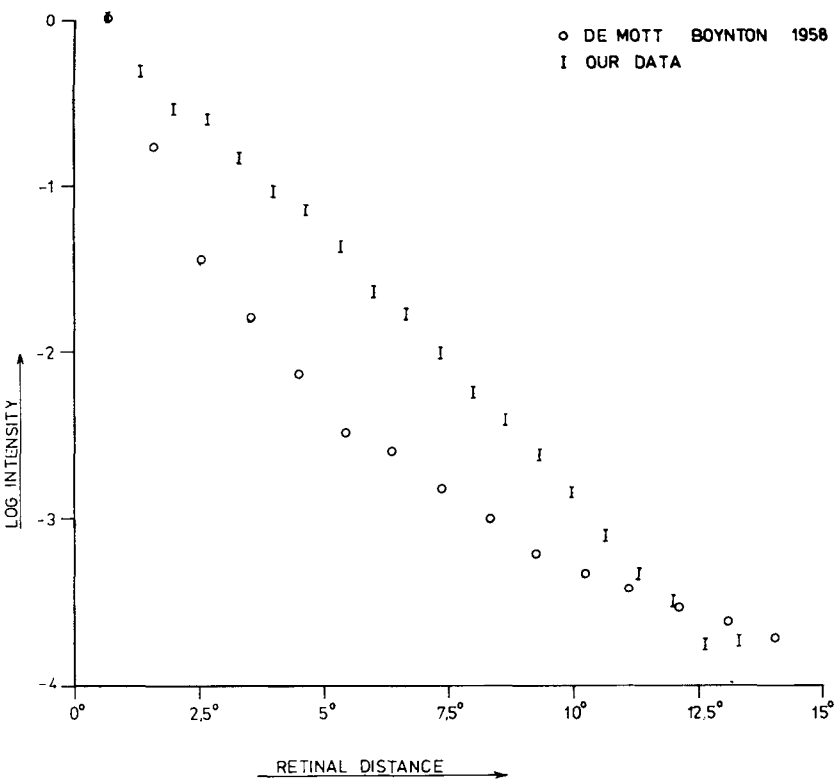

Fig 6 Stray light distributions: relative intensities as a function of retinal distance from the center of a point source image The curve indicated by open circles is found by Demott & Boynton from measurements on excised eyes. The curve indicated by I's is found by means of the pupil balance method

about 5° temporal with such intensities that some amount of background illumination is needed to obtain SPR. During measurement this background is the stray light from the annuli concentric around the stimulus.

With the annulus intensities needed to get SPR one creates a constant background intensity on the stimulus location. Also because the stimulus intensities are fixed during measurement, all conditions on and just around the testfield remain constant. From the annulus intensities one can calculate the desired stray light distribution of a pointsource (See Fig. 6).

When we compare our results with those of Demott & Boynton (who measured directly on excised eyes) we see a rather large discrepancy, while their results are in contradiciton with psychophysical measurements, which give much narrower stray light distributions. We conclude that our distribution is not simply the physical one, but also neural effects are involved. This however is what also happens when one tries to evoke pupil responses on local stimulation. Care must be taken because neural interaction is intensity dependent.

We thank Prof. Dr. M.A. Bouman for his interest in the project and his criticism of the manuscript.

SUMMARY

We have been studying pupillary responses to the presentation of several stimuli to the human eye. We were able to measure these responses in detail by means of an infra-red television system. Our aim was to generate local retinal responses. A difficulty one meets trying to get local responses is the occurrence of straylight in the eye, that is why we searched for a stimulus of which the straylight does not contribute to the pupillary response.

During experiments with alternating colored fields we found that when both fields are equal in brightness, each alternation initiated a typical pupillary contraction, which we called S.P.R. We can describe this type of reaction by a system of a few color selective channels, each containing an adaptation mechanism. By means of this reaction we can match two different stimuli by alternating them. We call this the pupil-balance-method. With this method we can produce spectral sensitivity curves, powerful tools in detecting color defectives.

As can be expected, the relative intensities for which S.P.R. occurs are strongly dependent on existence and type of background illumination, because this illumination influences the reception of straylight. This fact enables us to set up an experiment, based on variation of a concentric surround field, that gives us an insight in the straylight distribution of a point source.

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VIDEO-PROCESSING PUPILLOGRAPHY AS A METHOD FOR OBJECTIVE PERIMETRY IN PUPILLARY HEMIAKINESIA

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For an objective judgement of the retinal sensoric function, pupillography is a well-known method. The infrared pupillography first described by Matthes (1941) has been modified later by Alexandridis (1971). This objective method of pupillary response determination to study the pupillary hemiakinesia can be used for objective perimetry and has recently been applied by Harms, Aulhorn & Ksinsik (1972) as well as by Cibis, Campos & Aulhorn (1975).

The generally uncomplicated set-up needed for infra-red pupillography

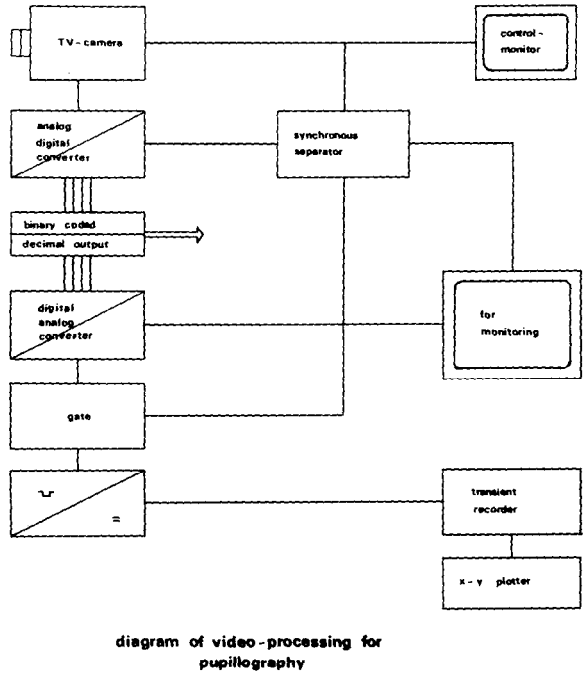

Fig. 1a Diagram of video-processing for pupillography

has the following drawbacks: the amount of reflected light which records the areal changes of iris size depends on the individual degree of iris pigmentation; therefore, absolute or comparative data for interindividual comparison are not available (Müller-Jensen, 1976). Application of this method in objective perimetry, for which threshold stimuli are applied, gives rise to a number of difficulties in its practical use.

Therefore, our aim was to devise a method which

- does not bother the patient,
- allows recording of minimal pupil changes,
- enables examination without disturbing the adaptation,
- permits continuous direct control of the pupil, and
- permits fixation as well as vigilance.

These requirements are met by our method, in which TV processing is used in connection with a highly sensitive infrared vidicon. Videoprocessing has already been utilized by other authors in pupillographic measurement (Mertz & Roggenkämper, 1972), but not for objective perimetry.

The experimental device used is shown in Fig. 1a:

- The camera is fitted with a lens permitting 1 . 9 enlargement of the pupil on the processing monitor.
- By retouching the digital picture, iris and pupil appear only in the shades black and white (Fig. 1b).
- The infrared sensitive silicon vidicon that works without inertia, enables pupillar analysis without interfering with the spectral sensitivity of the eye.
- Data processing is achieved as 'on line'.

The measurement is achieved as 'on line'. The measurement of the pupil response is limited by the frame of the monitor, which is 20 mseconds.

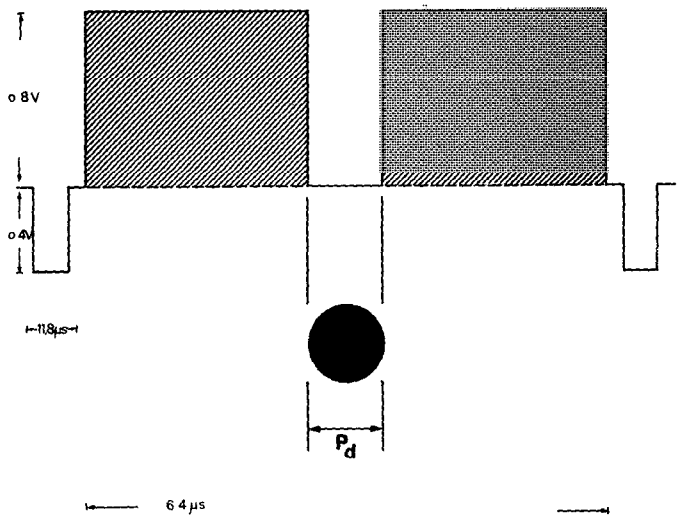

Fig 1b. By retouching iris and pupil appear only in black and white

Recording of the slightest movement in the pupil is limited by the structure of the vidicon-target, which is 600 lines; in our set up this is 10 μm (10^{-6} m). During processing a constant delay of 200 ms – the time needed for calculation – must be taken into account when the latency of the pupillogram is evaluated. Original recordings of pupillograms are shown in Fig. 2.

The practical use of this method is demonstrated by the examples in Figures 3 and 4, in which static perimetry is compared with pupillographic measurements. The pupillomotoric threshold is achieved, when at least 50% of the stimuli gives a positive result. Even with the smallest stimuli of 7′ a static profile can be obtained (Fig. 3). The difference between the psychophysic and the pupillomotoric threshold amounts to 10 dB only with a parallel course of the profiles.

Figure 5 represents pupillographic results of some cases of homonymous hemianopia, due to occlusion of the posterior cerebral artery. In accordance with the hypothesis presented by Harms et al. (1972), disturbances in the pupillokinetics arise from a failure of the central visual pathway (suprageniculate lesion), but they do not correspond congruently to the loss of the visual field as is the case in lesions anterior to the geniculate body.

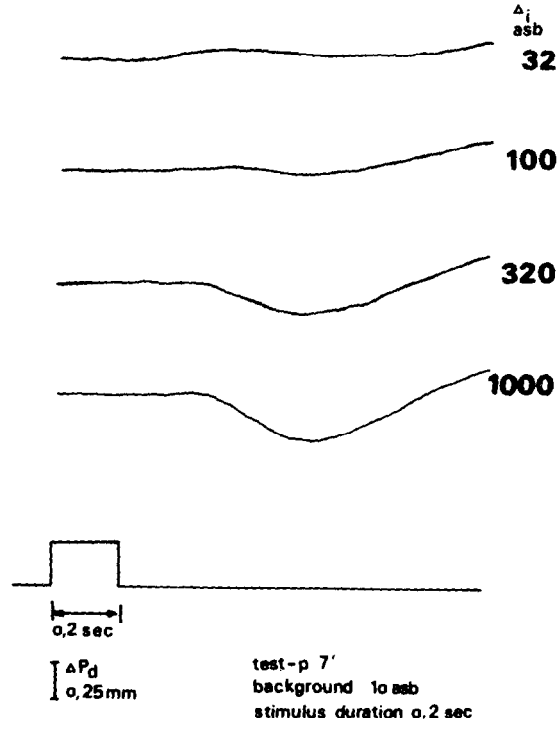

Fig 2. Pupillogram: original recordings in 0° visual field.

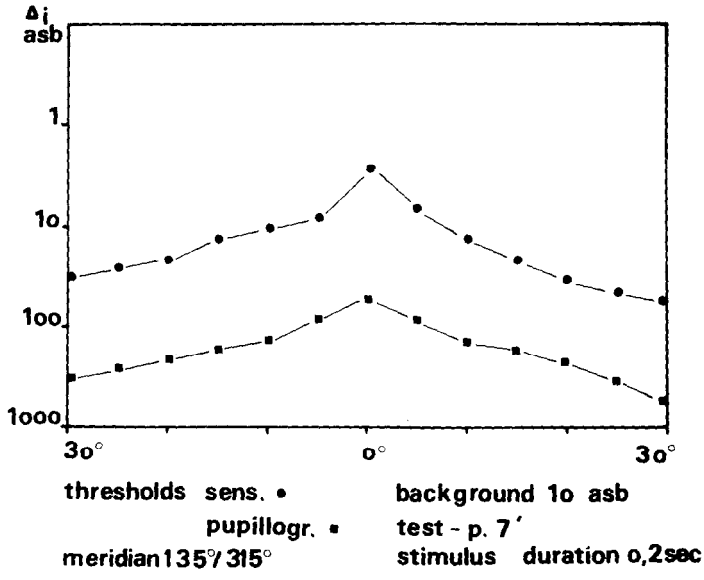

Fig. 3

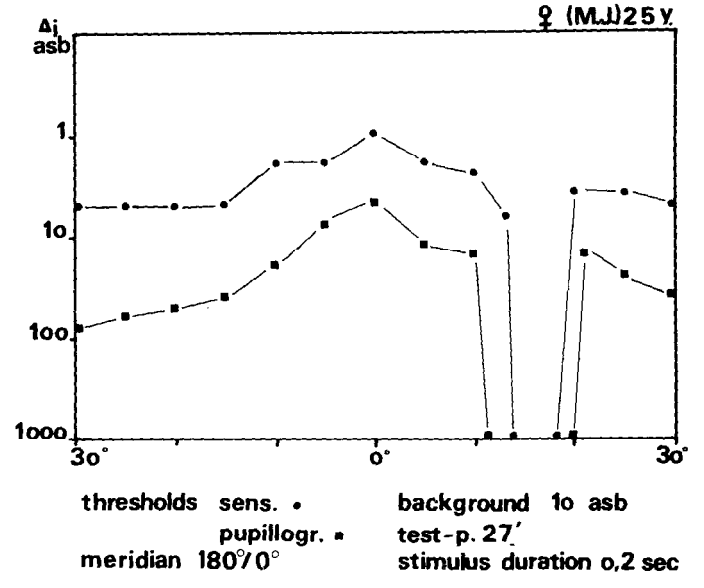

Fig 4

Fig 3 and 4 Static perimetry by determination of the psychophysic and pupillographic thresholds

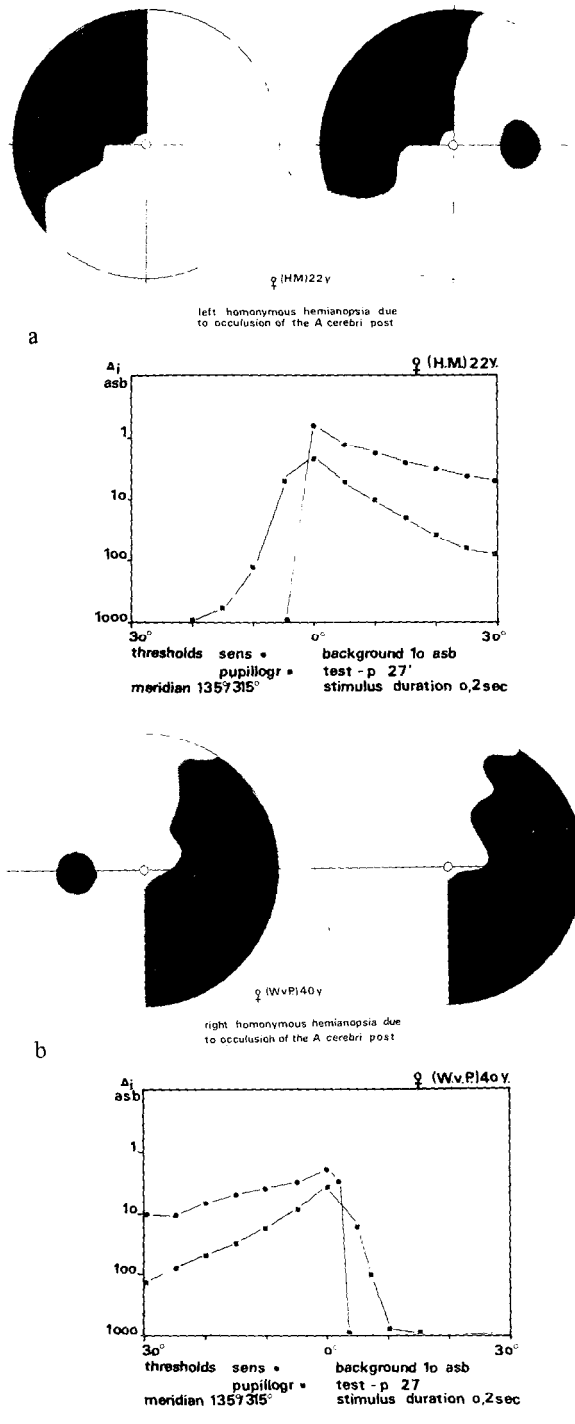

Fig. 5a and b Incomplete pupillary hemiakinesis in suprageniculate lesions.

The difference between the psychophysic and pupillographic results cannot be attributed to stray light effects only, as can be demonstrated by perimetry of the 'blind spot' (Fig. 4). The present results, however, show that with a suitable pupillographic method weakened positive pupillar reactions are measurable. Because of the possibility of unspecific reactions due to stray light phenomena we cannot definitely prove the all-or-none existence of stray light effects It seems that there exists no absolute but a relative hemiakinesia of the pupil in suprageniculate lesions.

SUMMARY

Description of a method for objective perimetry: An infrared-sensitive TV camera has been fitted into a projection perimeter. The consensual pupil light reflex was measured and registered with a special TV processor. The course of sensory and pupillomotor thresholds were measured.

In patients with homonymous hemianopsia due to lesions above the lateral geniculate body a pupillary hemihypokinesia was registered.

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DISCUSSION

OF THE SESSION ON OBJECTIVE PERIMETRY

Bynke to Ellenberger You used a flash method instead of a pattern method. Did you have a particular reason for this?

Ellenberger If a sudden occlusion of blood flow occurs, you will have a since these responses are more or less related to visual acuity.

Bynke to Ellenberger You talked much about latency time, less about amplitude. How was the amplitude in ischaemic optic neuropathy?

Ellenberger The amplitudes were almost always reduced, when there was a visual field defect. There was no correlation with the latencies.

Drance to Ellenberger Finding an increased latency on the second uninvolved eye in ischeamic optic neuropathy, an interesting statement was made without producing evidence for it I wonder, why you would think of a non-ischaemic factor?

Ellenberger If a sudden occlusion of blood flow occurs, you will have a dead nerve or a dead section, the underlying nerve tissue being not sick. Here an abnormal conduction of the nerve fibers was found before or in the absence of an occlusion. It was only a suggestion.

van Lith to Ellenberger It was said that a lengthening of the latency time could be specific for a demyelinating process In our findings and also in those of Holliday, increased latencies occur also in cases of pressure on the visual pathways, for example in intracranial tumours. In both groups you may find the combination of very low cortical potentials with increased latencies, a good visual acuity and normal fields Missing the diagnosis tumour may be dangerous.

Ellenberger In the patients you are referring to, with early compressive lesions of the visual pathways, I would probably be able to find minor alterations in the visual field. It is really striking, how in demyelinating diseases all these psychophysical measures return to perfectly normal.

SUMMARY OF SESSION III: OBJECTIVE PERIMETRY

G.H.M. VAN LITH

The session on objective perimetry, which might not be a familiar subject to perimetrists, has provided us with a good deal of information. We heard about the ERG, the VERs and the pupillary reflex as a tool for objective perimetry. The group of investigators working in this field is rather small and progresses are rather slow. We are not that far that we can think about problems of kinetic or static perimetry, having still problems in measuring sensitvity at one place without stray light responses with a fairly small spot and besides that within a reasonable time.

In my opinion, the best results up to now are obtained with perimetrical measurements by means of the pupillary reflex. Though development is not as advanced that it can be used as a routine, application may be worthwhile in those cases, in which the existence of a field defect is doubtful or in which it is questionable at which level the cause of the defect has to be localised. Hopeful results were reported by Aoyama et al., van der Kraats et al. and Hellner et al.

Concerning the ERG, I feel that the contactlens electrode, which was introduced by Riggs in the early forties, now forms an impediment for further progress. A contactlens is uncomfortable to the patient and easily causes light scatter. A second problem in the application of the ERG for perimetrical measurements is the smallest recognisable ERG response which can be detected. Outside the fovea, responses, obtained with a stimulus spot smaller than 5°, appeared to be too small to be used for clinical purposes; outside the posterior pole they are even too small to be detected.

The reason for this is that the cone mediated ERGs appear to be largely dependent on the cone density. Therefore, the idea of Foerster of the Tübingen group to use rod dominated ERGs or DC potentials may give new hope for the future. The cone mediated ERGs could then be limited to the sensitivity testing of the posterior pole, of which good examples were presented by Matsuo and Hamazaki.

Before attending this Symposium, it was a problem for me as an electrophysiologist, if a testing of the posterior pole only could be called 'perimetry'. Now having heard about psychophysical methods of macular perimetry or perimetry on other small spots of the retina, which methods could probably be labelled as 'microperimetry' or 'local perimetry', I see the scope of electroperimetrical methods also opened for the VERs, which are sub-

stantially mediated by the macular cones. The latter is even more the case if instead of luminance stimuli, structured stimuli are used, a method of which Fonda, using grating patterns, gave clear results. From this part of electrophysiology, viz. the cortical potentials evoked with structured stimuli, many new data may be expected in the next few years.

In conclusion, I am of the opinion that objective perimetrical methods are not developed far enough to be applied for clinical purposes, but that it really is worthwhile to keep on going in this direction, since it provides objective data and data at various levels of the visual system.

PERIMETRY UNDER TELEVISION OPHTHALMOSCOPY

KAZUTAKA KANI, NAOKO ENO, KUNIOMI ABE & TAKASHI ONO

(Hyogo, Japan)

INTRODUCTION

When we examine the visual field in the cases of retinal disease, it is important to observe the retinal point where the stimulating target is located. This would, however, be impossible with an ordinary perimetric method. A few attempts were made to examine the visual field under direct ophthalmoscopy. Trantas (1955) tested the photosensibility of the retina with a small point (black or colorful) projected onto the retina using an ophthalmoscope. Inatomi (1967, 1968) examined hemianopsias using a fundus camera with a test object behind the object lens. Awaya (1972) used a Euthyscope and named his method 'Spot scotometry'. Their background brightness was selected very high because they had to see the fundus with this illumination. The luminance of the test object was unchangeable. We specially built a new equipment for the purpose of the fundus-controlled perimetry so that it was possible to make a quantitative perimetry.

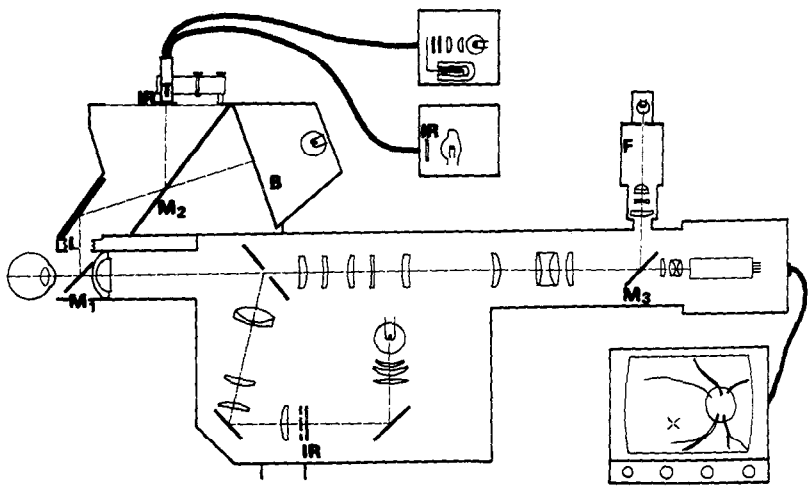

Fig 1. Block diagram of equipment. M_{1-3} Semitransparent mirrors. L Corrective lens holder. IR Infrared filters. T Test object with marking projector. B Background. F Fixation target

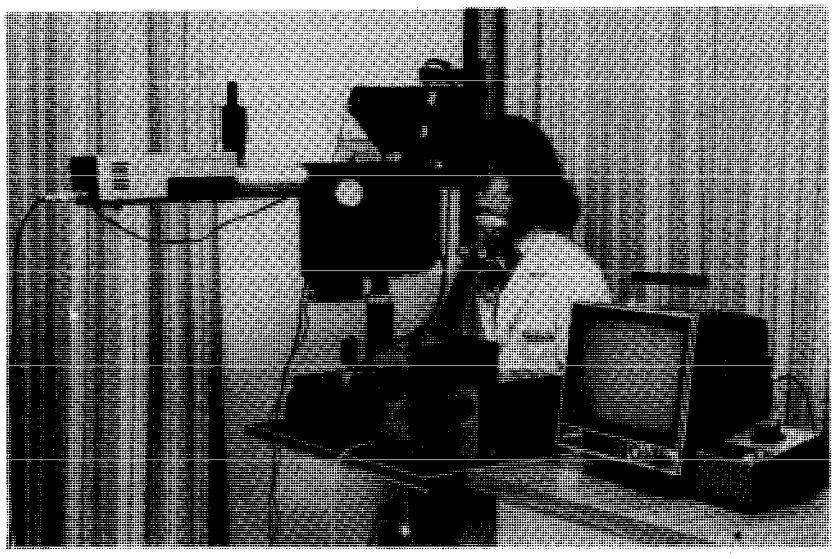

Fig. 2. Panoramic view of equipment.

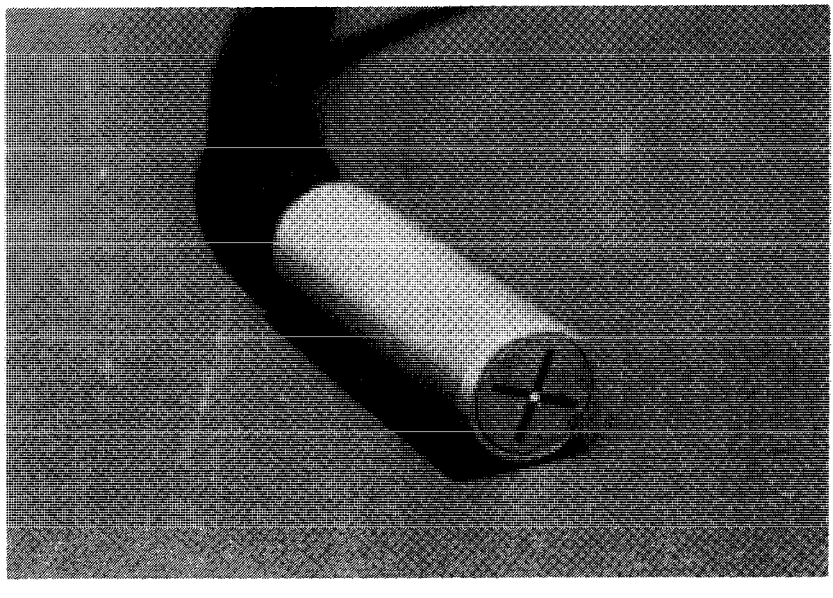

Fig. 3 Test object with marking projector.

METHODS

The equipment was composed of two parts; an infrared television fundus camera and a perimeter. A Topcon fundus camera (Model II) was modified for our purpose. An infrared gelatin filter (Fuji IR 90) was placed at the iris diaphragm (IR in Fig. 1). With the aid of a silicon array vidicon television camera (Akai VC-70), the fundus picture was demonstrated on a monitor television.

The background and the test object were provided by a semitransparent mirror (M_1) placed between the cornea and the object lens. With another semitransparent mirror (M_2), background (B) and the test object (T) were combined. An incandescent lamp produced a continuous white light which was attenuated by neutral density filters. An electronic shutter produced a continuous or a short-duration light. The light was relayed to the perimeter through a fiberoptic guide.

When the test object is small and/or dark, the location of the object cannot be distinguished on the television picture. To show the location of the test object, glassfibers were arranged in a cross shape around the test object and illuminated by infrared rays (Figs. 3 & 4).

RESULTS

Fig. 5 illustrates the results obtained by kinetic and static perimetry, using either a Tübinger perimeter or our instrument. Both examinations were

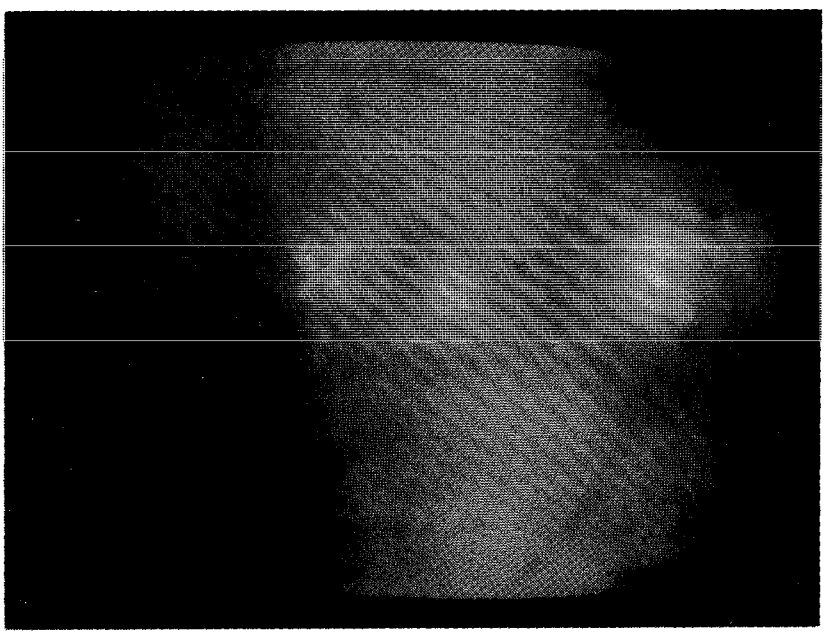

Fig. 4. Fundus picture on television monitor with test object located at the cross line center

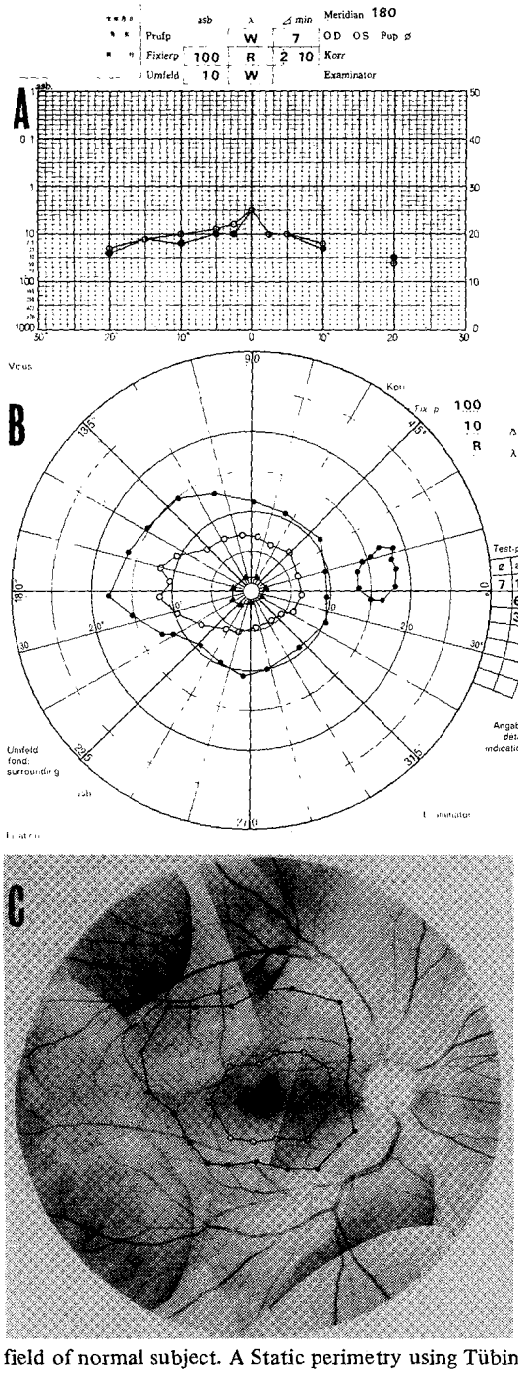

Fig. 5. Visual field of normal subject. A Static perimetry using Tübinger perimeter (○) and our equipment (●). B Kinetic perimetry using Tübinger perimeter. C Kinetic perimetry using our equipment. Visual fields were inverted as against fundus picture.

made with the background brightness 10 asb., the test object 7 min. and the exposure time 100 msec. Neither mydriatics nor miotics were used.

To investigate the influence of the infrared ray on the visual field, the infrared ray was first switched off, and then switched on immediately when the test object was perceived. No differences were noted between these results.

DISCUSSION

In our equipment, the light of the background and the test object is provided with a natural view system using a semitransparent mirror. In general, the perimetry is carried out with this system because it has the merit of the light quantity being unchanged even when the eye or the head of the subject makes a slight movement. In other methods, the perimeter is placed at locations 2, 3 or 4 in the fundus camera (Fig. 6).

When the test object is placed behind the object lens (2), a good focus cannot be obtained because of the limitation of the nonspherical object lens which is being used to remove corneal reflex.

The light for fundus illumination goes into the subject through the periphery of the pupil. If the test object is placed in the illuminating system (3), the light quantity changes greatly with a slight motion of the eye or the head according to the Stiles-Crawford effect. The retinal focus produced by this light will not be good because of the optical distortion of the pupil periphery.

The light which emerges from the fundus goes into the fundus camera through the center of the pupil. This will be useful for placing the test object in the observation system (4) if reflexes from the lenses are removed. We placed the fixation target there.

An infrared marking projector is used to indicate the test object. The perimetry can, of course, be carried out without using such marking procedure if we utilize the method of fixing the test object, for instance, at the center, and the fixation point moved. However, it would be difficult to bring the desired retinal point to the test object precisely. Moreover, to

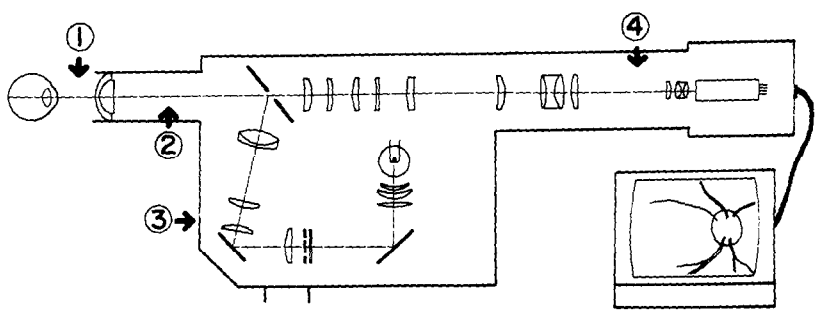

Fig 6 Perimeter may be placed: (1) between object lens and cornea, with natural view system. (2) behind object lens (3) in illuminating system (4) in oberservation system.

perform kinetic perimetry with this non-marking method would be inadequate because visual inhibition will occur during a saccadic eye movement.

This equipment can be used not only for perimetry but also for amblyopic examination or therapeutic purposes and for eye movement examination. We intend to perform these investigations in the very near future.

SUMMARY

Static and kinetic perimetry was carried out during which the location of the test object on the fundus was confirmed coincidentally by an infrared television ophthalmoscope. The equipment was composed of a fundus camera, an infrared television and a perimeter. The result was compared with that obtained by a Tübinger perimeter.

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QUANTITATIVE MACULOMETRY USING A NEW INSTRUMENT IN CASES OF OPTIC NEUROPATHIES

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(Kobe, Japan)

In optic neuropathies, we often find central scotomas with normal peripheral visual fields. These central scotomas can be classified into four types: the general depression type, the sieve-like depression type, the island-like field type, and the complete depression type, which can be measured by Tübinger's static perimetry on a horizontal or vertical line (Fig. 1).

However, the patient's difficulty in finding a fixation point due to the central scotoma makes any accurate measurement of the central visual field extremely awkward. For this purpose we have developed a new apparatus by attaching a light stimulus system to an ordinary fundus camera and thus we are able to examine accurately the position in the macula.

METHODS

A schematic diagram of our new apparatus is shown in Fig. 2. The optical system consists of an observation, an illumination and a light stimulus section. Light stimulus is provided through a half mirror (HM) in the observation section. We placed the ring scale on the focal plane in the observation section. Then, thanks to the free movability in all directions of the ap-

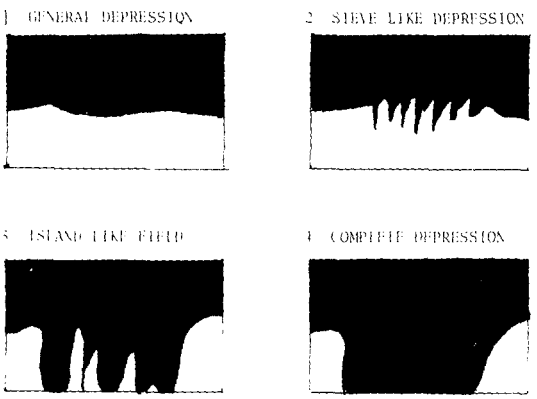

Fig 1

paratus, we can trace accurately and constantly the fovea under the ring scale. The concentric circles indicate 2.5, 5.0 and 10 in the angle of view and angular divisions are at 45 degrees.

The brightness of the background illumination can be changed by a variable resistor and various combinations of ND filters (FL). We chose for a brightness of 198 asb. By doing so, the patient will not be dazzled and we can observe the fundus accurately. The target size of light stimulus can also be changed as follows 102′, 51′, 25.5′, 12.75′, 6.37′ and 3.19′ in the angle of view. As for this brightness we may choose any combination from 0.0 to 2.0 which represents the neutral density filters of the values shown in the whole log. units (NDF). The maximum brightness is 1000 asb. coming through 0.0 log. units filter combinations. The duration of the light stimulus can be varied by a shutter (S) as follows: 1000, 500, 250, 125, 67, 35, 17, 8 and 4 msec. The patient's pupil is dilated by mydriaticus. By tilting and rotating adjustable mirror (RM), we are able to project light stimulus into any point in the fundus. The fellow eye is fixed by 4 red points.

RESULTS

In the first place, by means of this apparatus, we can measure the threshold inside 10 degrees from the fovea by using the static method and this measurement is likely to indicate the visual acuity of the patient. Secondly, by the kinetic method, we can obtain a rough idea of a central field such as the exact position of an appearing visual island in a completely depressed field.

a. Static measurement

The target size of the white light stimulus is 6.37′, and the duration of light stimulus is 250 msec. For convenience sake decimals are omitted in our charts, i.e., 1.2 log. unit will be recorded as 12. Thresholds of each position within 10 degrees in normal cases were obtained for 10 persons, aged 25 to 45. The data show that the measurements are almost stable (Fig. 3).

We will now show 2 cases of optic neuropathy.

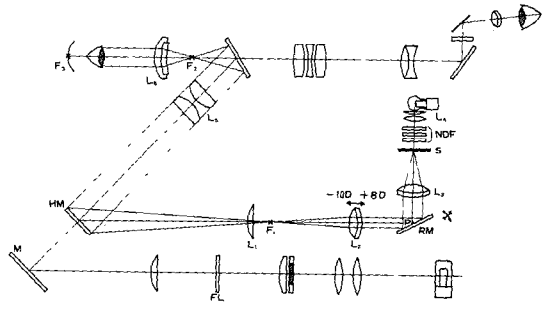

Fig 2

1. A 24 year old male (acute retrobulbar optic neuritis)

It began with a subacute onset. In February 1975 the patient complained of blurred vision in his left eye which was rapidly progressing and reached a visual acuity of 20/500. In spite of treatment in another clinic, there was no effective evidence of improvement. He was admitted to our clinic on December 7. Since March 1976 his visual acuity improved, thanks to repeated lumbar puncture. On May 14 it reached 20/25. The maculometric pattern at that time is shown in Fig. 4. This corresponds to the sieve-like depression type.

2. A 32 year old female (suspected M.S.)

Since July 1969 she has noticed sensory disturbance of both lower limbs and ophthalmoplegia in the right eye, but remissions of these signs occurred.

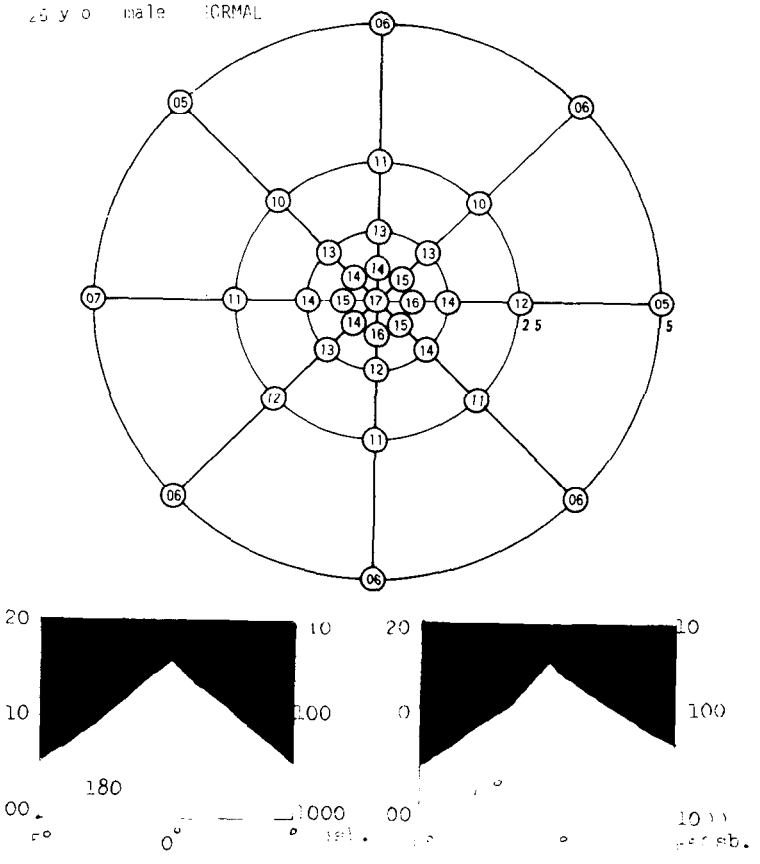

Fig 3.

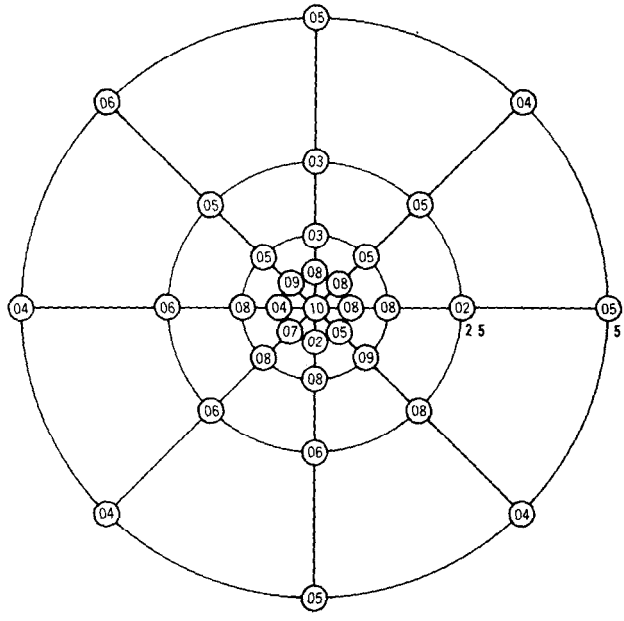
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Fig. 4.

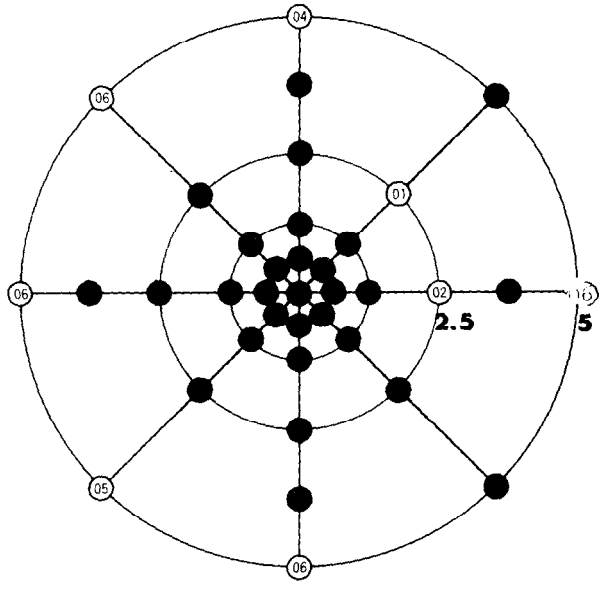
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Fig 5

Since August 1974 there was defective vision in her left eye with no improvement. The maculometric pattern is shown in Fig. 5. We noticed an island-like field.

b. Kinetic measurement

We used 1000 asb. continuous light for kinetic measurements.

1. A 34 year old male (syphilitic optic neuritis)

The patient began to experience gradual progressive loss of vision in both eyes in February 1975. In July of the same year he was hospitalized at our clinic where he was craniotomised and the chiasmal region expolarated. The visual acuity of both eyes gradually improved. The kinetic field in October is shown in Fig. 6. Some 'mothhole-like' fields in the scotoma are observed similar to the island-like fields.

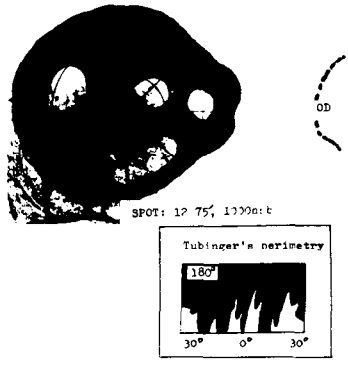

Fig 6

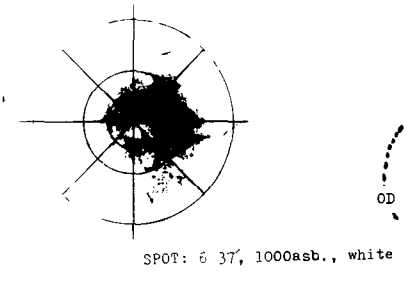

Fig 7

2. A 54 year old female

At the beginning of April 1976 the patient noticed a defective vision in her right eye. Thanks to systemic steroid therapy and acetylspiramycin therapy her vision improved. On July 20 we noticed a few small spot-like scotoma remaining, as shown in Fig. 7. Agglutination test for toxoplasma was positive.

Our new apparatus enables us to measure the exact thresholds of the various positions in the macula applying either the kinetic or static method. By using the obtained measurement data it will be possible to obtain exact knowledge of the condition of the disease and to obtain important indications for the treatment of optic neuropathies which will lead to restoring the vision of the patient.

SUMMARY

In optic neuropathy it is frequently necessary to make repeated examinations of variations of central scotoma of the same patient, but we have experienced difficulty in examining the fixation of the eye. We have now developed a new instrument for more accurate maculometry.

We attached a light stimulus equipment similar to the Tübinger perimeter to a fundus camera, and project a test object into the eye observing the fundus and examine the accurate position in the macula within 5 degrees from the center. It becomes thus possible to measure the threshold of each position in the macula when the patient is unable to fix the eye. The case of the normal eye and that of optic neuropathies will be presented.

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PHOTOPIC AND MESOPIC CENTRAL STATIC PERIMETRY IN MACULOPATHIES AND CENTRAL NEUROPATHIES

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INTRODUCTION

In this paper a description is given of the typical visual field defects found in pathological conditions of the macula and some other disturbances of central vision, as demonstrated by means of single stimulus meridional static perimetry under photopic and mesopic conditions. Particular attention is paid to the comparative intensity of the defects under photopic and mesopic conditions. It appears that this comparison is of diagnostic significance. This paper describes the continuation of the study we performed in 1971 into the functional loss of central serous choroidopathy (Greve et al., 1972, 1974). A detailed description of functional loss associated with Drusen and disciform macular degeneration has been given elsewhere (Greve et al., 1976). In this paper the importance of photopic and mesopic static perimetry is illustrated by 9 case histories.

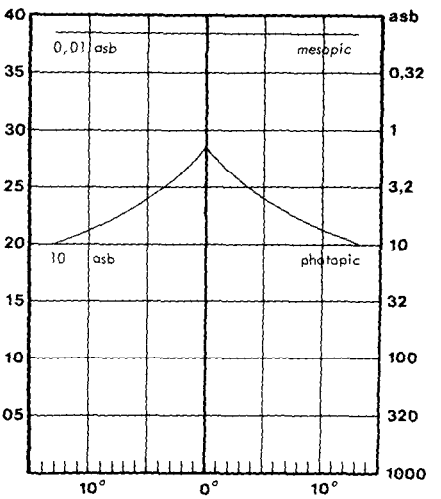

Fig 1 Normal mesopic and photopic sensitivity curves.

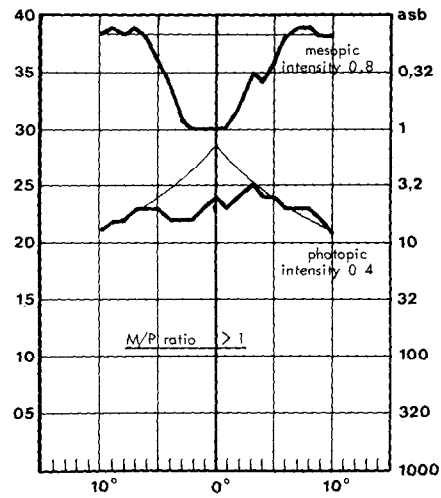

Fig 2 An example of a defect with a photopic intensity of 0.4 log units and a mesopic intensity of 0 8 log units M/P ratio greater than 1

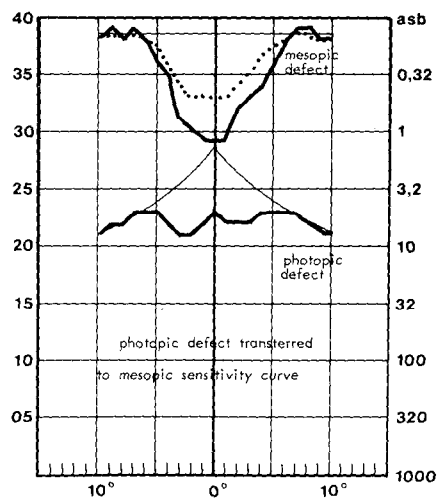

Fig 3 Comparison of photopic and mesopic intensity by transfer of the photopic defect to mesopic curve (broken line) On each position the photopic intensity is subtracted from the normal horizontal mesopic curve.

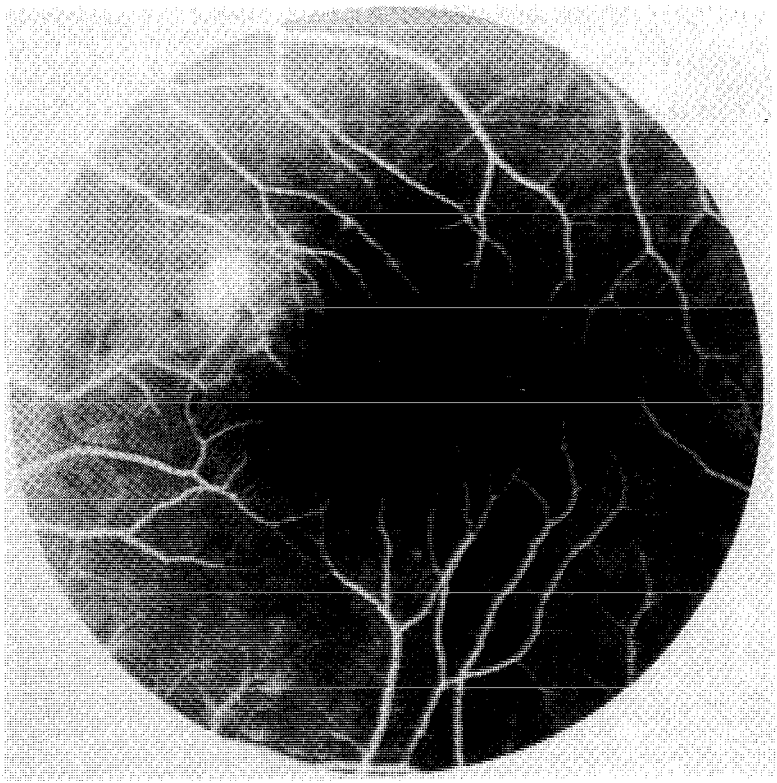

Fig 4 *Case 1* Central serous choroidopathy. F F A.: see text

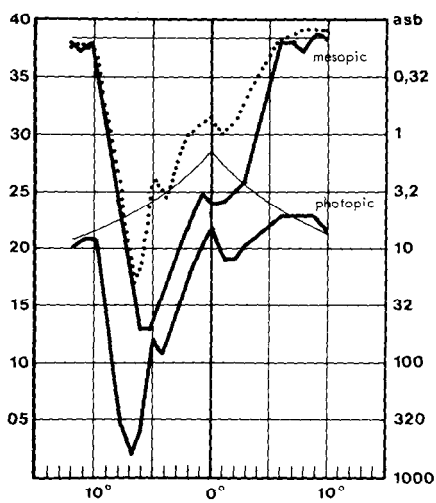

Fig 5 *Case 1* Static perimetry in 225° and 45° meridian; see text

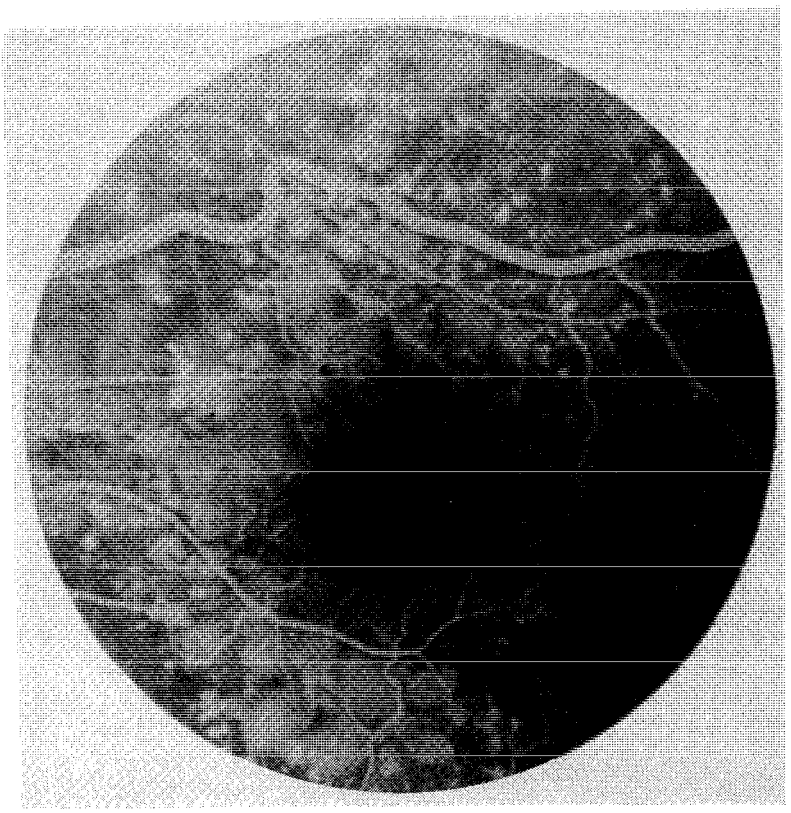

Fig. 6. Case 2. Drusen F.F A , left eye: see text

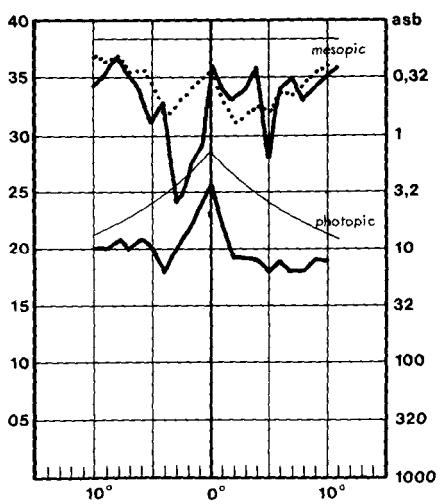

Fig. 7 Case 2. Static perimetry, in 90° and 270° meridian, left eye: see text

In the case histories and in the discussion the intensity of the defects is considered. This intensity is expressed in log units. The method of calculating the intensity of defects has been described in Greve (1973) and Greve (1975). The difference in the intensity of defects measured at photopic and at mesopic adaptation levels is expressed in an M/P (mesopic/photopic) ratio.

If the M/P ratio equals 1, this means that the intensity of the defects is the same under both mesopic and photopic conditions. If the M/P ratio is less than 1 the photopic intensity is greater.

The normal photopic and mesopic visual fields are shown in Fig. 1. In Fig. 2 a schematic example is given of a defect which has a greater intensity under mesopic than under photopic conditions. In this case the photopic intensity is 0.4 and the mesopic intensity is 0.8. The comparison of the photopic and mesopic intensities can best be made by subtraction of photopic intensity of the defect from the normal mesopic sensitivity curve as in Fig. 3.

Correction of the patients' refractive errors for the examination distance used is essential. The M/P ratio can be affected by the presence of obvious lens opacities.

Kinetic mesopic campimetry and perimetry was described by Jayle et al. (1956) These authors concluded that visual field defects in some pathological conditions of the macula were larger under mesopic conditions. A comparison of the intensity of the defects, as precisely as is possible with static perimetry, has to our knowledge not been described in the literature.

CASE REPORTS

Case 1

A man of 36 years with central serous choroidopathy, complained of blurred vision with the left eye. The visual acuity of the right eye was 1.25 and of the left eye 0.75. The fundus showed the typical macular edema with a detachment of the neuro-epithelium and the pigmentepithelium, which was confirmed by F.F.A (Fig. 4). The visual field shows the typical central and paracentral defect (W-type) with a deep defect corresponding with the R.P.E. detachment, the M/P ratio is greater than 1 (Fig. 5)

Case 2

A woman of 67 years. Visual acuity in the right eye is 0.9 and in the left eye 1.0. Both eyes have the clinical picture of Drusen. The left eye is in an earlier stage than the right eye. The left eye showes only Drusen, some of them confluent (Fig. 6). Static perimetry shows paracentral defects that have a greater mesopic intensity (Fig.,7). The left eye has large confluent Drusen and a local retinal pigment epithelium (R.P.E) detachment (Fig 8). There is probably also some foveal edema. Static perimetry shows a central and a paracentral defect and here again the mesopic intensity is greater than the photopic intensity (Fig. 9).

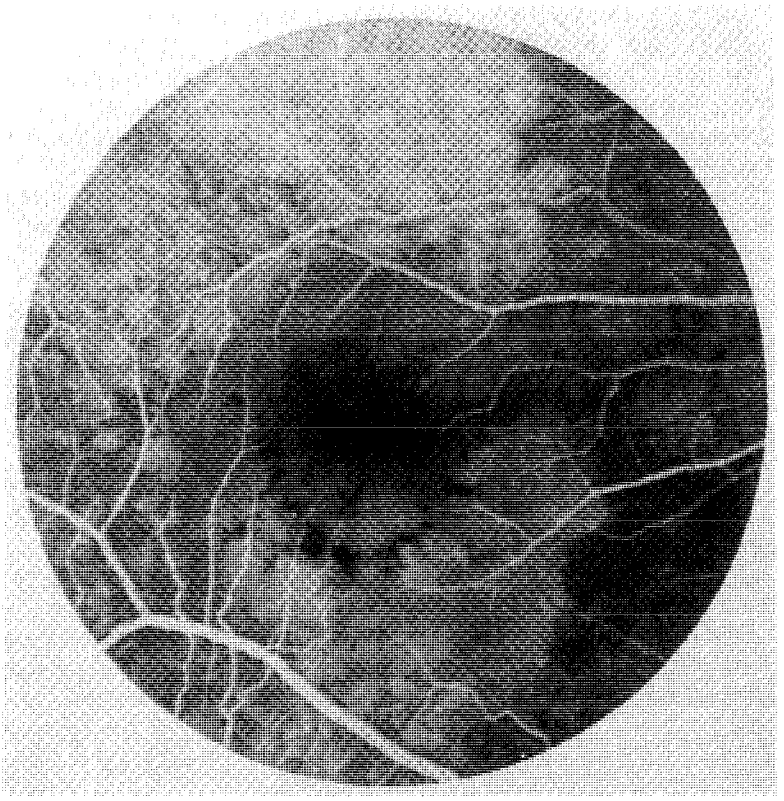

Fig 8 *Case 2* Drusen F F A right eye.

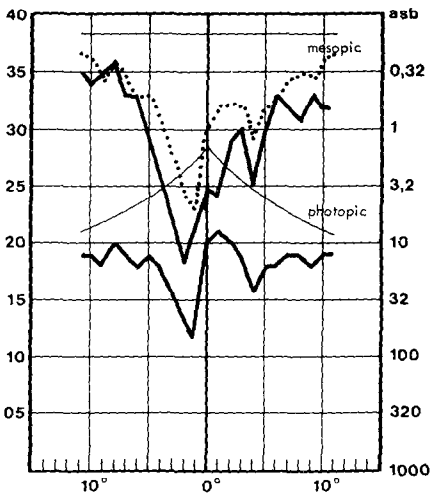

Fig 9 *Case 2* Static perimetry, in 120° and 300° meridian, right eye: see text

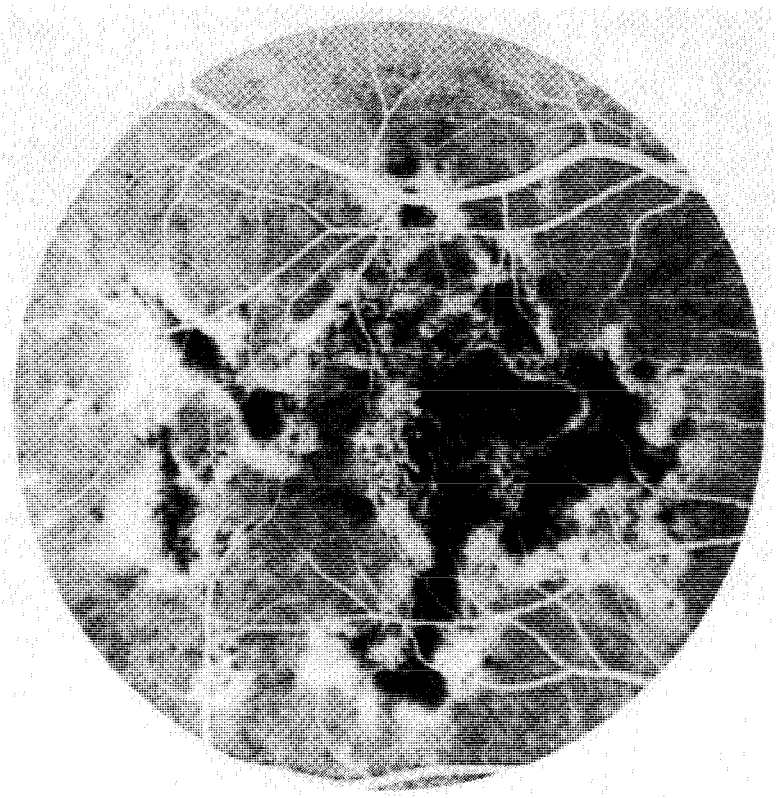

Fig 10. Case 3 Acute multifocal placoid pigment epitheliopathy F.F A of cured stage: see text

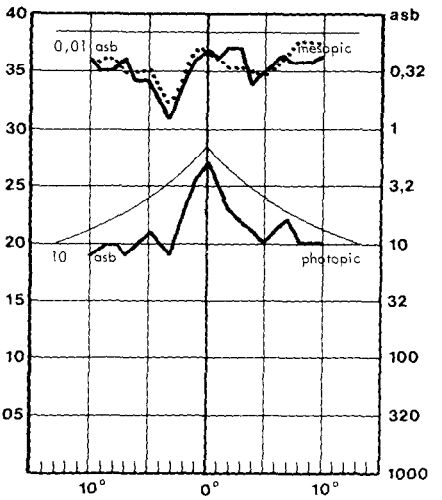

Fig 11 Case 3 Static perimetry, in 90° and 270° meridian; cured stage: see text.

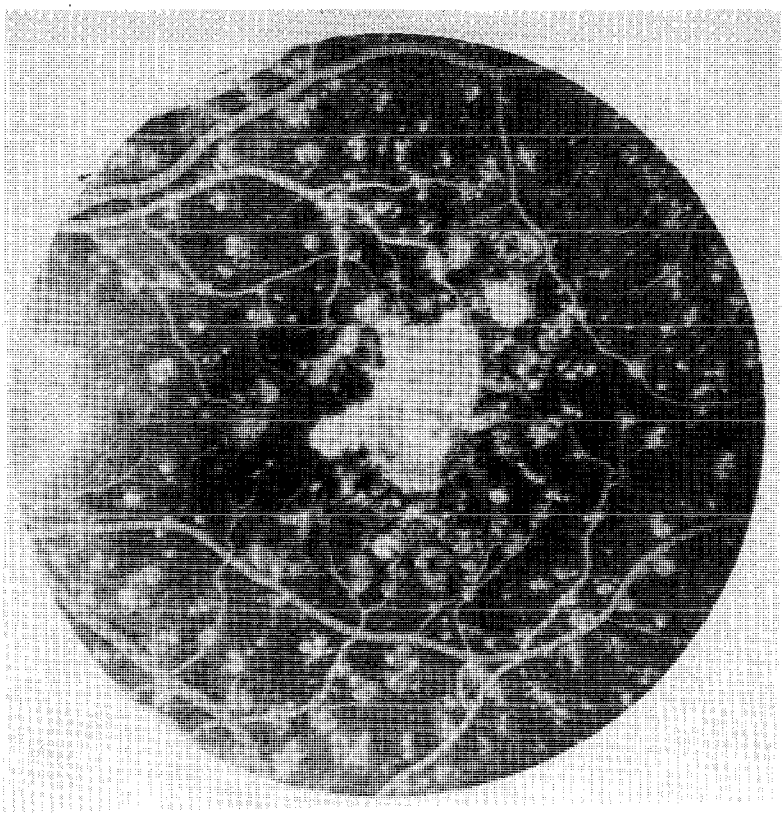

Fig. 12 *Case 4* Non-exsudative senile macular degeneration F F.A.: see text

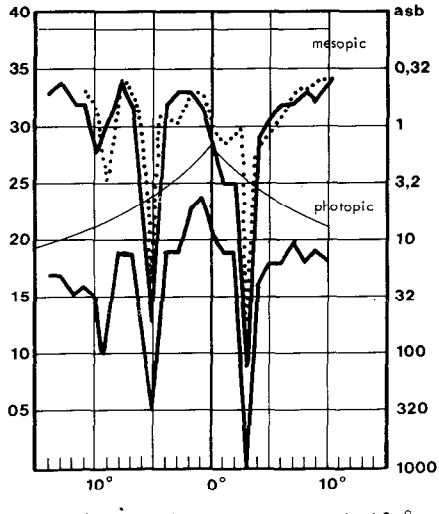

Fig 13 *Case 4.* Static perimetry in 135° and 315° meridian: see text.

Case 3

A woman of 27 years had a sudden fall of visual acuity in December 1974 Visual acuity of both eyes: 0.25. On examination of the fundus the multifocal grey-yellow lesions were seen with some cells in the vitreous. (Also cells in the anterior chamber and corneal K.P.) Diagnosis was acute multifocal placoid pigment epitheliopathy. The proces healed in a few weeks but left extensive changes of the R.P.E. In February, her visual acuity was 1.0. The F.F.A. photograph shown here is of the cured stage where extensive healed lesions of the R.P.E. are seen (Fig. 10). In contrast to this F.F.A. picture, static perimetry shows only relative paracentral defects. M/P ratio is approximately 1 (Fig. 11).

Case 4

A woman of 68 years presented with a dry senile macular degeneration and a visual acuity of 0.75. F.F.A. shows Drusen and a non-exsudative macular degeneration (Fig. 12). Static perimetry shows a central and paracentral defect with an M/P ratio of 1.0 (Fig. 13).

Case 5

A woman of 73 years complained of decreasing visual acuity and metamorphopsia. The corrected visual acuity of the right eye was 0.75 (left eye 1.0). The right fundus showed a cellophane aspect of the inner retinal layers and stretching of the retinal vessels. F.F.A.: irregular centripetally stretched vessels of the macular area. No lesions of the R.P.E., no leakage (Fig. 14). S.P.: relative central and paracentral defect; M/P ratio approximately equal to 1 (Fig. 15).

Case 6

A man of 40 years presented with the complaint of a gray spot close to the centre of the right eye. In the right fundus a small round dark spot could be seen in the papillomacular nerve fibre bundle (Bos & Deutman, 1975). F F.A. showed no abnormalities. Static perimetry demonstrated a relative centrocoecal defect with a M/P ratio smaller than 1 (Fig. 16).

Case 7

A woman of 48 years had a sudden decrease of visual acuity in the left eye with painful eye movements. The visual acuity of the right eye was 1.25 and of the left leye 0.16. The fundus showed no abnormalities. S.P. demonstrates the typical irregular central and paracentral defects. The M/P ratio is approximately 1. The diagnosis was retrobulbar neuritis (Fig 17)

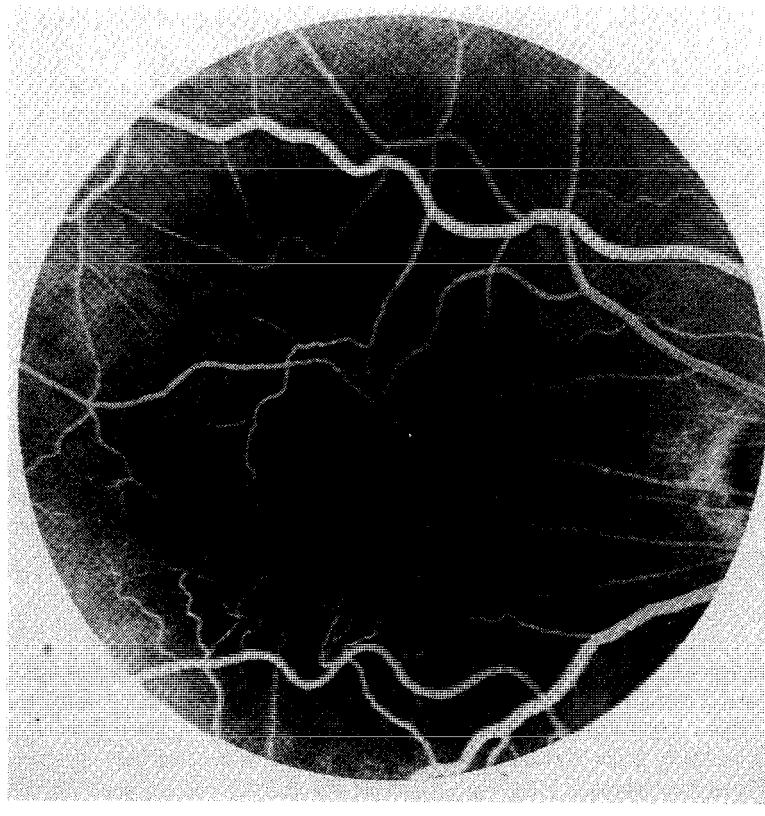

Fig 14 Case 5 Preretinal fibrosis, F F A., see text

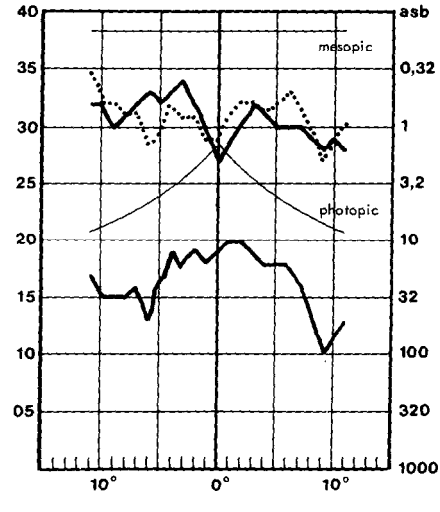

Fig 15. Case 5 Preretinal fibrosis, static perimetry in 225° and 45° meridian, see text.

Case 8

A woman of 74 years had a good visual acuity in 1970 Her visual acuity then dropped to 0.3 and 0.25 in the right eye and the left eye respectively which could not be explained by nuclear lensopacities. A pallor of both optic discs was seen. Static perimetry showed a relative central defect with an M/P ratio of approximately 1. The diagnosis was optic atrophy (Fig. 18).

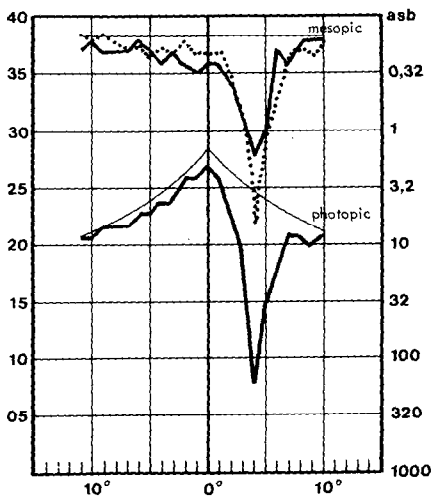

Fig. 16 *Case 6* Neuroretinopathy, static perimetry in 180° and 0° meridian, see text (normal F.F A).

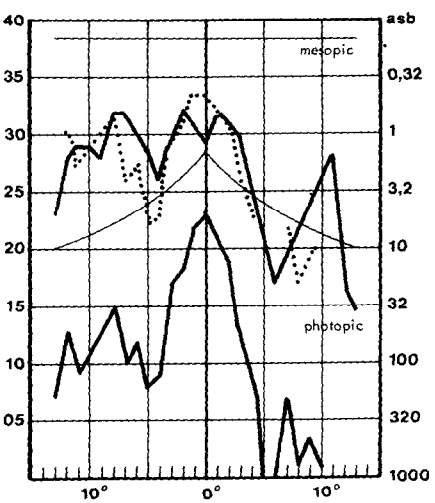

Fig 17. *Case 7.* Retrobulbar neuritis, static perimetry in 225° and 45° meridian, see text

Case 9

A man of 56 years complained of a paracentral dark spot in both eyes since a cholecystectomy 3 months ago. He had a visual acuity of 1.0 in both eyes and his fundus showed no abnormalities. Static perimetry demonstrates homonymous paracentral defects with equal mesopic and photopic intensity (Fig. 19).

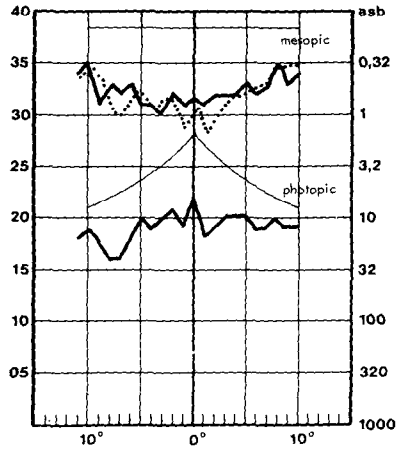

Fig. 18 *Case 8.* Optic atrophy, static perimetry in 225° and 45° meridian, see text.

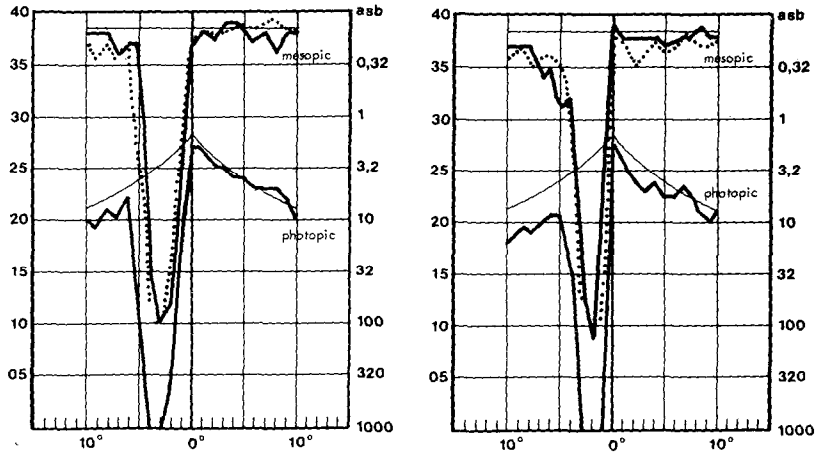

Fig. 19 *Case 9* Homonymous paracentral defects, static perimetry in 180° and 0° meridian, see text (left and right eye).

Table 1

1	M	36 years	central serous chorioidopathy	M/P > 1
2	F	76 years	drusen-disciform macular degeneration	M/P > 1
3	F	27 years	multifocal placoid pigment epithelopathy	M/P ≈ 1
4	F	73 years	non-exsudative senile macular degeneration	M/P ≈ 1
5	F.	73 years	preretinal fibrosis	M/P ≈ 1
6	M	40 years	neuroretinopathy	M/P > 1
7	F	48 years	retrobulbar neuritis	M/P ≈ 1
8	F	74 years	optic atrophy	M/P ≈ 1
9	M.	56 years	homonymous paracentral defects	M/P ≈ 1

DISCUSSION

A survey of the cases described is given in Table 1. Cases 1 and 2 show a maculopathy associated with fluid under the retinal pigment epithelium or under the retinal neuro-epithelium. In these cases the M/P ratio is considerably more than 1; in other words, the intensity of the visual field defects is larger at the mesopic adaptation level than at the photopic adaptation level. The difference between the first 2 cases and the cases 3 and 4 is that in the latter there is no fluid under the retina. In cases 3 and 4 obvious lesions are present in the retinal pigment epithelium. In these cases without fluid the M/P ratio is approximately 1.0. Case 3 also demonstrates that the visual function can be good in spite of extensive scars in the retinal pigment epithelium.

In case 5 the deeper layers of the retina are not involved In this case of premacular fibrosis there is, as expected, no difference between the mesopic and photopic intensities of the relative defect.

Case 6 is one of the cases of neuro-retinopathy which have recently been described by Bos & Deutman (1975). In this condition the retinal pigment epithelium is not visibly damaged and there is no fluid under the retina. The M/P ratio was less than 1.0.

Finally, the 3 last cases show neural defects in the optic nerve and the post-chiasmal (probably occipital) part of the visual system. In these 3 cases the M/P ratio was 1.0.

The best method at present available for the determination of the visual function in the central and paracentral visual field is static perimetry. Even when the visual acuity is still quite good severe paracentral defects may exist at an early stage of a maculopathy or neuropathy.

Kinetic perimetry is not suitable for registering defects like these. Static perimetry enables us to measure the precise intensity of the defect, which is necessary for a comparison between the mesopic and photopic intensities, and for the follow-up of a defect.

The choice of meridian in which the meridional static perimetry of performed is based, where possible, on the data supplied by the fundus photograph or fluorescein photograph. When the data provided by the photographs does not help the choice based on the results of the detection phase.

The most important conclusion which can be drawn from these findings is that the conditions of the retinal pigment epithelium which are associated with fluid either under the retinal pigment epithelium or under the neuro epithelium give rise to visual field defects for which the ratio mesopic/photopic intensity is more than 1.0. To our best knowledge this conclusion is new.

Conditions of the retinal pigment epithelium in which no fluid is present show visual field defects which have the same intensity under both mesopic and photopic conditions (M/P ratio equals 1.0).

Visual field defects associated with disease of the superficial layers of the retina, the optic nerve of the retro-chiasmal visual system show no difference between the mesopic and photopic intensities, or in some cases the photopic intensity may even be greater. In glaucoma also (not described here) we could discover no difference between the mesopic and photopic intensities of visual field defects.

The examination of the central visual field by means of comparative mesopic and photopic static perimetry is therefore of value for the diagnosis of the presence of fluid under the retinal pigment epithelium or the retinal neuro-epithelium.

This method is easy to perform and not time-consuming (provided that the necessary perimetric apparatus is available). Central static perimetry, in any case, provided important information about the *typical appearance* of the loss of visual function in some disturbances of central vision. The comparative mesopic and photopic examination adds a further diagnostic value. We therefore recommend the inclusion of this type of examination in the routine examination of maculopathies and central neuropathies.

SUMMARY

Central static perimetry at two levels of adaptation is an excellent means for the differentiation of maculopathies and central neuropathies Differences of the intensity of mesopic and photopic defects are expressed as an M/P ratio

The M/P ratio is greater than one in case of macular oedema and smaller than or equal to one in some cases with neuropathies.

The typical perimetric features of several types of lesions are discussed.

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VISUAL FIELD DEFECTS IN VITAMIN B12-AVITAMINOSIS

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The differential diagnosis in binocular diseases of the optic nerve is especially difficult, because a visible manifestation of the disease in the region of the optic disc is found in very few cases only. Even if a papilledema or a slight blurring of the edge of the disc exists, the diagnosis is only negligibly facilitated, since these signs are of no specific nature, but only give reason to believe that in this case the optic nerve disease is located close behind the eyeball.

Neuritis only comes into question as the cause of binocular diseases of the optic nerve in exceptional cases. Intoxications, damage through deficiency of vitamins and proteins, and hereditary degenerative diseases are the main causes. Loss of visual acuity, which occurs in all these diseases, is only an unspecific sign – only the speed and extent of visual acuity decay can give definite pathognomonic indications. Better differentiation is given by testing of the visual field. Typical field defects, which occur in binocular diseases of the optic nerve, are shown in Fig. 1. Very atypical defects can, of course, be found in binocular diseases also, for example in binocular vascular processes, or in tumours exercising pressure on both optic nerves. Most binocular primary optic nerve diseases, however, result in field defects of the types illustrated above.

In the last few years we have repeatedly found field defects in cases of vitamin B12 deficiency. The type of scotoma with this constantly binocular optic nerve damage seemed to be a genuine absolute or relative central scotoma in most cases. Centrocoecal scotomas, however, were also found. I should now like to present a survey on the binocular field defects of eleven patients, where a deficiency of vitamin B12 was found for certain in the serum.

The examination of the vitamin B12 level was carried out in all cases by Dr. Castrillon-Oberndorfer in the Tübingen Medical Clinic using the Schilling test. Since this test is made with marked vitamin B12, it can only be done in isotype laboratories, i.e., in the larger clinics. Disturbances in the vitamin B12 metabolism can lead to a reduced as well as to an increased secretion of radioactive vitamin B12 in the urine, according to where the cause of the B12 deficiency lies.

Vitamin B12 resorption disturbances occur idiopathically, but they can also appear secondarily in a variety of other internal diseases such as hepato-

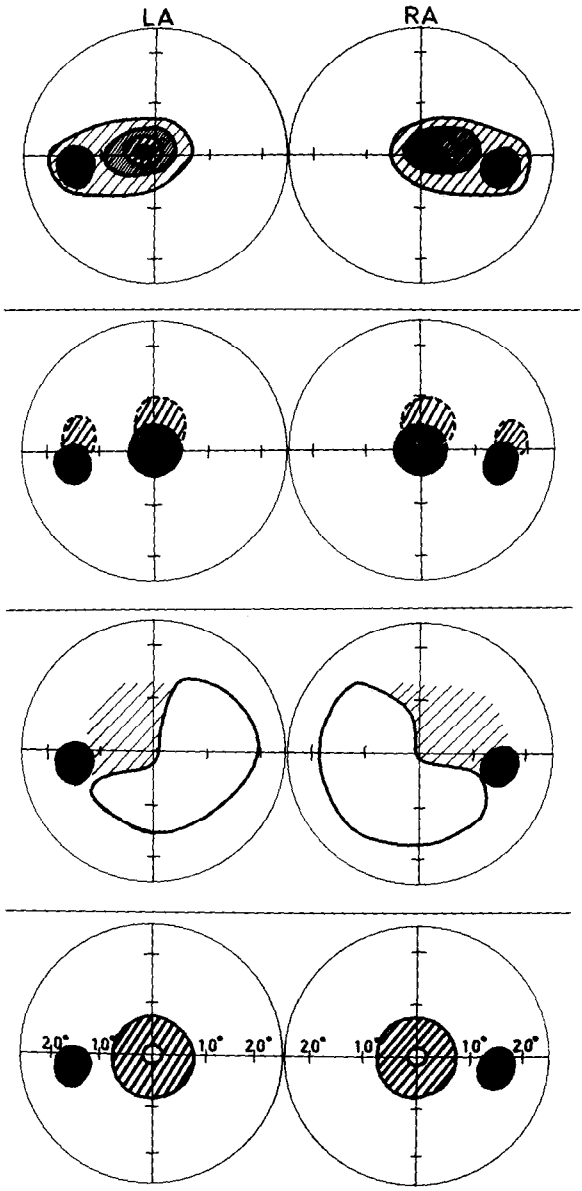

Fig. 1 4 types of central scotomas in binocular diseases of the optic nerve:
a) centrocoecal scotoma – frequently in tobacco-alcohol amblyopia or in myambutol intoxication.
b) absolute central scotoma with eccentric fixation at the edge of the scotoma. Frequently found in Leber's disease
c) bitemporal relative defects including the visual field centre – frequently in dominant hereditary optic atrophy.
d) paracentral ring scotoma – frequently in protein deficiency.

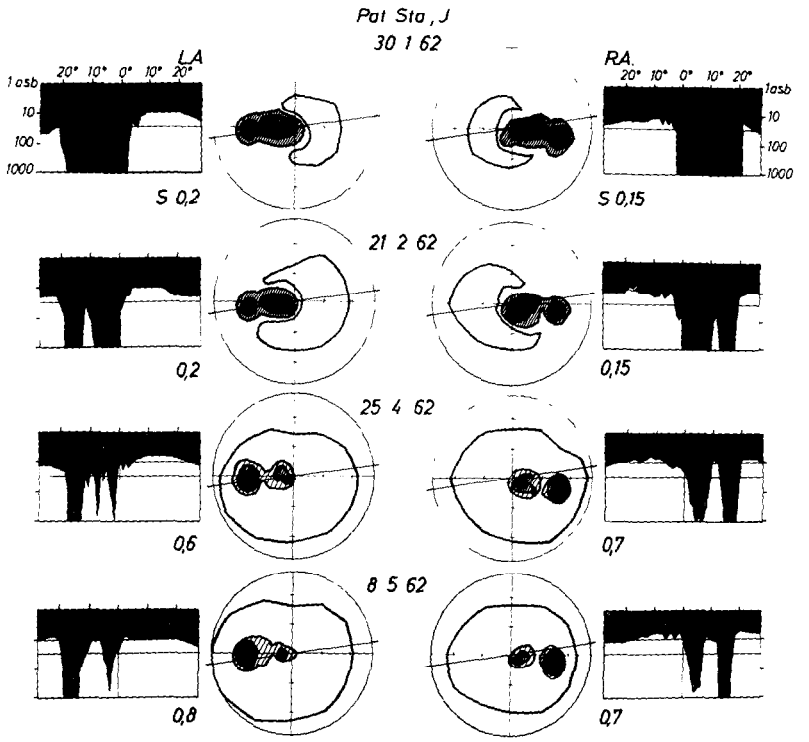

Fig. 2 Tobacco-alcohol amblyopia with a clear improvement in the visual field defects on stopping misuse

Table 1

Vit B12 Deficiency + Tabacco - Alcohol misuse		Vit B12 Deficiency only	
St J	centrocoecal	Sch E	central
H A	central	Sch L	central
F S	centrocoecal	N G	central (Tabacco +)
B G	centrocoecal	K U	centrocoecal (MS?)
L M	central	M I	central (Tabacco +)
St E	central		

pathies, pernicious anemia, multiple sclerosis, and especially in excessive intake of tobacco and alcohol. Tobacco-alcohol misuse alone, however, leads to typical visual field defects, even if there is no idiopathic vitamin B12 deficiency, i.e. to centrocoecal scotomas (Fig. 2). Previously, when no medical treatment was carried out other than total abstinence, we frequently saw an improvement in these cases also.

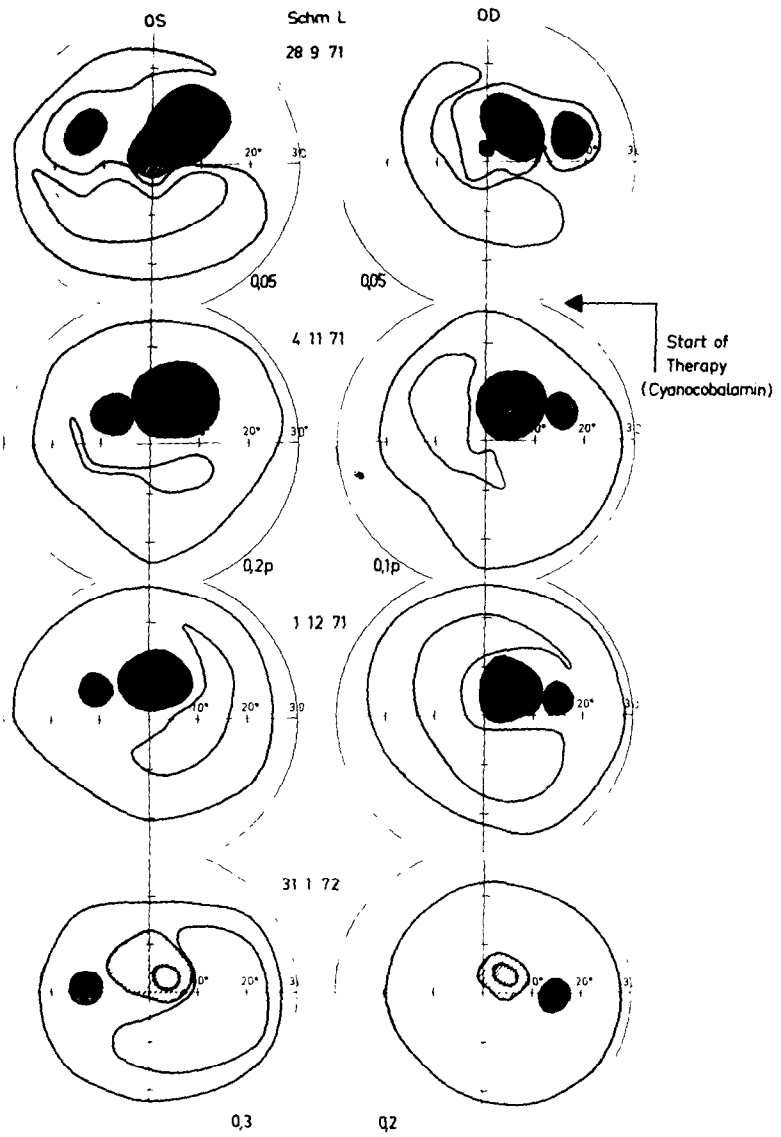

Fig. 3 Vitamin B12 deficiency – improvement in visual field defects with hydroxocobalamin therapy.

In Table 1 we shall analyse our 11 cases, and from the survey we can learn whether or not a typical field defect exists in vitamin B12 disturbance.

The result is not clear. with a proved deficiency of vitamin B12 combined with tobacco-alcohol misuse, centrocoecal and central scotomas occur. On the other hand, with a proved deficiency of B12 alone, without tobacco-alcohol misuse, small, round central scotomas without centrocoecal character were found in four out of five cases; and in the only case of a centrocoecal scotoma there is a questionable encephalomyelitis disseminata. We found no type of scotoma in vitamin B12 avitaminosis, other than genuine central scotomas, which usually seemed to be displaced in the same direction because of the binocular nature of the field damage, or centrocoecal scotomas.

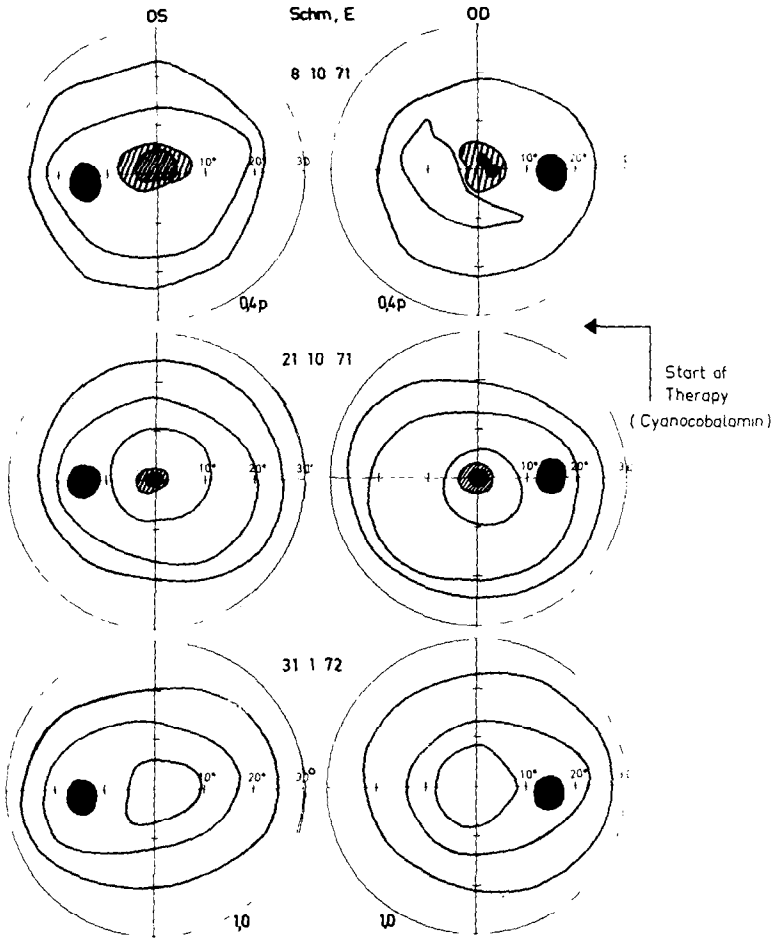

Fig. 4 Vitamin B12 deficiency. Restitutio ad integrum with hydroxocobalamin therapy.

I realize, of course, that the number of cases in our survey is much too small to be able to maintain that the typical field defect with isolated vitamin B12 deficiency is a round central scotoma without centrocoecal character. I should, nevertheless, like to present this provisionally as a still unproved hypothesis for further work, for I believe that knowledge concerning typical visual field damage in diseases, of which the pathogenesis is still uncertain, can contribute towards their elucidation. If it should become confirmed that isolated B12 deficiency only leads to simple central and not to centrocoecal scotomas, which are, of course, typical of tobacco-alcohol intoxications, then the place of damage or the damaging mechanism in the region of the optic nerve must be a different one in vitamin B12 deficiency than it is in tobacco-alcohol amblyopia.

In ophthalmic practice it follows from such considerations that with every binocular central scotoma, and with every binocular centrocoecal scotoma, a vitamin B12 resorption disturbance must be considered. Once this etiology has been included in the sphere of one's observations, it is found not at all so infrequently. The field defect with a vitamin B12 disturbance decreases quickly and often even completely, if the optic nerve atrophy has not existed for too long and has not led to total degeneration of the fibres. Precisely this fact: that the therapy is so simple, leading to good results in cases of early discovery, obliges us to make a diagnosis as soon as possible. Hydroxocobalamin was used in every case for the substitution. With the help of the Schilling test, it could be proved that the vitamin B12 deficiency was eliminated after this medication.

In the last figures two cases of vitamin B12 avitaminosis are shown, in which the resulting central scotomas had existed for months. After hydroxocobalamin substitution an extensive diminution of scotomas resulted. In the first case, in which the defect was absolute before the substitution, a relative central scotoma still remained (Fig. 3). Whereas in the second case, where the scotomas were only relative before therapy, a complete restitutio ad integrum followed (fig. 4).

SUMMARY

A report is presented on visual field defects of a large group of patients with reliably manifest B12-avitaminosis. The visual field defects are similar to those of the tobacco-alcohol-amblyopia but they are not equal. In some cases improvement of the visual field defects after B12-substitution is shown.

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VISUAL FIELD DAMAGE AFTER PHOTOCOAGULATIVE TREATMENT FOR DIABETIC RETINOPATHY

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INTRODUCTION

In order to evaluate the functional results of photocoagulation in diabetic retinopathy, up to now only the central visual function capable of being saved has been considered, whereas little attention has been given to the visual field one is forced to sacrifice. If eye surgeons have minimized visual field damage in photocoagulated eyes for a considerable time, this is because early treatments, with coagulations reasonably isolated from each other, produce defects which, although numerous, were well circumscribed (Meyer-Schwickerath, 1968; Zetterström, 1972), often indeed unrecognizable (Zetterström & Gjötterberg, 1973) and, moreover, always well-tolerated by the patients (Okun & Cibis, 1966, Velissaropulos et al., 1971, Irvine & Norton, 1971, Wessing, 1969, François & De Laey, 1977). The earliest visual field diagrams to appear in ophthalmological literature contributed to an undervaluation of visual field changes. They were, in fact, often obtained with a single large, bright test object and they had significance only for peripheral exploration. Thus, the conviction arose that photocoagulation never produces nerve fibre defects. Therefore, a long time was to pass before it became recognized that this kind of defect could develop in eyes in which the treatment was carried out without allowing enough space between one application and the other (Wessing, 1969) or in eyes repeatedly treated around the optic disc (Little, 1972, Zweng et al., 1972).

The first perimetric investigation with more than one isopter was made by Riaskoff (1972). This author distinguished two types of defects those which are circumscribed and due to the coagulation destruction of the retina, and those wich are more extensive and due to lesions in the nerve fibre or to occlusion of peripheral arterial branches.

Another multi-isopter perimetric study, still more detailed, with the Goldmann perimeter was recently published by Frank (1975) on the visual field changes following extensive argon-laser photocoagulation The author devides them into four groups. 1) constriction of all isopters, observable in cases treated by 'peripheral retinal ablation', 2. isopter constriction and scotomata in cases subjected to 'peripheral ablation' associated with 'focal treatment'; 3. nerve-fibre defects in eyes repeatedly coagulated at various time-intervals or in eyes with preretinal hemorrhage, and 4. 'gun barrel' fields, the cause of which is inexplicable to the author himself.

Considering the relatively scant contribution to a branch of perimetry

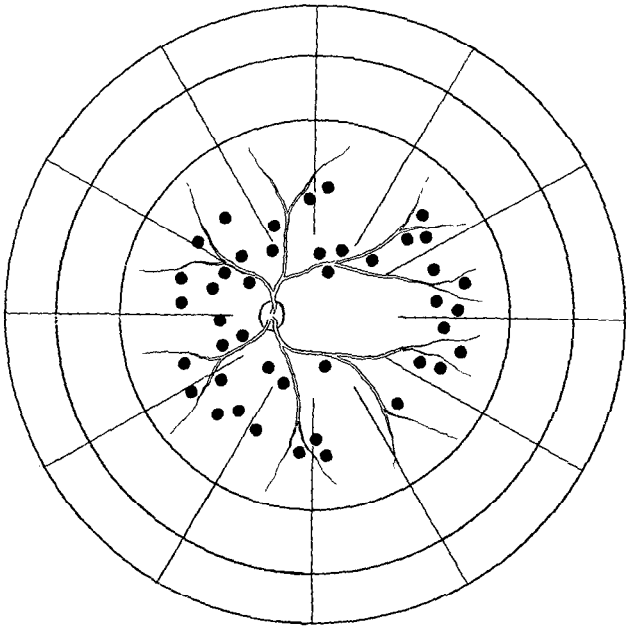

Fig. 1 Isolated photocoagulations.

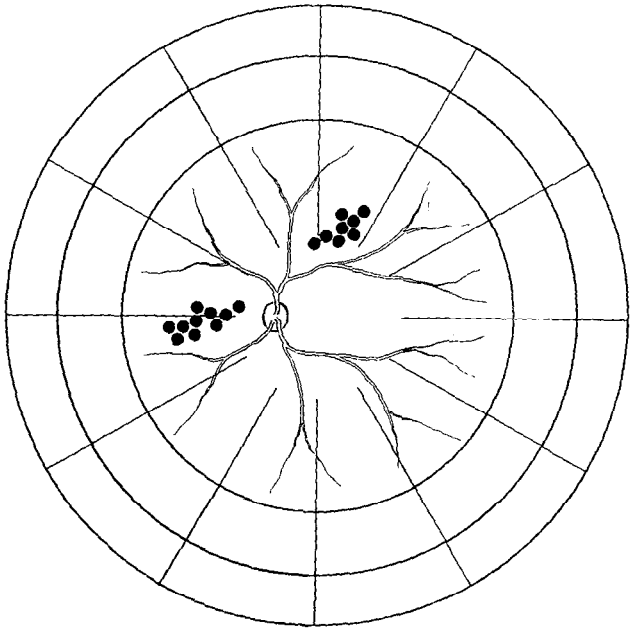

Fig 2 Confluent photocoagulations

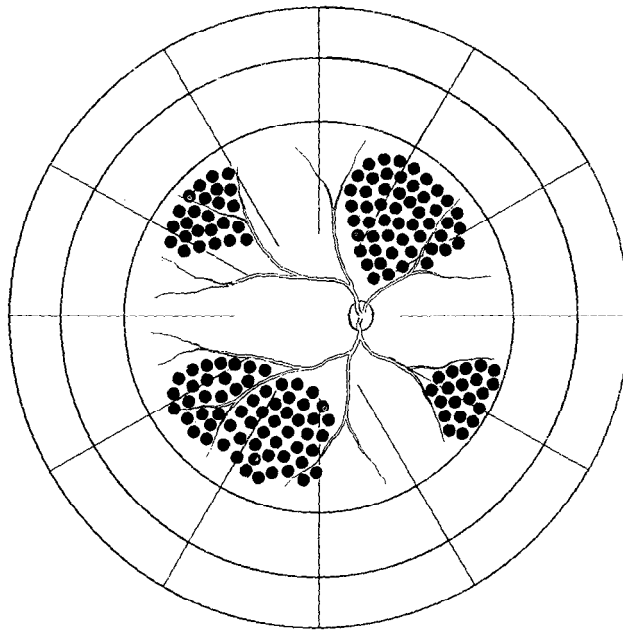

Fig 3. Extensive photocoagulation

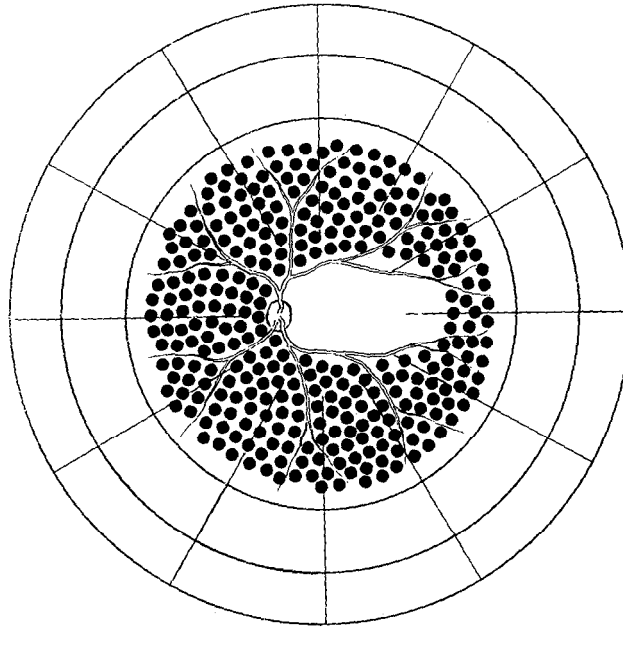

Fig 4. Panretinal photocoagulation

becoming more important every day, we deem it necessary to analyse this type of visual field damage both with kinetic and static exploration in order to evaluate not only their horizontal characteristics (shape and extension), but also the vertical (profile and depth) and to establish, if possible, a relationship between such characteristics and treatment procedure.

CLINICAL DATA AND METHODS

Twenty-eight eyes were examined. They were photocoagulated with different procedures, which will be explained subsequently.

A xenon photocoagulator (MIRA, Boston, USA) of the Eye Clinic of Sassari University (Italy) was used for the treatment. The light beam of the

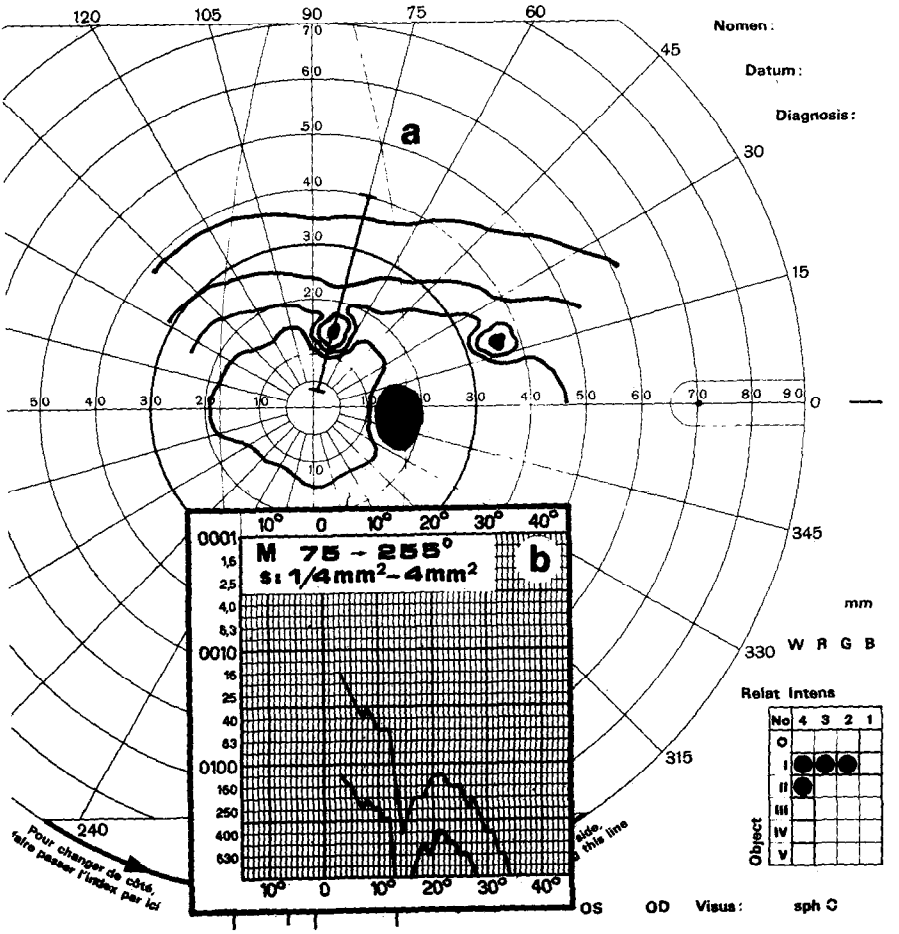

Fig 5. Circumscribed defects produced by isolated photocoagulations (a = kinetic method; b = static method)

instrument was regulated to an aparture of 5° at the lowest intensity and with the minimum exposure time necessary to produce a retinal whitening (normally 0.3-0.5 sec.).

Twenty-one eyes were treated with the 'focal' method, i.e. with applications focussed directly onto the lesions. In 12 of these the coagulations were isolated (Fig. 1) as they were intended to destroy small hemorrhages or small areas of neovascularization. In 9 eyes they were confluent (3-10 applications) (Fig. 2) to ensure the coagulation of more extensive hemorrhages, or neovascularisation areas, than in the former cases. In the remaining 7 eyes a more extensive examination was carried out with applications grouped in one or more retinal sectors (e.g., to destroy extensive neovascularizations) (Fig. 3)

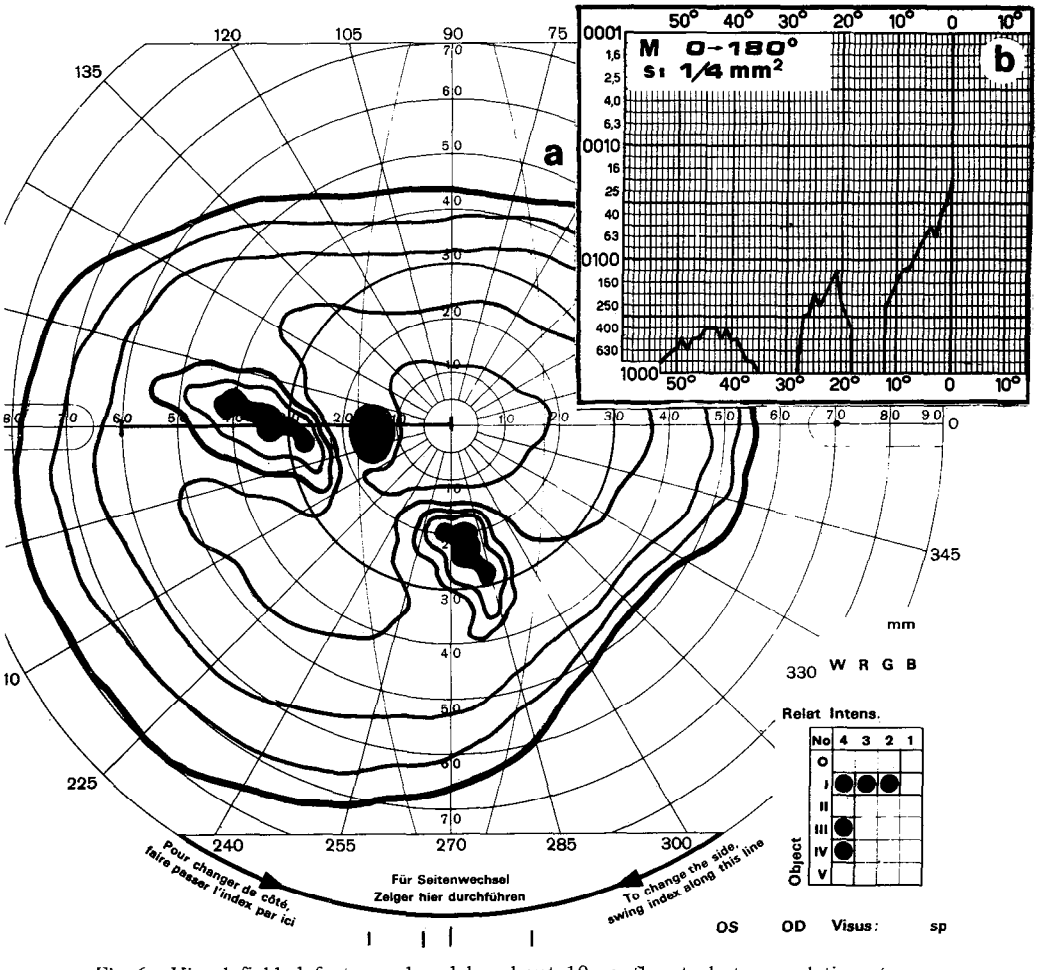

Fig. 6 Visual field defects produced by about 10 confluent photocoagulations (a = kinetic method; b = static method).

or distributed over the whole pericentral and retro-equatorial area ('panretinal photocoagulation') (Fig. 4).

Visual field examination was carried out on all eyes. Extension and form of the defects were analysed by the kinetic method, both isopterically and scotometrically, using as many test objects compatible with the eccentricity of the lesions as possible. Defect depth analysis was made with the static method along the most relevant meridian. A Goldmann perimeter, equipped for static examination, was used for this purpose.

RESULTS

Isolated photocoagulations

Normally, isolated photocoagulation produces an irregular round-shaped visual field defect of small dimensions, which is often difficult to reveal by kinetic perimetry if previously topographic indications are not given. Scotometric examination shows that the defect is denser at its centre than at its periphery and that its maximum width, which can be determined by sufficiently small and not very bright stimuli, is approx. 5°-6° (Fig. 5a).

Static exploration indicates that the defect has a rather steep profile and a small central portion of absolute density. The latter sometimes does not appear, but this only occurs when the static exploration is done on an axis which does not exactly cross the centre of the scotoma or without sufficiently small test-objects (Fig. 5b). In the kinetic diagrams these small scotomata produce a moderate isopter irregularity.

Confluent photocoagulations

When some 3-10 coagulations are confluent, so that in time they produce one entire scarred area of 1-2 disc diameters, the corresponding perimetric defect reproduces the shape of the retinal lesion reasonably faithfully.

Scotometric examination with several test objects and, even more, static exploration shows that normally the defect has a central nucleus of absolute density, which is surrounded by a peripheral zone where the sensitivity increases steeply from the centre towards the margin of the scotoma, and so reaches the liminal value of the surrounding untreated retina (Fig. 6a and b). In the kinetic diagrams these defects sometimes produce marked isopter irregularity.

Extensive photocoagulation

If coagulations, applied close to each other, are distributed over one or more retinal sectors or over the entire pericentral and retro-equatorial area, as in the case of the so-called 'panretinal photocoagulation', the perimetric damage does not reproduce the shape of the lesion except in respect of the posterior margin. In fact, towards the periphery the defect extends to the absolute limits of the visual field, even if in this part an ophthalmoscopically visible untreated retinal area remains.

In these cases static examination reveals that retinal sensitivity decreases at the posterior margin of the defect with a steeply declining profile, without any sign of peripheral recovery.

If several retinal areas are treated with an extensive photocoagulation, leaving untreated spaces in between, kinetic examination shows a typical

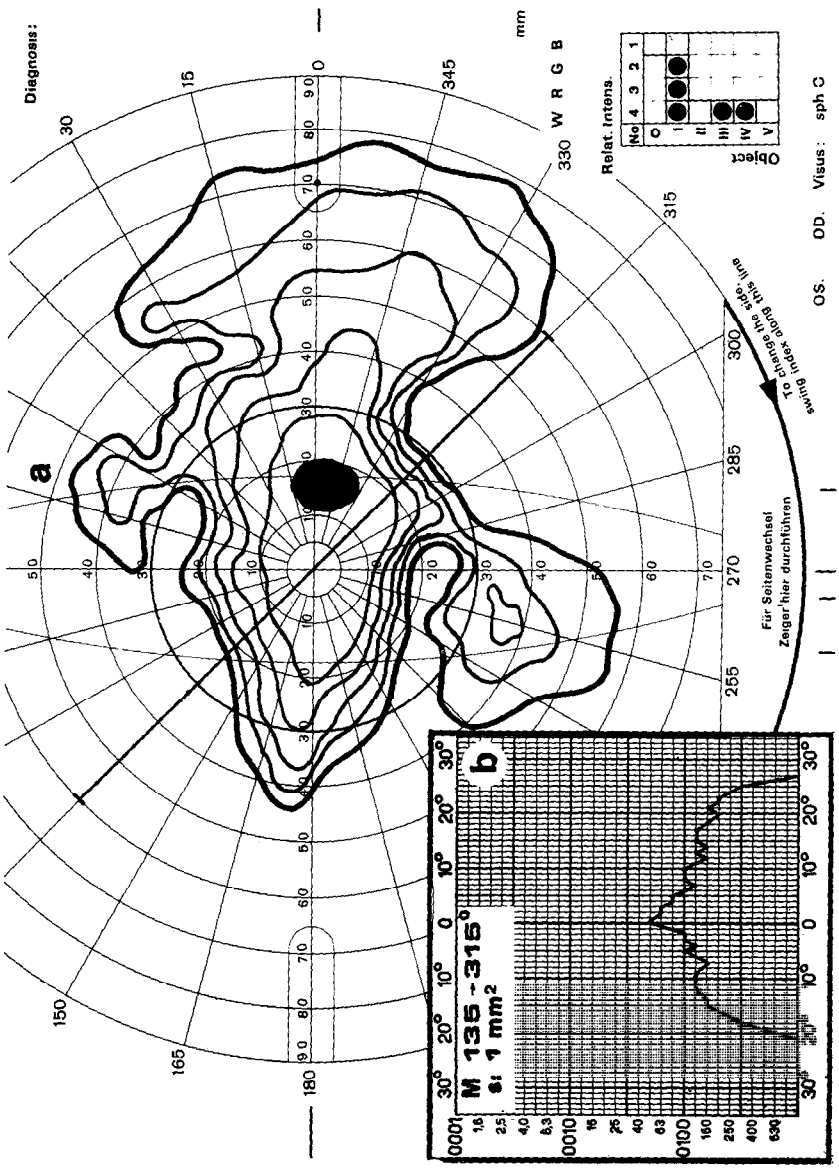

Fig. 7 Typical irregular visual field after extensive photocoagulation (a = kinetic method; b = static method)

irregular visual field. This is composed of a central nucleus (corresponding to the central retina which must obviously always be left free of photocoagulation) and of peripheral areas connected to the central nucleus by means of more or less slender bridges or isthmi (Fig. 7).

A 'panretinal photocoagulation' produced, on the contrary, a marked *concentric contraction of the visual field. In this case, kinetic perimetry* shows small topographic differences among the various isopters; which means a sharp decrease of the retinal sensitivity of the margin of the defect (Fig. 8a). Static diagrams indicate, in even more detail, this sensitivity diminution and show – in the central portion – a more or less altered profile proportional to the severity of the diabetic lesions in the macular area (Fig. 8b).

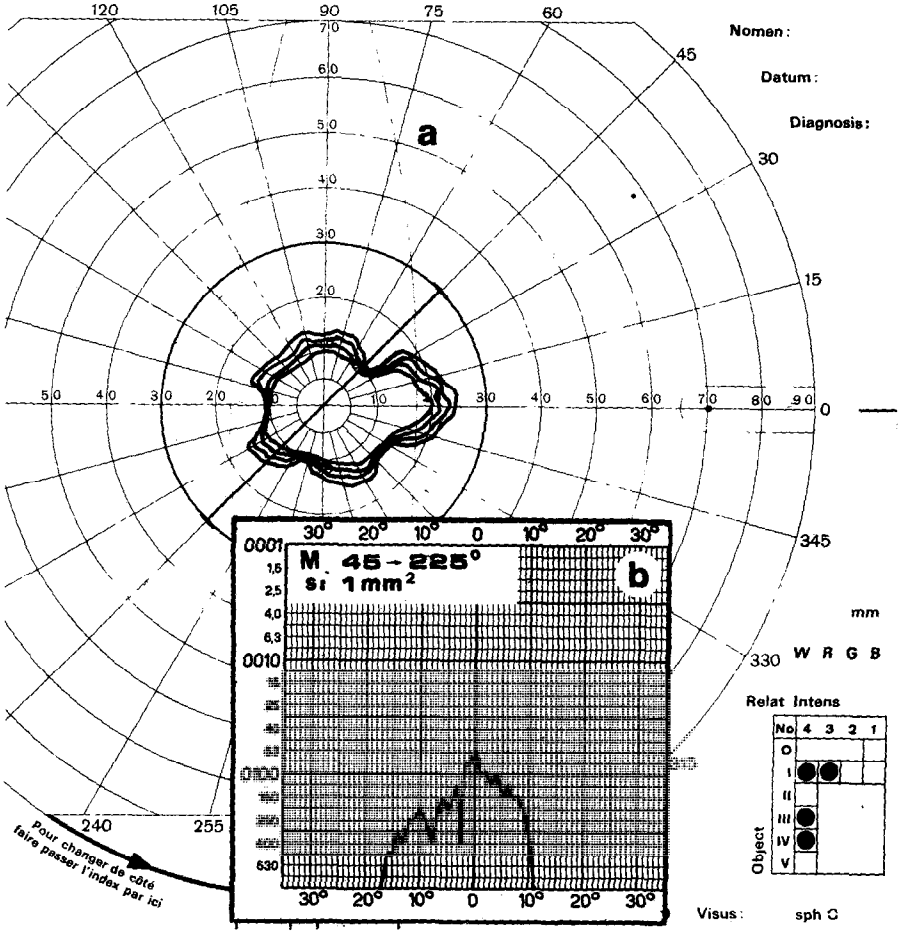

Fig. 8. Concentric contraction of visual field after panretinal photocoagulation (a = kinetic method; a = static method).

CONCLUSIONS

Treatment of diabetic retinopathy with isolated or confluent coagulations, not exceeding approximately 10 applications, produces circumscribed damage to the visual field. The defects have a central nucleus with absolute density and a peripheral portion of relative density.

Extensive photocoagulation, besides inducing visual field defects corresponding to the retinal lesions, causes a breakdown in the never fibre conductivity, so that the more peripheral retinal areas become irreversibly nonfunctional.

These results confirm that the selective action of xenon coagulation takes place at the pigment epithelium and at the adjacent layers, without involving the fibre layer, provided that applications ar not too close together and are in limited numbers. Thus damage to the visual field by photocoagulation for diabetic retinopathy is well tolerated as long as applications remain isolated or at least not too confluent. Small multiple scotomata are not noticed by the patient, but are only revealed by a careful perimetric examination. On the contrary, visual field damage after extensive treatment is more serious; the patient is immediately aware of a more or less severe visual impairment.

Nevertheless, this should not inhibit the use of the more destructive photocoagulation methods, since their application is reserved for the more severe cases of diabetic retinopathy, where the visual function is seriously and imminently threatened. It would seem obvious that in these cases even a large sacrifice of the peripheral visual field can be acceptable in exchange for the conservation of a usable central vision.

SUMMARY

Single coagulative spots produce small perimetric defects, whose extension is a little greater than the corresponding treated retinal area. These effects have an absolute nucleus and a periferal ring of reduced sensitivity.

The same condition is observed in cases where coagulative spots are in conglomerate groups of no more than about 6-8. In case of extensive photocoagulation with a large number of spots grouped close to one another, the corresponding perimetric defect is absolute and extends to the periphery, thus excluding from the visual field even a portion of untreated peripheral retina. All these effects were studied both with kinetic and static perimetry.

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RETINAL PHOTOCOAGULATION AS A PHYSIOLOGICAL EXPERIMENT

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The invention of retinal photocoagulation with incoherent light and its improvement with coherent light has made it possible to cure many retinal diseases that until now did not respond to treatment, and it has thus given rise to great hopes.

At first, the ophthalmologist, using a technique that is utterly destructive of the retinal tissues, was very cautious in its application, but he soon found that, paradoxically, its consequences for the visual field were of little or no importance. This resulted in excess use of the therapy. If patients did not complain, it was because there were efficacious physiological compensations. Therefore, it is necessary to first describe carefully the deficiencies of the visual field which are observed, and, secondly, to try to understand their physiological mechanism.

In fact, with this method the ophthalmologist makes a real physiological experiment as he destroys small elective areas of sensorial cells, and he has the advantage of performing this destruction on man – the only living being able to respond accurately to tests. The clinical point of view was described by Zigirian, and we shall not refer to it here.

Let us first consider the case of a single spot of coagulation. It destroys the sensorial cells and, consequently, creates an area of no perception in the visual field. This area is always greater than the luminous impact for heat diffuses in the retinal tissue. The resulting scotoma itself is of greater dimension, as it is rare that the slope of a scotoma is abrupt, and it would be necessary to explore the borders with a sufficient number of minor tests to reach complete precision. Nevertheless, the scotoma remains small and it is difficult to locate it in the visual field by static or kinetic perimetry. So far it is not embarrassing for the patient, unless it is a macular one. It is submitted to the usual laws of scotoma, positivation followed by negativation according to the time passed since its establishment, positivation in flickering illumination or during sudden modifications of luminosity, translation of the scotoma in kinetic perimetry, different loss of reaction time when entering or leaving the scotoma according to the laws of the skiascotoma.

When the impacts are numerous, they may be near enough to each other as to give a true carpet of coagulations in the area where the retina is no

longer functional. The scotoma becomes larger and may have a very great extension. Nevertheless, it keeps the characteristics of the classifical peripheral scotoma which we already described. So far, it has not remained unnoticed by the patient who perceives it like a more troublesome loss of his visual field as it is situated in the inferior or paracentral regions.

There is a third, more current, case than the previous ones, which is not so easy to explain. The coagulations are numerous but they are spaced from each other and they result in disturbances which are difficult to show and, consequently, to describe.

Clinically, the phenomena are the following:

a. The test, by means of kinetic or static perimetry on a meridian from the periphery to the center, is submitted to alternating vision and non-vision. The patient hesitates, does not know where he is and gives the wrong answers. This situation is expressed by hatching the zone of hesitations on the schema.

b. If only the first outcome of the test is taken into account, the inscribed isopter is not circular but festooned with indentations of varying sizes. The indentation may be large enough to stimulate a vascicular deficiency.

c. If one tries to draw an isopter with different but corresponding combinations of surface and intensity (as is possible to do when using the Goldmann perimeter) it is a surprise to find that the corresponding laws are perturbated. The different combinations give non-corresponding curves; it is the small surface combined with a great intensity which is excentrically perceived. The large surface with low intensity is perceived nearer to the center and sometimes very far from the first.

These three facts need an explanation· if we make a series of black circular dots on a sheet of paper, these will schematically represent the retinal photocoagulations.

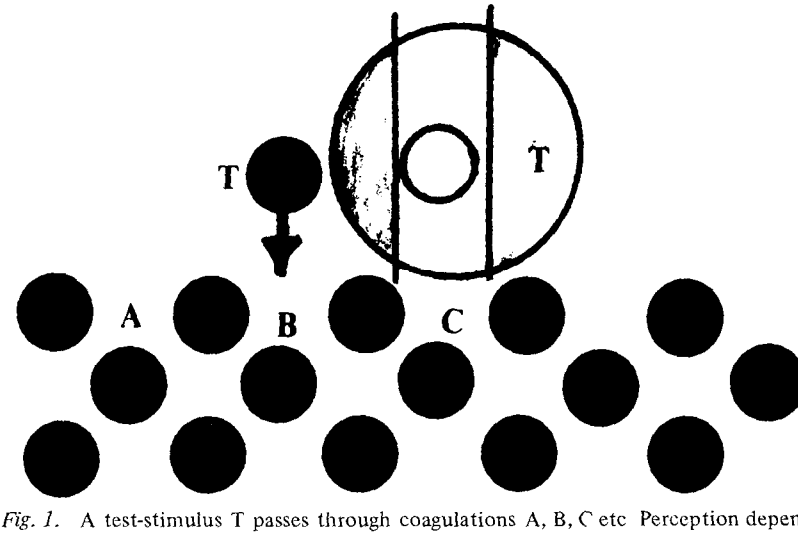

Fig. 1. A test-stimulus T passes through coagulations A, B, C etc Perception depends on the size of the stimulus (see text)

Let us suppose that a perimetric test of circular shape approaches the area dotted with black points. It may pass between two points and it will be perceived, but it will soon encounter a point where it shall not be perceived and so on. The alternatives of perception and non-perception and the hesitating by the patient are thus well explained.

If the perimetric test approaches the dotted area in different places as if for drawing an isopter it will not be perceived when it will be hidden by a black point, but it will be perceived when it passes between two points. The isopter is festooned: the festoon is regular in the case of a geometrical regular pattern, it is not when it is irregular, and its indentations may be very large, simulating a vascicular deficiency.

Let us now consider the condition in which a test is inserted between two dots. If its surface is equal or smaller than the interval, nothing happens and the test is perceived normally. If its surface is larger, it is laterally amputated by the two dots representing the coagulations. According to the threshold law $IS^n = Cte$ the surface is too small to reach the threshold, and it is not compensated by an increased intensity. The test will not be perceived. It will be necessary to go farther towards the center of the field to find an interval where the amputation of the surface with a non-modified intensity corresponds to the threshold. On the contrary, if the test is small

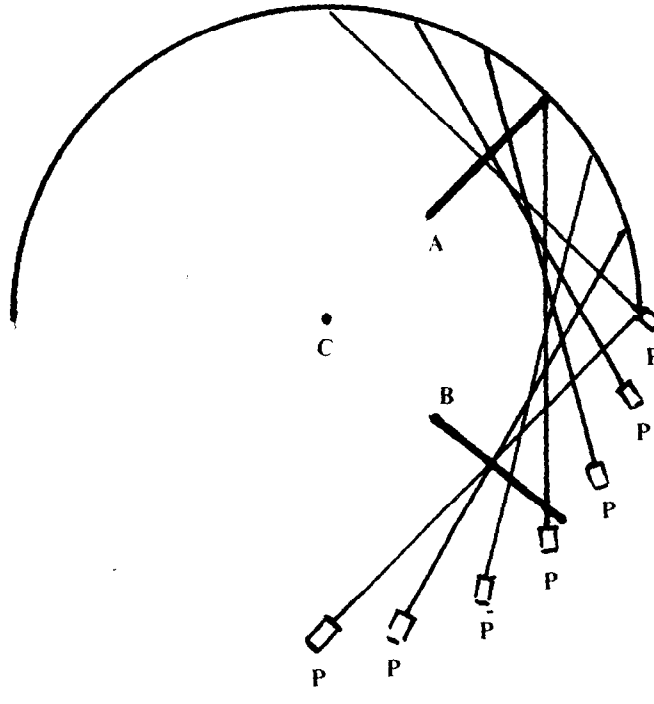

Fig. 2 Direction of the light-beam of the stimulus-projector (P) in relation to the transparent slides A and B

and strongly luminous it will easily pass between the dots and will be perceived. The paradox is apparent and easily explained.

We were not satisfied with this theoretical explanation and we have worked out an experimental model.

A transparent slide on which small dots of black paper were sticked has been interposed on the luminous beam path of the Goldmann apparatus projector. Each dot interrupts the ray and creates an area of aperception as if it were a spot of coagulation. Unfortunately, the special geometry of the Goldmann apparatus created some difficulties and we soon found that the slide should be put in two different positions (A, B) to be swept by the projector beam in the middle and the peripheral regions of the field.

Figure 2 demonstrates this. From another point of view the spots obtained are not perfectly circular. In the periphery the error is slight, but it is strong in the central region. The conditions were drawn in such a way that they are truly realised for the two positions of the slide.

The results were in good accordance with our suppositons, and the perimetrical schema in Fig. 3 is a good illustration of the above three clinical statements.

In kinetic perimetry, there are additional phenomenas due to the speed of movement over the dotted area.

In general, these phenomena add up and require a stronger luminous intensity from the patient. This is the major characteristic of these coagulated retinas. They need more light. All patients complain of this and the recording of their adaptation curve is always very diminished.

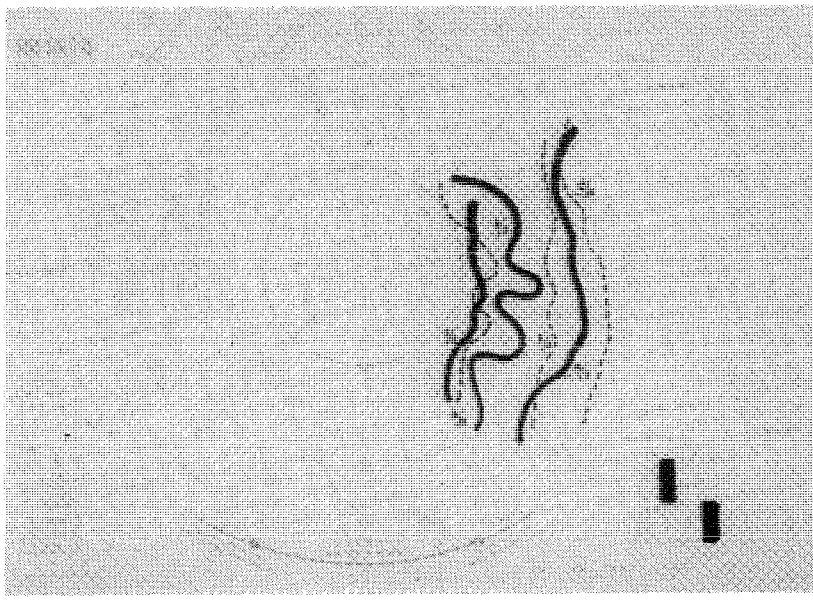

Fig 3 Results of perimetry with dotted slides interposed in the light-beam of the projector.

There remains a second variety of visual field deficiencies the vascicular deficiency, but we shall not consider these now.

In conclusion: it is necessary to be aware of the fact that photocoagulation is a technique that may be dangerous. Its consequences on the visual field extent must always be taken into consideration whenever it is decided to use it. So far, the described clinical deficiencies are well explained by theoretical physiological considerations.

SUMMARY

Photocoagulation destroys the sensorial elements of the retina and so realizes a true physiological experiment. The present study is performed with spaced peripheral coagulations and with panretinal photocoagulations. The site of the isopters is modified and the summation laws are perturbated. Summary of the principal deficiencies of the visual field occurring during photocoagulations.

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RESTITUTION OF THE RETINAL SENSITIVITY AFTER CURED RETINAL DETACHMENT

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Gaillard's monography (1962) is a thorough report on functional restitution of the retina after operations for detachment. His examinations – like other authors' works – deal with central visual acuity (Küper et al. 1966, Gundry et al. 1974), visual fields and dark adaptation (Menezo et al. 1975). The pupillomotor excitability profile (Alexandridis et al. 1975), the electroretinographic and the electrooculographic response of the re-attached retina (Karpe 1952, Rendahl 1957, Schmöger 1963, Alexandridis et al. 1975 a,b) have also been examined.

The present paper reports on the threshold values for light perception of circumscript retinal areas for different adaptation levels in patients, successfully operated for retinal detachment. The examinations were carried out by means of the Tübingen projection perimeter, using the method of static perimetry in a meridian containing an approximately equal area of healthy and of formerly detached retina. The two areas have been compared as to their change of sensitivity in dependence on the background illumination. The main aim of this examination was to establish whether both retinal photoreceptor systems recover within the same time after the operation.

In all cases the round white stimulus of 116′ was used for testing. The stimulus duration was 300 msec. Measurements were made first at dark adaptation and then with background illumination of 3×10^{-3} cd/m^2, and 3×10^{-1} cd/m^2.

The test meridian was always chosen perpendicular to the border-line between formerly detached and intact, never detached retina. 26 patients, between 15 and 69 years of age, in whom a retinal detachment had been successfully operated by the Schepens' method were examined. The choice was made according to the following criteria

The retinal detachment was of the idiopathic type, affecting approximately 2 quadrants, other changes that could have influenced the function were ruled out. One group (8 patients) was examined relatively early after the operation, i.e. 25 days on the average. A second group of patients (15 patients) were examined after an average of one year after the operation In both groups the retina had not been detached very long before the operation (3 to 14 days). A third group was formed by 3 patients with long standing detachments of more than two months.

RESULTS

Among the 8 patients of the first group one patient, 3 weeks after the operation, showed a normal perimetric profile outside the macular area under all background conditions. Another had a decrease of sensitivity under all background conditions in the area of a formerly detached retina, the loss with dark adaptation being 0.5 log unit more than with light adaptation. The other 6 patients showed a normal sensitivity profile of the formerly detached retina with light adaptation, but they had a significant loss of sensitivity with dark adaptation, up to 1.5 log units if compared to the sensitivity of the intact retina. Fig. 1 shows a typical example of this group. This difference in the post-operative behaviour of the 2 receptor systems is only transient in a large proportion of the successfully operated eyes, as shown by the results in the second group. Out of the 15 patients of this group, examined after an average of one year post-operatively, eleven did not show any loss of sensitivity outside the macular area at all adaptation levels (Fig. 2). One patient showed a decrease with all adaptation conditions and only three patients still had a disturbed profile at dark adaptation, whereas the sensitivity was normal at light adaptation. The loss of sensitivity in the scotopic profile was less than one log unit. Finally, all three patients of the third group, i.e. with detachments of long pre-operative standing, exhibited a considerable decrease of sensitivity of the re-attached retina at all adaptation levels (Fig. 3), confirming the results of our earlier examinations (Alexandridis et al. 1975).

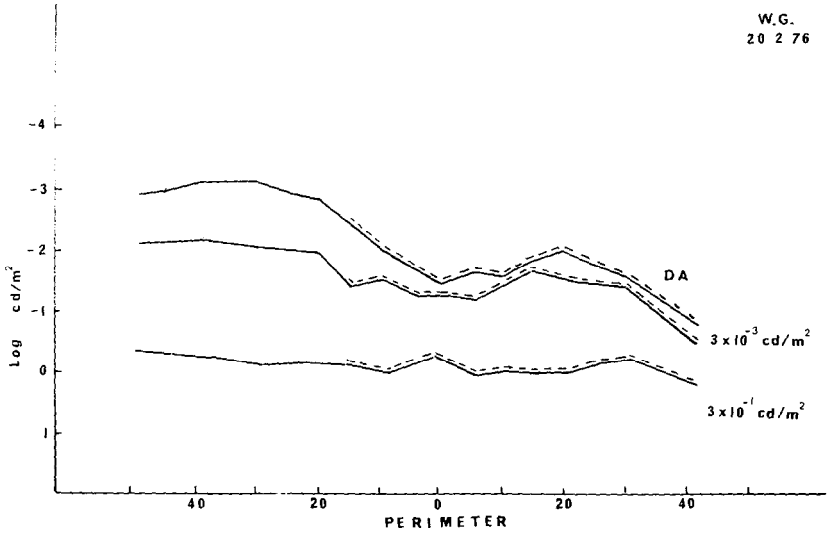

Fig. 1 Retinal sensitivity profiles at different adaptation levels, three weeks after successful detachment operation. Dashed line: formerly detached and post-operatively re-attached retina. Background illumination is indicated for each curve. Stimulus diameter 116', stimulus duration 0,3 sec. (1 patient)

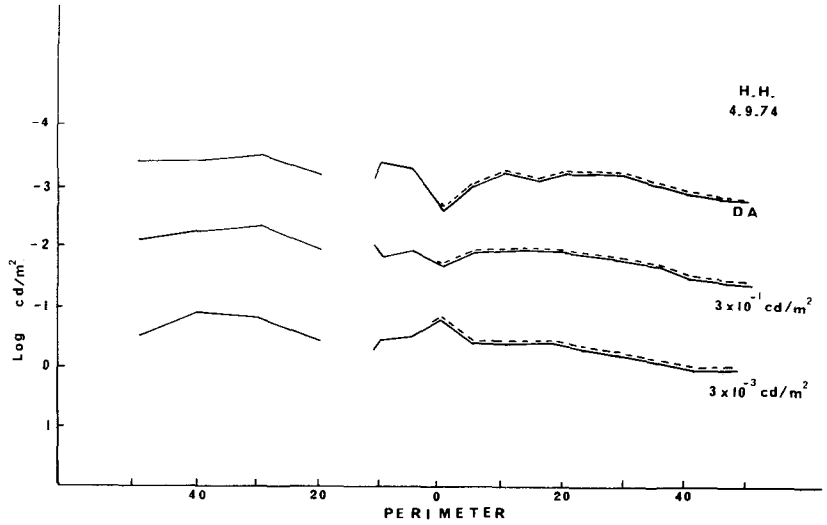

Fig. 2. Retinal sensitivity profiles at different adaptation levels, 1 year after successful detachment operation. Dashed line: formerly detached and post-operatively re-attached retina Background illumination is indicated for each curve Stimulus diameter 116′, stimulus duration 0,3 sec (1 patient)

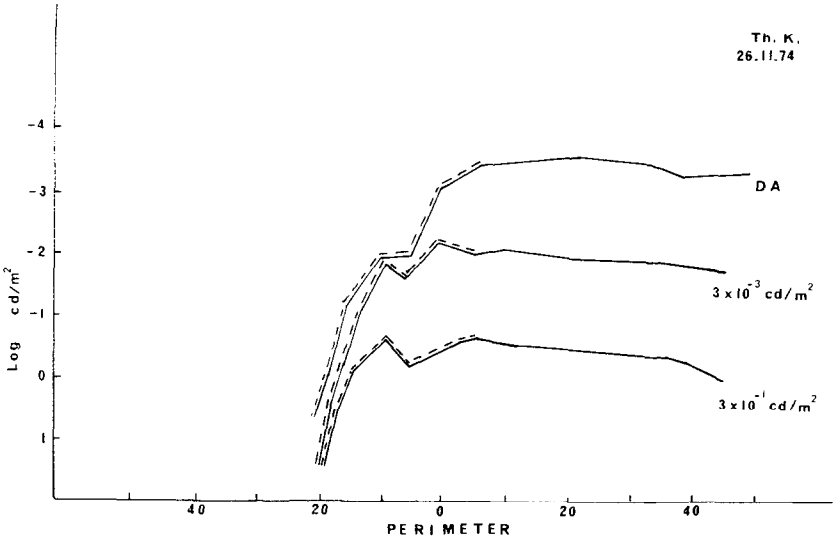

Fig 3. Retinal sensitivity profiles at different adaptation levels, 1 year after successful operation of long standing detachment. Dashes line: formerly detached and post-operatively re-attached retina. Background illumination is indicated for each curve Stimulus diameter 116′, stimulus duration 0,3 sec. (1 patient)

SUMMARY

It can be seen that after a successful detachment operation the functional recovery of the two receptor systems does not take place within the same time, the rods recovering slower. This is only true for retinas having been operated on shortly after the detachment. Long standing detachments result in irreversible degeneration, so that despite operative treatment the sensitivity of the retina is lost or forever considerably reduced.

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SUMMARY OF SESSION IV· VISUAL FIELD IN DISEASES OF THE FUNDUS AND OPTIC DISC TOXIC AMBLYOPIA

E. AULHORN

Corresponding to the very heterogeneous theme of this research group, the scientific objects of this session also differ greatly. They deal with four main subjects:

1. Perimetry during fundoscopic observation by means of television control

This new type is especially suited for the functional investigation in diseases of the retina and chorioidea, since with its help it is possible to examine the light-difference sensitivity at the point of damage very accurately. Using traditional perimetry it is common knowledge that, with small damaged areas, we can never be certain that these have really been registered perimetrically.

The first results given by the Japanese research group Eno, Abe and Isajama seem to be very encouraging. With this new nethod we can make a big step forward as regards the improvement of perimetric results in diseases of the fundus. The functional defect of a fundus lesion no longer has to be traced primarily by a perimetric approach – which often means 'seeking' – but by ophthalmoscopic view with an aimed, reproducible, and time-saving perimetry. A further important advantage of the new method is that information concerning the fixation point in the retina can be obtained during the perimetric examination. This is not only important for diagnostic but also for scientific reasons, for example in studies on amblyopia.

The discussion, mainly carried on by Harms, Goldmann and Aulhorn (Aulhorn reported on her own experience with fundus perimetry), showed that there are still many technical difficulties to be overcome using this new method, especially concerning the illumination of the fundus. Nevertheless fundus perimetry represents an important step forward for which the Japanese group must be congratulated.

Goldmann suggested that the problem could also be solved in another way. If one takes photographs of the fundus and uses the same projectorsystem as in perimetry one can make very exact marks on the photograph and compare this with the position on the perimetric chart With this two-step comparison there are no problems of illumination; however, the advantage of simultaneous registration as in television-perimetry is lost.

2. The second theme concerned *differential static perimetry using the mesopic-photopic ratio*, given in an interesting paper by Greve. Central visual field defects are either retinal or central nervous by origin. Greve stated that, if a defect has a greater intensity under mesopic than under photopic conditions, this indicates macular edema. He believes that the mesopic-photopic ratio can also help to differentiate chorioretinal and neural lesions. As to the location of the damage, future investigation must show whether or not the relation between the sensitivity curve under photopic and mesopic conditions does indeed give more information than traditional, purely photopic perimetry.

In the discussion, Friedmann also illustrated the usefulness of his analyser for central and paracentral defects. Greve said that it is preferable to use single stimulus static perimetry (degree by degree) in these cases and that he did not know how to measure a mesopic/photopic difference with the Visual Field Analyser. Most of the discussion time, however, was occupied by theoretical considerations by Weale and Greve about the mesopic-photopic ratio, and about the question as to how to determine the basic normal line of the mesopic examination, Greve determined this line experimentally according to the results from normal subjects and found remarkably little scatter.

3. The third theme concerned *toxic amblyopias*. Unfortunately, two papers on Ethambutol-neuritis and Chloroquin-retinopathy were cancelled. Only the paper by Aulhorn on the different types of central scotomas in tobacco-alcohol-amblyopia and in B12 avitaminosis was given. She reported several cases of tobacco-alcohol amblyopia, which at the same time had a vitamin B12 deficiency. In some cases the visual field defect could be improved by substitution of hydroxocobalamin. She discussed the question whether or not one could deduce the primary cause from the position and form of the scotomas (central scotomas or centrocoecal scotomas, respectively).

Marmion pointed out in the discussion that similar defects appear in cases of diabetes, which respond well to B12 substitution.

4. The fourth theme-group comprises *experimental follow-up studies in circumscribed diseases of the fundus*, for instance defects after retinal photocoagulation in diabetic retinopathy and visual field defects after retinal detachment. Zingirian and Dubois-Poulsen reported on their experience with perimetry after photocoagulative treatment of diabetic retinopathy. Alexandridis and Wedler talked about the retinal sensitivity after cured retinal detachment. From the results we can see that such follow-up studies are urgently required for obtaining clarity as to the location and the prognosis of retinal damage.

In the discussion Enoch and Aulhorn emphasized the difficulties of localising the perimetric process of examination exactly at the point of retinal damage. (Here, perimetry under 'television ophthalmoscopy' would be much more favourable!). Dannheim pointed out that the effect of coagulative treatment on the form of the scotoma thereby caused would depend

upon whether or not the coagulation lies near the optic disc of more peripherically, and whether or not the scar caused by coagulation affects the outer retinal layers only or also the inner layers.

At the end of the session Aulhorn made the point that the topics of this research group had until now included toxic amblyopia as well as the fundus and optic disc, and that according to the decision of the committee, the scope of this group was now to be limited to diseases of the fundus including the optic disc. For the sake of uniformity toxic amblyopia will later belong to the sphere of the research group 'Neuroophthalmology'.

VISUAL FIELD DEFECTS IN DISEASES OF THE FASCICULUS OPTICUS

H. HARMS

(Tübingen, W. Germany)

Where the optic nerve begins i.e. the optic disc, the distribution of nerve fibres results from their origin and course in the retina, where it ends, i.e. at the entry into the chiasma, a complete rearrangement has taken place, characterised by the displacement of the macular fibres into the middle and nasal part of the optic nerve and by the preparation of semi-decussation. This displacement over the 35-55 mm length of the optic nerve is not easy to survey. Consequently, we can expect that focusses of disease at the beginning and end of the optic nerve give rise to field defects, having a characteristic form and position. This is not necessarily true, however, of the middle part of the nerve.

type of visual field defect / diagnosis (nr)	I retinopapillary type	II central and cecocentral scotoma	III pericentral scotoma peripheral defects	IV optic chiasm type
nr	32	53	33	29
optic neuritis [multiple sclerosis]	—	[17]	[9]	2
toxic amblyopia	—	[9]	—	—
hereditary optic atrophy	—	[11]	—	—
ischemic optic neuropathy	[17]	—	1	—
drusen in the optic disc	4	1	4	—
lesion of the optic nerve	2	—	[8]	1
tumor of the median fossa cranii	3	—	3	[20]
other cause	6	3	3	3
uncertain	—	12	5	3

Table 1. Frequency of the types of visual field defects in the various diseases of the optic nerve.

We shall now try to answer the following questions with regard to optic nerve diseases:
1. To what extent is it possible to localise the causative process from the form of the visual field defect?
2. Can we reach any conclusion as to the type of optic nerve disease on the basis of the perimetry results?
From two series of records of our perimetry department, each consisting of 700 findings, we chose the ones where damage or disease of the optic nerve was thought to be present.

The 147 cases found were grouped as follows
1. Visual field defects of the retino-papillary type.
2. Central and cecocentral scotomas.

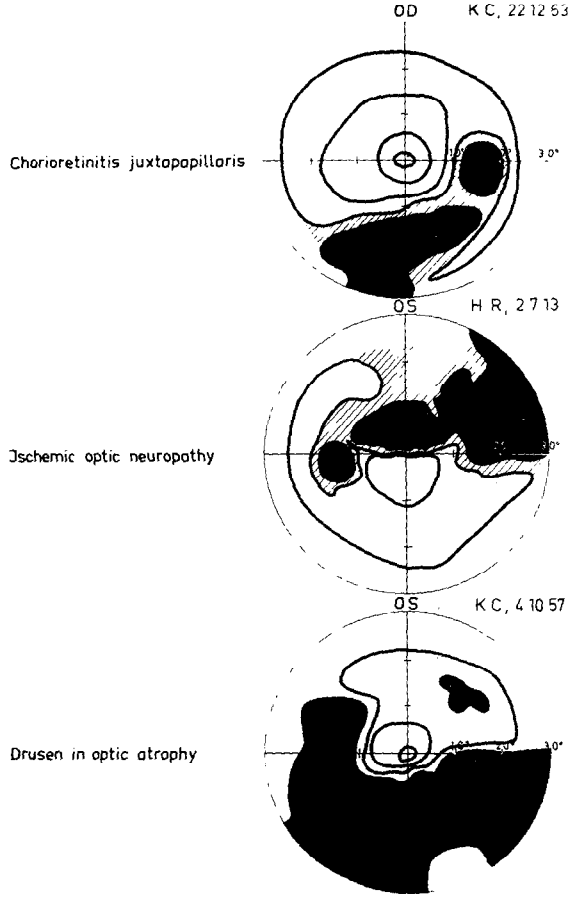

Fig. 1. Field defect type I: a) Chorioretinitis juxtapapillaris; b) Ischemic optic neuropathy; c) Drusen in optic atrophy.

3. Pericentral scotomas and peripheral defects.
4. Defects of the optic-chiasm type.

In the first group we expected to register processes at the beginning of the optic nerve, in the second and third group in the middle part, and in the fourth group at the end of the optic nerve.

Separation of group I and II was difficult. Cecocentral scotomas can have the typical form of the nerve fibre course in the retina, but more often they change into a central scotoma and vice versa. Therefore, we preferred to classify them in group II. In group IV we have included all defects affecting both eyes, which may have their origins in the area surrounding the optic chiasm, i.e. not only the typical disturbances of a bitemporal nature, but also binasal defects and homonymous hemianopsias. The classification into these four groups was sometimes doubtful, of course, and at the same time rather arbitrary, but this lies in the nature of such classifications.

In Table 1, the diagnoses are shown on the lefthand side. Some diseases have a high localisation value, as for example in the first group ischemic optic neuropathy, here, the primary process certainly occurs at the beginning of the optic nerve (Fig. 1). Accordingly, nearly all the cases are in the first column.

One would assume that the same would apply to the 'drusen' of the optic disc, but we find half of these cases in column 3 (Fig. 2). This can be explained by the fact that often only very thin nerve fibre bundles are destroyed in this alteration of the optic disc, so that small spot-like defects

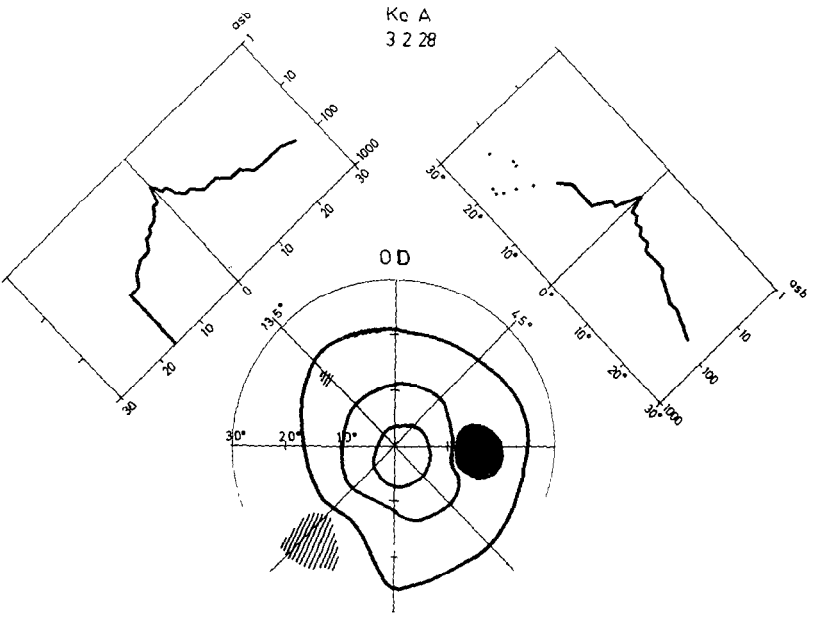

Fig 2. Field defects type III: Drusen in optic atrophy

must arise, as shown in column 3. The place in which the defects occurred can no longer be recognized by its form.

The tumours in the middle cranial fossa, however, have a much higher localisation value, and they are mainly found in column 4 (Fig. 3). Only at the very beginning of the disease can the visual field of only one eye be affected in the location of the chiasmal region. The localisation value of the other diseases of the optic nerve mentioned is much lower. As a result, the possibility of localising the causative process purely on the basis of the form and location of a defect in the visual field is indeed rather limited.

Nevertheless, can we reach any conclusion as to the type of optic nerve disease on the basis of perimetric results? From the distribution of the various diagnoses over the four columns, we can see that this must be possible to a certain degree. More than half of the cases in the second column include almost exclusively cases of retrobulbar neuritis (mainly in

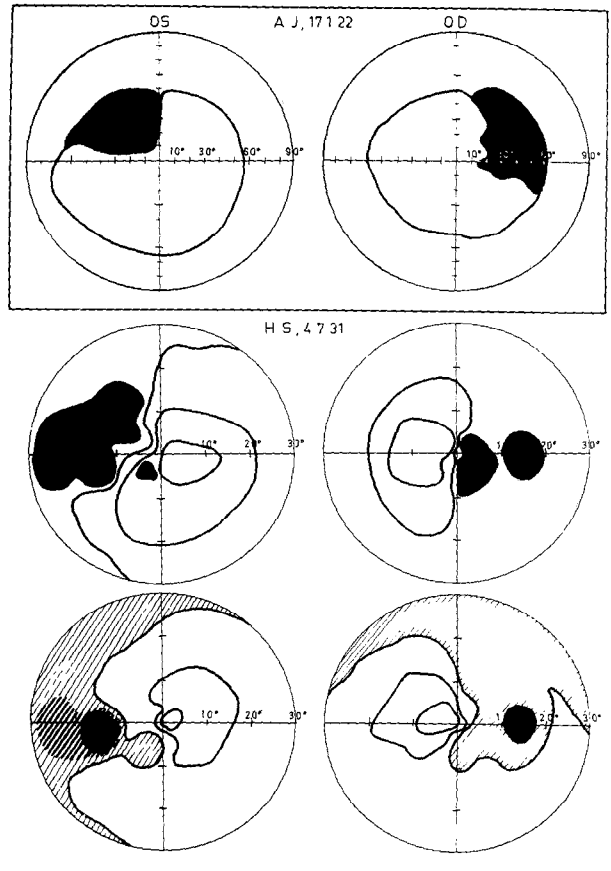

Fig 3 Field defects type IV: Bitemporal hemianopsia a) Meningioma tuberculi sellae; b) Hypothysis adenoma before and after operation.

multiple sclerosis), toxic neuropathy, and hereditary optic atrophy. The third column, however, shows a more mixed picture of diagnoses, whereas the fourth is totally governed by tumours of the middle cranial fossa.

The perimetric findings, however, give us even more distinctive features if we pay greater attention to the intensity of the disturbance to its location and its alteration in each case In this sense, Dr. Aulhorn just reported the field defects in toxic amblyopia (see this volume, p.). Moreover, most of the cases of retrobulbar neuritis in multiple sclerosis have a central visual field defect (Fig. 4). If the initial stage of neuritis is very severe, an almost complete loss of visual field can occur. The function of the optic nerve, however, is restored within a few days or weeks by a characteristic way of a central scotoma.

There are, however, also minor cases of retrobulbar neuritis in which only a slight 'depression' or flattening of the visual field profile can be seen

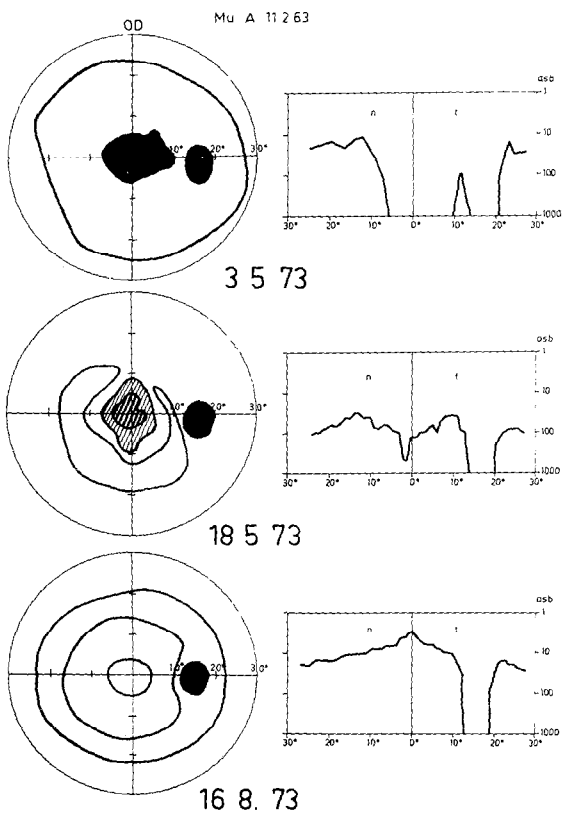

Fig 4 Field defect type II: Central scotoma (encephalitis acuta); Optic neuritis in regression

in the centre (Fig. 5). Finally, of course, the various places, corresponds with the nature of multiple sclerosis (Fig. 6). fact that successive circumscribed field defects are found in one and the same patient, sometimes central and sometimes paracentral in various places, corresponds with the nature of multiple sclerosis (fig. 6).

Dominant hereditary infantile optic atrophy deserves special mention (Fig. 7). This, in fact, is not so rare, if one pays special attention to it. It is characterized by a considerable reduction in visual acuity, by a small relative disturbance of the visual field, lying temporal next to the fixation point, and by a disturbance of colour vision, usually tritanopia. The optic disc shows only a slight temporal pallor. If profile perimetry is not carried out, the visual field defect can easily be overlooked. On the whole, it follows from this that typical clinical processes and typical patterns of disturbance are present in a number of diseases, which can lead us to the diagnosis.

Visual field disturbance represents only one of the clinical symptoms, and can only be of full value in connection with the other clinical symptoms. In Table 2 some of these have been grouped according to their frequency in the various forms of defect. We can pick out two symptoms only. It is striking that a narrowing of the arteries on the disc is mainly found in field defects of the retino-papillary type. This can only mean that this form of defect must have a mainly vascular genesis. Furthermore, the different behaviour of the various groups of defects is interesting as regards regression. As far as controls were made, characteristic differences arose in the various groups.

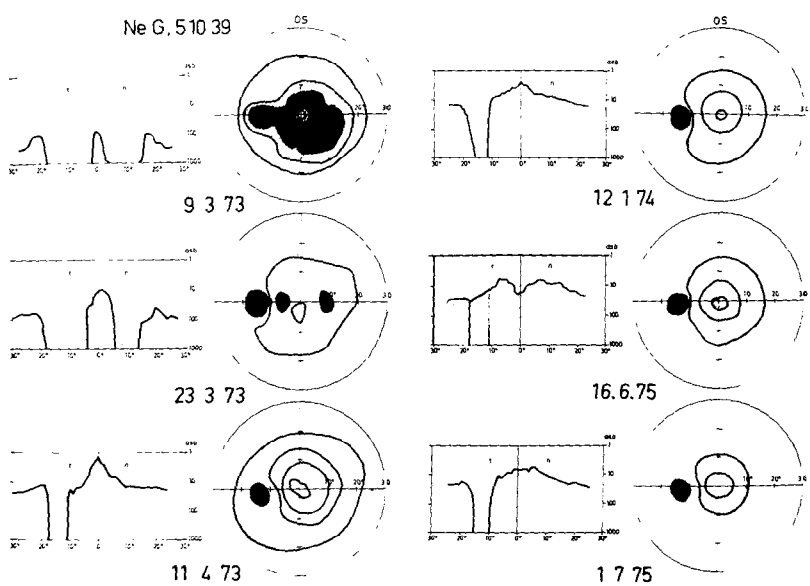

Fig. 5 Field defect type II/III: Paracentral and central scotoma in course of retrobulbar neuritis

In two-thirds of the cases of the retino-papillary type, the visual field did not improve, and in one-third they improved only partially.

In central and cecocentral scotomas, nearly half of the re-examined cases showed a complete regression and almost a quarter showed partial improvement. It should be noted that in more than half of the cases the paracentral and peripheral defects did not improve, but this can probably be attributed to traumatic optic damage, in which nerve fibre bundles that cannot regenerate themselves were destroyed. In the group of defects of the chiasm type, mainly caused by intracranial tumours, lack of regeneration and deterioration prevail.

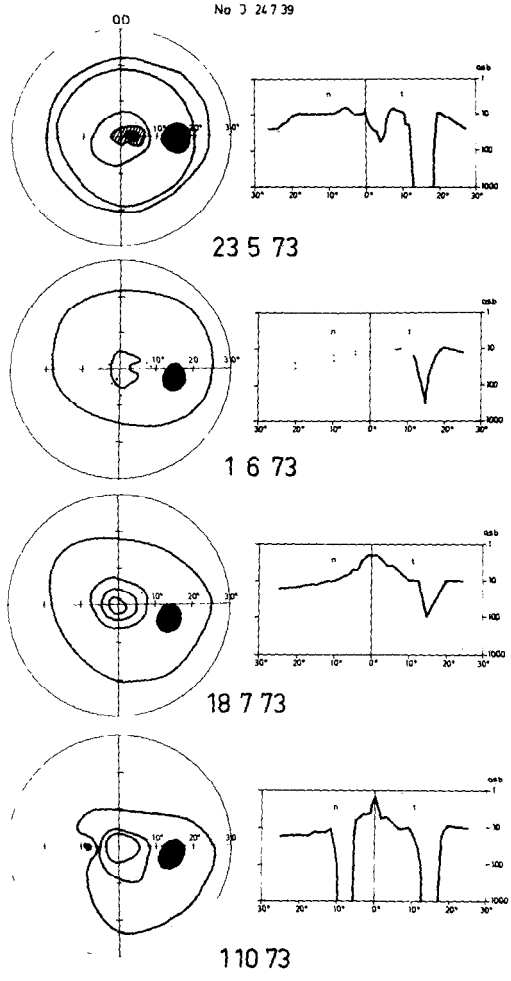

Fig. 6 Field defect type II/III: Retrobulbar neuritis; Change of position of scotoma in multiple sclerosis.

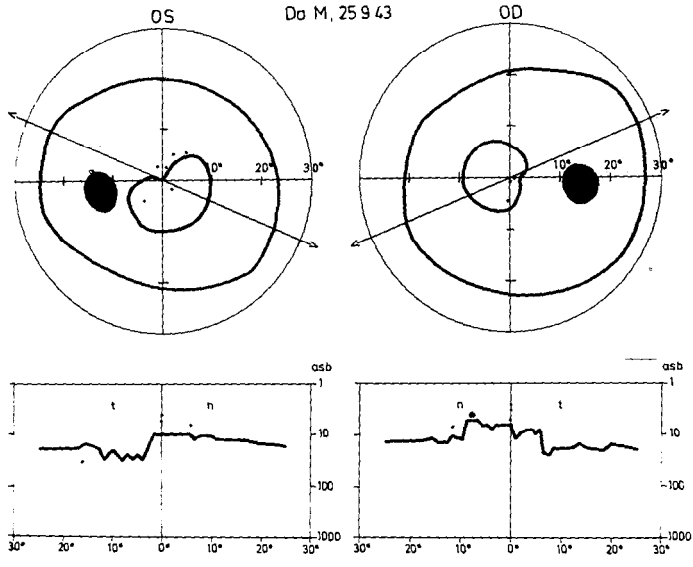

Fig. 7. Field defect type II: Dominant hereditary infantile optic atrophy.

type of field defect / other symptoms / nr		I 32	II 53	III 33	IV 29
optic disc	normal	3	16	8	6
	papilledema	[19]	11	7	4
	primary atrophy	4	[26]	[18]	[19]
	secondary atrophy	6	—	—	—
small arteries in optic disc		[18]	4	6	5
further evolution of visual field defects	complete regression	—	[13]	5	2
	partial regression	8	[7]	4	7
	no regression	[14]	9	[14]	[7]
	deterrioration	—	—	2	[7]
	no reexamination	10	24	8	6

Table 2. Frequency of pathological symptoms in the optic disc and regression of function in the various types of visual field defects

In summing up the above, we have to point out that the form and location, as well as the course of visual field defects – taking into consideration all other pathological symptoms of the case – enable us to recognize the disturbances of the optic nerve with a large degree of probability in many cases, but never with absolute certainty.

SUMMARY

This report deals with the correlations between the diseases of the optic nerve and some typical defects of visual function. Several examples of acute and chronic diseases are discussed in regard to the morphologic changes, the early visual field defects and the further development of functional defects. It is tried to correlate them to the site of the lesions and their etiology.

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DIFFERENCES IN THE PROCESSING OF PERIPHERAL STIMULI

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Experimental studies of peripheral vision have revealed a number of basic differences which may be important for clinical perimetry.

CORRECTION OF PERIPHERAL REFRACTIVE ERROR

It is well known that the periphery exhibits large and variable refractive errors. The importance of correcting such errors for absolute threshold determinations has previously been demonstrated by Fankhauser & Enoch (1962). Uncorrected peripheral refractive errors can also affect motion detection. Motion thresholds for a one second exposure increase systematically with eccentricity. However, with correction of refractive error, motion thresholds are reduced by approximately 50%. Furthermore, the intersubject variability is also reduced. Whereas the data without correction show marked intersubject veriability, those obtained with correction can be described by a single curve. It is concluded that for a one second exposure duration at a moderate photopic luminance level, peripheral motion detection is ordinarily limited by refractive rather than by retinal factors. (Leibowitz, Johnson & Isabelle, 1972).

The effect of peripheral refractive error correction on resolution for a sine wave grating test-object was determined using some of the same subjects who had participated in the motion experiment. No differences between thresholds obtained with or without refractive error correction were observed. A similar study utilising different refractive techniques and a Landolt C test-object was carried out at the University of Montreal with the same results; peripheral error correction did not influence resolution. Since the refraction as well as the testing procedures in the two studies were different, it was decided to test some of the same subjects from the first experiment in Montreal using the methods and procedure of the second study. The data were in agreement with the previous investigation. The peripheral refractive errors normally present in these observers have no influence on resolution either for a sine wave grating or for a Landolt C test object even though for some of the observers, the same correction improved their ability to detect motion in peripherally presented stimuli. For a detailed description see Millodot, Johnson, Lamont & Leibowitz, 1975.

These experiments demonstrate that unlike the foveal region where re-

fractive errors influence both motion detection and resolution, reduction of blur in the periphery differentially improves motion perception but not resolution.

IDENTIFICATION VERSUS LOCALISATION OF PERIPHERAL STIMULI

A number of studies have suggested that individuals with cortical brain damage may nevertheless be able to localise stimuli within their scotomatous regions. This phenomenon, sometimes referred to as 'blindsight', is thought to depend on intact subcortical structures (Weiszkranz et al., 1974). Such data are in agreement with the concept that different neurological mechanisms are responsible for the localisation of visual stimuli as opposed to identification and form perception (Held, 1970).

As is generally true in psychophysical studies with human observers, there is always a question regarding the criterion of response used by the subjects. It is well known that if subjects are 'eager' to report the presence of a stimulus, that their measured sensitivity will be higher in comparision with a subject who is cautious or 'reluctant' to respond. Thus, the reported threshold in the first case will be lower, while in the second case it will be higher. To avoid the difficulties inherent in the problem raised by the subjective criterion, psychophysical procedures are available which produce a threshold measurement independent of the subject's willingness or reluctance to respond.

We have devised a procedure using criterion free methods in which the percentage of correct responses for two stimuli with identical physical characteristics is determined for different tasks. In the first case, the subject is simply asked to report whether or not a peripheral light was flashed. This is referred to as the identification task. In the second case, the subject is told that one of two lights has been presented in either the upper or lower visual field and that even if it was not visible, to indicate by an upward or downward eye movement the location where the light most probably appeared. This is referred to as the localisation task. In the identification task, the effect of criterion is eliminated by means of signal detection procedures. For localisation, the method of forced choice eliminates any effects resulting from the subject's criterion or willingness to respond.

We have tested twenty normal subjects using this procedure. The results indicate that the method can be applied to inexperienced observers with high reliability. The percentage of correct responses for the identification task (referred to as d' in signal detection methodology) is consistently slightly lower than for forced choice localisation. Of greater interest are the data from two subjects with homonymous hemianopia. Both were approximately twenty years of age. One had suffered a brain injury as a young child while the other had received a penetrating brain wound several years prior to testing. For both subjects, thresholds were determined in the non-scotomatous half field using both the identification and localisation procedures. The results were similar to those obtained with the non-brain damaged observers. When tested in the scotomatous area however, the percentage of correct

responses for the identification task fell to the chance level while the percentage correct for localisation was essentially the same as in the non-scotomatous region. Even though both subjects insisted that they could not see the stimuli, they nevertheless where able to localise them accurately. The principal difficulty with this procedure was that the hemianopes continually questioned the value of an experiment in which they were asked to localise stimuli which were not visible!

The results confirm, with criterion free methodologies, the data from previous studies which suggest a selective loss for idenfication as opposed to localisation. They support the theoretical position that different processing mechanisms are involved in reacting to peripherally presented stimuli depending upon whether the task is that of identification or of localisation.

DISCUSSION

Both of these studies, designed in the context of a general interest in peripheral vision, suggest some fundamental differences in peripheral function with respect to both refractive error and to testing methodology. The significance of these data for clinical perimetry remains to be determined. We are hopeful that the analytic methods inherent in clinical procedures will be helpful in the explanation of these results, and that the continued cooperation between basic vision researchers and clinical perimetrists will prove to be mutually beneficial.

SUMMARY

Uncorrected peripheral refractive error has been demonstrated to degrade increment thresholds and motion detection. However, for the same observers whose peripheral motion thresholds are improved by peripheral error correction, there is no change in visual acuity for a sinusoidal grating or a Landolt C between 20 and 60 degrees of eccentricity. Evidence for different processing also derives from the observation that the localization of stimuli presented at 4.2 degrees eccentrically is indepent of stimulus energy, while the detection of the same stimuli follows the classical psychophysical function in relation to either time or intensity of stimulation. Different processing modes are also suggested by the observation that patients with cortical brain damage who are unable to report the presence of stimuli verbally in scotomatous areas, are nevertheless able to localize the same stimuli when tested by means of a non-verbal forced choice response measure. Such data may be interpretable in terms of differences in optic tract fibers and/or the locus of central representation.

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SOME AETIOLOGICAL ASPECTS OF THE HOMONYMOUS HEMIANOPTIC SCOTOMA

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INTRODUCTION

In the field of ophthalmology, the examination of the visual field plays an important role in the analysis of the causing factors of intracranial disorders.

In the last 6 years, I have seen 10 cases of homonymous hemianoptic scotoma which were associated with various clinical symptoms. The cases were examined at Tokyo Medical College Hospital from 1969 to 1975. The visual fields were examined by Goldmann and Tübinger perimeters. Occasionally, Amsler chart and U-O test were used for a further detection of minor alterations of the central visual field. Also, Friedmann's Visual Field Analyser has been utilized as an additional tool of the examination since 1973.

CASE REPORTS

The data of the 10 patients are shown in Table 1.

Case 1: A 64 year-old man, who had an accident while he was driving a car and suffered forehead and thorax injuries. After the accident, he was admitted to a hospital and he visited our clinic about 1 month later.

He had a left homonymous upper quadrantanoptic scotoma (Figure 1).

Case No.	Age/sex	Homonymous Quadrantanoptic Scotoma		Homonymous Hemianoptic Scotoma	Congruity	Neurological Diagnosis
		Upper 1/4	Lower 1/4			
1	64/m	+			+++	Suspected occlusion of the Calcarin artery
2	38/m	+			+	Multiple Sclerosis
3	23/m		+		++	Arteriovenous malformation
4	22/m		+		+	no filling of M.C.Artery (following C.A.G.)
5	46/f		+		+	Meningioma
6	45/f		+		+	Meningioma
7	26/f		+		+	unknown
8	51/m			+	+++	no filling of parietal branch of M.C.Artery
9	63/m			+	+++	Intracerebral hemorrhage
10	49/m			+	++	Subarachnoidal hemorrhage

Table 1 Data for 10 patients with homonymous hemianoptic scotoma.

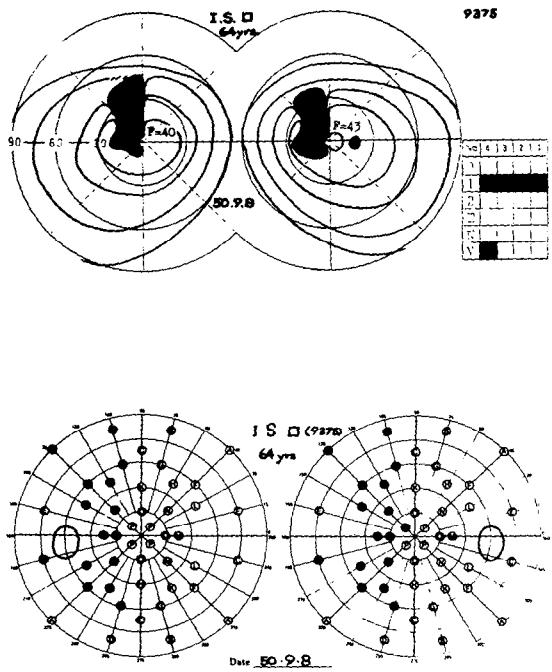

Fig. 1. Homonymous upper quadrantanoptic scotoma with macular sparing. Kinetic Goldmann fields (upper) and F.V.F.A. (lower).

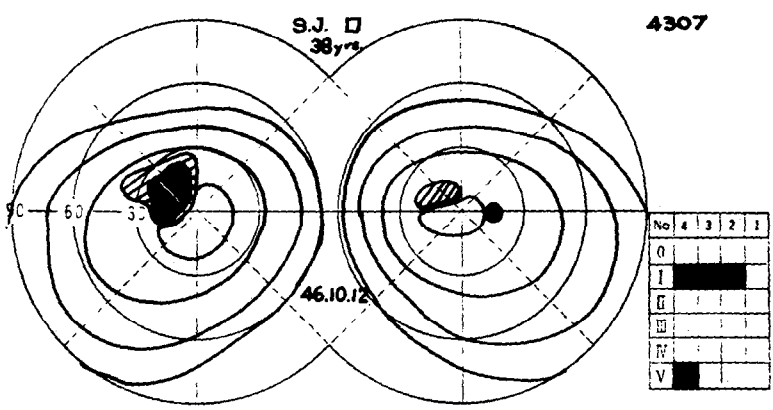

Fig 2. Homonymous upper quadrantanoptic scotoma, caused by multiple sclerosis.

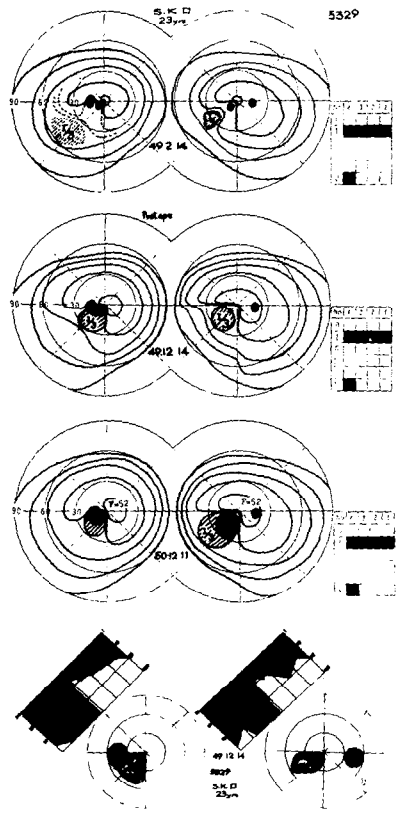

Fig. 3. Kinetic Goldmann fields (upper), static and kinetic Tübinger central fields (lower) in case 3. The upper part of this figure shows the preoperative visual fields, and the lower part shows the postoperative visual fields.

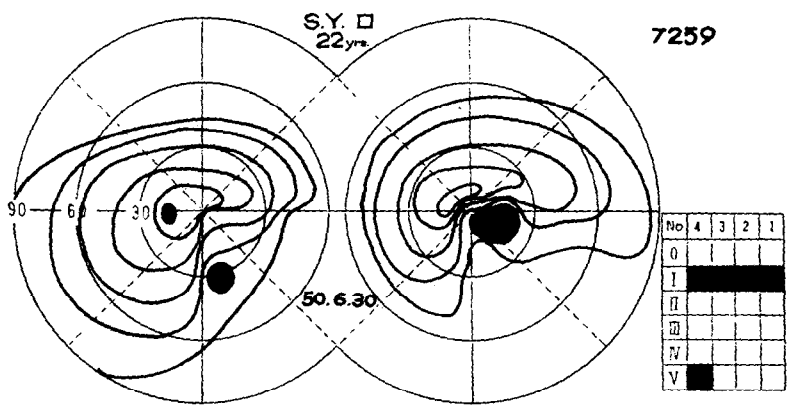

Fig 4. Homonymous lower quadrantanoptic scotoma following carotid angiography

The other ophthalmic and neurological examinations did not show any significant abnormalities.

From the shape of the visual field, the causing factor of the visual field change in this case may be attributed to a tentative occlusion of the branch of the posterior cerebral artery.

Case 2: A 38 year-old man, who had been suffering from a hemiplegia since 1970. Neurological diagnosis was multiple sclerosis. He had a left homonymous upper quadrantanoptic scotoma (Figure 2).

The other ophthalmological examinations did not show any significant abnormalities.

Case 3. A 23 year-old man, who had suffered from an attack of severe headache and vomiting. The next day he complained of a visual field defect. Ophthalmoscopy revealed normal discs. I.O.P. and visual acuity were also normal. Perimetry showed a complete left homonymous lower quadrantanoptic scotoma (Figure 3, upper).

Arteriovenous malformation was detected by the carotid angiography on the right side. After surgery his visual field became symmetrical thereby increasing the congruity (Figure 3, lower).

Case 4: A 22 year-old man, who had a fracture of the parietal region of the skull due to a car accident. Left carotid angiography showed an epidural

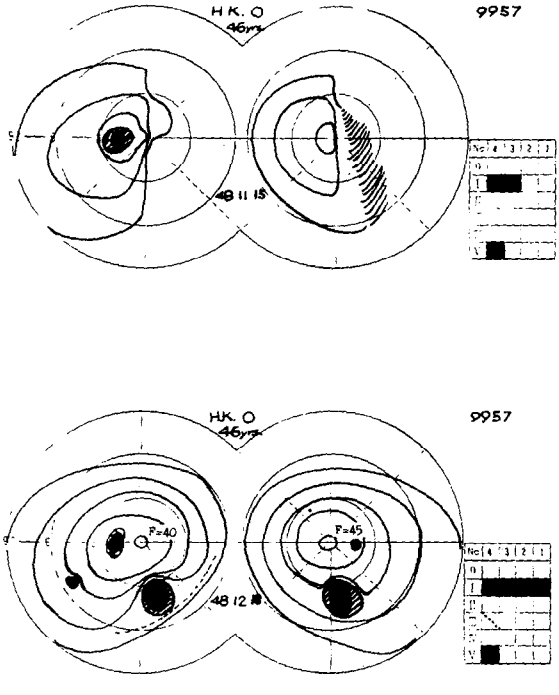

Fig 3. Kinetic Goldmann fields in case 5. The upper part shows the preoperative visual fields, and the lower part shows the postoperative visual fields.

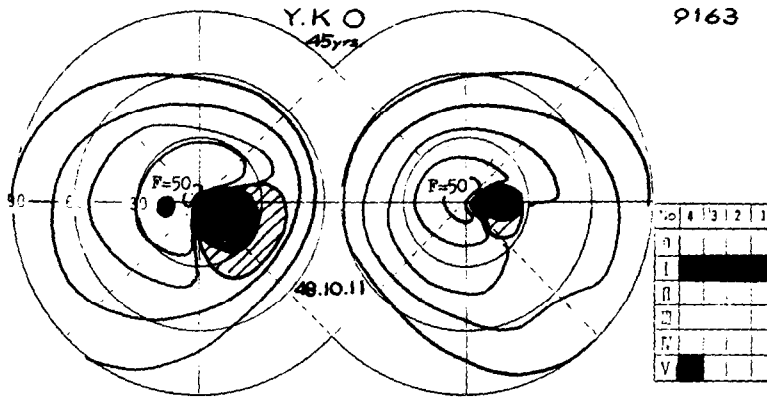

Fig 6. Kinetic Goldmann fields of case 6.

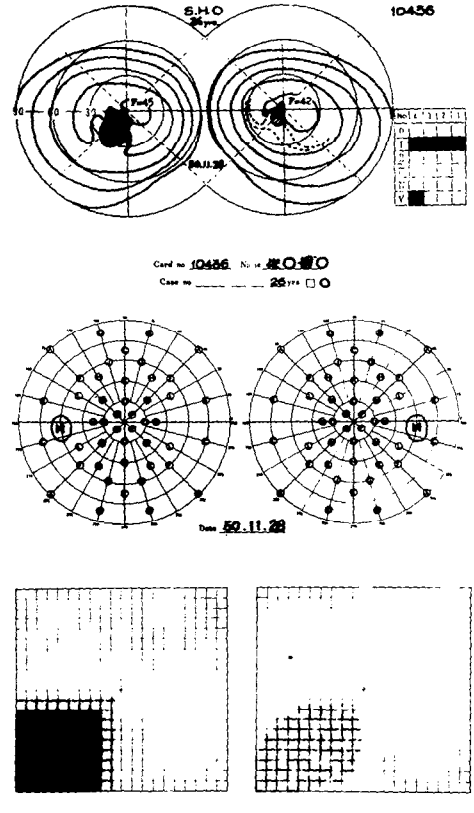

Fig 7 Kinetic Goldmann fields (upper), F V F.A. (middle) and Amsler chart central field (lower) of case 7.

hemorrhage. During the examination, a spasm of the left middle cerebral artery was observed. After the angiography a right hemiparalysis developed. The epidural hemorrhage was immediately removed by surgery and passage of the middle cerebral artery was restored. The hemiparalysis and motor aphasia remained. Two years after the accident, perimetry was possible. The result of this perimetric examination is shown here (Figure 4).

Quadrantanoptic depression was found at each isopter. The lesion may be attributable to an ischemic change of a spasm of the middle cerebral artery. The most damaged area of the lesion remained as a scotoma.

Case 5 A 46 year-old woman had been suffering from episodes of headache and numbness of the right lower extremity for the last year prior to admission.

Ophthalmoscopy revealed papilloedema. The perimetric examination showed right homonymous hemianopsia and an enlargement of the blind spot (Figure 5, upper).

Left carotid angiography and scintillation scanning were done and a tumor was found in the occipital lobe. The tumor was removed, and it was diagnosed as an menigioma. During the operation, the tumor was noticed to be nearly as large as a child's fist and originating from the cerebral falx.

After the operation, her visual field changed to a right homonymous lower quadrantanoptic scotoma (Figure 5, lower).

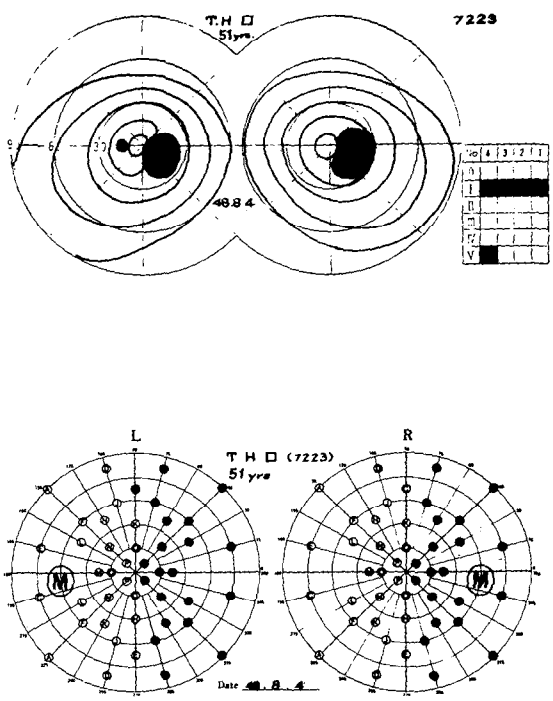

Fig 8 Kinetic Goldmann fields (upper) and F.V F.A central fields (lower) of case 8.

Case 6: A 45 year-old woman, who was examined at the neurosurgical department because of a sudden onset of severe headache and semicomatous condition. Her condition recovered 4 days after the admission, but Gerstmann's syndrome had developed.

Perimetry revealed a right homonymous lower quadrantanoptic scotoma (Figure 6).

Neurological examination revealed a tumor in the occipito temporal region. An operation was performed. The tumor was a meningioma arising from the left sided tent (which is adjacent to the lateral sinus), complicated by hemorrhage.

Case 7: A 25 year-old woman. At the age of 18 she had an exophthalmic goiter, which was cured after three years of treatment. Because of blurred vision she was admitted to our clinic. A left homonymous lower quadrantanoptic scotoma was found (Figure 7). The visual acuity was 1.0 for both eyes. Other ophthalmic and neurological examination did not reveal any other abnormalities.

After three month without treatment the visual field returned to normal.

Case 8: A 51 year-old man was hospitalized because of a right sided hemiplegia and homonymous hemianopsia which were discovered 5 months previously. On admission a homonymous hemianoptic paracentral scotoma was observed (Figure 8). His visual acuity was 0.7 for both eyes after correction. Macular degeneration was oberserved in each eye.

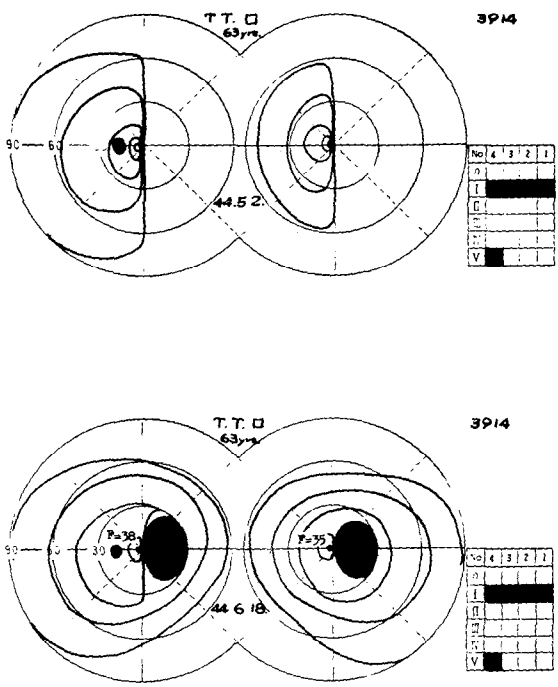

Fig. 9 Visual fields of case 9

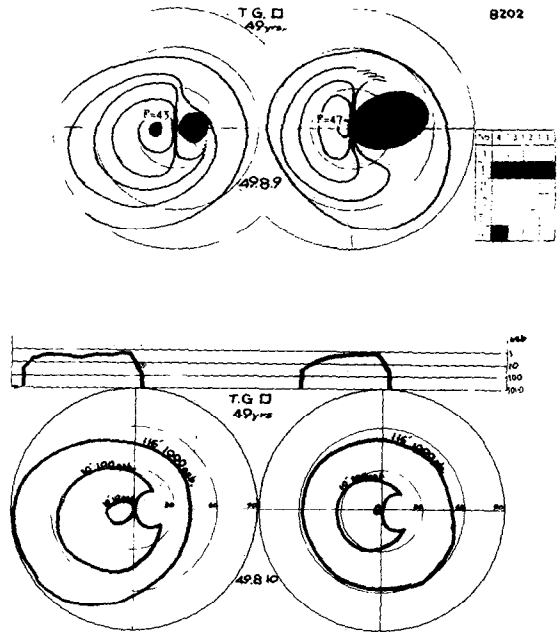

Fig. 10. Kinetic Goldmann fields (upper), static and kinetic Tübinger central fields (lower) of case 10.

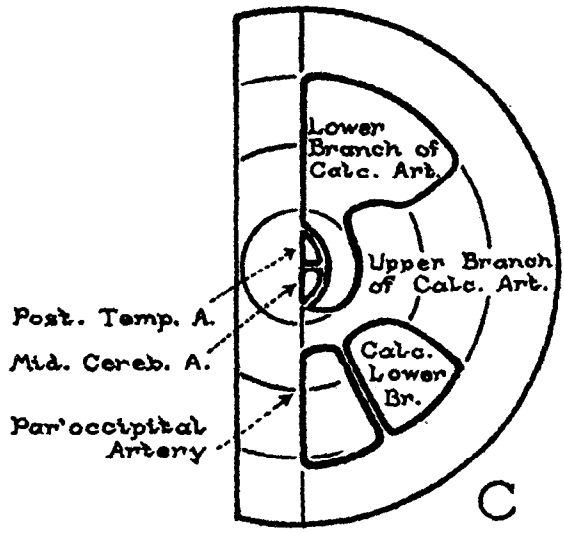

Fig. 11. Blood supply of the occipital cortex and corresponding visual field areas. Redrawn from Smith & Richardson (1966).

Left carotid angiography demonstrated an occlusion of the parietal branch of the middle cerebral artery

Case 9 A 63 year-old man was admitted to our clinic because of a visual field defect. Perimetry revealed a right homonymous hemianopsia (Figure 9 upper). After six weeks the visual field improved to a homonymous hemianoptic paracentral scotoma (Figure 9, lower)

The neurological diagnosis was a left sided intracerebral hemorrhage in the occipital lobe. No operation was performed.

Case 10 : A 49 year-old man. In a car accident, one month prior to admission, he received a blow on the occipito-parietal region. Subarachnoid hemorrhage was found and it was treated.

On admission a right homonymous hemianoptic paracentral scotoma was noted (Figure 10), and a right sided paralysis of the oculomotor nerve was present. Neurological examination did not show any significant abnormalities.

DISCUSSION

The cases reported illustrate the homonymous hemianoptic scotoma. It is well known that such a visual field change is caused by damage to the occipital pole. In our cases, the causes of the scotoma were presumably located in the posterior region of the post-chiasmal pathway or striate cortex in the occipital lobe. Therefore, the scotomata in both eyes were noted as congruous in our cases.

Harrington (1971) and other authors reported that congruous homonymous hemianopsia is most frequently seen in lesions of the striate cortex in the occipital lobe. The more posteriorly the lesion is located in the optic pathway, the more symmetrical the visual field defects of both eyes become. Kajiyama (1974) reported that vascural lesions cause more congruous visual field defects than tumors.

Data from our 10 patients are summarized in Table 1. Cases 1, 8 and 9

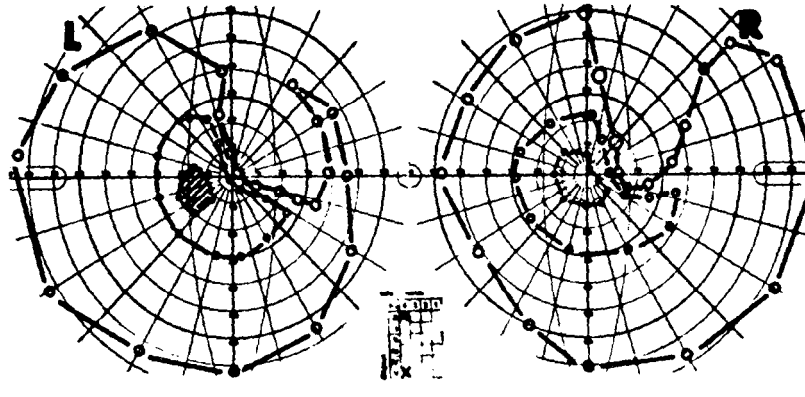

Fig. 12 A visual field defect following vertebral angiography. Redrawn from Bynke & Stigmar (1966)

showed complete congruous scotoma. These cases had vascural lesions. In the vascural lesion group, case 3 and 10 also showed marked congruity. In case 3, the congruity increased after the operation (probably due to a removal of the ischemia in the surrounding tissue following the operation).

In the vascural lesion group only case 4 showed poor symmetry, but this case had an extensive lesion with occlusion of the middle cerebral artery in the postchiasmal pathway. The remaining 4 cases showed poor symmetry; of these cases, case 5 and 6 had a meningioma whereby the tumor may have played a direct role in the alteration of the visual field, but the poor symmetry of the visual field defects was caused by the indirect influence of brain oedema.

In an anatomical study of 32 human brains Smith & Richardson (1966) analysed the correlation between the visual field and the vascular distribution of the visual cortex. A simplified schema of their findings is shown in Figure 11. The scotoma shown in the first case resembled the shape of the scotoma which occurs after a disturbance of the lower branch of the calcarin artery. Bynke & Stigmar (1966) reported on the occurrence of a homonymous hemianopsia following cerebral angiography. Their visual field defect following vertebral angiography is shown in Figure 12. This defect also resembles a scotoma due to occlusion of the lower branch of the calcarin artery.

Only case 1 revealed an obvious macular sparing. This macular sparing may be caused by the lower branch of the calcarin artery, which does not distribute to the macula area in the cortex.

SUMMARY

10 cases with homonymous hemianoptic scotoma caused by various lesions of the brain are reported. There are 2 cases of homonymous upper quadrantanoptic scotoma, 5 cases of homonymous lower quadrantanoptic scotoma and 3 cases homonymous paracentral hemianoptic scotoma

The lesions of the brain of our 10 cases were located in the occipital lobe.

In our cases, most of the scotomata in both eyes showed good symmetry. 3 cases, showing completely congruous scotoma, were caused by a vascural lesion. Two cases, which were caused by a tumor, showed poor congruity.

Only one case revealed an obvious macular sparing. This macular sparing may have been caused by the calcarin artery, which does not supply the macular area in the visual cortex.

ACKNOWLEDGEMENT

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ON ATYPICAL CHIASMAL VISUAL FIELD DEFECTS

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(Amsterdam)

The visual field defects caused by processes in the chiasmal area are typically bitemporal defects. The most frequently seen tumour in this area is the chromophobe adenoma of the pituitary gland, the defect which is caused by this tumour begins in the supero-temporal area as a sort of centripetal wedge. Other tumours, in order of incidence, are craniopharyngiomata and meningiomata.

This article describes the results of visual field examination in 37 patients with a chromophobe adenoma and 9 patients with a meningioma in the chiasmal area (one patient had both an adenoma and a meningioma). Attention is drawn to the frequent occurrence – at least in our cases – of atypical, i.e. not obviously bitemporal, visual field defects, even with carefully performed perimetry. In particular, the number of cases in which a central defect is present, with or without other defects, is larger than we had expected. These are the cases which are often not recognized and may for years be treated as neuritis.

In the standard works of Traquair, Dubois–Poulsen and Harrington homonymous defects (see also François & Verriest, 1953, Verriest, 1975, and Klingler, 1950) and paracentral defects with a bitemporal character are described. Sometimes the bitemporal character is only apparent in one half of the visual field. Solitary central defects are rare in the literature (varying from 0–11%, average ± 3%: Schlezinger, 1976, de Schweinitz, 1923, Henderson, 1939, Hirsch & Hamlin, 1954, Wendland, 1955, Lyle & Clover, 1961, Davidoff & Feirhing, 1948, Nurnberger & Korey, 1953, Bakay, 1950, Asbury, 1965).

PATIENTS

The patients came from our own department or from the neurological or neuro-surgical departments. They do not give a complete picture of all the cases of chromophobe adenoma and nemingioma in the chiasmal area which are under treatment in our hospital. Visual field examination was not performed on an unknown, but small, number of patients because the visual acuity was too poor or the patient was too ill or the examination had already been performed elsewhere.

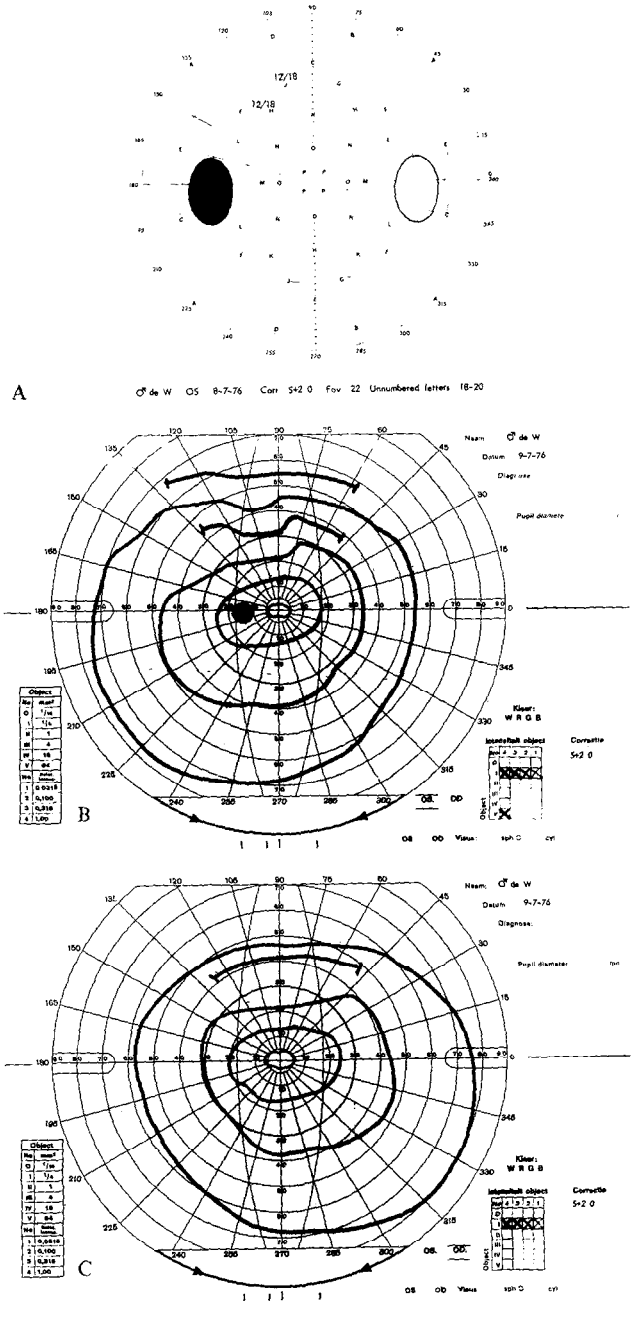
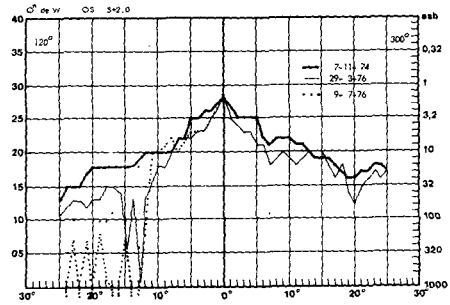


Fig. 1. An example of a typical bitemporal defect due to a chromophobe adenoma, with a follow-up of 3 years The results of the visual field analyzer and Goldmann Perimeter show hardly any defect; there is only a slight supero-temporal depression in



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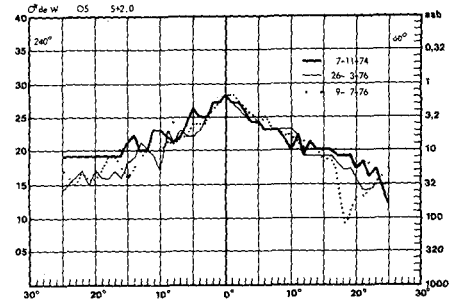

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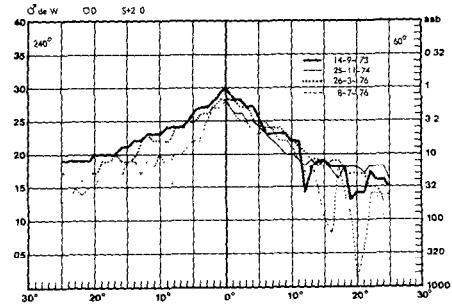

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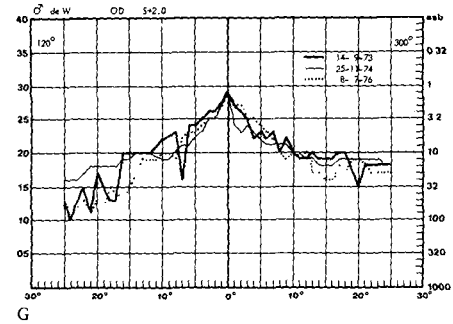


G

the left eye The 60° meridian of the right eye and the 120° meridian of the left eye beautifully demonstrated the early bitemporal defects and their progression

Examination procedure

The examination consisted of M.S.S.P. with the Visual Field Analyzer (VFA), kinetic perimetry with the G.P. or T.P., and S.S.S.P. with the T.P.*. Where early defects were suspected S.S.S.P. was always performed in the 75° and 105° meridians and circular S.S.S.P. in the 15° parallel.

In Fig. 1 an example is given of the first examination and the progression of a typical early bitemporal defect. One observes that the defect is first found by S.S.S.P. in the meridians to the left and right of the vertical meridian, at a stage where kinetic perimetry reveals no defect.

RESULTS

The results of the visual field examination are given in Tables 1 and 2.

In 10 of the 27 patients with chromophobe adenoma atypical defects were found (27%). It is remarkable that unilateral central defects were found in 3 cases.

As was to be expected, the number of atypical defects is larger in the meningioma cases; an atypical defect was found in 5 of the 9 cases (55%).

We shall illustrate our findings by means of 4 case reports

Table 1 Types of visual field defects in 33 patients with a chromophobe adenoma

TYPICAL defects	2 no defects
	6 early bitemporal defects
	4 bitemporal quadrant-anopias
	11 bitemporal hemianopsias
	4 bitemporal mixed defects
10 ATYPICAL defects	3 unilateral central defects
	2 unilateral blind
	2 bitemporal paracentral
	1 bandshaped defect
	2 homonymous hemianopsias

Table 2 Types of visual field defects in 9 patients with a meningioma

TYPICAL defects	5 bitemporal defects
4 ATYPICAL defects	1 bilateral central defect
	1 unilateral central defect
	1 blind in one eye/other eye centrocoecal
	1 temporal-central/other eye horizontal-temporal

* M.S.S.P. = multiple stimulus static perimetry
S.S.S.P. = single stimulus static perimetry
T.P. = Tübinger perimeter
G.P. = Goldmann perimeter

Case reports

Case 1 A woman of 59 years had a reduced visual acuity since 4 months. The first diagnosis was retrobulbar neuritis. Later an enlarged sella was found on X-ray examination. She was operated on 20-05-1975 and a chromophobe adenoma was found. Perimetry of the right eye shows a slight reduction of sensitivity in the 60° meridian. In the left eye a central defect was found without typical aspects. Both visual fields returned to normal (Fig. 2).

Case 2. A woman of 40 years had a reduced visual acuity since 3 months. There was also absence of olfactory sense. She complained of headaches and vomiting. Her character had changed. After computer tomography a large meningioma of the olfactory nerve was found. She was operated on 17-12-1975.

Perimetry shows bilateral central defects: a large absolute defect in the left eye (S.P.) and a small central defect in the right eye (G.P., VFA) (Fig. 3).

Case 3 A man of 49 years suffered from decreased libido and blurred vision since 1½ year. The first diagnosis was retrobulbar neuritis. On later X-ray examination an enlarged sella was found. He was operated on 14-10-1974 and a chromophobe adenoma was found. Perimetry showed an atypical central defect in the right eye and a paracentral temporal defect in the left eye (Fig. 4). On earlier examinations the temporal defect of the left eye had been misinterpreted after a dubious examination. The visual field of the left eye returned to normal after operation.

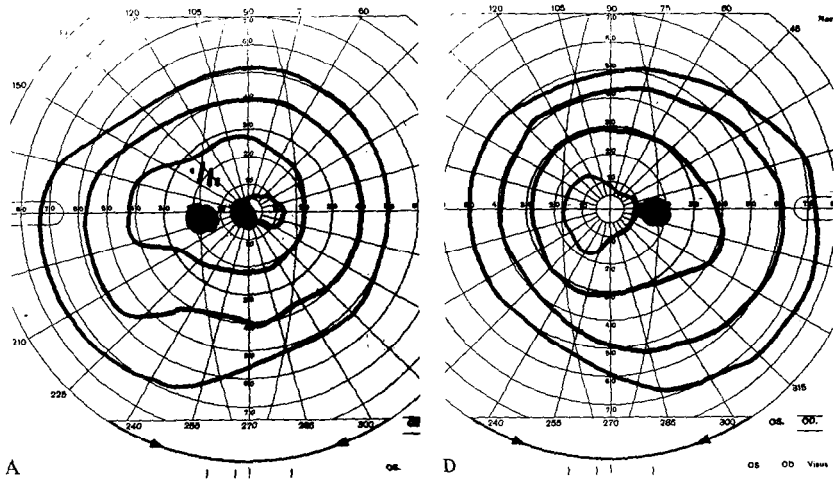
Case 4 A man of 36 years complained of blurred vision and later of decreased libido. The first diagnosis was retrobulbar neuritis. After extensive X-ray examination a pathological sella was found He was operated on 17-01-1975 and a chromophobe adenoma was found.

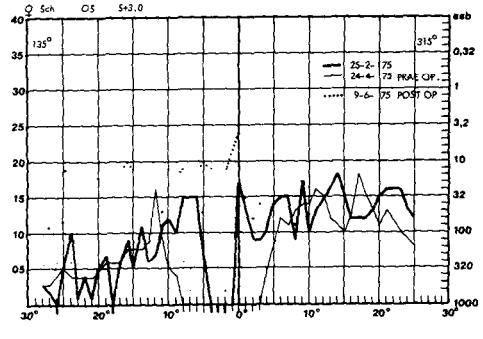
Perimetry shortly before the operation showed bilateral paracentral defects (G.P.). On earlier examination these defects were much smaller and their bitemporal character was almost missed (VFA).

Both visual fields returned to normal after operation (Fig. 5).

First symptom

All the patients with atypical defects first sought medical advice on account of visual complaints. In 4 of the cases of chromophobe adenoma loss of libido had been noticed earlier. A striking point in the case histories was the length of time which elapsed between the first visual complaints and the diagnosis in the case of atypical defects on the average 13 months. One of the patients with chromophobe adenoma had had visual complaints for 7 years and was being treated for neuritis. Neuritis was a diagnosis which was very often made. 3 patients had had visual complaints for 2 years. One patient was referred with the diagnosis of preretinal fibrosis. One of the





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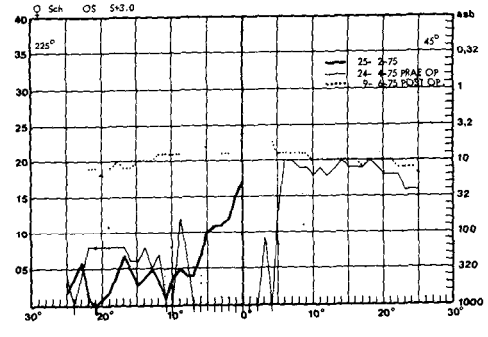

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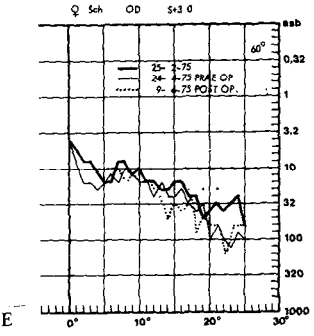

E

Fig 2. Case 1 See text

patients with a meningioma had had visual complaints for 7 years, another had been blind in one eye for 18 months.

COMMENTS

The percentage of atypical visual field defects in this series is high. The 3 cases with central visual field defects associated with chromophobe adenoma form 8% of the total. In the case of meningiomata in particular atypical defects are frequently seen.

The ophthalmologist in general practice will not often see tumours of the chiasmal region. He will, therefore, be less likely to consider the possibility of such a lesion in connection with atypical chiasmal defects. The diagnosis of retrobulbar neuritis is thus often made in these cases. It is of particular

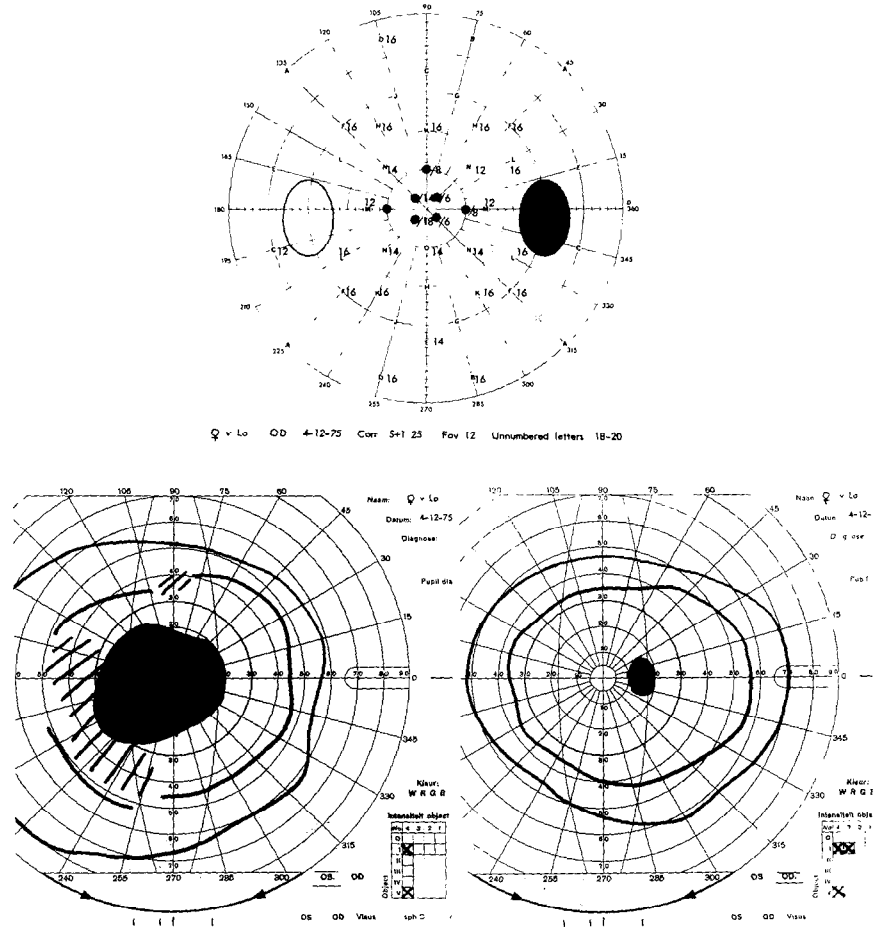

Fig. 3 Case 2 See text

importance for ophthalmologists who work with a neurological or neurosurgical centre to consider the possibility of a tumour in the chiasmal region in connection with atypical defects like these. When central defects are unexplained it is advisable to investigate the possible presence of a tumour of the pituitary gland (X–ray sella, case history, prolactin level, etc.).

Bitemporal hemianopsia is not the only defect which should be sought when a pituitary tumour is suspected. The differential diagnosis of bitemporal defects has been discussed by Aulhorn (1975).

Visual field examination is important for the diagnosis of processes in the chiasmal region:

1. Discovery of early bitemporal defects.
2. Registration of the typical temporal aspects of paracentral defects.
3. Registration of temporal defects in the other eye when there are atypical defects in the first eye.
4. Registration of progression and in particular the development of typical characteristics when the defects were atypical at first.

Defects that start off as atypical may get typical i.e. bitemporal aspects after some time. The importance of frequent follow-up examination in such cases is stressed. The importance of early diagnosis is apparent from the good prognosis in cases where the tumour is operated on early.

The explanation of the occurrence of central visual field defects in chiasmal processes is usually sought in involvement of the optic nerve (thus a post-fixed chiasma in the case of a chromophobe adenoma or a meningioma situated anteriorly). Paracentral defects with a bitemporal character are considered to be associated with midline or posterior chiasmal lesions (pre-fixed chiasma). This hypothesis could not be confirmed as far as the chromophobe adenomata were concerned by a study of the operation reports.

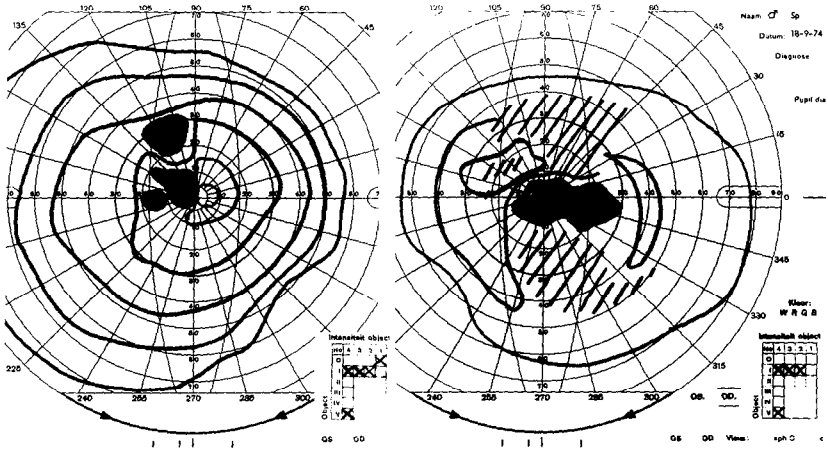

Fig 4 Case 3 See text

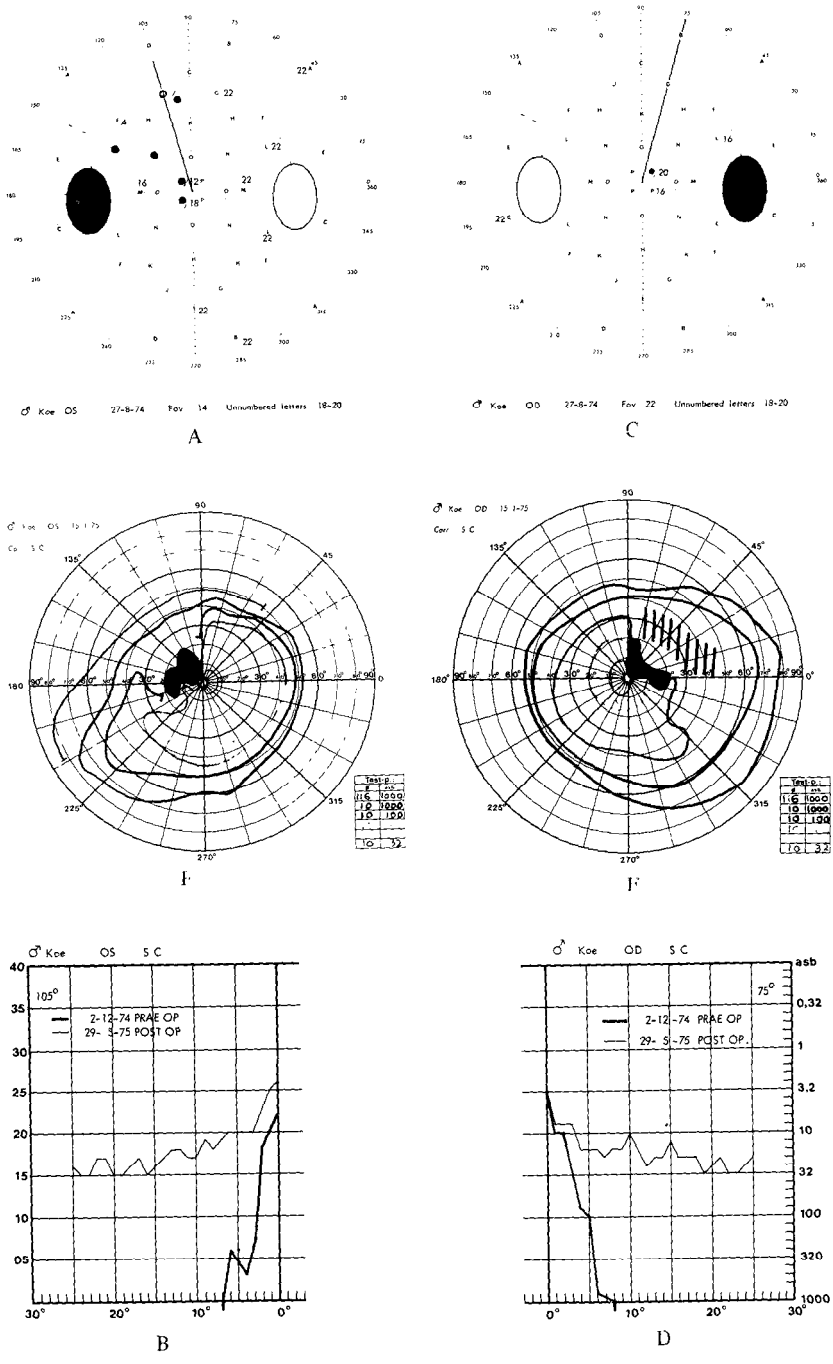

Fig 5 Case 4 See text

SUMMARY

The results of careful kinetic and static perimetry in 37 cases with pituitary adenoma and 9 cases with meningioma in the chiasmal region are reported.

In 10 cases of chromophobe adenoma atypical defects were found (27%) and in 5 cases of meningiomas (55%). Most of the atypical cases were first diagnosed as retrobulbar neuritis.

Central, paracentral, homonymous and other atypical defects can be symptoms of tumours in the chiasmal region. The frequency of the occurrence of such atypical defects is higher than expected after reading textbooks and literature.

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VISUAL FIELD DEFECTS ASSOCIATED WITH CHORIORETINAL FOLDS

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Expanding orbital lesions and papilledema from increased intracranial pressure are conditions that often are associated with the formation of broad light and dark striae in the peripapillary and papillomacular areas of the fundus These striae are caused by folding of the choroid and the retina. The ophthalmoscopic and fluorescein angiographic appearance of chorioretinal folds have been well described previously (e.g. von Winning 1972). Histopathologic observations have also been published (Wolter 1962), but the functional consequences of choroidal folds appear to have escaped attention. We have studied the visual field changes associated with choroidal folds in five cases. A full report will be published elsewhere (Frisén & Holm 1977).

In addition to peripapillary and papillomacular choroidal folds, all our patients had papilledema from raised intracranial pressure at the time of the first examination. The papilledema was quite moderate in degree, and fairly symmetrical. It appeared to be of recent origin. In all instances, there were extensive but shallow temporal scotomata, often with an irregular border.

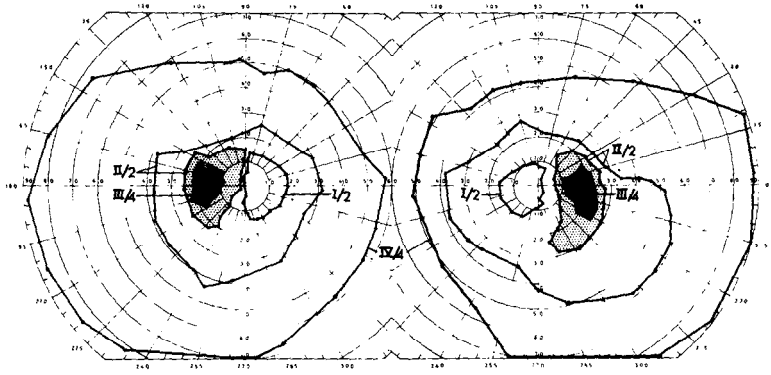

Fig. 1. Visual field changes due to bilateral, moderate papilledema and peripapillary choroidal folds. Case of left frontal lobe hemorrhage, without signs of hydrocephalus. Both the choroidal folds and the scotomata persisted during resolution of the papilledema.

The medial limit of the scotoma tended to approach the vertical meridian (Fig. 1). In one case with a small tumour in the posterior 3rd ventricle, the visual field abnormality mimicked a classical bitemporal field defect closely enough to cause a referral diagnosis of pituitary tumour. The field defects were always more extensive than could be expected from the degree of papilledema alone but coincided with the choroidal folds closely enough to reflect any irregularities in their distribution (Fig. 2 A and B).

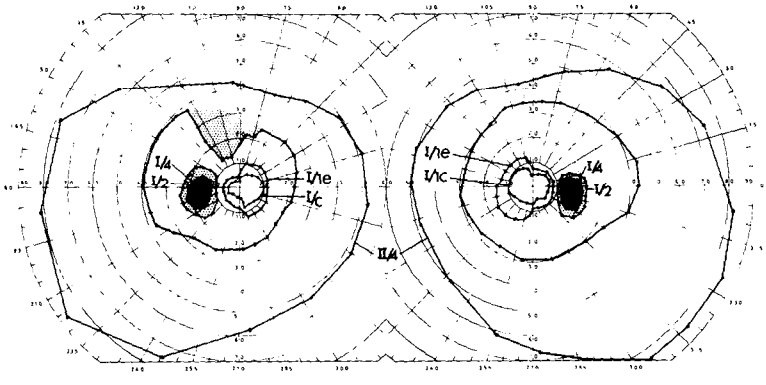

Fig. 2 Visual field changes due to moderate papilledema and choroidal folds. Cause unknown. A. Note the left upper temporal depression (stippled area), which corresponds in location to positive scotoma. B. The area of choroidal folding in the lower part of the left papillomacular bundle corresponds in location to the left upper temporal depression in A. Both the choroidal folds and the scotomata persisted long after the resolution of papilledema.

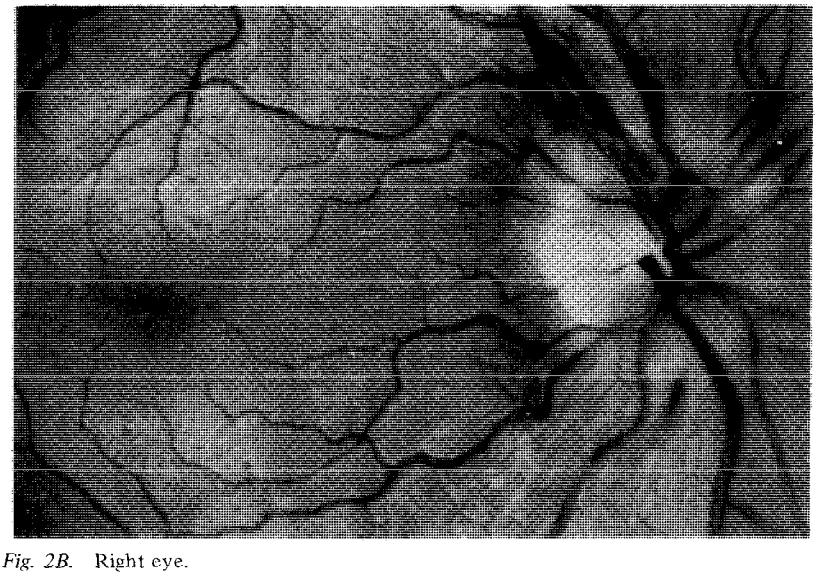

Fig. 2B. Right eye.

All patients complained of blurred vision but visual acuity was impaired only in those cases where folds traversed the fovea. One single patient had a positive scotoma corresponding to a localized area of choroidal folding (Fig. 2).

Proof that papilledema was not solely responsible for the field defects described here comes from the fact that both choroidal folds and the temporal scotomata persisted long after the resolution of the papilledema, in one case for more than four years. We have also seen one case with choroidal folds from orbital tumour with the same type of field defect, but without disc swelling. Other causes for the field defects than choroidal folds were carefully excluded. Specifically there were no signs of tilting of the optic discs, fundus ectasia or optic nerve pits, and there was nothing to suggest ascending or descending optic atrophy. In all instances, the primary intracranial lesion was remote from the anterior visual pathway. Two cases had a widely dilated 3rd ventricle with the possibility of stretching the optic chiasm from behind, but the asymmetry of the scotomata, and their failure to respect exactly the vertical meridian speak against this hypothesis. Furthermore, there were no signs of the characteristic form of optic atrophy associated with chiasmal lesions (see Lundström & Frisén 1976). Against this background we consider the choroidal folds the most likely explanation of the field defects. As choroidal folds are known to change the alignment of retinal rods and cones (Wolter 1962), we consider it likely that the threshold elevations described here are related to the Stiles-Crawford effect.

The temporal scotomata associated with choroidal folds deserve emphasis as a common variety of falsely localizing temporal field defects. Careful perimetry with particular attention to the vertical meridian and an outer

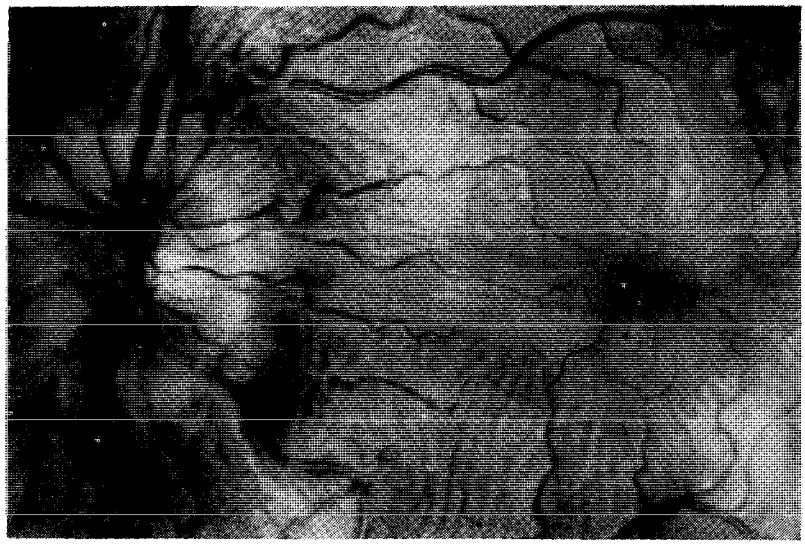

Fig 2B Left eye

limit of the field disturbance should facilitate differentiation between choroidal folds and chiasmal lesions, careful ophthalmoscopy has the same potential. In cases of doubt, fluorescein angiography may be indicated as this method enhances choroidal folds (von Winning 1972).

SUMMARY

Chorioretinal folds are frequently associated with relative defects in the temporal visual field. On cursory examination, these defects may appear to respect the vertical meridian. Bilateral chorioretinal folds may thus produce field defects suggesting a chiasmal lesion. We believe that bilateral chorioretinal folds are a common cause of falsely localizing bitemporal field defects, particularly in patients with papiledema from raised intracranial pressure.

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PITUITARY LESIONS AND VISUAL FIELD DEFECTS: SELECTED CASES

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This communication will report selected aspects of visual field studies on a series of 61 patients with pituitary tumors. These patients were part of a larger series of 85 patients who underwent transsphenoidal hypophysectomy.

Of the 61 patients with pituitary tumor, 28, or 46%, had visual field defects as tested with multiple isopter procedure on the Goldmann perimeter. Specific attention was given to correction of refractive errors, and multiple lenses were used where necessary to eliminate refraction scotomas.

Three cases in this series presented unusual features and will be described in detail.

Case 1. LOSS OF VISION IMMEDIATELY AFTER TRANSSPHENOIDAL HYPOPHYSECTOMY

One patient in the series of 85 lost vision postoperatively. He was a 69 year old male physician with massive suprasellar extension of a chromophobe adenoma, who had refused treatment 3 years before. He finally returned when his visual acuity had fallen to 20/40 OD, 20/200 OS, and his visual field defect had progressed to a marked superior bitemporal hemianopsia (Figure 1). Four hours after transsphenoidal surgery according to the method

Table Reason for Transsphenoidal operation

Pituitary Tumors		61
Chromophobe	21	
Acromegaly	16	
Forbes-Albright	13	
Cushings	8	
Craniopharyngioma	2	
Cholesteatoma	1	
Empty Sella		2
Metastatic Cancer		17
Diabetic Retinopathy		5
	Total	85

of Hardy (1965), he complained of sudden loss of vision in his 'good' right eye. His examination revealed the right pupil to be extremely sluggish, whereas the left was reacting. He was re-explored for postoperative bleeding within 6 hours of the first operation, but there was no appreciable hemorrhage or edema in the operative site, and the chiasm and the optic nerve were not prolapsed into the pituitary fossa. Two days postoperatively visual acuity was found to be 20/400 OD, 20/200 OS, and the visual field showed further loss of field in the right eye, with only a contracted inferior nasal island now remaining in the right eye; however, the field had reexpanded on the left side (Figure 2). There has been no change in acuity or fields over a 3 year period of followup.

Although many of the 21 patients with chromophobe adenomas had significant suprasellar extension of the tumor, with resultant displacement and stretching of the chiasm and optic nerve as seen on pneumotomography, only this one patient experienced visual loss. With regard to the cause of this single visual complication, the rapidity of the loss suggests a

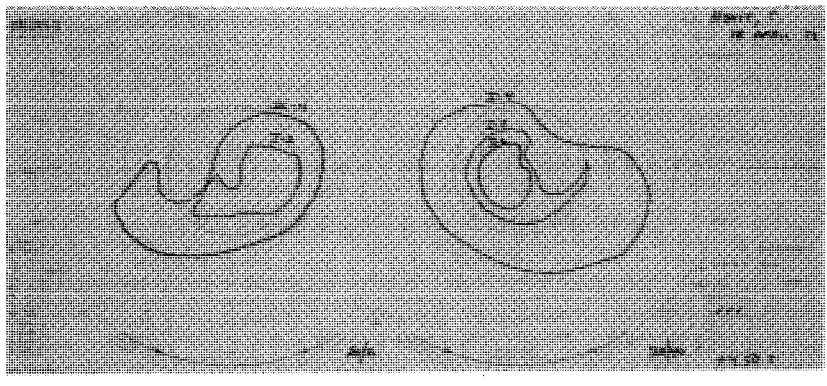

Fig. 1 Preoperative visual fields of Case 1.

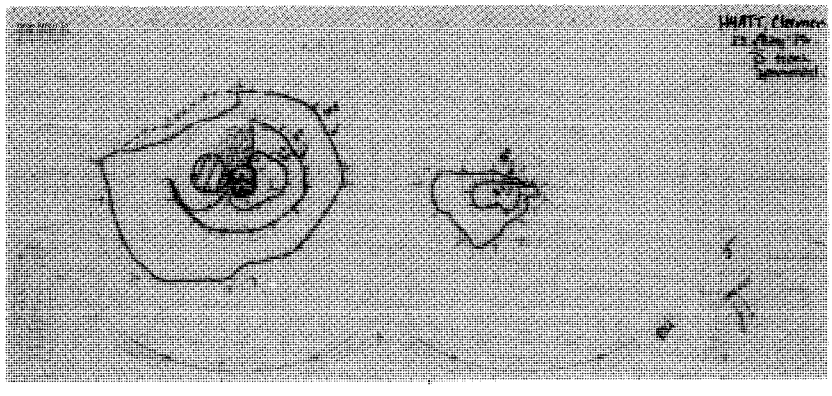

Fig. 2. Postoperative visual fields of Case 1

vascular mechanism, and direct inspection of the operative site excludes hemorrhage or edema as the cause. With regard to the safety of transsphenoidal hypophysectomy, it seems clear that there are fewer cases of postoperative optic-nerve and chiasmal damage with this surgical approach than with the alternative, namely, subfrontal craniotomy.

Case 2. EARLIEST FIELD DEFECT IN THE SERIES

This 56 year old woman complained that newly prescribed glasses were distorting her vision. When repeated refraction disclosed no change and 20/20 vision, she was referred for a second opinion. Color vision was normal in each eye, but visual fields showed a relative superior bitemporal defect (Figure 3). Skull X-rays revealed an enlarged sella. Pneumotomograms confirmed the expected pituitary tumor with gross suprasellar extension and, at surgery, a chromophobe adenoma was found. Postoperatively the visual fields returned to normal.

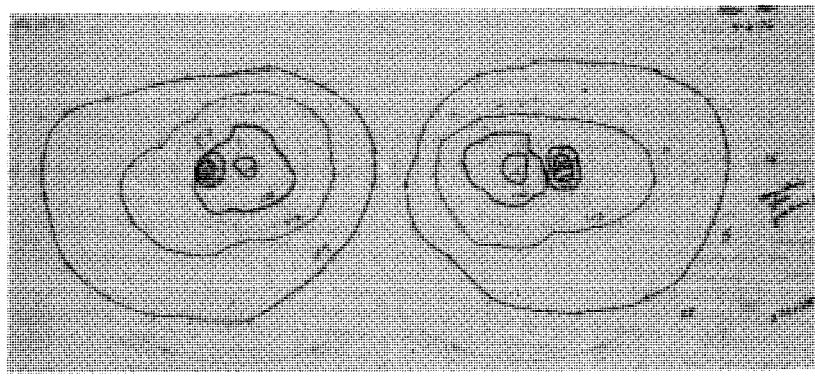

Fig 3 'Early' bitemporal field loss of Case 2

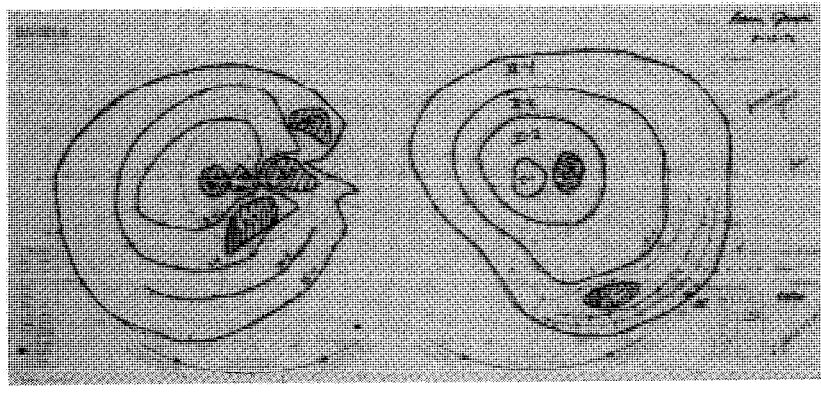

Fig. 4. Completely atypical field loss of Case 3.

With the increasing availability of quantitative perimetry, patients with visual complaints due to pituitary tumors are being identified earlier and earlier in their course. But because the pituitary tumor may extend as much as 10 mm above the level of the diaphragm sella before it displaces the chiasm (Walsh & Hoyt, 1969), and because some patients have gross displacement of the chiasm with no visual field defect, even *early* field defects must be regarded as a *late* sign of pituitary tumor. As this present series cotinues, we plan to study the relationship of the size of the pituitary tumor to the presence or absence of visual field defects and to report this anatomic – perimetric correlation.

Case 3. COMPLETELY ATYPICAL FIELD DEFECT WITH CHIASMAL TUMOR

This 63 year old man noted decreasing vision OS. On examination, visual acuity was 20/20 OD, 20/30 OS. Color vision was decreased and the Marcus Gunn pupil was found OS. Visual field showed a marked superior and inferior nasal disturbance, which amounted to a hemianopia with smaller test objects. However, the defect was restricted to the left visual field, the right was normal (Figure 4). After computerized tomography demonstrated a contrast enhancing lesion within the sella, visual fields were repeated and again no abnormality could be detected in the right eye. This patient is being studied further and, if possible, the histologic nature of his tumor will be added in proof to this report.

Many students of field defects in chiasmal disease have reported on atypical defects produced by sellar and parasellar lesions. In addition to the common bitemporal defects, these include central or temporal scotomas, homonymous hemianopsias, and arcuate scotomas (Hollenhorst & Younge, 1975). Rarely, binasal hemianopsias have also been reported (O'Connell & de Boulay, 1973). In this case, a nasal hemianopic defect was found in only one eye, clearly unusual. The other 27 patients with field defects in this series all had temporal or bitemporal field defects.

SUMMARY

Results of visual field studies in 61 patients with a pituitary tumor are reported. 46% had a visual field defect. Three cases are given special attention: a case with loss of vision immediately after operation, a case with early bitemporal defects and a case with an atypical defect.

I offer grateful acknowledgment to Professor Theodore S. Roberts, Chairman of the Division of Neurosurgery at the University of Utah College of Medicine for his gracious cooperation in allowing me to study some of his patients.

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PERIMETRIC DETECTION OF CHIASMAL INJURY AFTER CONTUSION OF THE SKULL AND BRAIN

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The mechanism, pathomorphology and clinical signs of traumatic lesions of the brain have been fully described by Unterharnscheidt (1972); the old concept on the 'contre coup'-effect has been disproved experimentally (Sellier & Unterharnscheidt 1963). The physical effect resulting from a blow to the skull (Sellier & Müller 1960) can be studied on a model of a thin-walled globe filled with water because the cerebral tissues actually have a relatively uniform density. The actual spread of the forces in action (pressure gradient) can be observed on the basis of this model, the greatest impact occurs at the site of trauma, and the least at exactly the opposite point, at the so-called counter-pole. This kind of pressure is hydrostatic and free of gravital forces, if the atmospheric pressure is reduced to zero, the pressure at the site of impact will be positive, at the counter-pole, however, it is negative; in an incompressible fluid medium, situated in a rigid shell, the place exhibiting unalterated pressure is called the nodal-point and it is located in the equatorial plane (Fig. 1). In cases of frontal impact against a freely movable skull, directed towards the center of the skull or close to it, the nodal-point will actually move backward due to the deformibility of the skull and the compressibility of the fluid content (Fig. 2), in this case the total amount of pressure will not change, but the positive gradient will increase, and the negative will decrease. From a physical point of view there will be no difference if a skull in motion is decelerated, or if the motionless but freely movable skull experiences an accelerative trauma due to a blunt blow. In cases where the axis of a blow runs tangential to the skull, rotational powers will be set free due to gravital forces resulting from the difference of the relatively inert intracranial content and the positively or negatively accelerated skull, thus leading to tearing of bloodvessels and nerves.

Traumatic lesions of the optic chiasm have been regarded as a rare event (Laursen 1971). Usually, they result from severe fronto-basal traumas to the skull, but such lesions may also be revealed perimetrically following frontal as well as occipital minor injuries

A personal observation of median splitting of the chiasm due to a motorcycle-accident was reported one year ago (Fulmek 1975b); the frontal deceleration-trauma caused an impression-fracture of the frontal bone and of both walls of the frontal sinuses, a deformation of the skull leading to an actual splitting of the sphenoid, while the optic canals swung side-way tear-

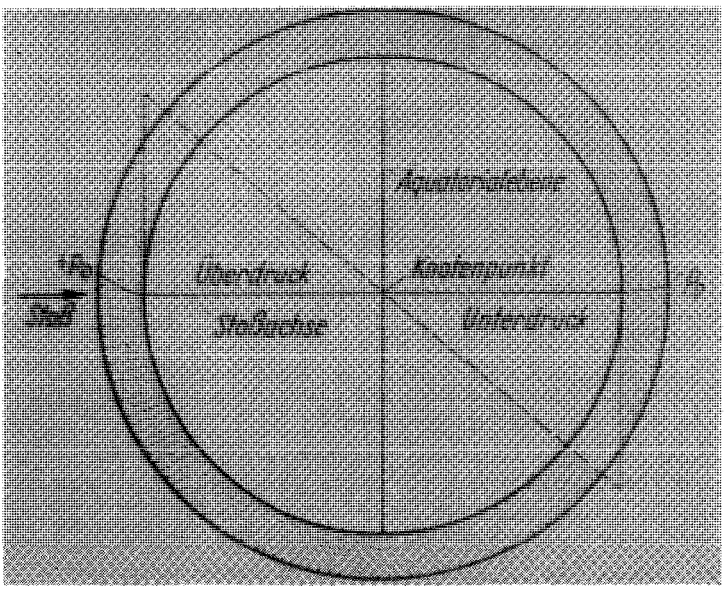

Fig. 1. Schematic course of pressure gradient due to blow from the left against a thin-walled globe filled with water (Sellier & Unterharnscheidt 1963).

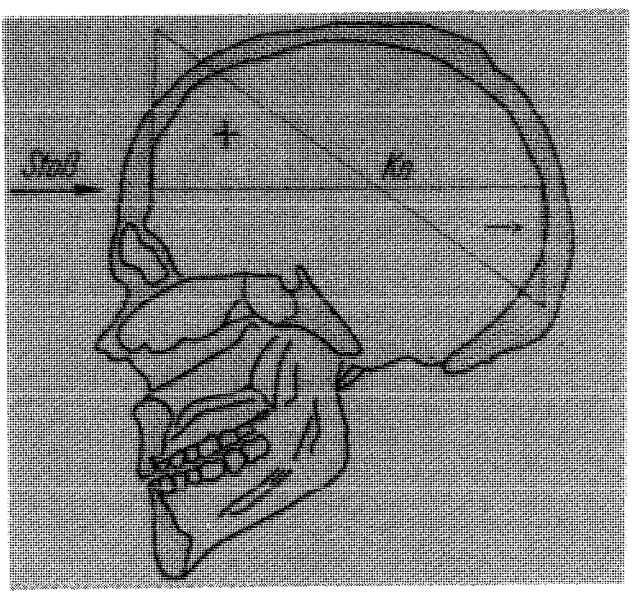

Fig. 2. With frontal impact (Stoß) against the free movable skull, the nodal-point (Kn) is shifting backwards due to the deformability of the skull (Sellier & Unterharnscheidt 1963).

ing the chiasm along the midline. This lesion resulted in almost complete bitemporal hemianopia (Fig. 3) with macular sparing on the right and central scotoma on the left side.

Similar visual disturbances and bitemporal field defects may follow minor injuries in water sport without any concussion or skull fracture (Fulmek 1975c).

Today we should like to report on two more cases:

Case 1

A 19-year-old boy jumped from a two-meter diving-board headlong into a swimming-pool hitting the bottom with the right side of the crown of his head. A bump, a buzzing head and acoustic impairment was followed by bleeding from the left ear, hence, the patient was induced to hospitalisation in the First Ear-Nose-Throat-Clinic of the University with the diagnosis 'contusio capitis, otitis media traumatica' (Arch.Nr.6910, A.Z.24423 · 30.6.-4.7.1975). Radiological examination of the skull, especially of the left petral bone, did not show any pathology; both eyes were normal, visual acuity reached 6/6, Jg I. However, perimetry revealed a traumatic lesion of the chiasm with left-accent (Fig. 4) by relatively incongrous bitemporal constrictions, and a 'diminution of the blind-spot' (Fulmek 1974a+b) on the left side. Fourteen months later only remnants of the bitemporal hemianopia in both upper quadrants with left-accent were present, both blind-spots were normal.

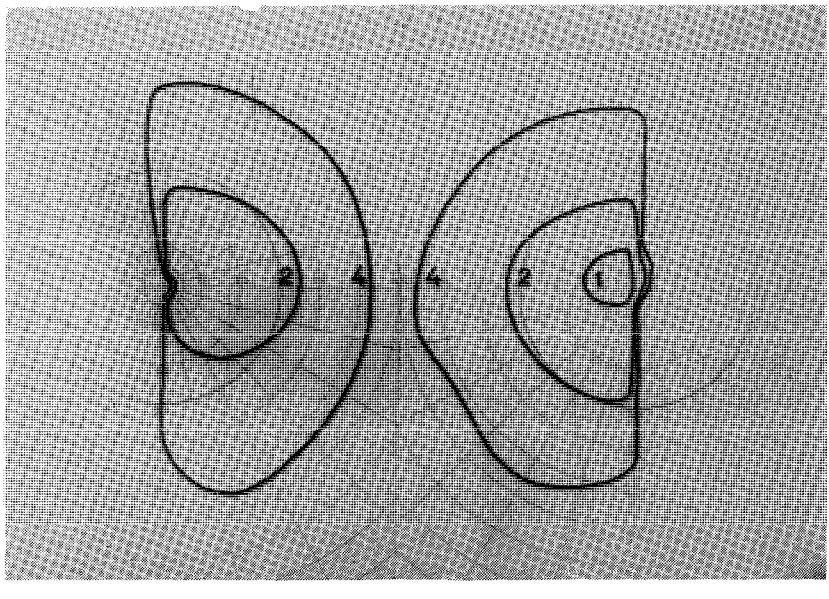

Fig 3 Almost complete bitemporal hemianopia following a motorcycle-accident (Fulmek 1975b)

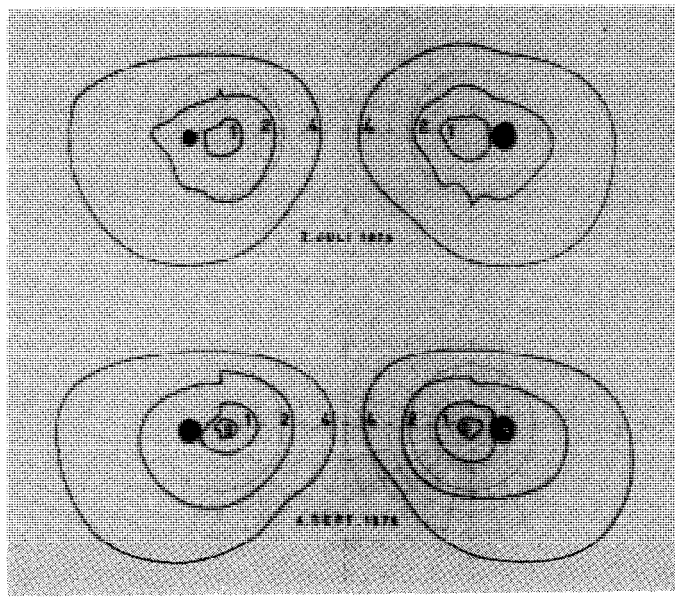

Fig. 4 Chiasmal lesion after a header from the diving-board into a swimming-pool, hitting the bottom with the crown of the head

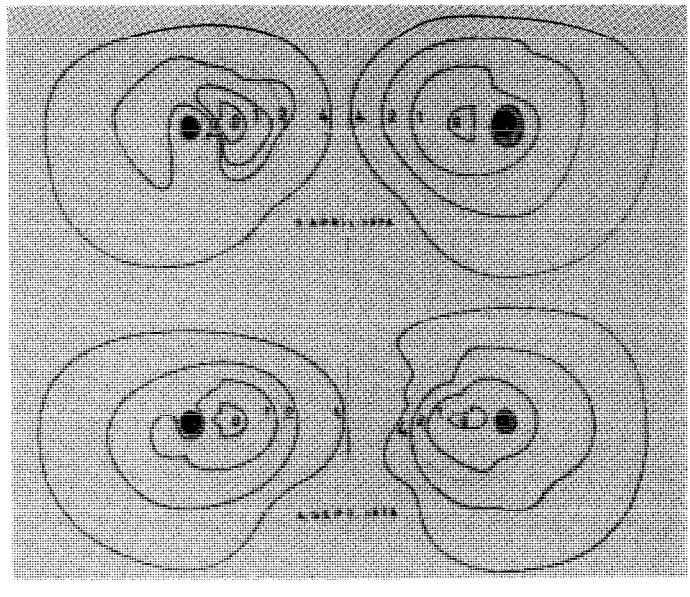

Fig. 5 Chiasmal lesion after a blunt blow on the back of the head

Case 2

A 13-year-old boy was balancing on the back-legs of his school-chair as a schoolmate brought him to crash; he bumped with the back of his head against a wall of the room. Two days later, a headache and eye-troubles arose. Eight days after the accident both eyes were quite normal with full visual acuity and normal ocular pressure. Perimetry indicated a crossed relative depression (Fig 5) of the right temporal-upper and left temporal-lower quadrant of the visual field due to a lesion of the chiasm with left-accent Both radiological findings of the skull and the neurological statement were normal. The vasodilatator Cosaldon retard and vitamines accelerated recovery. Four months later slight anisocoria with larger pupil of the right eye was the only pathological finding. The visual fields showed, besides a crossed relative bitemporal constriction of the right-lower and the left-upper quadrants, a peripheral defect of the nasal-upper quadrant of the right eye.

DISCUSSION

Injuries due to pure impression and to pure acceleration trauma, respectively, are the extremes of the continous series of traumatic physico-mechanical forces (Unterharnscheidt 1974). If the actual blow is strong enough, the impression-traumas produce primary damage of the tissue at the site of the injury, while a translation-trauma causes mainly alterations at the counter-pole, the so-called 'contre-coup' lesions. These primary traumatic lesions can be distinguished from the secondary ones due to circulatory disturbance appearing after an interval without pathological manifestation. Serious traumatic lesions of the skull and brain by a blunt blow, such as in motorcycle-accidents, may cause primary splitting of the chiasm, minor accidents may provoke vascular disturbances of nutrition with delayed clinical manifestation Exact perimetry (Fulmek 1975a) is a pre-requisite for clinical diagnoses of posttraumatic chiasmal lesions

SUMMARY

After discussion of the pathomechanism of skull trauma by a blunt blow leading to chiasmal lesion, fronto-basal injuries of the skull are considered, it is shown that typical defects of the visual field resulting from chiasmal damage can be revealed not only in cases of serious industrial or traffic accidents with brain concussion and skull base fracture, but also following minor injuries without unconsciousness and radiologically visible fracture.

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EXPERIENCES WITH A PROTOTYPE 100 HOLE FRONT PLATE FOR THE VISUAL FIELD ANALYSER IN NEURO–OPTHALMOLOGY

A.I. FRIEDMANN

(London, England)

The description of this 100 hole prototype plate has been given in the paper on the use of this plate in Glaucoma. The distribution and 32 patterns of the 100 stimuli were shown in the paper on 'Experience with a new 100 hole plate'

Figure 1 shows the visual fields in a case that presented with dense bitemporal visual field defects due to Ethambutal neuro-toxicity. The drug was withdrawn, and gradually his visual acuity and visual fields improved until his visual acuity became normal, as did his visual fields on examination with the perimeter and tangent screen.

However, the 100 hole plate shows a large temporal area in which function slightly but definitely depressed. Goldmann static perimetry profiles through the 45° meridian (to avoid the blind spot) and the 225° meridian, shows the former to be abnormal and the latter to be normal.

Figure 2 shows the visual fields in the case of a young woman treated with Nalidixic acid which resulted in papilloedema of benign intra-cranial hypertension. The blind spots are enlarged, and there are arcuate type field defects.

Figure 3 shows the visual fields examined by the 100 hole plate and Goldmann kinetic perimetry in the left eye of a patient after removal of a pituitary adenoma. The right field was normal by both techniques.

I have already discussed the use of the eccentric fixation device with the 100 plate to 'pattern bomb' the visual field with a large number of stimuli. I have little doubt that employing this technique will allow the earlier detection of visual field defects in the central field, and will also teach us a bit more about the natural development of visual field defects in neuro-opthalmology.

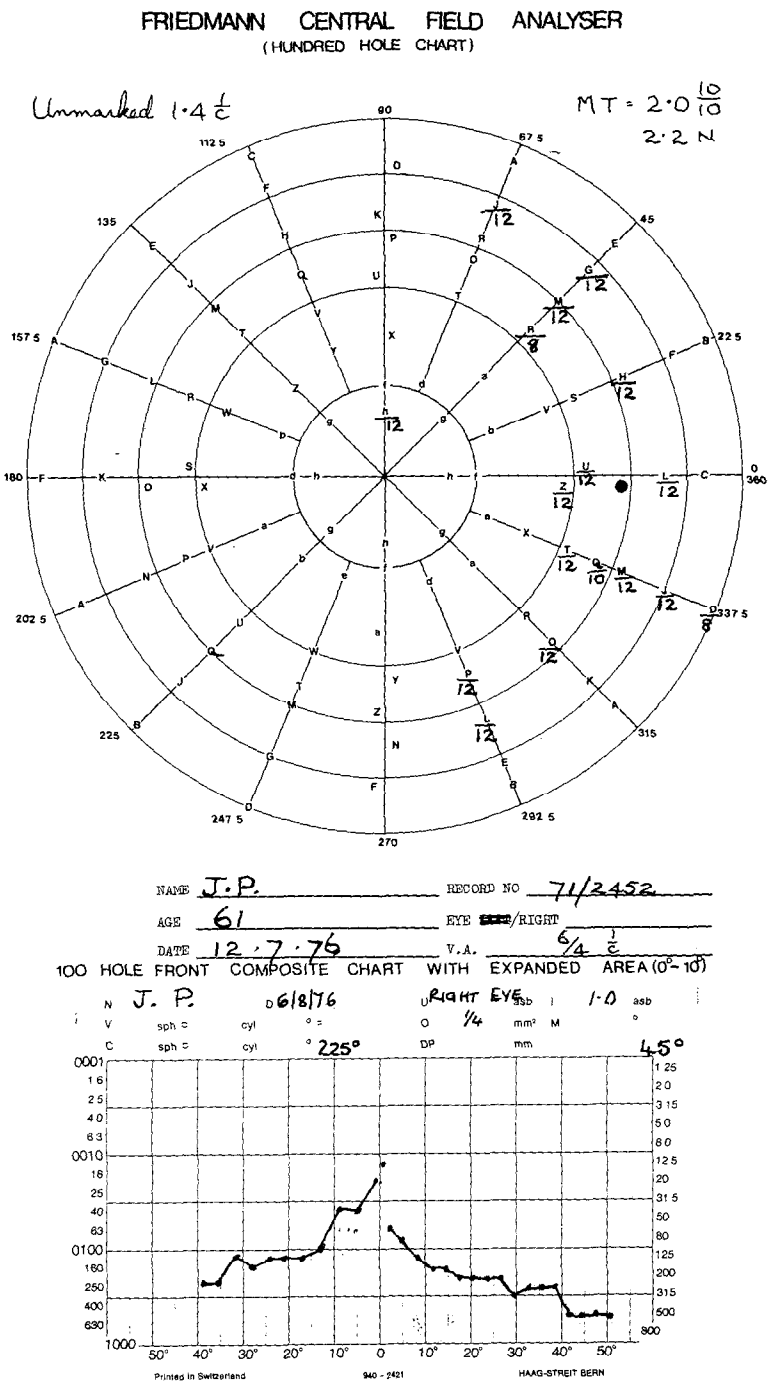


Fig. 1. J P. This patient presented with a dense bitemporal field loss due to Ethambutal neuro-toxicity 100 hole plate shows persisting visual field loss which accords with Goldmann static perimetry profile through the 45° and 225° meridian.

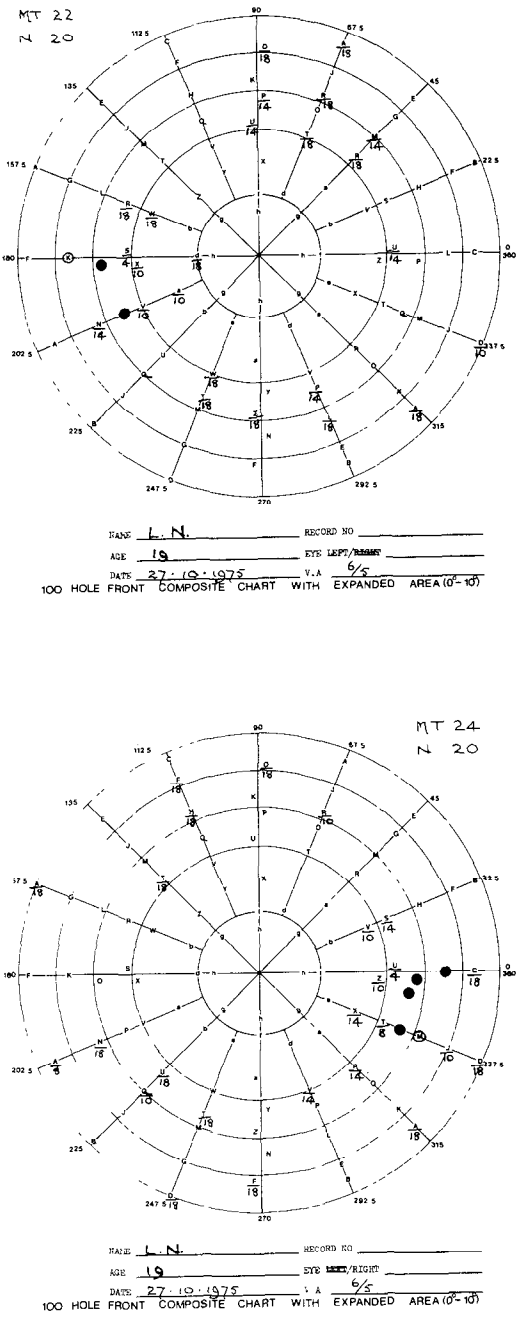
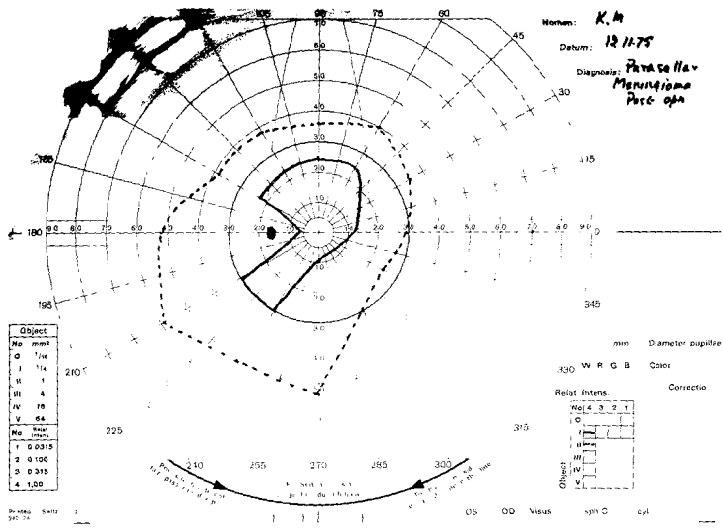


Fig. 2. Right and left visual fields examined on the 100 hole plate in a case of benign intra-cranial hypertension in a young woman treated with Nalidixic acid The blind spots are enlarged and there are arcuate type of defects



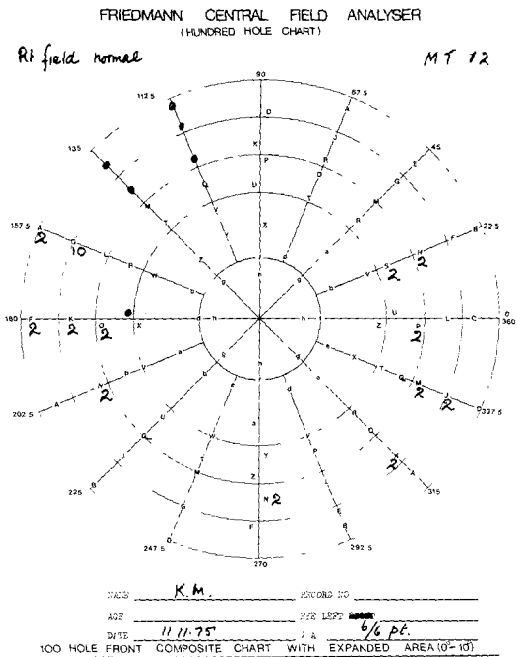


Fig 3. 100 hole visual field and Goldmann kinetic visual field in the left eye of a patient after removal of a pituitary adenoma There is good agreement between the two

SUMMARY

The paper compares results obtained with the standard 46 hole front, the new 100 hole front, Goldmann Kinetic and Goldmann Static perimetry in neuro-ophthalmology.

I wish to acknowledge the help given by my technicians Miss Graham, Miss Glock and Mrs. Speed.

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CLINICAL FEATURES OF CONGENITAL HOMONYMOUS HEMIANOPIA: A STUDY OF EIGHT CASES

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(Miami, Florida, USA)

Eight cases of congenital homonymous hemianopia were reviewed in order to learn the clinical features indicative of the congenital origin. Patients with severe neurologic deficits were excluded. We included only those patients who, by virtue of relatively normal growth and development and good general health, would appear to have an acquired homonymous hemianopia, and who would therefore present the greatest clinical dilemma (Table 1).

RESULTS

There were four females and four males ranging in age from 10 to 46 years with an average of 24 years. Two patients (Cases 1 and 6) had had a difficult delivery that required forceps, and one had respiratory distress at birth. One patient (Case 5) had a history of maternal viral infection. Five of the patients had emotional or learning problems that required either psychiatric help or special schooling.

Seven patients had corrected visual acuity of a least 20/30 in each eye. The exception (Case 7) had poor visual acuity in the left eye due to strabismic amblyopia. Five of the patients had right homonymous hemianopia and three had left homonymous hemianopia. The hemianopia was complete in four cases, congruous in three, and slightly incongruous in one patient. Six patients had symmetric optokinetic nystagmus. In seven cases, the disks were abnormal, characterized by pallor or hypoplasia. Six patients had abnormal ocular motility, two had congenital cataracts, and three had some form of nystagmus. One patient (Case 5) had a mild congenital right hemiparesis as suggested by an underdeveloped right thumbnail.

Three patients (Cases 4, 5, and 7) had undergone extensive diagnostic procedures. One patient (Case 4) had a normal brain scan, lumbar puncture, and carotid arteriography. Another patient (Case 5) had normal pneumoencephalography and underwent craniotomy that showed chiasmatic arachnoiditis. A third patient (Case 7) had normal skull roentgenograms and brain scan, and a pneumoencephalogram revealed an enlarged left lateral ventricle. An electroencephalogram in another patient (Case 6) exhibited decreased alpha rhythm over the right occiput and roentgenogram showed an irregular vertex suggesting birth trauma. One patient (Case 8) had decreased electroencephalographic activity over the left cerebral hemisphere. Follow-up ex-

Table 1 Summary of eight cases of congenital homonymous hemianopia

Case No.	Age, Yrs	Sex	Milestones	Neuropsychiatric History	Visual Acuity	Visual Fields	Opticokinetic Nystagmus	Disks	Other Ocular Findings	Follow-
1	46	F	Difficult forceps delivery	Negative	$20/^{25}_{20}$	RHH congruous	Negative	Small	XT, RHT	2 yrs
2	14	M		Emotional problems	$20/^{15}_{15}$	LHH congruous	Negative	LE. pale and small	Cataracts	4 mos
2	33	F	Neonatal hypoxia, difficulty reading	Psychosis at 38 years of age	$20/^{30}_{15}$	RHH congruous	Positive	LE. pale RE. small	XT, RHT nystagmus	10 yrs
4	10	F	Special school	Emotional problems	$20/^{15}_{15}$	LHH complete	Negative	LE. pale RE. small		8 mos
5	31	F	Gestational viral infection, gran mal seizures	Gait problem, right thumbnail smaller	$20/^{25}_{20}$	RHH slight incongruity	Negative	Pallor in both eyes	ET, latent nystagmus	5 yrs
6	19	M	Forceps delivery	Negative	$20/^{20}_{20}$	LHH complete	Negative	Normal	LHT	2 yrs
7	27	M	Decreased visual acuity LE and patch at 6 years of age	Subcutaneous neurofibromas	$20/^{15}_{70}$	RHH complete	Negative	Pallor in both eyes LE. small	RHT cataracts	6 yrs
8	13	M	Delayed speech, slow learning	Aggressive behavior, psychiatric care	$20/^{20}_{20}$	RHH complete	Positive	Pallor in both eyes	LHT, ET, nystagmus	

RHH indicates right homonymous hemianopia; LHH, left homonymous hemianopia; XT, exotropia; ET, esotropia, RHT, right hypertropia; LHT, left hypertropia

aminations were obtained in seven of the eight cases and there were no changes in the visual acuity and fields, motility measurements, or disks compared with the results of the initial examinations.

DISCUSSION

The occurrence of homonymous hemianopia in congenital porencephalic cysts is well documented (Lansche et al., 1958, Patten et al., 1937). Hoyt et al. (1972) recently emphasized the features of the disk changes in three patients with congenital cerebral atrophy and contralateral hemianopia. They found that the optic disk of the eye ipsilateral to the side of the cerebral atrophy was small and had temporal pallor, and the contralateral optic disk displayed a 'butterfly' pattern of atrophy.

When a patient with a previously unrecognized congenital homonymous hemianopia presents with incidental headache, minor neurologic symptoms, or following head trauma, the clinician has a difficult management problem. The features of the patients described here may help to support a diagnosis of congenital hemianopia.

Our patients were usually unaware of any defect in their visual fields. The hemianopia most frequently had the traits associated with occipital origin including congruity of the field defect, symmetric optokinetic nystagmus, and absence of temporal and parietal lobe signs. It is a reliable general rule that a right homonymous hemianopia in a right-handed patient is due to a left occipital lobe lesion, if he otherwise appears normal with neurological testing.

Associated congenital abnormalities were common, including optic atrophy or disk hypoplasia, strabismus, nystagmus, cataracts, seizures, and asymmetry of the thumbnails, a small thumbnail on the side of the hemianopia suggesting a congenital hemiparesis. Several patients also had had difficulty with gestation, delivery, or the neonatal period. Frequently, there was a history of emotional, behavioral, or learning problems, but none of the patients demonstrated overt mental retardation.

The disk abnormalities were felt to be the most supportive clinical findings. The atrophy or hypoplasia of the optic nerve heads appears due to the retrogeniculate lesion responsible for the hemianopia. This requires trans-synaptic degeneration across the lateral geniculate body and is therefore indicative of a lesion that is either congenital or of long standing.

SUMMARY

Eight cases of congenital homonymous hemianopia were reviewed, and the following features were found to be the most helpful in supporting the diagnosis of congenital etiology

1 The patients were usually unaware of the field defects.
2 The hemianopia was usually congruous when incomplete.
3. The optokinetic nystagmus was usually symmetric.
4. Associated congenital ocular and neurologic abnormalities were common.

5. Atrophy or hypoplasia of the optic disks was found in 7 of the 8 patients.
6. There was often a history of neonatal or gestational difficulties followed by emotional, behavioral, and learning problems without mental retardation.

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A PORTABLE HEMIANOPSIA TESTER

H. BYNKE & A. HEIJL

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Everybody working with clinical neuro-ophthalmology is familiar with the problem of visual field examination in less cooperative patients. The confrontation test may be the only method possible in such cases. This test may disclose even minor hemianopsias if two hands are presented symmetrically in the field or if coloured targets are used. A drawback is that it is too simple and crude to permit such variations of the procedure that may be necessary to confirm the existence of a field defect.

THE INSTRUMENT

We have constructed a portable hemianopsia tester, which in our hands has been found superior to the confrontation test in less cooperative patients, adults as well as children, whether bedridden or seated.

The instrument is a simple static perimeter. A central, red fixation light and four yellow test lights, one for each quadrant of the field, have been mounted on a plate sized 15 x 21 cm. All the lights are light emitting diodes. By pressing a button the test lights are exposed and by rotating two step-wheels their number, position and intensity are regulated.

If the instrument is held 30 cm in front of the patient's eyes, the eccentricity of the test lights is 15°. One or two test lights at various positions, or all four, may be exposed simultaneously. The exposure time of 0.2 seconds is too short to allow the patient to direct his eye at the stimulus. The intensity level may be varied at 9 steps with a ratio between adjacent steps of 1/2.

The testing procedure may be adapted to the condition of the patient. It is often suitable to present two and four test lights simultaneously, but in dysphasia and in children, the four 1-light positions may be exposed at decreasing intensity and the patient asked to point at the lights.

Ability of the instrument

In order to test the ability of the instrument, it has been applied to patients with diseases of the CNS. One group consisted of 70 cooperative patients, whose visual fields were checked by kinetic Goldmann perimetry or tangent screen examinations. Another group consisted of 27 patients, who did not

cooperate with these methods. Fourteen of them did not even cooperate with the confrontation test.

In the group of cooperative patients, there were 33 total or subtotal hemianopsias or quadrantanopsias. All these defects were demonstrated by the instrument, but 7 of the 54 relative defects were missed. These defects were small. In some cases defects were found but could not be interpreted because of varying answers. These fields were designated as questionably positives.

In the group of less cooperative subjects, the instrument disclosed hemianopic defects in 7 patients. Five of them did not cooperate with the confrontation test, an in 2 cases this test was negative. In all the 7 cases, the disclosed defects were consistent with other clinical findings, and in 2 cases the general condition subsequently improved so that the defects could be verified by Goldmann perimetry on later occasions.

DISCUSSION

The instrument disclosed 83, or if the questionably positives were included, 92% of the hemianopic defects known to exist. This result would have been improved by increasing the number of test lights. However, we refrained from doing this, since the primary purpose was to produce a handy instrument, able to disclose large and moderate-sized hemianopsias in less cooperative patients. That this purpose has been achieved is proved by the fact that defects were found in 7 patients, who could not be adequately examined by other methods.

SUMMARY

A pocket-size static perimeter provided with four test lights, one for each quadrant of the visual field, has been constructed and applied to 190 visual fields in 97 patients. The instrument's main advantage is its ability to disclose hemianopic defects in bedridden and certain sick patients and in children not cooperative with other methods, including the ordinary confrontation test.

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DISCUSSION

OF THE SESSION ON VISUAL FIELD IN NEURO-OPHTHALMOLOGY

Bynke to Harms (1) As expected, the central sectoma was frequently found in your material, Dr. Harms. I have never got any explanation why this defect is likely to occur in diseases of the optic nerve. Do you know? (2) You had a case with drusen and optic atrophy Was that primary drusen or refractile bodies after papilloedema?

Harms to Bynke (1) Your first question is difficult to answer. If we do not know we apply a theory, and this theory talks about great vulnerability of the macular fibres However, I have no certain proof that it is right. (2) Primary drusen.

Frisén to Bajandas Could you explain your finding that the ipsilateral disc was pale temporally? I would think that temporal side of the disc would be least affected, since the major part of 'atrophy' must concern the arcuate bundles

Bajandas to Frisén We did *not* state a finding of temporal pallor of the ipsilateral disc. We simply found that in seven of the eight patients there was some recognizable abnormality of the disc. hypoplasia, pallor, or asymmetry

Friedmann to Bajandas Were do you think the site if the lesion is?

Bajandas to Friedmann The patients had excellent visual acuity and there was no asymmetric involvement of the optic nerves. When incomplete hemianopsias existed, there were very congrous. Furthermore, the patients had no overt neurological problems and normal optokinetic nystagmus. Thus, the lesions were probably occipital Birth trauma was our most likely diagnosis

Bynke to Furuno One of your cases had a subarachnoid haemorrhage (SAH) I have seen three cases of SAH with homonymous hemianopic scotomas In my cases, the mechanism was obscure. No aneurysms were found Can you explain the mechanism in your case?

Furuno to Bynke Our case was a traumatic SAH. So it may have been a traumatic injury of the visual pathway.

Van Dijk I congratulate you, Dr. Furuno, of having only one of ten cases with the diagnosis unknown

Frisén to Greve. Please explain how a chiasmal lesion can cause unilateral visual loss.

Greve to Frisén: The lesion must be localized in the intracranial portion of one optic nerve, i.e. in the chasmal region but not in the chiasm itself.

Lüddeke to Greve: Would it not have been better to talk about atypical tumour localizations?

Greve to Lüddeke: Atypical field defects arise from 'atypical' localization of the tumour in some cases. However, we could not find a good correlation between the site of the lesion and the type of the defect. The practical implication is that even in non-bitemporal defects we should suspect a lesion in the chiasmal region.

Dannheim to Frisén: Did your bitemporal defects change with a change of the correction?

Frisén to Dannheim: No, they did not.

Bynke to Frisén (1) Are you sure that the choroid is involved or could it be only retinal oedema? (2) I do not quite agree with you that this is a common problem, but I admit that I have faced it mainly in craniopharyngioma with papilloedema.

Frisén to Bynke (1) I have accepted the terminology mostly used in the literature, i.e. chorioretinal folds. I think that the choroid is predominantly involved. (2) Considering the frequency I have seen ten cases during the last six months.

Riss to van Dijk I was surprised that you got so many normal fields in your cases of chromophobe adenoma, Dr. van Dijk. Could it be a matter of technique?

Van Dijk to Riss: I used the kinetic Goldmann perimeter. Multiple isopters were examined and in some cases multiple lenses were used to eliminate questionable refraction scotomas. So I think our technique is alright. The normal fields could be explained by the fact that the tumours were small and lacked any suprasellar extension.

Lagerlöf I am a bit surprised that you do only kinetic perimetry and not static. I have seen several cases with normal fields with the Goldmann perimeter but field defects with the Friedmann analyser.

Goldmann The whole thing is why the patient comes to the doctor. With very early endocrine disturbances the adenoma is small and does not compress the visual structures. By blood analysis it is now possible to diagnose adenomas 2 mm. in diameter. This must be the reason.

Drance I have no difficulties in accepting the fact that dr. van Dijk had good kinetic fields. Obviously the patients had intrasellar adenomas, which did not cause field defects. However, I found it difficult to understand why the case with extrasellar enlargement and the nerves and chiasm sitting on the top of the tumour had no field defect. I would suspect that a different method of perimetry would have disclosed the defect in that case

Van Dijk· The solution of the problem outlined by dr. Drance requires two things which we now plan to do. Firstly, we need a technique to estimate the volume of the tumour, not only its size in millimeters. The second thing is a meticulous static as well as a kinetic perimetry.

Dannheim The value of static perimetry in chiasmal lesions was demonstrated by me in Marseilles two years ago. One cannot compare kinetic perimetry with peripheral isopters with static perimetry of the central visual field.

Lynn. The solution of the problem may lie in the size of the test object. We come back to the photometric dysharmony. The sensitivity to a tiny bright spot of light is decreased in certain cases. Dr. van Dijk used the number 1 size test object, but to find the defects the number zero size test object must be used in addition to static perimetry.

Bynke I must emphasize the interesting fact that dr. Fulmek has shown in a previous paper that the traumatic bitemporal hemianopsia can be treated by surgery in certain cases.

Friedmann: I want to report a case of a young man of 19, who was horseriding and was thrown from his horse, fell on his head and was knocked unconcious. When he woke up he was found to have the typical field defects. But further investigation showed a pituitary tumour. This indicates that we must be very careful in such cases.

Bynke Dr. Friedmann has just demonstrated that it may be advantageous to increase the number of stimuli. I am now going to finish the session by showing you that for other purposes it may be good to do the reverse thing, i.e. reduce the number of stimuli.

Bajandas to Bynke When does the manufacturing of your instrument start and what is the price?

Bynke to Bajandas A small series of the instrument has been manufactured by our research engineer, Mr. R. Öhman. The cost is 1500 Swedish crowns, i e. about 900 DM.

SUMMARY OF SESSION V: VISUAL FIELD IN NEURO-OPHTHALMOLOGY

H. BYNKE

First I wish to express my gratitude to Professor Aulhorn and her group here in Tübingen and also to other members of the Organizing Committee for a very good symposium. Everything has been planned in detail. We are both admiring and satisfied.

We have thus felt the importance of detailed organization for a good meeting. But what about the organization of the research within the groups? I think that the groups have different prerequisites to find a common path in their research. In neuro-ophthalmology this is difficult. The basis of our research is the brain with its millions of pathways. This heterogeneity was demonstrated yesterday, when we travelled all the way between the eye and the visual cortex, presenting field defects due to legions at various levels, neuro-physiological aspects and new examination methods. In conjunction with this, I regret that because of lack of time it has been necessary to reject several good papers.

As regards research-planning in neuro-ophthalmology I am against a detailed organization. Good research needs freedom to survive, and it is of course not suitable and not even possible to have the chairman's frontal lobes directing the research within the group. Instead, the aim must be to let the members become acquainted with each other and have them interchange ideas and papers. This has already been achieved. When we come home and our brains are once again geographically but not mentally separated. I am sure that they will have been sufficiently stimulated to continue their research in freedom.

A NOTE ON STRAY LIGHT IN THE TÜBINGEN PERIMETER

R.A. WEALE

(London, England)

No paper received; to be published in *Brit. J. Ophthal.*

THE EFFECT OF PUPIL SIZE ON MULTIPLE STATIC QUANTITATIVE VISUAL FIELD THRESHOLD

C.H. BEDWELL & S.A. DAVIES

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INTRODUCTION

The relationship between pupil size and visual perceptual threshold in the human eye is more complex than that of an optical instrument, such as the camera. Though reduction in pupil size decreases retinal illumination, the effect on vision is partly compensated by retinal summation changes adjusting to retinal light adaptation. In addition there are also other physiological aspects that can affect these thresholds.

With aging, there is a gradual reduction of light sensitivity, Drance et al. (1967) and Lyne & Phillips (1969), associated with a decrease in pupil size, reduction of transparency of the optical media, some degeneration of the retina and associated structures, Fisher (1967) and possibly also a reduction in nerve conduction efficiency. With increasing obliquity of viewing stimuli are imaged on more eccentric areas of the retina, with differing receptor density, type, and interconnections, affecting summation. Also increasing with obliquity is the optical effect of the thickness of the pigmented inner edge of the iris, this thickness increasing with increasing pupil size, and the Styles-Crawford effect on oblique incidence to the retina, Weale (1956, 1974), Jay (1962), and Ronchi (1973).

In general, the effects of obliquity of viewing on visual field thresholds are much more significant for the peripheral fields beyond 30 degrees eccentricity, than that for the central field within this range with which we are concerned. For example, in the case of The Visual Field Analyser. Greve (1973) found that a change in pupil size between 2mm and 6mm had an insignificant effect on central visual field thresholds.

The present study was undertaken to determine possible interactions between pupil size, sex, and stimuli eccentricity, and hence their functional and clinical value, in addition to assessing the possible value of dynamically monitoring pupil size during visual field investigation.

THE EXPERIMENT

Because of its wide-spread clinical use, and the considerable research data that had been obtained, Bedwell (1971, 1972), and Bedwell & Obstfeld (1970), Greve (1971, 1973), multiple static quantitative perimetry in the form of the Visual Field Analyser, Friedmann (1966) and Bedwell (1967) was used for the visual field investigation. Infra-red photography was used

to determine pupil size of the subject, while viewing The Visual Field Analyser screen, so that retinal light adaptation was not affected.

So that the effect on accommodation would be negligible 5% ephedrine was used to dilate the pupil, and 0.2% thymoxamine to constrict.

Twelve male and female subjects between the ages of 18 and 23 years were studied, all of whose eyes had no ocular abnormalities, and a visual acuity of 6/6 or better.

Because of the random distribution of the visual field stimuli locations, only the eight meridians containing four observations were used. Thus an experimental factorial design of pupil x eccentricity x sex was set up, (3 x 8 x 2).

RESULTS

The effects of pupil size x sex summed over eccentricity on threshold are shown for sex in diagram 1, and pupil diameter x eccentricity summed over sex on threshold in diagram 2, for the small, the normal, and the large pupil. The dilated pupil was found to lower the threshold and the constricted pupil had a negligible effect ($P < 0.005$). Threshold was lowest for males with a dilated pupil and highest for females with a normal pupil, with a maximum difference of 0.14 log units. With increasing accentricity from 12.5° to 20.0° there is a consistent trend for threshold values to be raised ($P < 0.001$) by up to about 0.1 log units.

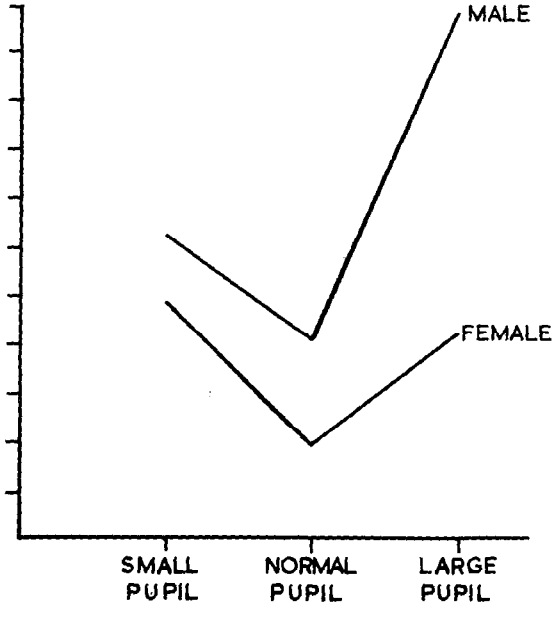

Fig. 1 Pupil Dia X sex summed over eccentricity

The effect of sex was that the threshold for males was lower than that for females ($P < 0.005$).

DISCUSSION

The finding that males have a lower threshold than females was interesting. A possible explanation may be that in visual perception tests males tend to have a better performance, whereas on aural tests the position is reversed.

Variations of threshold of within 0.2 log units are usually accepted clinically as within normal physiological limits, in this technique of visual field investigation. As the variation in threshold was an approximate maximum of 0.14 log units for variations in pupil size of between approximately 3.5 to 9.5 mm. diameter, one could say that the variation was within physiological limits. However, as the effect of other variables on visual field threshold have also to be considered, it is possible that under certain circumstances, especially where the pupil may be dilated in young males, and the very earliest indications of visual field reduction are being sought, it may be pertinent to take the effects of pupil size into consideration. In more every day clinical situations, where the pupil variations are less, and less strict tolerances need be observed, then the variations in pupil size likely to be encountered normally, do not appear likely to have a significant clinical effect.

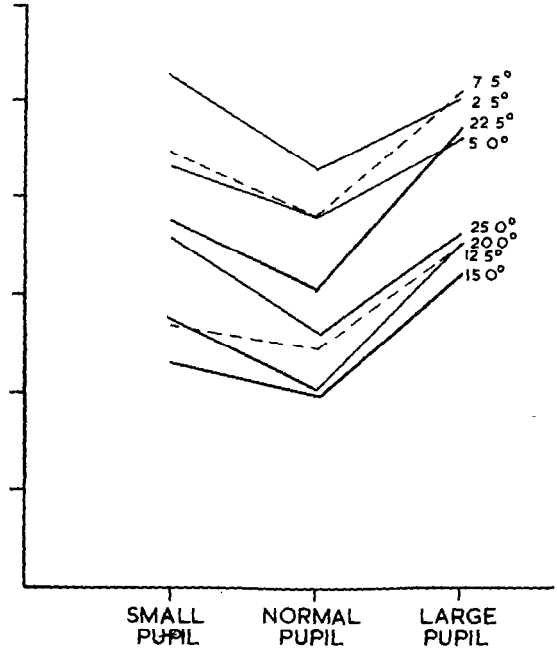

Fig 2 Pupil dia. X eccentricity summed over sex

SUMMARY

Using infra-red photography, the effect of variations in pupil size on visual field threshold were determined, employing the techniques of multiple static quantitative perimetry over the central field with The Visual Field Analyser. To minimise any effect on accommodation ephedrine and thymoxamine were used to produce mydriasis and miosis. The maximum effects of pupil size, eccentricity, and sex were 0.14 log units. Males were found to have a significantly lower threshold than females, the dilated pupil lowered the threshold, and increasing eccentricity raised it.

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HUMAN PSYCHOPHYSICAL ANALYSIS OF RECEPTIVE FIELD-LIKE PROPERTIES. VI. CURRENT SUMMARY AND ANALYSIS OF FACTORS AFFECTING THE PSYCHOPHYSICAL TRANSIENT-LIKE FUNCTION*

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This paper summarizes various properties of a new transient-like psychophysical response used in conjunction with the Westheimer function as a diagnostic test in quantitative perimetry. The Westheimer function (Fig. 1 (a)) indicates that detectability of a small test spot (I) varies according to the background field disk (II) size upon which it is presented (a large surround field (III) – the cupola – is also provided for general adaptation purposes and to minimize stray light effects). As background field disk size (II) is increased, the Westheimer function initially decreases (summation-like properties) until a 'minimum' is reached, and then increases (inhibition-like properties) up to an approximate asymptote. A similar procedure is employed for evaluation of the transient-like function (Fig. 1 (b)). However, the Westheimer function background field disk is replaced with a 'windmill' target similar to that used by Werblin in electrophysiological studies of the *Necturus* retina. The rationale underlying the transient-like response and its stimulus design has been described elsewhere (Enoch, Lazarus & Johnson, 1976).

The transient-like response is defined as the threshold difference between stationary and moving windmill conditions (Fig. 1 (b)). Previous studies have presented extensive analyses of relevant parameters of both stationary (Enoch & Johnson, 1976) and moving (Johnson & Enoch, 1976) windmill targets and their relation to the Westheimer function. Here, we only describe several general characteristics.

As windmill size is increased, the magnitude of the transient-like function initially increases up to a critical dimension, beyond which the function then decreases (Fig. 1 (b)). A maximum transient-like response is obtained when the inner diameter of the windmill vanes equals the Westheimer 'minimum' size, and the outer diameter of the windmill vanes corresponds to the appropriate Westheimer asymptote. Thus, both the Westheimer and transient-like functions appear to exhibit approximately equivalent areas of spatial interaction.

* This research was supported in part by National Eye Institute Research Grant No EY-01418-03 (To JME) and by a National Eye Institute Post-doctoral Fellowship No EY-00173 (to CAJ) The National Eye Institute is part of the National Institutes of Health, Bethesda, MD

In addition to exhibiting similar area-dependent relationships, the Westheimer and transient-like functions also share several other attributes. First, dichoptic testing indicates that the transient-like function reflects retinally-based responses (Johnson & Enoch, 1976), a finding which has been previously well-established for the Westheimer function. Examination of both psychophysical functions in various clinical populations has confirmed this result. Another similarity is that the inhibition-like portion of the Westheimer function (Fig. 1 (c)) and the transient-like function (Fig. 1 (d)) both 'drop out' or become greatly reduced as the test spot (Field I) luminance approaches its increment threshold value. For both functions, the test field luminance should be preferably 0.8 log units or more above its increment threshold value to adequately evaluate the full magnitude of the effects.

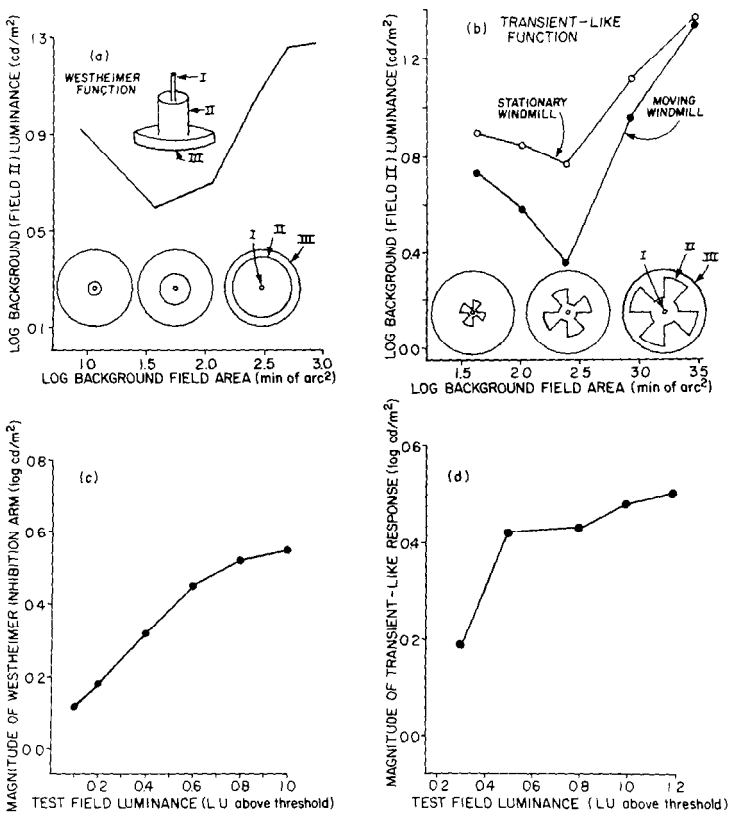

Fig. 1 (a) Foveal Westheimer function and schematic representation of stimulus display. (b) Foveal transient-like function and schematic representation of stimulus display. (c) Magnitude of the Westheimer inhibition-like arm (foveal data) at various test field (I) luminance levels above initial threshold determined against the large surround field (III) alone. (d) Magnitude of the maximum transient-like response (foveal data) at various test field (I) luminance levels above threshold determined against the large surround field (III) alone.

Both the transient-like and Westheimer functions display an increase in the area of spatial interaction as the stimulus display is moved from the fovea to greater visual field eccentricities (Fig. 2 (b)). It will also be noted that the rate of increase in interaction area with eccentricity is essentially equivalent for both functions. Further, the magnitude of the transient-like function becomes greater with increasing eccentricity (Fig. 2 (a)), a result which is also found for the inhibition-like portion of the Westheimer function. Finally, the Westheimer and transient-like functions are greatly affected by the presence of blur. The magnitude and shape of both functions become altered with the presence of blur, making it essential that an optimal correction is provided for each test locus.

Along with the many similarities between the Westheimer and transient-like functions, there are also several differences. First, the Westheimer function may be elicited with either a flashing or a steady-state test spot (I). The transient-like function, however, requires a flashing test spot, and cannot be evaluated adequately with a steady-state test field. Also, two independent

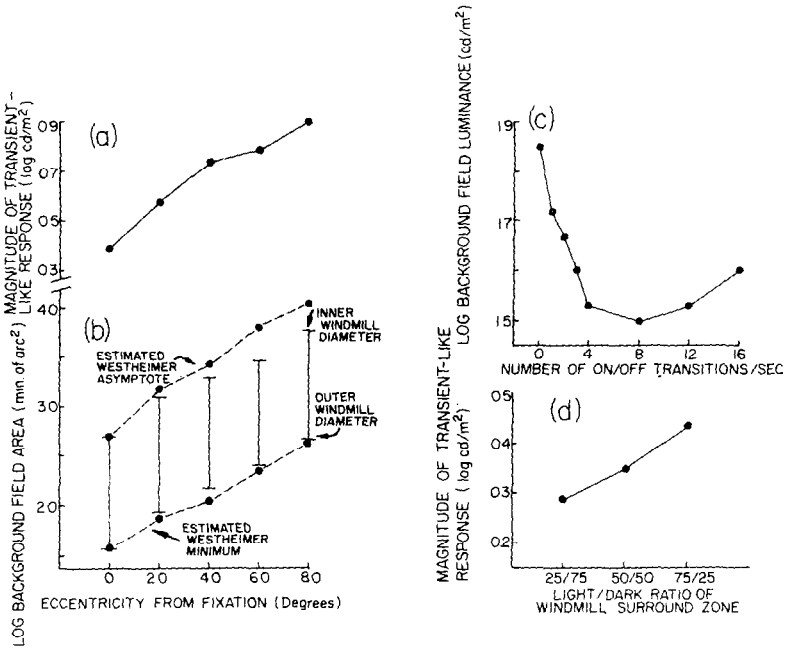

Fig. 2 (a) Magnitude of the transient-like response as a function of eccentricity from fixation. (b) Windmill vane dimensions for maximum transient-like function, and Westheimer function minimum and asymptote dimensions are plotted as a function of eccentricity from fixation (c) Windmill background field luminance needed to bring the test flash to threshold as a function of the number of on-off transitions per second produced by the four vaned moving windmill (d) Magnitude of the transient-like response as a function of the light/dark (% of annulus illuminated/ % not illuminated) ratio of the windmill surround zone

Note: On Fig 2b the designations inner and outer windmill diameters are reversed

thresholds can be determined for the moving windmill condition; one in which the test spot is seen but doesn't appear to be flashing, and one in which the test spot is both seen and is flashing. Differences between the two thresholds become augmented as the windmill velocity is increased. Such a 'two-threshold' type of event does not occur for either the stationary windmill condition or the Westheimer function. The 'test spot is seen and is flashing' criterion provides a reliable, optimal evaluation of the transient-like function. Additional differences between the Westheimer and transient-like functions are concerned with the presence of several complex perceptual phenomena associated with the moving windmill target. These include motion after-effects, disappearance of all or part of the moving windmill when the display is located in the peripheral retina, and brightness enhancement effects, all of which are described more thoroughly in Enoch, Lazarus & Johnson (1976).

Several stimulus parameters are also important for eliciting the optimal transient-like response. Magnitude of the transient-like response is influenced by velocity of the moving windmill (Fig. 2 (c)). A velocity for which the windmill generates approximately 6-8 ON-OFF transitions per second is optimal. Direction of rotation (clockwise vs counterclockwise) has a negligible influence. The number of vanes of the windmill is not a critical parameter, both for stationary (Enoch & Johnson, 1976) and moving (Johnson & Enoch, 1976) windmills, provided that the illuminated area of the windmill target is the same. Orientation of the stationary windmill does not affect threshold determinations, assuming that astigmatism has been corrected and that an asymmetric target is not used at the border of a sharp field defect (Enoch, Johnson & Fitzgerald, 1976). For both the stationary (Enoch & Johnson, 1976) and moving (Johnson & Enoch, 1976) windmills, the light/dark ratio of the windmill surround zone affects the magnitude of the response. The transient-like function becomes greater as the light/dark ratio of the windmill target is increased (Fig. 2 (d)). This is a particularly significant parameter and has proven to be quite useful in the differential diagnosis of various clinical populations. In the companion paper (Enoch, Johnson & Fitzgerald, 1976) examples of utilization of this test in a clinical population are presented.

SUMMARY

A transient-like psychophysical function is being studied and developed for use as a diagnostic test in quantitative perimetry. The test is based upon a rotating 'windmill' target, similar to that employed by Werblin and others in electrophysiological studies of the retina. The transient-like response is defined as the difference in threshold between stationary and moving windmill conditions. The present paper summarizes our basic findings with respect to the transient-like function and describes its relationship to the Westheimer function, which has been previously adapted to quantitative perimetry and extensively studied in normal and clinical populations. In addition, the effects of several important stimulus parameters of the 'windmill' target (number of vanes, light-dark ratio, and rotation rate) are examined

with respect to the magnitude of the transient-like response. A discussion of optimization of the test conditions for clinical application will be presented.

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HUMAN PSYCHOPHYSICAL ANALYSIS OF RECEPTIVE FIELD-LIKE PROPERTIES. VII. INITIAL CLINICAL TRIALS OF THE PSYCHOPHYSICAL TRANSIENT-LIKE FUNCTION*

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INTRODUCTION

The accompanying paper (Johnson & Enoch, 1976) described a new transient-like psychophysical function believed to have origin in the retina and, on the basis of available electrophysiological evidence, may be first organized in the inner plexiform layer. This paper presents initial clinical trials intended to aid in localization of the transient-like function and clarify disease states wherein this function is altered.

The stimulus array includes a small flashing test spot centered within a windmill-shaped background field, both of which are projected onto a large surround field (the perimeter cupola). Details of the experimental technique are available in Enoch, Lazarus & Johnson (1976) and Enoch, Johnson & Fitzgerald (1976). We define the transient-like function as the difference in background luminance needed to bring test flash to threshold for the stationary and moving windmill conditions.

Transient-like responses, in conjunction with concurrent Westheimer function (Enoch, Sunga & Bachmann, 1970) measurements, have now been obtained for a variety of clinical populations. A format similar to that employed by Sunga & Enoch (1970) is herein utilized in an attempt to localize this response function in the visual pathway. We have selected (1) diseases known to effect only the choroid, pigment epithelium and retinal receptor layers, (2) other diseases which ordinarily influence the choroid, pigment epithelium and receptor layers, but may also have a broadening or spreading influence, (3) diseases known to affect the inner retina, differentiated from outer retinal diseases on a vascular support basis, and (4) diseases affecting the visual pathway at points central to the optic nerve head The format for presentation of data is described in the legend of Fig. 1.

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CLASS I – DISEASES OF THE CHOROID, PIGMENT EPITHELIUM AND RETINAL RECEPTOR LAYERS

An example of this disease category is shown in the left half of Fig. 1 which presents the data of F.W., an individual with histoplasmosis. A static perimetric cut in the vertical meridian O.S. is plotted in the lower portion of the

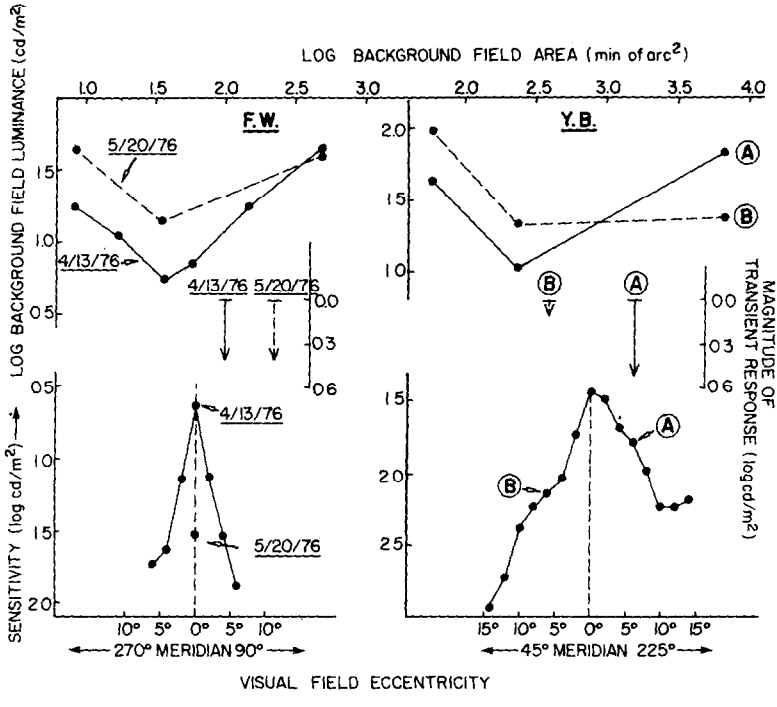

Fig. 1 For each case, the bottom graph presents static perimetric data obtained along a meridian of interest. The lower left ordinate and the abscissa along the bottom apply to these data Westheimer functions, obtained at the visual field locations indicated on the static perimetric plot, are displayed in the upper portion of the graph. They are described by the upper left ordinate and the abscissa along the top. A 'V'-shaped curve indiates a normal Westheimer function, whereas a 'flattening' of the right arm of the 'V' indicates loss of inhibition-like properties Transient-like functions at the same visual field loci, shown in the center of the graph, are described by the right-center ordinate Length of the arrow-like figures indicates the magnitude of the transient-like response.

(Left graph) Results for F.W , a 37-year old caucasian male with peripapillary and peripheral punched out lesions O U. and a hemorrhagic lesion O D compatible with the diagnosis of histoplasmosis The macula O.S showed only pigment epithelial defects. Vision was O.D. Count Fingers, O.S. 20/25. Data here were obtained for O.S.

(Right graph). Results for Y.B., a 24-year old black female with a family history of glaucoma and a two-year history of elevated intraocular pressures. She had markedly cupped disks, a Seidel scotoma O.D and a Bjerrum scotoma O.S Vision was O.D $20/25^{-1}$, O S $20/40^{-2}$ Data were obtained for O D

graph. Note that foveal sensitivity fell nearly a log unit between April 13 (4/13) and May 20 (5/20), 1976. Despite this large foveal sensitivity loss, the transient-like function (arrow-like figures in center of graph) was virtually unaltered, and the Westheimer function (upper part of graph) showed only modest change for the two dates, still exhibiting its characteristic V-shape on May 20. In other cases of histoplasmosis and angioid streaks of the retina we have observed no meaningful or consistent change in either the Westheimer or transient-like functions in spite of substantial reductions in sensitivity and (where applicable) acuity.

CLASS II – OUTER RETINAL DISEASE PROCESSES WHICH IN SOME INSTANCES SHOW CHANGES IN THE WESTHEIMER AND TRANSIENT-LIKE FUNCTIONS

Included in this disease category are senile macular degeneration, central serous retinopathy, chorioretinopathy, and post-photocoagulation edema. To date, our largest patient population in this category is senile macular degeneration, of which two groups have been defined. One group exhibits local changes in retinal sensitivity, but essentially unaltered Westheimer and transient-like functions. The second and somewhat larger group shows changes in retinal sensitivity and alterations in transient-like and/or Westheimer functions. In all cases of this second group, an orderly progression of (1) retinal sensitivity loss, to (2) Westheimer function loss, to (3) transient-like function loss has been noted. Several examples of these senile macular degeneration cases are presented in Enoch, Johnson & Fitzgerald (1976) Currently, we are attempting to determine whether the first group is an earlier form of the condition exhibited by the second group, or whether the groups represent two separate disease processes Although the patient populations of other diseases within this category are somewhat smaller, the findings to date are consistent with those of the two senile macular degeneration groups.

CLASS III – INNER RETINAL DISEASES (VASCULAR SUPPORT BASIS)

To date, this category includes branch artery occlusions, glaucoma and diabetic retinopathy. In each case of a branch artery occlusion there was unequivocal loss of retinal sensitivity, loss of the inhibition-like portion of the Westheimer function ('flattening' of the right-hand portion of the V-shaped curve), and reduction in the magnitude of the transient-like function. Results for a representative case of a branch artery occlusion are presented in Enoch, Johnson & Fitzgerald (1976).

Results of a representative glaucoma patient (Y B.) are shown in the right half of Fig. 1. The static perimetric data (lower graph) indicate a relative field loss at point B in comparison to control point A. Note that both the transient-like (middle portion of graph) and Westheimer (upper portion of graph) functions at control point A are clearly present. At point B, however, both the magnitude of the transient-like response and the in-

hibition-like portion of the Westheimer function (the right-hand portion of the V-shaped curve) are greatly reduced. Similar findings are present in the larger population of glaucoma patients studied to date, although it is not yet clear as to whether the Westheimer or the transient-like function is altered first or more profoundly during the progression of the disease.

Extremely interesting preliminary results have been obtained from individuals with diabetic retinopathy. Extensive follow-ups (psychophysics, fluorescein angiography, fundus photos, electrophysiology) are being conducted on these patients and a more complete discussion will be presented at a future date. Fig. 2 presents the initial sample data of three diabetic

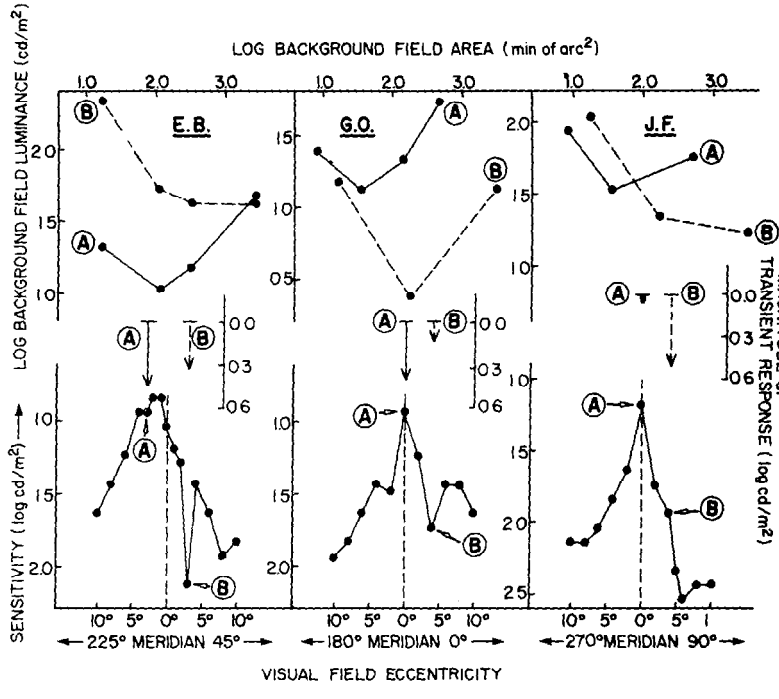

Fig 2 Data format as for Fig 1.

(Left graph) Results for E B , a 58-year old black male who has been a diabetic since age 40 and is on NPH insulin In addition he has hypertension controlled by medication Background retinopathy was present O.D. A neovascular net was present inferotemporal to the macula O.S. (O'Hare classification $N_1F_0H_0$). Vision was O.D 20/20, O S. $20/50^{-1}$ Data were obtained for O S

(Center graph) Results for G O., a 31-year old caucasian male who has been a diabetic since age 14 and is on NPH insulin He has been followed for six years with background retinopathy but without definite neovascularization. Vision was 20/15 O U. Data were obtained for O D

(Right graph) Results for J F., a 33-year old caucasian female who has been diabetic since age 20 and is on insulin Background retinopathy with microaneurysms and dot and blot hemorrhages were present without evidence of neovasculorization. Vision was 20/25 O.U Data were obtained for O.S

retinopathy patients. In the left-hand portion of Fig. 2, patient E.B. shows a localized sensitivity loss at point B of the static perimetric plot (lower part of graph) relative to control point A. Both the Westheimer and transient-like functions are present at control point A. The transient-like function at point B is only slightly affected, whereas the inhibition-like zone of the Westheimer function is greatly reduced. The opposite result was obtained for patient G.O. (center part of Fig. 2). Here, the Westheimer functions at both points A and B are intact, while the transient-like function at point B is function but a markedly reduced transient-like function. However, at point B the transient-like function is intact while the inhibition-like portion of the Westheimer function is virtually absent. Thus, both forms of differential loss of the two functions are present in the same eye. Clearly, such a marked differential effect needs to be clarified. However, it is important to note that either the Westheimer or transient-like function may be affected on a relatively independent basis.

CLASS IV – DISEASES AFFECTING THE VISUAL PATHWAY AT POINTS CENTRAL TO THE OPTIC NERVE HEAD

Dichoptic studies indicate that both the Westheimer and transient-like functions are retinally-based (Johnson & Enoch, 1976). Ample previous data exists to indicate that the Westheimer function is relatively unaffected in pathology central to the optic nerve head Very limited findings to date suggest that the same is true of the transient-like function, although further examination of this patient population is desirable.

DISCUSSION

Our current findings indicate that pathology of the inner retina (vascular support basis) may alter both Westheimer and/or transient-like functions. The present data suggest that the two functions may mediate independent response processes in the inner retina. We are intrigued by the results in senile macular degeneration wherein the Westheimer function appears to be affected prior to the transient-like function, and hope to pursue this inquiry further. Similarly, we are most interested in the fact that, at a given point in the visual field, either one or the other or both of these functions can be altered in certain disease states, e.g., diabetes. Obviously, these are potentially powerful tools for diagnostic analysis and evaluation of therapy and the fact that they can be applied on so local a basis provides them with great analytical power for assessing disease processes.

The working hypothesis developed for this analysis has been presented in detail in Enoch, Johnson & Fitzgerald (1976).

SUMMARY

The psychophysical transient-like function, summarized in the previous paper in this series, has succesfully been adapted to perimetric testing. The present article describes our initial clinical trials using the transient-like func-

tion. By examining clinical populations with known, definable pathology, we are attempting to define a locus (or zone of action) of pathology-induced response alterations in the transient-like response. Results of the transient-like function are compared with the Westheimer function and 'repeat static' tests, which are taken sequentially. Some potential diagnostic capabilities of these tests are discussed.

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ON THE LUMINANCE AND SIZE OF TEST-POINTS IN 'MULTIPLE-STIMULUS' PERIMETRY

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Of all perimetric methods, the 'multiple-stimulus' method is most probably the quickest. The fact that this great advantage competes with the similarly advantageous process of every screening method, i.e. examination at given points only, is unavoidable and shall not be discussed here. Our work is rather intended to comment on the luminance and size of the test-marks used in the 'multiple-stimulus' method, that is, on the perimetric stimulus value of the test-points.

The basic principle of every 'multiple-stimulus' method is the simultaneous presentation of several test-points, which in every case must be at the same distance from the threshold of light difference sensitvity for the subject with healthy eyes. Only if this demand is met does a lacking perception of a test-point in a group of three or four simultaneously presented test-points really mean that a scotoma exists. However, not only the simultaneously presented test-points, but also the following groups of test-points and the ones following these, and so on, must always be of the same stimulus value, for if the stimulus value of one group lies higher above the threshold of light difference sensitivity than the stimulus value of the following groups, a scotoma will be more easily represented in the area of the second group than in that of the first group.

The demand that the stimulus value of all the test-points must lie at the same distance from the threshold of light difference sensitivity in the visual field is, therefore, extremely important, and no effort should be spared in the development of new instruments to meet this demand. The stimulus value can be altered by varying the size of the test-point or test-point luminance. In normal perimetry the threshold is generally determined by altering the test-point luminance.

If one wanted to introduce the same principle into the 'multiple-stimulus' method, the uniformity of stimulus values would have to be obtained at all points in the visual field by making the test-points brighter the further they lie from the fixation point, at least under photopic conditions. This method is, however, technically very large-scale. It is far more advantageous for all simple screening-instruments, including those with which 'multiple-stimulus' methods are carried out, to obtain uniformity of stimulus value at all visual field points through different sizes of test-points.

The selection of the right test-point sizes can only be carried out with

the help of very accurate psychophysical experiments. We should like to show the results of such experiments as follows, and with it should like to make a contribution to the development or further development, respectively, of good screening-methods, especially of 'multiple-stimulus' methods.

We examined five subjects with healthy eyes using a test-arrangement specially produced for this experiment. The age of the subjects was between 20 and 30 years. The examinations were done monocularly on the horizontal nasal visual field meridian, between 0 and 30 degrees eccentricity. The subject was at a distance of 2.8 m from the white background, which had a luminance of 10 asb. At first the light difference threshold in the retinal centre was recorded five times in succession with a specified given size of test-mark by increasing the threshold determination. The test-point was then presented nasally at 22 points between 0 and 30 degrees eccentricity, using the threshold luminance found for the fovea. With the same size and constant luminance, the test-point at these eccentric points was of course of perceptible at first. At each point the size of the test-point was increased until it could be perceived with a constant luminance.

The alteration of test-point surface was done in steps of at least 0.01 log E. The smallest size of test-point was 2.29′ diameter, and the biggest 132′. The same experiment was carried out with four other constant test-point luminances. Five curves resulted as seen in Figure 1. In each case the five luminances were the threshold values of the test-point centre, obtained with the test-point sizes: 2.29 min, 3.20 min, 4.58 min, 6.41 min, and 8.71 min.

At the same time the examination data obtained in this way provide a contribution to spatial summation of the human retina. Our summation curves differ from most others represented in literature in so far as they are obtained centrally and paracentrally with especially small test-points.

Fig. 2 shows six curves obtained by the method described above. The

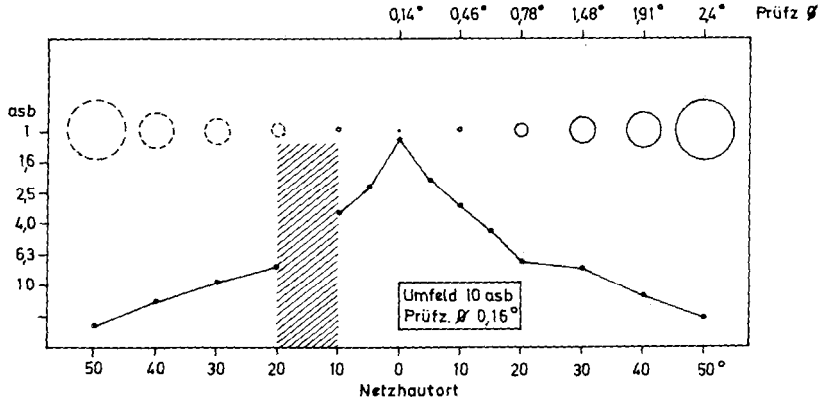

Fig 1 Comparison of the method of static perimetry by changing the test-point diameter with constant luminance (circles at the top) and the method of static perimetry with constant test-point diameter varying the luminance (curve below)

logarithm of the test-mark surface (angular minutes) on the ordinate is plotted against the retinal position on the abscissa. It can be clearly seen that, when using a constantly low luminance in all retinal areas, the curves show a steep course, but with higher luminances they show a flat course. All the curves have a steady increase of the test-mark surface necessary for the achievement of threshold.

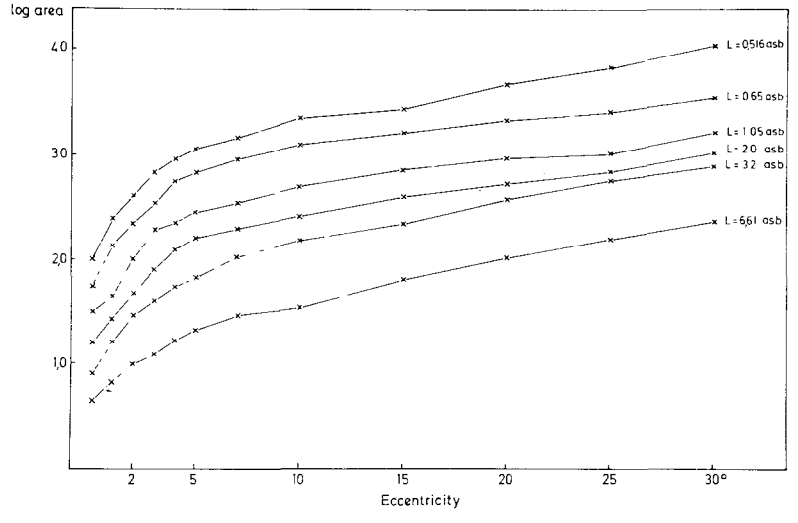

Fig. 2 Six curves gained with static perimetry by changing the test-point diameter with constant luminance Test-point luminance equals the threshold values of the test-point centre Logarithm of the test-point area (angular minutes^2) is plotted against retinal eccentricity

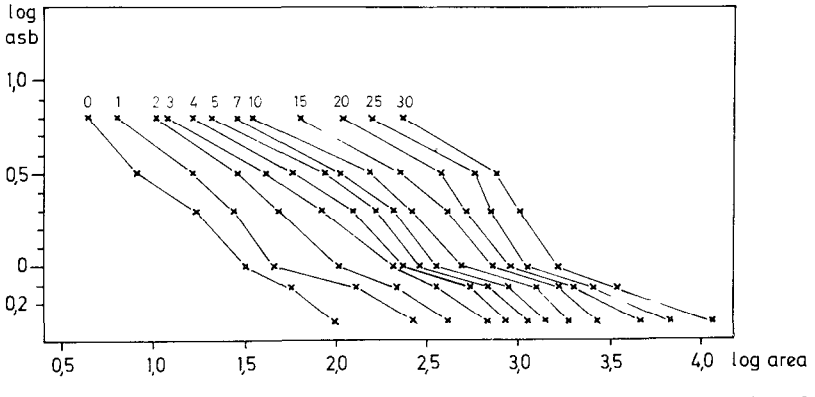

Fig 3 Summation curves gained from the values of the curves of Fig 2. Logarithm of the area is plotted against the luminance of the target

Fig. 3 elucidates the above with the plotted summation curves. For each retinal position the logarithm of the area is plotted against that of the luminance of the test-mark in angular minutes. From 0 to 3 degrees eccentricity there is an almost linear course of curve; in retinal areas lying more peripherally, a marked flattening of slope is registered as an expression of increasing summation areas.

To make a comparison of these resultas with those of static perimetry possible, using the Tübinger perimeter, the meridian values of the sensitivity curves of 20 subjects were used for a test-point diameter of 26 angular minutes. The threshold luminance required for the test-point size of 26 angular minutes was extrapolated from the summation curves shown in Fig. 4. The curve obtained in this way lies within the standard deviation of light difference curves and of the Tübingen merimeter, which may demonstrate the reliability of the present results.

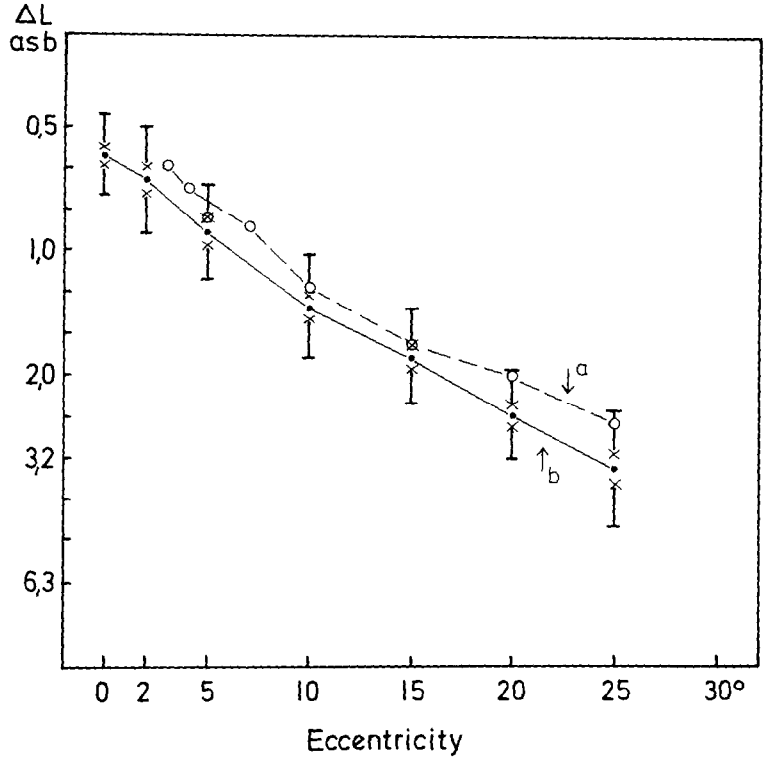

Fig 4 Comparison between the light difference threshold curves of 20 subjects gained with the Tübingen Perimeter
Curve b) with mean value and standard deviation. (Target size 26 minutes of arc.)
Curve a) shows extraapolated luminance values for a test-point of 26 minutes of arc from the curves of Fig. 3

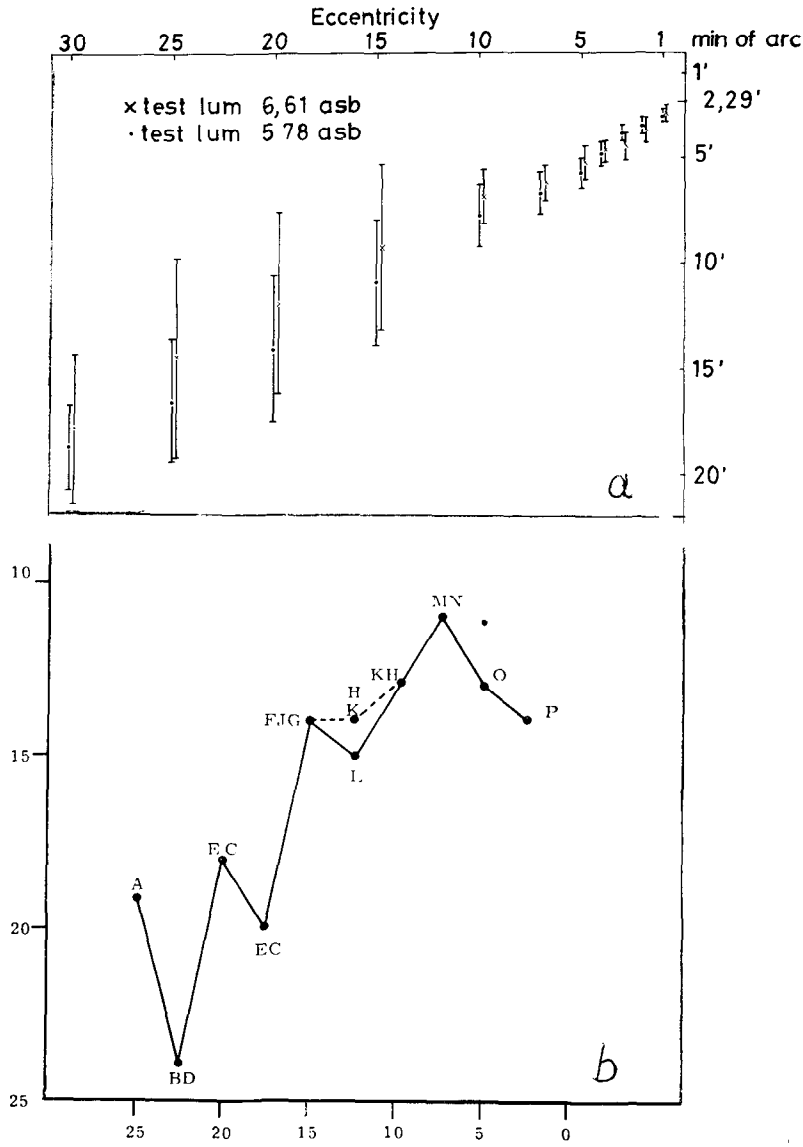

Fig 5a illustrates the continuous increase of the test-point diameter when using the method described

Fig 5b shows the interrupted increase in size of the test-points of the Friedmann analyser

For the multiple-stimulus methods the results of our experiment show that the increase in size of the test-points towards the periphery of the test-field must be chosen continuously according to the recorded progression (Fig. 5a and 6). An interrupted increase in size, as chosen for the Friedmann Analyser, could possibly influence the results of the experiment.

SUMMARY

Basically static perimetry can be performed in two different ways, either by changing the luminance and keeping the size of the target constant or by changing the size of the target and keeping the luminance constant. In the clinical application static perimetry is usually performed by changing the luminance and keeping the size of the target constant For physiological reasons, however, the second method seems to be valuable too, because the increase of the size of the target towards the periphery has a closer correlation to the increase of the receptive fields towards the periphery. In this paper for static perimetry the necessary increase of the size of the target while keeping its luminance constant is shown by the results of 5 sound-test persons.

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KINETIC PERIMETRY WITH SUPRA-THRESHOLD STIMULI

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Kinetic perimetry with supra-threshold stimuli may be used in two ways. either for the evaluation of the threshold of perception by asking the patient to report when the stimulus disappears (Frisén, in press), or for the assessment of qualitative changes in sensation of supraliminal stimuli (Chamlin, 1949; Frisén, 1973).

The first method has two advantages over static perimetry: the sensitivity is higher, as shown by the perimetry of angioscotomata In patients with good responses scotomata as small as 10-20′ may be picked up. The testing, on the other hands, is easy and quick. For the hemispheric perimeter a white target of 10′, 0.3 to 0.6 log unit above threshold, moved evenly at a rate of 2-3° per second, was found to be optimal. Applied in this way the evaluation of a whole meridian takes no longer than about 20 seconds. For confrontation perimetry the sensitivity of this procedure is lower.

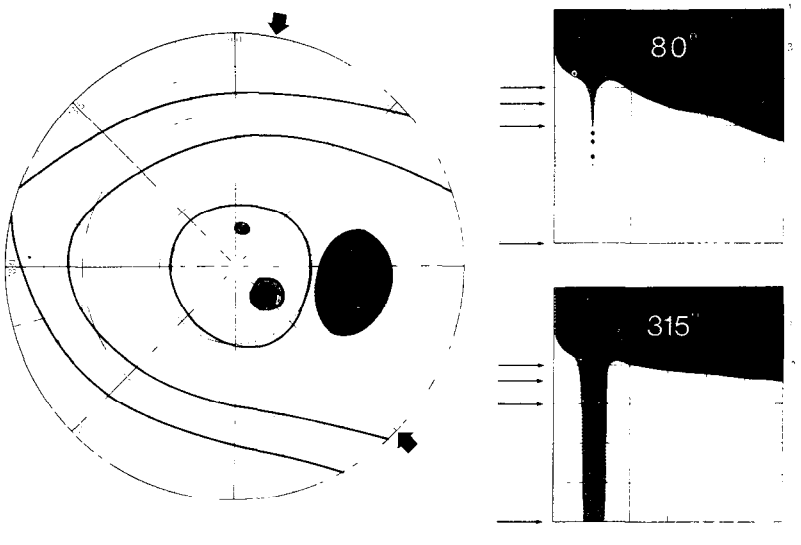

Fig. 1 An absolute and a tiny relative scotoma caused by two chorioretinal scars following Xenon- and Argonlaser treatment of a recurrent central serous retinopathy Both scotoma were detected easily by a supraliminal moving target

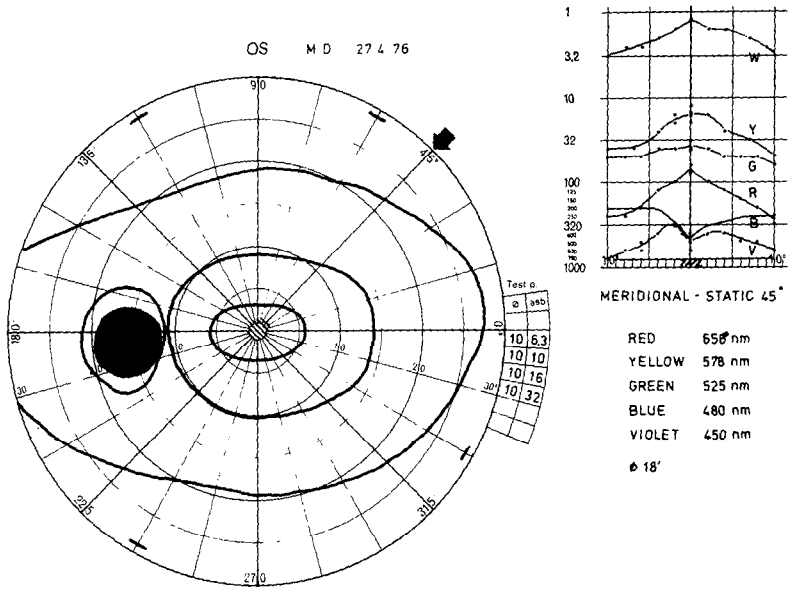

Fig 2. A discrete central scotoma of retrobulbar neuritis Kinetic perimetry is normal, static perimetry shows a central dip in the meridian for blue and violet only. The subjective alteration of sensation of supraliminal stimuli moved meriodinally across the center is present both for white and all colors, and was most pronounced for blue and violet.

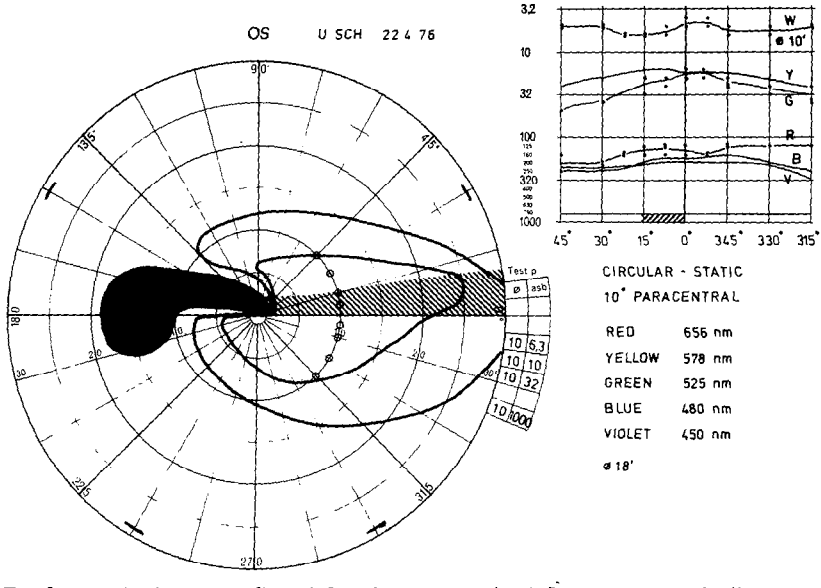

Fig 3. An absolute nerve-fiber defect due to an optic pit In a narrow band adjacent to the nasal horizontal a white or colored supraliminal stimulus moved in circular direction appears pale, blurred and faded. Kinetic and static threshold perimetry, however, is not affected in this area even for different colors.

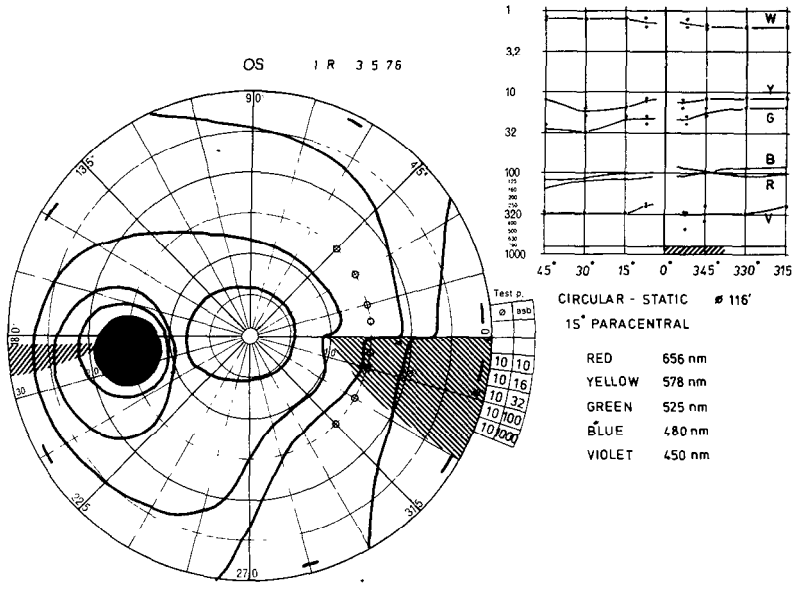

Fig 4. A visual field in chronic glaucoma with a nasal temporal sector in which supraliminal targets appear altered, whereas kinetic perimetry reveals only a discrete nasal step, static perimetry for white and different colors look quite normal. In this case a nasally extending cup correlates well with a sensoric disorder in the temporal field

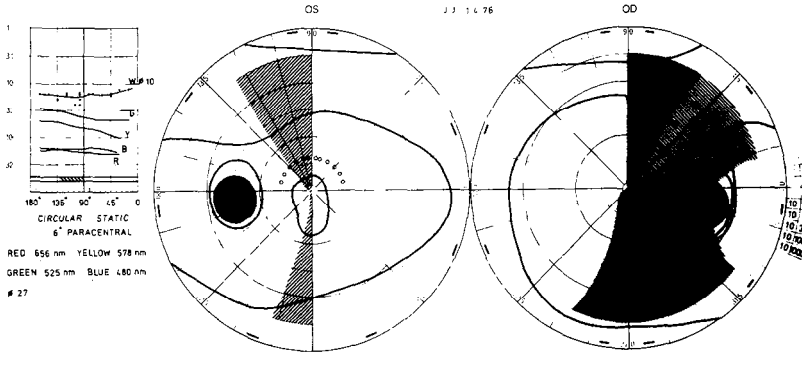

Fig 5 A uniocularly affected right field of a chiasmal syndrome In the left eye, except for an increased scatter, kinetic and static perimetry with white and colored stimuli showed no definite disorders. The supraliminal target, however, disclosed the sensoric disturbance in the left eye (The chiasmal syndrome is discussed elsewhere (Dannheim, this volume)

The example in Figure 1 is chosen from about 250 visual fiels, all plotted with a Tübingen- or a modified Rodenstock Perimeter.

Changes in sensation of supra-threshold stimuli in pathological areas of the visual field usually affect the sensation of brightness and contour as well as the saturation of colors. The majority of patients are more aware of the disturbance when colored stimuli of 20-120′ are presented. Blue is preferentially changed in central scotomata whereas red is often more affected than other colors in paracentral defects of the optical pathways (Frisén, 1973).

In Figures 2-5 the areas of disturbance of sensation of the supraliminal stimuli are hatched.

The method described in this paper is only rewarding in patients with steady fixation and good cooperation.

SUMMARY

A supra-threshold moving target is suitable for rapid detection of small scotomata. It may furthermore reveal disorders of sensoric functions which cannot be found by static and kinetic perimetry. Colored stimuli may be superior to white ones.

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DIFFERENTIAL KINETIC THRESHOLDS ACCORDING TO TEST-LUMINANCE ON THE INFERIOR TEMPORAL MERIDIAN AT THREE BACKGROUND LUMINANCES (PHOTOPIC, MESOPIC AND SCOTOPIC)*

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Differential kinetic thresholds at different test-luminances were studied on the inferior temporal meridian (315° for the right eye, 225° for the left eye) at three background luminances

- photopic · 1 asb.
- mesopic . 0.063 asb.
- scotopic · 0.0004 asb.

APPARATUS AND METHOD

The apparatus used was 'The Universal Explorator of Luminous Sense of Jayle and Blet', described in previous works (Jayle 1960)

Test-object the size of the object used in this experiment was an average angular value of 6′ for the photopic and mesopic backgrounds and 24′ for the scotopic background, corresponding to object I and III of the Goldmann perimeter.

The speed of the test spot was 5°/sec. and the movement was manual. The brightness of the object superimposed on the background was varied by steps of 0.2 log. unit.

Subjects 48 subjects, young males (20-25 years of age) with a normal ocular apparatus. Before the experiment, each was subjected to a dazzling light preadaptation for 3 m and to dark adaptation for 30 m.

EXPERIMENT

Recording of differential thresholds on the inferior temporal meridian

The localized differential thresholds were studied with an object of constant size and variable luminance. At first, the object was moved from non-seeing to seeing areas along the meridian from periphery to centre with a subthreshold brightness. Then, if it was not perceived at all, the brightness was increased by steps of 0.2 log. unit until it was perceived at a point close to the centre. After three consecutive positive answers, the threshold was considered as established. Its position was noted on the chart. Luminance

* This paper is an homage to our Director in Marseille, Professor Jayle, who conceived this work before his retirement

was increased again by 0.2 log unit and a second point was established in the same way as before, and so on up to the periphery.

INTERPRETATION OF RESULTS

A. Average results

The mean variations of thresholds are represented by 3 curves (Fig. 1): photopic, mesopic and scotopic have been placed arbitrarily on the same graph by means of a scale of 0.2 log. unit, x corresponding to the lowest luminance perceived. The shape of these 3 curves is nearly the same. The slope is approx. 0.2 log. unit per 10°. The object used in this experiment was supraluminal for the central area, and this is why only one threshold was checked near the centre.

In order to compare the three curves with those of various authors, they were plotted in a semi-logarithmic graph (Fig. 2) with increment thresholds (ΔL) expressed in natural numbers.

Between 12° and 60° the slope is nearly linear. At the periphery the gradient of thresholds drops more rapidly. Near the centre, the mesopic and scotopic curves are flatter, but the general shape of the 3 curves does not

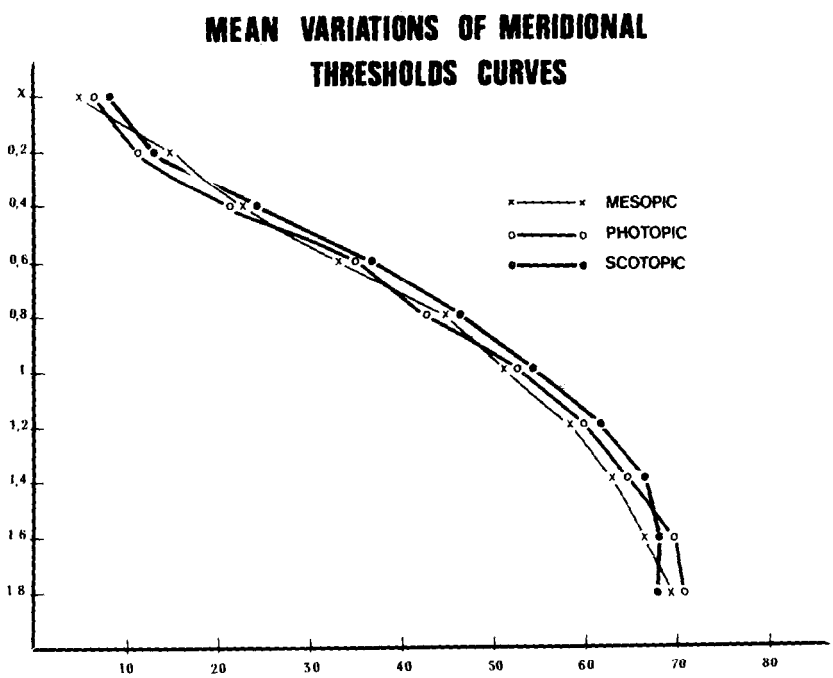

Fig. 1 Curves of mean values of meridional thresholds at 3 background luminances Ordinate: log. increasing luminance: x : less luminous perceived luminance 0, 2, 0, 4 .. log. unit of which x is increased. Abcissa: excentricity.

show any flat part as found by some authors in static perimetry. Statistical analysis showed no significant difference between the shape of the curves at the three background luminances except for the lowest perceived luminance, for which the mean meridional threshold points at mesopic and photopic backgrounds are, respectively, found at 5° and 5.70°.

In the middle part of the curves, the gradient of the thresholds appears linear and the differences of the corresponding mean threshold points on the three curves are no more than 1°.

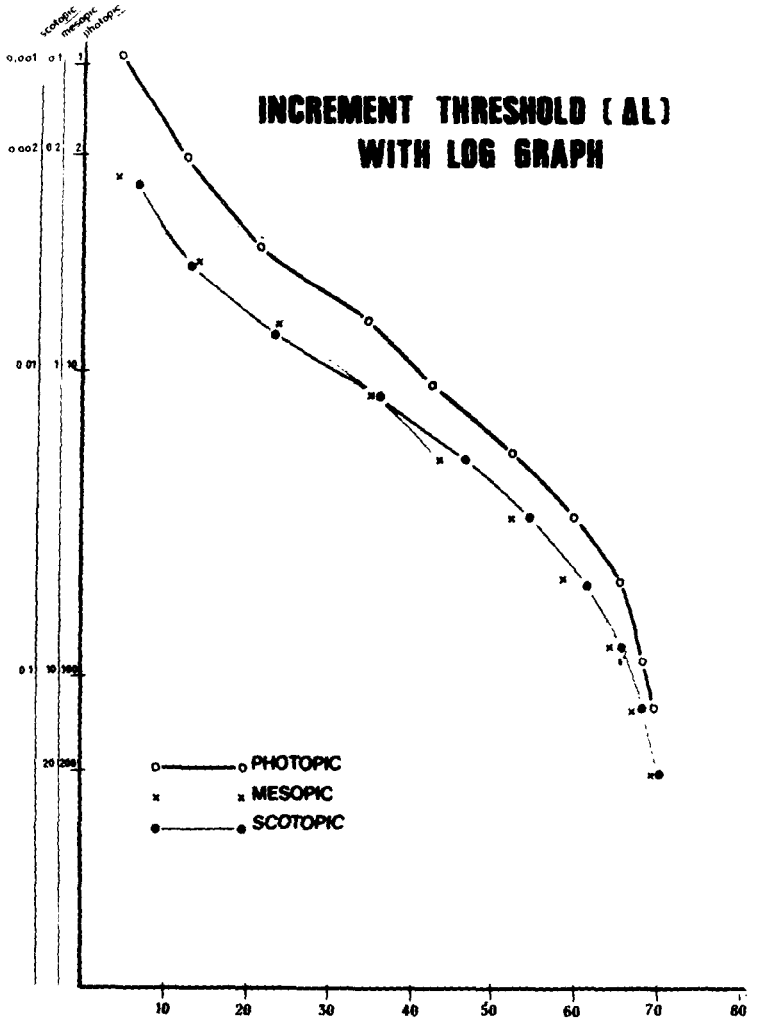

Fig. 2 Curves of mean values of increment thresholds (ΔL) expressed in natural number and plotted on a semilogarithmic graph. Ordinate: object brightness at different backgrounds

B. Standard deviations (Fig. 3)

For the three background luminances the standard deviation increases from centre to periphery to about 50°. Thereafter, it decreases. Standard deviations are large from 20° for mesopic and photopic backgrounds: 7°22 and 8°19, respectively. They are larger for the scotopic background: 9°97.

C. Individual results (Fig. 4)

Central area: the average curves do not represent the individual threshold variations exactly, especially in the central area.

At photopic background luminance, the less luminous test spot (2 asb.)

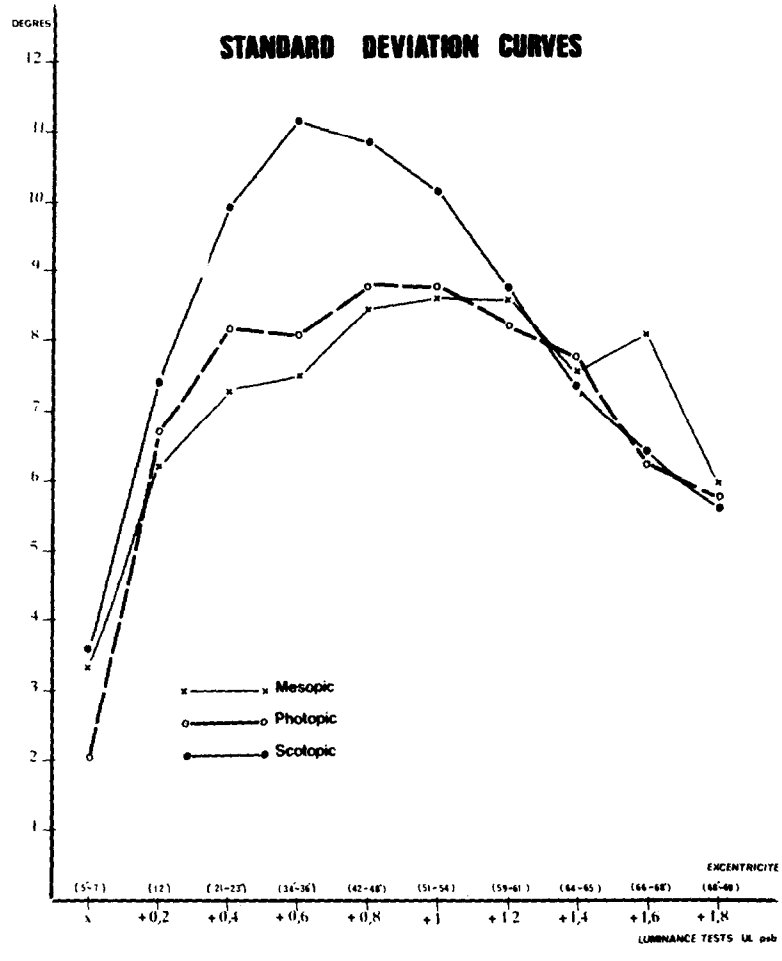

Fig. 3. Standard deviation curves.

is perceived at 5°74 by 34 subjects out of 48, and the 14 other subjects, who cannot see the test spot in the central area at that luminance, perceive it in this area if its brightness is increased by 0.2 or 0.4 log. unit. Some perceive it at, e.g., 10°. This finding is more definite at the mesopic level, as shown in Figure 4. At the scotopic level the phenomenon is more conspicuous.

Periphery· The threshold decreases abruptly between 60° and 65° with the brightest luminance and with the chosen size of object for each background. Individual curves show that the number of subjects reaching a threshold at 75° diminishes rapidly after 65°. Some subjects cannot perceive the object further than 60° even if the luminance is increased.

DISCUSSION

The shape of the photopic curve is the same as the kinetic threshold curves found by various authors. For Dubois-Poulsen & Magis (1960), Fankhauser & Schmidt (1957), Matsuo et al. (1965), the slope of the photopic curves is

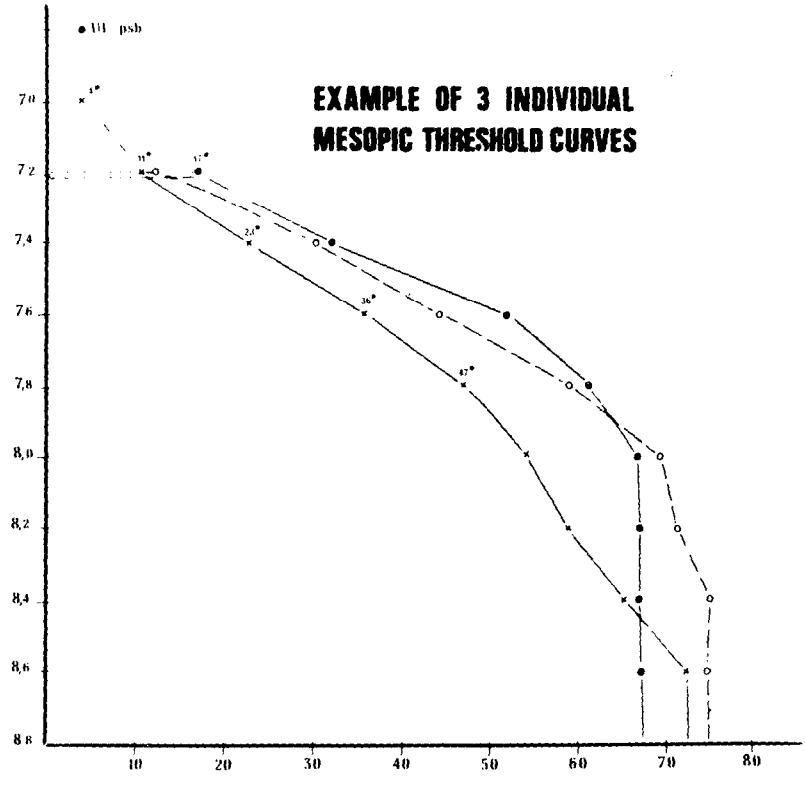

Fig. 4 Example of 3 individual mesopic threshold curves. Ordinate: luminance values in log. unit picostilb. Abcissa: excentricity

about 0.2 and 0.3 log unit per 10° according to the different object areas used.

In 1954, Goldmann found a flat kinetic threshold curve between 40° and 0° with an object of 4 mm² at a mesopic background luminance of 0.05 asb. In our experiment, the object area was 0.56 mm² at mesopic background (0.06) and this size accounts for the slant of the mesopic curve.

The choice of the three object sizes has been based on previous works by Jayle concerning 'equivalent isopters' and made it possible to obtain the three equivalent curves with the same slope. If criticism of mesopic kinetic perimetry depends on the flatness of a threshold curve, the slopes of our mesopic and scotopic curves are comparable with photopic curves found by us and by other authors; consequently, kinetic mesopic and scotopic perimetry are available.

For scotopic perimetry, however, the dispersions are too large for clinical use. For mesopic perimetry, the dispersions are nearly the same as those of photopic kinetic perimetry, even slightly better.

Individual curves show variations in the central area at photopic background as well as at mesopic background. Variations are larger at mesopic background but the general slope of the curves does not change. Also, in clinical examination it is recommended to compare for each subject the thresholds along a visual field between them rather than to a curve obtained by average results of normal subjects as was shown by Harms & Aulhorn (1959) (Fig. 5).

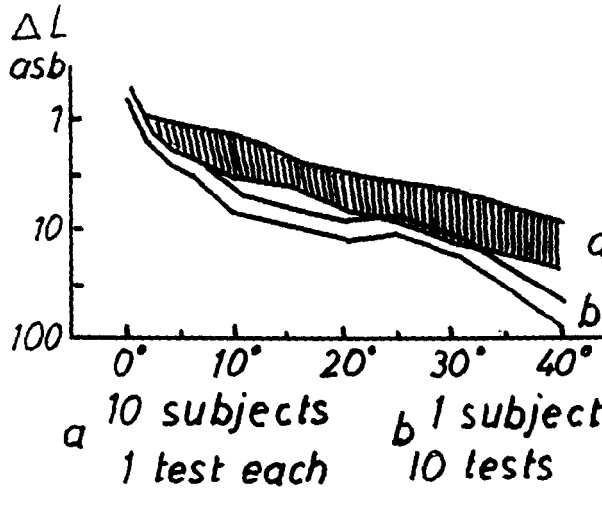

Fig. 5 (Harms & Aulhorn). Difference between two curves:
a: 10 subjects, 1 test each
b: 1 subject, 10 tests.

CONCLUSIONS

It is clear that at different adaptation levels the gradient of increment thresholds checked in suitable conditions is the same, and does not present any flatness between 12° and 60°. In the central area great variations occur both at the photopic background and at the mesopic and photopic backgrounds. Dispersions are better in the central area and larger in the intermediate part of the curve. Therefore, it is necessary to consider the spacing of isopteric points for each subject, in other words, the ratio of this different isopter's sensitivity at different adaptation levels. Steps of 0.2 log. unit brightness and a size of 6′ of the object are too big to explore the central area.

The mesopic background level is reliable, but the scotopic is not, because of the importance of dispersions.

SUMMARY

Study of kinetic differential meridian thresholds with a constant size and variable brightness of a test object at three luminance backgrounds: photopic 1 asb., mesopic 0.063 asb. and scotopic 0.0004 asb.

Gradient threshold curves have the same shape and the same slope with an object of 6′ for photopic and mesopic backgrounds and 24′ for scotopic background.

No flat part was found in the curves except near the centre where inter-individual differences are numerous. At the three backgrounds, dispersions were larger in the intermediate part of the field (from 12° to 60°) so that, to appreciate the gradient of sensitivity, it is necessary to compare several isopteric points at different adaptation levels in the same subject. At scotopic background, dispersions are too large for clinical use, but at mesopic background, the slope of the curve and the dispersions are almost the same as those at photopic background and permit the rejection of criticism of this method.

ACKNOWLEDGEMENTS

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INTRODUCTION

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In the usual form of examination of the visual field we are looking for some organic interruption in the visual pathway of one eye. Since the visual fields of both eyes overlap and in order to avoid binocular rivalry, perimetry is generally carried out as a monocular examination. The absolute or relative scotomas diagnosed by this method are usually irreversible by nature or are only capable of regression in a long healing process. Successful diagnosis is principally independent of the method of examination and of the way in which the test stimulus is presented.

Apart from these organic deficiencies there are also functional scotomas which, however, only occur under certain conditions of seeing. In this category we include, for instance, the monocular decrease in function at luminance-borders and, most important, vicarious scotomas during binocular rivalry, whereby inhibitions in one eye are caused by various stimuli in the other. As you know, in cases of disturbed binocular vision such functional scotomas play a particularly important part in preventing diplopia. Studying this image inhibition in cases of strabismus, known as suppression, enables the researcher to obtain further knowledge of the working of the visual cortex in an experiment designed by Nature.

By testing suppression the ophthalmologist gains insight into the individual mode of vision of his squinting patient. This allows him to draw important conclusions for the prognosis and, besides that, to test the success of his treatment. Furthermore, in order to judge suitability for certain jobs, in particular suitability for driving, the doctor needs as detailed data as possible on the field of vision of both eyes during binocular vision.

Up to now, the type of examination for determining the visual field of squinting patients used to be carried out under conditions mostly quite different from those found in everyday situations. In particular, the fusion stimuli in the whole of the visual field, always present under normal conditions, are neglected by most writers on this subject Moreover, the routine sensory tests on squinters cover only the circumscribed area of binocular visual field around the fixation point of the dominant eye.

It would take too long to compare in detail here all results gained so far from examinations using the various methods. A brief survey shows, however, that in some cases individual authors have ascertained very differing extent and intensity values of the inhibited areas. Thus, for instance the high

rate of anomalous binocular fusion in Bagolini's horopter experiments is difficult to reconcile with the large regional suppression zones determined by other methods.

It seems desirable, therefore, both from a scientific and a practical point of view, to examine once again the function of the fixing and of the squinting eye in the whole visual field during binocular vision. Not only should modern techniques be used which take account of normal conditions but, for comparison, also methods which are more dissociating. In this way we shall perhaps be able to better understand the image-suppression mechanism. A comparative study of the various forms of squint could also be useful in this field.

We know very little about the sensory changes in the peripheral binocular visual field after squint operations. Corresponding evaluations of such cases could perhaps show us, particularly in the many incurable cases, to what measure an acceptable binocular co-operation, at least at the periphery, can be achieved after a reduction of the angle of squint. I believe it would be a sensible measure to investigate all these questions according to a common plan within a research group.

In the following papers Dr. Campos and I shall report on some results in this interesting field of research.

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PERIMETRY OF SUPPRESSION SCOTOMAS WITH PHASE DIFFERENCE HAPLOSCOPY

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In a sensory examination of patients with strabismus without diplopia, we can find two different adaptive mechanisms to the deviation of their eyes: suppression and anomalous correspondence. While in the case of normal correspondence the impressions of the squinting eye have to be completely suppressed in order to avoid diplopia, an anomalous correspondence that has been adapted to the motoric deviation allows, at least theoretically, an extensive cooperation of the squinting eye during the act of binocular vision.

The examination of the visual field of one eye during the act of binocular vision of a squinting person, i.e., the haploscopic perimetry, should, therefore, reveal major suppression in cases of patients with normal correspondence, and less suppression in cases of patients of anomalous correspondence. From the studies of other authors, however, we know that it is usually impossible to detect suppression in cases of normal correspondence under haploscopic conditions, whereas in almost every case of anomalous correspondence a regional suppression can be found. Harms (1937) even concludes from his results that the existence of a regional suppression can be proof of anomalous correspondence.

We have done some more research on the interaction of both adaptive mechanisms with haploscopic perimetry for various forms of squint and using a variety of examination techniques. In order to separate the images of the two eyes we made use of the principle of phase difference haploscopy (Aulhorn, 1967). All examinations were carried out at a distance of 1.43 m from a projection screen. The tested section of the visual field had a diameter of 60 degrees. The following methods of examination were possible with the projectors used:

1. Binocular or haploscopic threshold perimetry with moving or stationary test-point. In addition, a binocular fusion pattern could be offered.
2. Presentation of a monocular, continuous stimulus with a large surface area. Here we used a grid pattern as used by Lang (1973) for his examinations of microtropia. The persons examined have to indicate which parts of the monocularly offered pattern are not seen under binocular conditions. We have called this method 'Rasterskotometrie': this means that we are able to find out the position and extent of scotomas using a regular pattern.
3. Presentation of a retinal rivalry pattern with image differentiation by means of different contours.

50 patients without spontaneous diplopia, mainly with considerable deviations and anomalous correspondence were examined. As expected, the results depended to a great extent on the examination technique. I should like to give you, therefore, the main results of the examinations, grouped according to the method used.

When haploscopic perimetry with a moving testpoint was used, scotomas of the deviated eye could almost always be detected in the area of the fixation point. Extent and intensity of the inhibition, however, could not be proved, because the limits of the scotoma could not be reproduced. Outside the fixation point area no suppression could be detected, so that binocular perimetry, in which the test point is presented to both eyes, always reveals two maxima of light difference sensitivity.

When a stationary stimulus was haploscopicaly offered, no case of greater diminution of the light difference sensitivity could be detected.

On the first graph (Fig. 1) you can see the haploscopicaly determined light difference sensitivity of both eyes of a patient with strabismus divergens. The curve of the left fixing eye is marked by a broken line, the curve of the right squinting eye by a single line. The dotted line shows the light difference sensitivity of the right eye, established by a monocular examination. On the x-axis you can read the angle of squint, which in this case is 20 degrees.

The second graph (Fig. 2) shows the profiles of a patient with strabismus convergens and amblyopia of the left eye. Even the deviated eye showed, under monocular as well as binocular conditions, the same light difference sensitivity accompanied by a central depression which is characteristic of amblyopia.

In contrast to the results gained by means of these classical perimetric methods we found, when we used the monocular presentation of a grid pattern, easily reproducible areas of inhibition which showed a characteris-

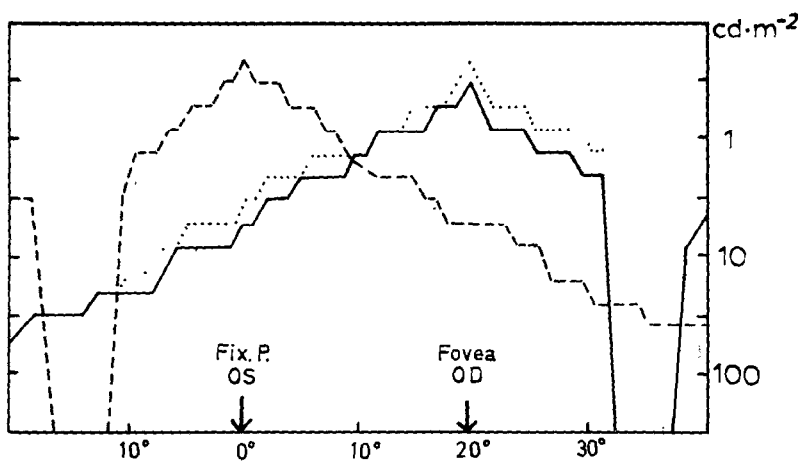


Fig 1 Haploscopic profile perimetry —— fixing OS; ——— deviated OD . OD monoc.

tic extent and positions of the form of squint in question.

Graph 3a (Fig. 3a) presents the fixation point scotoma of the deviated right eye within the circular test area in a case of strabismus convergens. Even if the patient changes the fixation from the left to the right eye, without altering the position of his eyes, the scotoma is still in the area of the center of the visual field of the deviated eye (Fig. 3b).

Such localized inhibition areas in the temporal visual field can be found in most cases of strabismus convergens. In cases of divergence the scotoma generally occupy a large part of the nasal half of the visual field of both eyes. In the following example we examined the left eye, once during the squinting situation, and once during fixation (Fig. 4a, b). In both cases we find a large inhibition area which has a vertical limit on the homolateral side. The centre of the visual field of the second eye is included in both cases.

The fact, that a good reproduction of the regional suppression is possible by means of the described scotometry shows that the form of presentation of the monocular stimulus is particularly important for the proof of suppression. A constant stimulus is apparently suppressed more often than a stimulus which changes in intensity or position during the test.

While with scotometry we define those parts of binocular visual fields where no binocular vision exists, the participation perimetry or the examination with a constant retinal rivalry pattern enables us to obtain information on those areas of the visual field in which binocular cooperation might be possible.

Graph no. 5 (Fig. 5) shows the data of a patient with strabismus convergens to whom we presented retinal rivalry patterns with horizontal and vertical contours, respectively. In the right half of the test field the left eye dominates, in the left half the right eye.

Only within a relatively narrow area between the points which are pro-

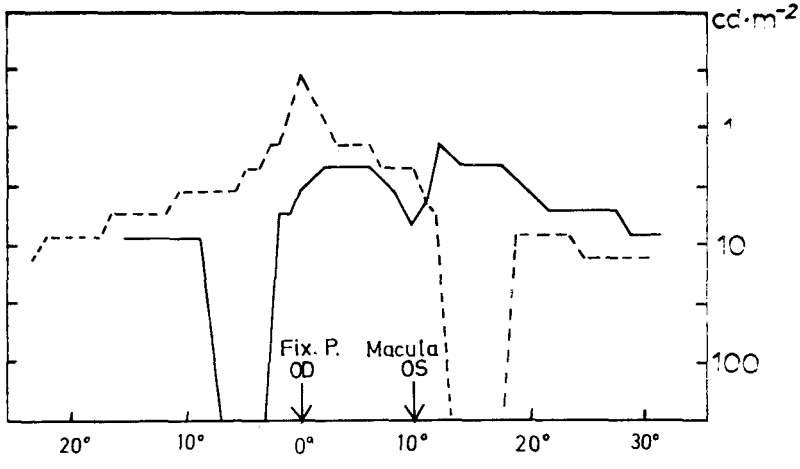
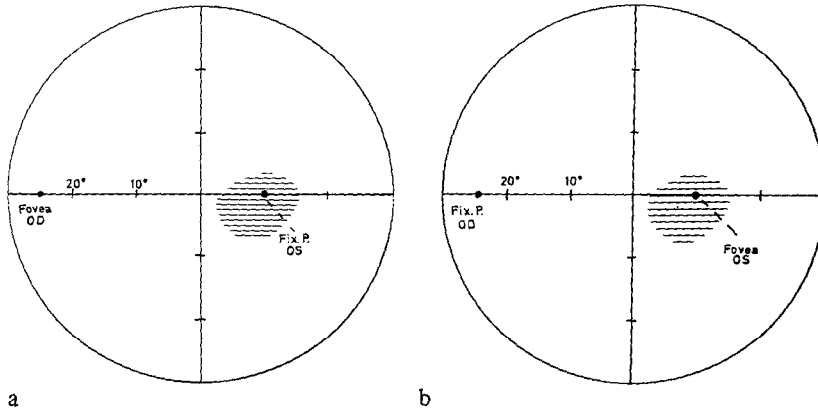
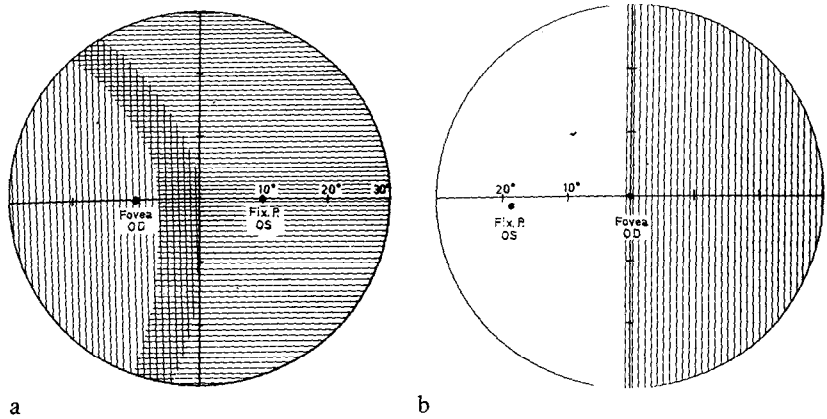


Fig 2 Haploscopic profile perimetry ----- fixing OD; deviated OS (amblyopic)



a b

Fig 3. Scotometry of the right eye. Strab. conv., HARC a) right eye is squinting; b) right eye is fixing.



a b

Fig. 4 Scotometry of the left eye Strab diverg ; DARC. a) left eye is squinting; b) left eye is fixing.

jected on the maculae, can retinal rivalry be observed. We assume, therefore, that the binocular visual field of a squinting person with considerable deviation and anomalous correspondence is largely composed of two monocular parts. Hereby we can observe a very useful phenomenon. of the two monocular pictures of an object only the one is used that falls on a retinal point with a higher functional value than the corresponding retinal point of the other eye. A binocular interaction comparable to normal vision would then only exist where the images fall on parts of the retina with similar functional levels.

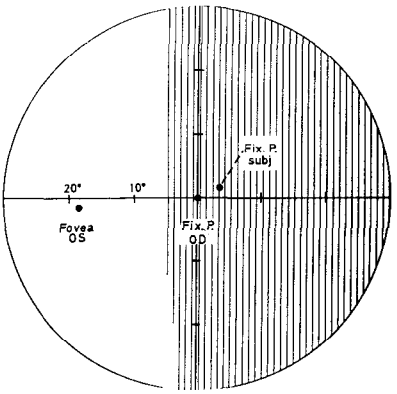


Fig 5 Areas of dominance in the binocular visual field using dissimilar contures. Strab converg ; HARC.

SUMMARY

Patients with strabismus convergence and divergence without diplopia were examined under haploscopic conditions with a special projector device. The perimetry was done primarily with a kinetic and a static stimulus of 5 or 10 min of arc to measure the intensity of suppression. In a second test we used a grid pattern of 60 degrees in diameter as a continuous stimulus for the examined eye, while the other eye was exposed to a white background only.

The examinations revealed that the method of stimulus presentation had a strong influence on the light difference sensitivity. With static stimulation there was no real demonstrable suppression. With a moving stimulus we usually found a 'Fixation Point Scotoma' at the subjective position of the fixation point. The extension and intensity of the scotoma during the examination decreased and was strongly dependent on the velocity of the stimulus movement. When the steady grid pattern was presented we found constant areas of suppression which were absolute for the given stimulus.

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BINOCULAR CAMPIMETRY IN SMALL-ANGLE CONCOMITANT ESOTROPIA

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The von Graefe technique for binocular visual field (b.v.f.) examinations in strabismic patients makes use of a red filter placed before the fixing eye and a white light source which is presented perimetrically. With this method, the central area of the deviated eye, where the patient saw only one red light, was interpreted as area of suppression, while in the periphery there was mainly diplopia.

Accordingly, suppression was traditionally considered as the only antidiplopic mechanism effective in strabismic patients. Fairly recently, however, Bagolini showed, by means of an horopter apparatus suitably arranged for the control of binocularity, that in small-angle esotropia the main anti-diplopic mechanism is anomalous retinal correspondence (a.r.c.) in the sense that a change in spatial localization in the deviated eye allows a sensorial fusion (of anomalous type) of two retinal images, rather than a suppression of one of them. Suppression prevails in large-angle deviations. These findings are obtainable if fusionable stimuli are used as test-targets.

Bearing in mind these results, we performed b.v.f. examinations with the von Graefe technique. We tried to verify the existence of a binocular cooperation i.e. a binocular single vision of anomalous type in small-angle esotropia.

METHOD

We selected 5 patients with non-alternating esotropia, ranging from 6 to 20 prims diopters. All had particularly deeply-rooted a.r.c. tested with Bagolini's striated glasses: diplopia was obtainable with red filters denser than n. 9* of Bagolini's bar.

Perimetrical examinations were carried out with a white stimulus, 1.5° diameter, 2000 asb intensity as test-target (Fig. 1). One meter in front of the patient there was a white tangent screen as background, 10 asb intensity, in the middle of which there was a black fixation point, 1° diameter. For practical purposes a tangent screen at the distance (1 m) we used, can

* Red filters of increasing density have an increasingly dissociating effect; they are therefore useful for evaluating how deeply rooted an anomalous sensorial situation is

be considered as overlaying the fronto-parallel plane. This means that in a normal person all kind of fusionable stimuli presented on it are perceived singly and binocularly.

Experiment 1

Patients with a red filter before the fixing eye were asked when they could see only one red or one white light and also when they could see both together (i.e. when there was diplopia). The areas in which a single stimulus was seen, were then mapped.

Experiment 2

Patients wore a red glass on the fixing eye and a striated glass on the deviated eye. With red filters it is not always possible to distinguish an area of suppression from an area of anomalous binocular vision.

Accordingly, we also used a striated glass in order to check for binocu-

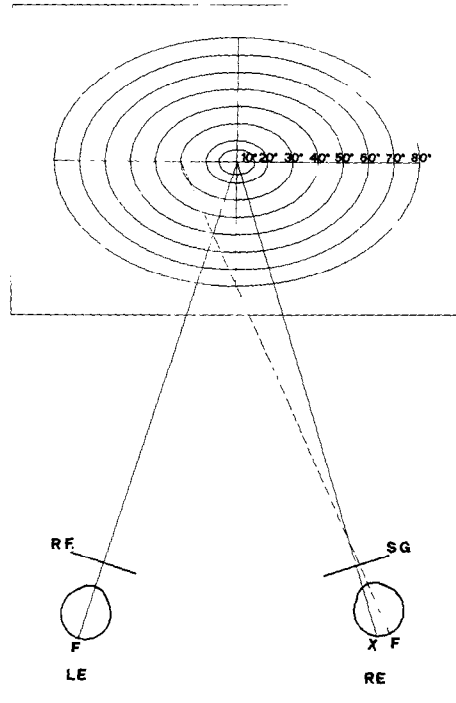

Fig. 1 Experimental set-up. In the case of an esotropic patient with anomalous retinal correspondence of harmonious type, the spatial value of the fovea (F) of the deviated eye (RE) is obtained by an extra-foveal area X. The patient fixes the center of a white tangent-screen, 10 asb intensity, wearing a red filter (RF) before the deviated eye and a striated glass (SG). The test-target (a white stimulus 1° diameter, 2000 asb intensity) is presented perimetrically. The areas of single vision are then mapped.

larity, that is, to find out whether a single perception is related to suppression or to binocularity. Patients had to indicate: a) when they saw a reddish light with a streak across it (superimposition of the images), b) when the streak disappeared (suppression) or c) when they saw a red and white light together, the latter with a streak across it (diplopia). The results were noted. In experiments 1 and 2, all patients were examined perimetrically with three red filters of different intensity: the densest filter was approximately two units lighter than that which provoked diplopia with Bagolini's bar.

Experiment 3

All patients were examined perimetrically and were wearing before each eye a striated glass, without red filters. They had to look at the fixation point and say whether the test target, which was moved perimetrically, was perceived as a light with two streaks across it (superimposition), as a light with one streak only (suppression), or as two lights, each with a streak across it (diplopia).

RESULTS AND CONCLUSIONS

1) All the patients in question exhibited a central area with no diplopia. The area, which was mapped with the use of a red filter only (see Figure 2, continuous line) was as extensive as that tested in Experiment 2 (in which a red light with a streak across it was perceived), and which is indicated by a dotted line in the same Figure.
2) These findings indicate that the area of single vision was an area of binocular vision and not of suppression. In fact, the light stimulating the deviated eye is perceived in the same directional localization as that perceived by the fixing eye, as can be deduced from the image of a streak

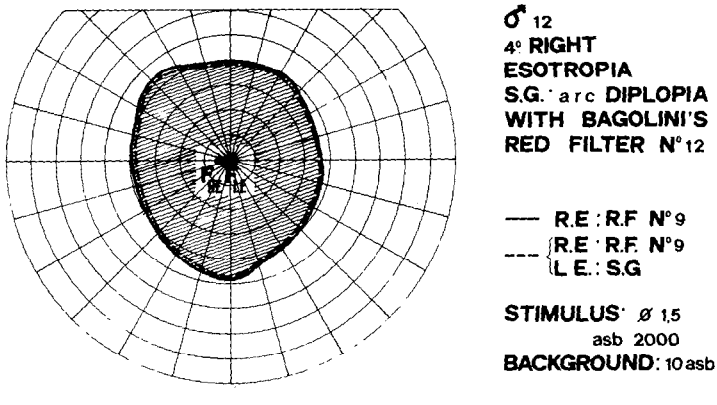

Fig. 2. The area of single vision obtained when using only a red filter (delimited by a continuous line) is the same breadth as that obtained when the patient wore a red filter before the fixing eye and a striated glass before the deviated eye. That is to say that in this area of single vision there is anomalous binocular vision and not suppression.

produced in the deviated eye by the striated glass. There is, therefore, a superimposition of the images of the two eyes, in spite of the deviated eye.
3) Hence we were able to confirm in a two-dimensional situation the existence of areas of binocular single vision, albeit of anomalous type, with a b.v.f. technique. These results are only obtainable using fusionable stimuli as test-targets. Other b.v.f. techniques which employ non-fusionable stimuli provoke retinal rivalry and hence favour suppression.
4) The cooperation (i.e. sensory fusion) between the two eyes could not be observed unless a test for binocularity was performed. For this reason we found an anomalous binocular vision in those areas in which previous authors thought there was always suppression.
5) Experiment 3 showed that the striations of the glasses could only be perceived within an arc of 30°; outside this limit the patients experienced difficulty in observing them. Within the abovementioned area there was always an anomalous binocular single vision. This means that, with the striated glasses, the area of binocular vision was much broader than with the red filter, and perhaps even included the whole visual field.
6) However, when red filters of increasing density were used in the course of experiments 1 and 2, the areas of binocular vision were seen to decrease in size. This is shown quite clearly in Figure 3.
7) In our opinion, this decrease is due to the dissociating effect of the red filters. It is likely that in esotropic patients the anomalous sensorial situation, i.e. the a.r.c., is presumably more deeply rooted in the center than in the periphery of the visual field. This is borne out by the fact that we can disrupt a.r.c. inducing-diplopia much more easily in the periphery than in the center of the visual field. We can, however, always find a filter dense enough to provoke diplopia not only in the periphery but also in the central part of the visual field. We would point out that across the binocular visual field of strabismic patients there are different degrees of sensorial adapta-

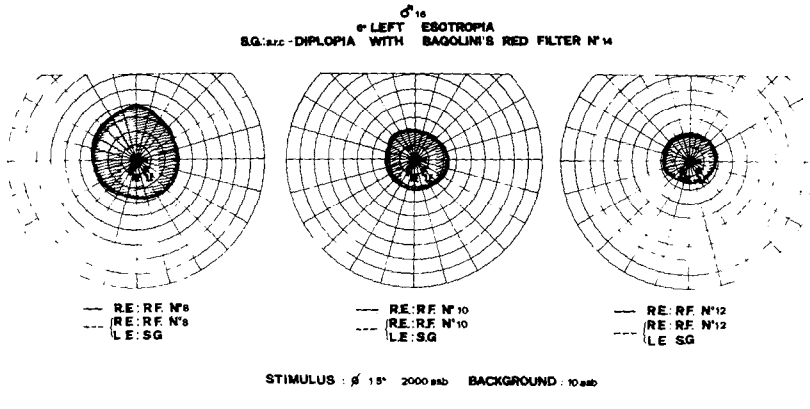

Fig. 3 With the same patients, three red filters of increasing density were used. The denser the filter, the narrower the area of anomalous binocular vision. The sensorial anomaly (anomalous retinal correspondence) is therefore more deeply rooted in the center than in the periphery of the visual field.

tion. Perhaps a more efficient antidiplopic mechanism is needed in the center rather than in the periphery of the visual field.

8) In conclusion, in the campimetric region observable using a tangent screen, there is, in patients with small-angle esotropia, an anomalous binocular vision over the whole visual field. The areas of single vision that one finds with the von Graefe technique in these cases are not always areas of suppression, but areas in which diplopia is eliminated by an anomalous cooperation between the two eyes.

SUMMARY

A red filter before the fixing eye, according to the von Graefe technique, was used for performing binocular visual field examination in patients with small-angle concomitant esotropia. In order to check for binocularity, that is, to find out whether a single perception is related to suppression or to binocularity, a striated glass was also anteposed to the deviated eye. It was shown that the area of single vision was an area of binocular vision and not of suppression.

Furthermore, it was possible to demonstrate that the anomalous sensorial situation, i.e. the anomalous retinal correspondence, is more deeply rooted in the center than in the periphery of the visual field.

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SUMMARY OF SESSION VII: FREE PAPERS ON SQUINT

V. HERZAU

As you have heard we are inaugurating a new RG for binocular perimetry. The main purpose of these group should be to learn more about the mode of function of the visual cortex using perimetric methods. Because we are mainly clinicians we are particularly interested in the sensory phenomena of disturbed binocular vision.

The main problem in all these examinations is that we always have to use a monocular stimulus, this means, we can never work under natural conditions.

As you have heard from the 2 papers yesterday the choice of stimulus to be used determines our findings.

Also the angle of squint obviously has a capability for binocular interaction in patients with anormalous correspondence: While we find in cases of large deviations a useful separation of the monocular visual field, Dr. Campos was able to show large areas of anomalous fusion in cases of microtropia.

THE CLINICAL ASSESSMENT OF THE CHROMATIC MECHANISMS OF THE RETINAL PERIPHERY

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(Waterloo, Canada / Parma, Italy)

The clinical value of studies of extrafoveal chromatic sensitivity derives directly from the usefulness of separating diseases characterized by a central scotoma, in which only the central bundle of the visual pathway is involved, from those in which the central scotoma is the expression of a disturbance of a photoreceptor population or of the whole retina. In this sense our work is not, strictly speaking, perimetry.

In other publications (Maione et al., 1976; 1975; in press) some of us have reported measurements, for normal and pathological eyes, of peripheral spectral sensitivity in the wavelength range 493-621 nm on blue, magenta and orange backgrounds of moderate luminance. Each test light was presented kinetically in a modified Goldmann perimeter at three levels of luminance (spaced at 0.3 log units approximately) to determine the excentricity at which threshold was reached. Sensitivity was defined by the threshold intercept at zero excentricity of the least squares regression line for those three luminances.

Many questions of clinical significance arose in our early work. Is there a true reduction with age of the sensitivity of the longwave mechanism in the periphery which is an expression of a subclinical degenerative senescense? Is the central scotoma in retrobulbar neuritis the psychophysical equivalent of a specific disturbance only of the papillo-macular bundle or of the lower resistance to stress of the nervous pathway (Potts et al., 1972) of the whole cone population. Are all macular diseases, in fact, localized at the macula or are the degenerative ones more extended?

A number of uncertainties were unresolved in that work

1. Thresholds were obtained over a wide range of excentricities (from a few degrees to beyond 50°) but it is evident from the work of Verriest & Kandemir (1974) that the regression between threshold and excentricity departs from linearity close to the fovea.
2. No account was taken of the non-neutrality of the attenuating filters of the Goldmann perimeter nor of differences in interference filter bandwidths.

In the work presented here these uncertainties were reduced by

1. Selecting test luminances which reached threshold in the region between 8° and 30°.
2. Spectral calibration.

This paper reports measurements of the threshold spectral sensitivity of normal and pathological eyes for blue and orange backgrounds at moderate luminances suitable for clinical work. Thresholds were measured statically at the fovea and kinetically outside it. The effect of changing the adaptation level is also reported.

It should be emphasized that the aim of the present work, in line with that of earlier reports (Maione et al., 1975; 1976; in press), is to determine a set of observing conditions which are viable in a clinical setting and which will reveal enough of each chromatic mechanism to identify it and its deviation from the norm (if any) without using the very high retinal illuminances which have been employed under laboratory conditions to isolate the chromatic mechanisms over very wide wavelength ranges.

MATERIALS AND METHODS

A Goldmann perimeter was employed with new modifications to the illumination of the dome and test targets. The dome was illuminated indirectly by means of an external projector. Dome luminance in the test region could be reduced from maximum in two steps of 0.3 log units each by introducing suitable diaphragms. The colour of the background light was controlled by glass filters (Schott. BG 12, 1 mm for blue and OG2, 3 mm for orange). Maximum luminances were 44 cd/m^2 for orange adaptation (measured directly with a Metrowatt Metralux K photoelectric photometer) and 2.2 cd/m^2 for blue adaptation (calculated relative to the orange light from the spectral transmissivities of the orange and blue filters and the colour temperature of the source). Details of the adaptation and test stimuli are given in Tables 1 and 2.

The test optical system was illuminated through a fibre optic channel by a second projector lamp. Test lights were defined by interference filters (Schott J L). The range of the Goldmann attenuating filters was extended by about 1 log unit using a supplementary 'neutral' filter (Wratten 96). The transmission characteristics of all filters were measured on a recording

Table 1 Adaptation conditions

Field size : 180°		
3 Adaptation levels : Luminance ratio	1:2:4	
Maximum adaptation luminance	Retinal illuminance (Trolands) (assuming a 3 mm pupil)	
	Photopic Units	Scotopic units
BLUE : 2 2 cd/m^2	16	191
ORANGE: 44 cd/m^2	311	78

Table 2. Test conditions

Field size: 64 mm² Schott interference filters			Goldmann attenuating filters							Supplementary Wratten filter
λ (nm)	Tm %	H (nm)	1	2	3	a	b	c	d	
443	36	13.2	1.67	1.12	0.63	0.42	0.32	0.21	0.10	1.24
476	44	13.4	1.53	1.03	0.57	0.39	0.29	0.20	0.10	1.18
524	45	11.6	1.53	1.05	0.56	0.38	0.29	0.19	0.09	1.15
552	42	10.7	1.55	1.03	0.56	0.38	0.29	0.19	0.10	1.14
582	47	11.7	1.55	1.08	0.58	0.41	0.31	0.21	0.10	1.15
621	39	10.6	1 46	1.06	0.59	0.41	0.30	0.20	0.11	1.13
663	35	13.8	1.30	1.01	0.57	0.40	0.30	0.20	0.10	1.16

The numbers listed in columns 4 to 11 are optical densities.

spectrophotometer (Optica Milano CF 4 R). The colour temperature of both the background and test sources was 3400 K (using a Megatron colour temperature meter).

Seven test lights were used in the range 443-663 mm. At each wavelength the foveal threshold was determined first (three trials) and this was followed immediately by kinetic perimetry along the nasal horizontal meridian at each of three test luminances (five trials for each luminance) which were selected so that the excentricities for threshold were restricted to the range 8°-30°.

Observations were deliberately not randomized: observations for each chromatic adaptation condition were completed in a block to facilitate stability of adaptation.

The relative spectral sensitivity was calculated from

$$\text{Log } S\lambda = D\lambda - \text{Log } E\lambda \cdot Tm \cdot H$$

Where
$E\lambda$ is the relative spectral power distribution of a black body at 3400 K,
Tm is the maximum transmissivity of the interference filters,

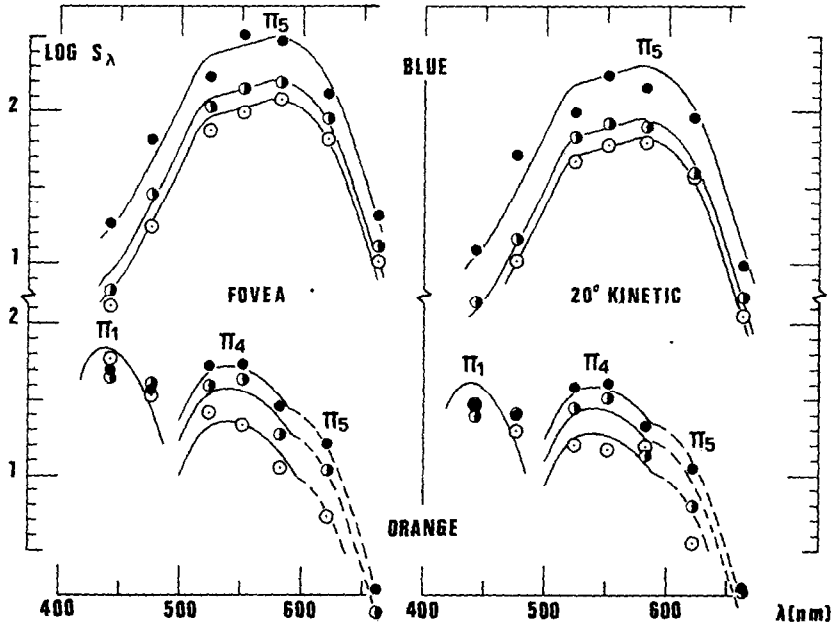

Fig. 1. Log. Spectral sensitivity: mean of 5 young normals (mean age 29 yrs: Range 20-34) measured under blue and orange adaptation (upper and lower graphs respectively) at the fovea and in the periphery (left and right graphs respectively). High ....⊙, intermediate ....◑ and low ....● adaptation luminances are in the ratio 4:2:1. The high adaptation luminance is 2.2 cd/m^2 for blue and 44 cd/m^2 for orange (see also Table 1). Curves are the π_1, π_4 and π_5 mechanisms of Stiles displaced vertically to fit the data.

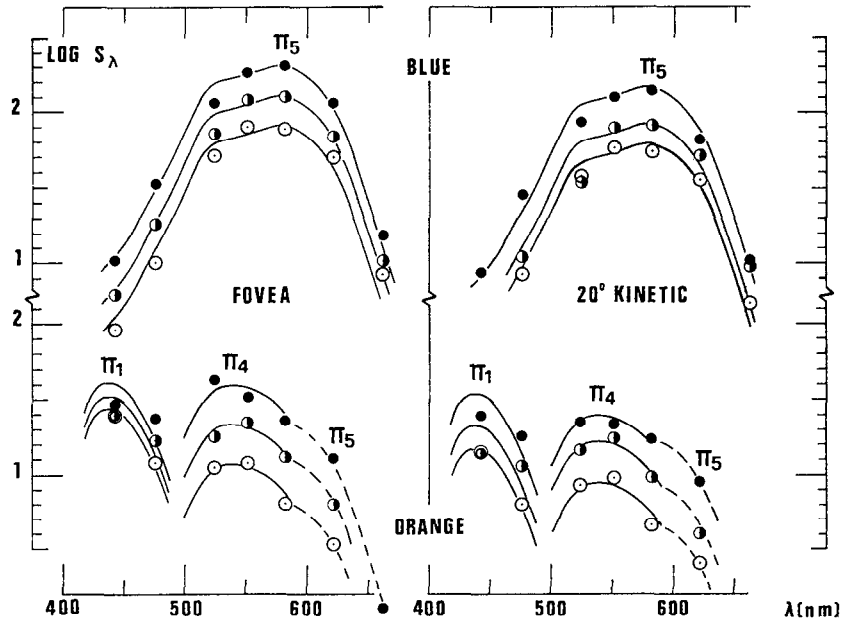

Fig. 2. Log. spectral sensitivity mean of 5 old normals (mean age 57 yrs: Range 45-79). Other details are as for Fig. 1

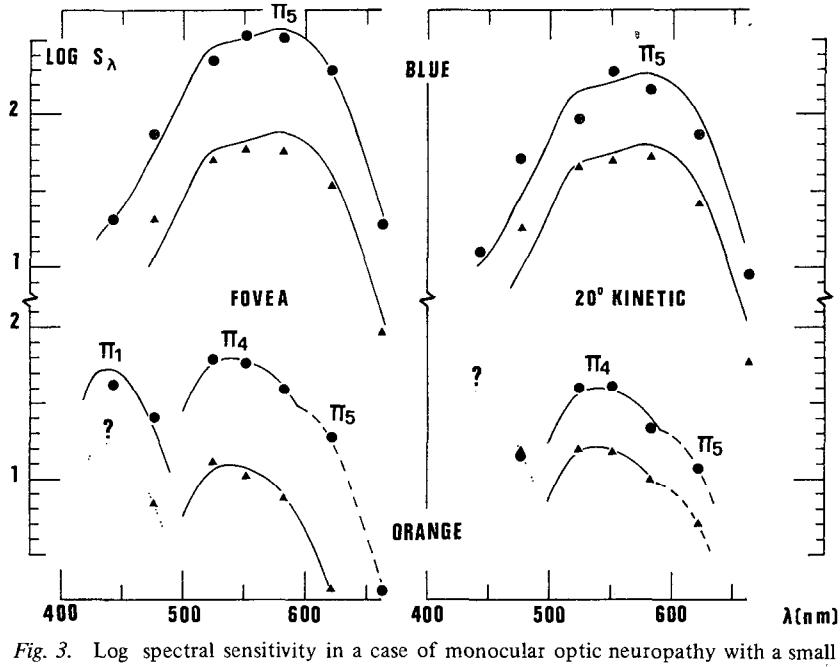

Fig. 3. Log spectral sensitivity in a case of monocular optic neuropathy with a small central scotoma. F.A , 34 yrs., female Low adaptation: O.D. normal. .●. O.S. optic neuropathy....▲. Other details are as for Fig. 1.

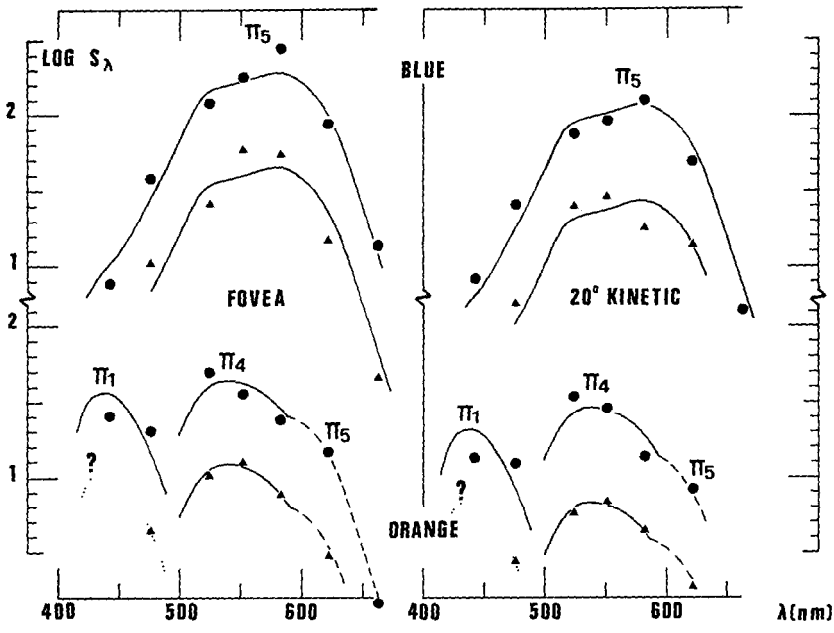

Fig. 4 Log. spectral sensitivity in a case of monocular optic neuropathy with a small central scotoma D'E.E , 45 yrs., female. Low adaptation: O.D. normal....●. O.S. optic neuropathy. .▲. Other details are as for Fig. 1.

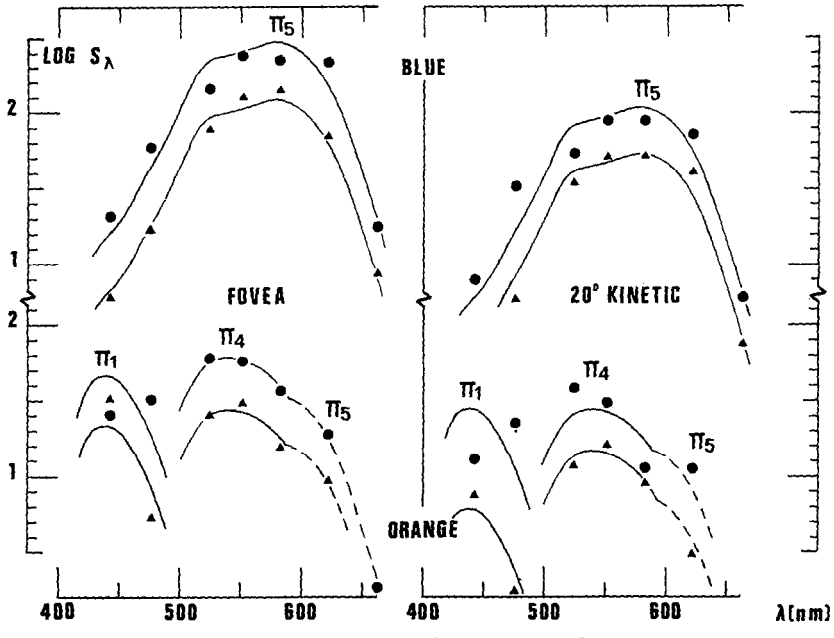

Fig. 5. Log. spectral sensitivity in a case of monocular inflammatory maculopathy. G.L , 47 yrs., female Low adaptation: O.S. normal....●. O.D. maculopathy....▲. Other details are as for Fig. 1.

H is the bandwidth of the interference filters at half Tm,
λ is the centre wavelength of the bandwidth H,
$D\lambda$ is the total density of all attenuating filters required to reach threshold.

The equation is an approximation, the validity of which depends on a) how closely E for a black body accords with that of the lamp and b) how closely the product. Tm · H represents the 'shape factor' of the interference filter and on the efficiency with which radiations are blocked outside the main transmission band. Internal evidence, however, indicates that the approximation is adequate for clinical purposes.

Observations were made on 5 'young' normals (Mean 29 yrs, Range 20-34), 5 'old' normals (Mean 57 yrs, Range 45-79), 2 cases of optic neuropathy each with a small central scotoma and 2 cases of maculopathy.

Both neuropathies and one maculopathy were monocular and in those cases observations were made on both the normal and the pathological eye.

RESULTS AND DISCUSSION

The results are shown in Figs 1-6. Sensitivities for 20° were interpolated using a least squares regression line.

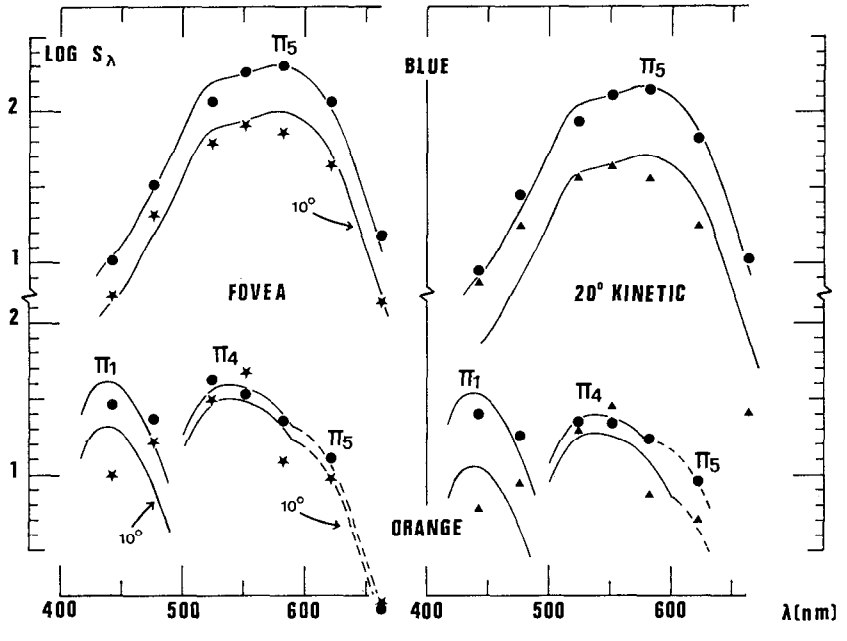

Fig. 6. Log. spectral sensitivity in a case of degenerative maculopathy in O D. with O S. blind. B.G., 52 yrs, male. Low adaptation: Mean of 5 old normals....●. (from Fig 2) O.D maculopathy . .▲, ★ (10° static and 20° kinetic respectively) Other de- are as for Fig 1

Normals

An attempt has been made to fit Stiles' π_1, π_4 and π_5 mechanisms to our results. This was simple for blue adaptation (Fig 1-2) where π_5 was found to describe the sensitivity functions at all 3 adaptation levels at the fovea and at 20°. The results did not show differences attributable to a significant variation in macular pigment from 0° to 20° but the good fit of π_5 can be interpreted as internal evidence for adequate accuracy of the above sensitivity equation. The luminance of the blue adaptation light is high when expressed in scotopic units (see Table 1) and its efficiency in suppressing the rod mechanism is evident in the results at 20°.

In orange adaptation, however, all three mechanisms seemed evident. Sensitivities at 443 and 476 nm were used to fit π_1; 524, 552 and 582 nm to fit π_4 and 582, 621 and 663 nm to fit π_5. The changes of π_4 and π_5 with adaptation level for normal subjects indicate that observing conditions were in the region where the Weber – Fechner law obtains.

π_1 seemed to be stable at all levels of orange adaptation, as expected, but only for the young and not for the old. π_1 was, however, poorly characterized by the data, the fit being better at the higher than at the lower level of adaptation. While this might be accounted for by rod intrusion at 20°, it is difficult to explain the same result obtained foveally. Unless, of course, fixation of the target was not accurate.

The orange filter employed has its 50% transmission at about 566 nm and at this wavelength the π_4 and π_5 mechanisms have nearly the same sensitivity. It is not surprising, therefore that π_4 and π_5 seem to be equally affected by changes in the orange adaptation level. A judicious change to a somewhat redder filter might help to reveal π_1 and π_4 at the expense of π_5.

All three mechanisms under all the observing conditions seem to be somewhat less sensitive in the old than in the young normals. It should be noted, however, that this difference between the means of each group is smaller than the interindividual differences within each group.

Pathology

The results for two cases of optic neuropathy are shown in Figs 3 and 4 and for two cases of maculopathy in Figs 5 and 6.

Both cases of optic neuropathy show significant depressions of the π_4, π_5 and probably the π_1 mechanisms both at the fovea and at 20°.

This agrees with the early observation of Engelking (1921) and with our own former observations (Maione et al., in press). It is also an experimental confirmation of the deductions made by Potts et al. (1972) from histology. The functional depression in neuropathies extends far beyond the limits of the central scotoma.

In both cases of maculopathy π_5 and probably π_1 also are depressed but π_4 seems to behave differently in the two patients.

G.L.'s condition was inflammatory and monocular and her π_4 mechanism was depressed (Fig. 5) but B.G.'s condition was degenerative and his π_4 was not significantly affected (Fig. 6). BG had a large scotoma in one eye

from the same disease and so the results for his other eye were compared with those of the 'old' normal control group. The central scotoma in that eye impeded adequate foveal observations and static thresholds were obtained at 10°.

Sensitivity losses in inflammatory conditions of the macular are global but it seems that, in degenerative diseases, π_4 is spared and that the π_5 mechanism may be more selectively involved, this is also true in the periphery. Inflammation is secondary to uveal diseases but degeneration first affects the retina. Marré and Marré (7) have concluded that foveal sensitivity losses increase with wavelength in retinal diseases. It is interesting to note that both maculopathologies involve sensitivity losses outside the macular area.

SUMMARY

Some questions are posed regarding the psychophysical phenomena of vision in relation to clinical diagnosis.

The 2-colour increment threshold technique of Stiles in applied at moderate luminance levels both peripherally (kinetically) and foveally (statically) for 5 'young' and 5 'old' normals and for 2 optic neuropathies and 2 maculopathies.

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ABSOLUTE THRESHOLDS FOR MONOCHROMATIC STIMULI OF VARIOUS SIZES AND DURATIONS ACROSS THE VISUAL FIELD

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The results of previous experiments (Ronchi, 1972, 1974) have led to suspect a sort of wavelength dependence of the spatio-temporal integrative properties of the dark-adapted retina, which is hard to be reconciled with the view that the response of the dark-adapted peripheral retina is mediated solely by rods. In this connection, we took into account also the decrease of critical duration at strong off-axis angles (Ronchi, 1971; Ronchi & Novakova, 1971), under the reasonable assumption that the minimal blur disc coincides with Riccò's area at any eccentricity. The present experiment aims at affording a further contribution to this problem.

The dark-adapted observer was given a fixation point. The test-spot was flashed on a dark background, along the horizontal meridian of the dark-adapted (nasal) retina. The light emitted by a 2800°K incandescent lamp, fed by stabilized d c., was filtered through interference Balzer filters. Monocular vision and natural pupil were employed. The absolute threshold was recorded by the use of constant stimuli methods, under four size (u)/duration (t_e) combinations, by inserting a neutral filter of variable optical density in the light beam. Four highly skilled young normal adults took part in the experiment

The plot of liminal density vs eccentricity is found to be practically 'flat' beyond the blind spot, for u=2°, t_e= 10 ms, u = 2°, t_e = 400 ms, u = 4'.5, t_e = 10 ms. On the other hand, for u=4°.5 and t_e=400 ms, the plot shows a complicated wavelength dependence. Some data are shown in Fig. 1.

Let us now consider the 'log liminal energy', defined as the sum of minus luminal density and log stimulus duration. Fig. 2 shows the log difference of threshold energy for either durations (400 and 10 ms), as a function of wavelength. At 7° from the fovea this quantity is only a little wavelength dependent if u = 2°, while it is clearly wavelength dependent if u = 4'.5. At 60°, on the other hand (Fig 2), the wavelength dependence is the same, whatever the target size.

The data reported above are difficult to explain from the assumption that one kind of receptor only is mediating the response at the absolute threshold. The question is whether one can infer, on the basis of the data reported above that either there exist various rod aggregates with different time constants, or that cones coalesce with rods, even at the absolute threshold.

If the size of Riccò's area were wavelength dependent (not only at the extreme red end of the spectrum, as demonstrated by Baumgardt & Ferlampin, 1968), the effectiveness of the absorbed energy would depend on the amount of 'destabilization' (Hofstetter, 1975) produced by involuntary

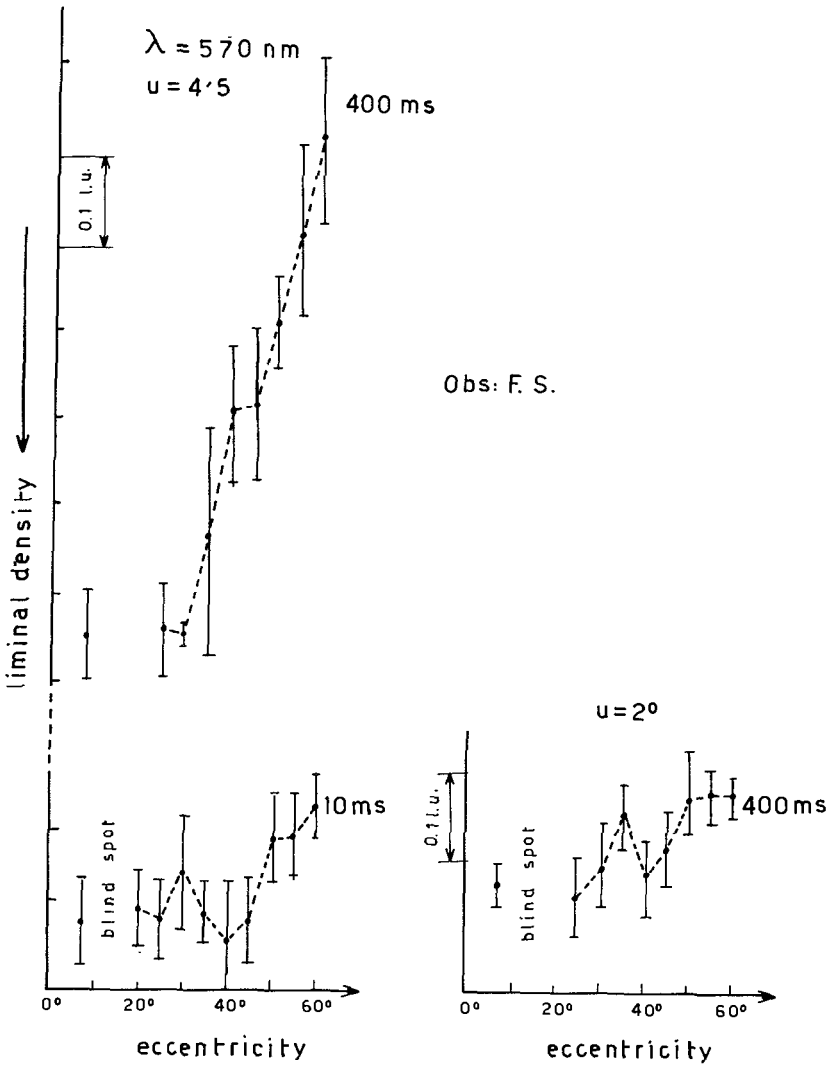

Fig 1 The optical density of the filter inserted in the light path, at absolute threshold, as a function of eccentricity Cosine correction for pupil area has been applied Labels denote the observer, the dominant wavelength of the stimulus, its angular size and duration. The quantity displayed on ordinates increases when passing from the top to the bottom. Bars denote the standard deviation

eye movements. The most favourable case would be that when the target size is small, compared with Riccò's area, and exposure time is long. In this connection it should be noted that chromatic aberration does not seem to be a factor of vital importance (Ronchi & Molesini, 1973).

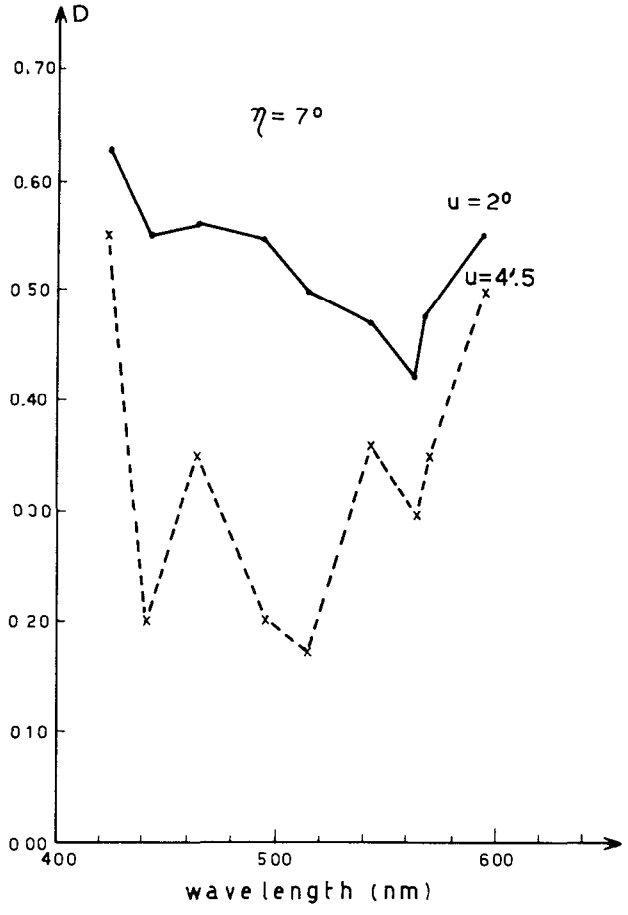

Fig. 2 Ordinate: log difference of liminal energy, for two different flash durations, 10 and 400 msec Abscissa: stimulus wavelength. Labels denote eccentricity and stimulus size

SUMMARY

Both eccentricity dependence of absolute thresholds and the time integrative properties of the dark-adapted retina are found to be wavelength dependent for some size-duration combinations but not for others. These results cannot be fitted in the model according to which the response of the dark-adapted retina is mediated solely by rods.

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COLOR PERIMETRY PARAMETERS

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Color perimetry has been controversial since its inception, almost a century ago (Feree & Rand, 1963, Traquair, 1957; Verriest & Israel, 1965; Wentworth, 1930). The definition and reproducibility of the normal color isopter has been the predominant problem. Confusion has risen from several sources. Colored targets can be defined in a physical sense for energy and in a physiological sense for hue, saturation and luminosity. Which of these characteristics is responsible for the observed variation in isopter size is unknown.

The purpose of this study was to determine if targets of equal subjective brightness or targets of equal raw energy had any effect on isopter size. Targets were matched for subjective brightness by the methods of critical flicker frequency (CFF) and brightness comparison The CFF luminosity curve corresponds quite well with the CIE luminosity cure (Bornstein & Marks, 1972), the international standard for brightness.

Seven subjects were studied who were color normal by the Farnsworth-Munsell 100-Hue color test. Brightness comparison was obtained from a deuteranope to minimize the effect of color on brightness. A Tübingen perimeter was utilized to obtain all data. Seven interference filters, blue through red, with 10-15 nanometer half-band widths, provided narrow spectral monochromatic stimuli. A 66-minute angular test target was illuminated by a Tungsten lamp at 2900 degrees Kelvin. An infrared absorbing filter removed infrared energy from the white light for the equal energy determinations. Raw energy was measured with a United Detector Optometer.

Critical flicker frequency values for equal brightness were obtained by determining when the stimulus at fixation was just perceptible as flickering at 20 cycles/sec. Brightness was varied by introducing neutral density filters over a range of 8 log units in 0.1 log steps. A deuteranope equated the brightness of the seven colored targets to a constant white stimulus. Kinetic color isopters for both equal luminosity and equal energy were obtained along eight meridians at 45 degree intervals for two end points, target visibility and color recognition. Meridians and test targets were randomized during the entire study.

Color perimetry was first performed in four subjects with targets of equal luminosity. There was intersubject variation, however, the relationship

between the color isopters remained constant for all subjects. Isopters for the achromatic threshold steadily decreased in size from the short to the long wavelengths and then seemed to plateau in the orange and red. The mean size of the chromatic isopters decreased from the short wavelength blue, blue green, green, light green to yellow, and then increased at longer wavelengths orange and red. The achromatic equal energy values for three subjects gave a smaller red isopter, while the other six isopters fell at the far periphery of the visible field. Equal energy color recognition thresholds again revealed a constricted red isopter when compared to the other isopters.

Equal stimulation of all three cone systems in the peripheral retina would seem to be the mechanism responsible for the achromatic threshold with targets of equal luminosity. The smaller achromatic isopters at longer wavelengths can possibly be explained in two ways. The inverse relationship between energy and wavelength might explain the smaller isopters. Another possibility is that the far peripheral retina may be relatively protanopic.

The chromatic threshold values require a separate explanation. One cone type may be preferentially stimulated resulting in a specific hue being perceived at a given distance from fixation. Saturation, uncontrolled in this experiment, may also be responsible for the variation in isopter size. The actual saturation of each target used was reduced in equal proportion due to the addition of the background luminance of the white light of the perimeter. Saturation discrimination data indicates that yellow is the closest of all colors to white and is therefore more difficult to distinguish from white than other colors (Wright, 1946). The physiologic effect of desaturation of our colored targets was greater in the yellow and less at the other wavelengths. Saturation could thus be responsible for the observed variation in isopter size since hue and luminosity were well controlled.

Equal energy thresholds for both visibility and color recognition gave a smaller red isopter. The simplest explanation for this finding is that more energy is required to stimulate the retina at longer wavelengths (Wald, 1945).

SUMMARY

Color perimetry was performed after equating colored targets first for luminosity and then separately for energy.

Achromatic thresholds for equally bright targets gave smaller isopters at longer wavelengths. Color recognition thresholds showed large blue, midzone red and green and small yellow isopters. Saturation could be the characteristic of color responsible for this variation in isopter size.

Achromatic and chromatic equal energy thresholds gave smaller red isopters. This phenomenon might be explained by the fact that more energy is needed to stimulate the retina at longer wavelengths.

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A NOTE ON THE SPECTRAL INCREMENT THRESHOLDS ON A WHITE BACKGROUND IN DIFFERENT AGE GROUPS OF NORMAL SUBJECTS

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We already studied the influence of age on the normal static achromatic increment thresholds for coloured objects by means of the Goldmann (Verriest & Israel, 1965) and of the Tübingen perimeter (Verriest & Kandemir, 1974). Now we completed the data of the 1974 paper by adding a young group formed by 11 subjects from 10 to 15 years, the mean age being 12.0 years, and a medium group comprising 13 subjects from 16 to 41 years, the mean age being 23.0 years. Of course, all experimental conditions remained unchanged, the chosen background luminance being 10.0 cd.m^{-2}.

When the mean sensitivities are plotted vs. the wavelengths, we state that the former old group (19 subjects from 60 to 76 years, the mean age being 64.4 years) is everywhere less sensitive than the two new age groups, and that from 20° the young group is more sensitive than the medium group

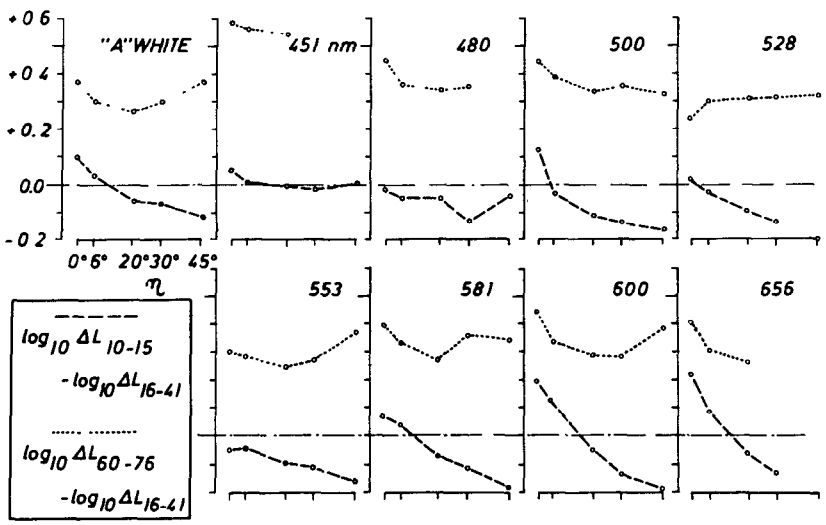

Fig 1 Differences between the mean sensitivities of the young group and of the medium group, and between that of the old group and of the medium group (log sensitivity vs eccentricity)

except for the shortest wavelength of 451 nm. Moreover, we state that, when compared to the medium group, the young and old groups are characterized by less prominent humps at 451 nm and at 600 nm.

When the same mean sensitivities are plotted vs. the eccentricities, it becomes more apparent that, when compared to the medium group, the young group is generally less sensitive at the centre and more sensitive at the periphery of the visual field.

The effects of age are even more evident when we plot against eccentricity the difference in sensitivity between the young group and the medium group and between the old group and again the medium group (Fig. 1): when compared to the medium group, the young group becomes even more sensitive from centre to periphery, except for the shortest wavelengths, while the sensitivity loss of the old subjects is generally maximal at 0° and 45°, and minimal at 20°; especially at the fovea, the sensitivity loss of the old subjects is maximal for the shortest wavelengths and minimal, not for the longest wavelength, but in the middle of the visible spectrum (as already shown by Verriest & Israel, 1965, and by Verriest, 1970).

In final analysis, the known prereceptoral changes explain clearly why with age one becomes less sensitive at the retinal periphery and for the shorter wavelengths. On the other hand, the fact that in the youngest as well as in the oldest group the foveal sensitivities to the longer wavelengths are further lowered than those at 20° can up to now only be explained by receptoral changes; the same holds for the explanation of the fact that the mean thresholds for 451 nm do not change from 10-15 years to 16-41 years, and that the humps at 451 nm and at 600 nm are less pronounced both in the young and in the old group than in the medium one.

SUMMARY

Mean energetical achromatic increment thresholds on a white background of 10 cd.m^{-2} were determined at 5 eccentricities, by means of 8 interference filters incorporated into a calibrated Tübingen perimeter, in 3 age groups of normal subjects (10-15, 16-41 and 60-76 years). Many of the differences between the means are very significant and only some of them can be explained by the known prereceptoral changes.

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NORMAL RESULTS OF KINETIC COLOUR PERIMETRY BY MEANS OF THE GOLDMANN APPARATUS

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Although we showed in several papers that the measurement of the static achromatic increment thresholds is surely a good kind of colour perimetry in order to recognize pathological conditions, we must also investigate whether useful results can also be obtained by using kinetic perimetry and even by studying the chromatic thresholds besides the achromatic ones. All the more so as such methods were much advocated and used with spectacular results during many past decades, since the actual perimeters allow to maintain a better control of the photometric and colorimetric conditions than in the past, and, finally, because such methods could be more familiar to and, easier and quicker for the clinicians

The purpose of this paper is a first step in this direction, i.e., to know the normal variations of the extent of the achromatic and chromatic peripheral isopters and of the dimensions of the blind spot using the Goldmann perimeter in common experimental conditions, and using some also easily available broad band selective filters· on the one hand the blue filter for colour perimetry and the complementary red and green filters for binocular perimetry that are delivered with the Goldmann apparatus (and of which the spectral transmittance curves were described as B, R' and V' by Verriest & Israel, 1965), and on the other one of the commonest yellow filters, namely the Bausch & Lomb Kalichrome C glass (of which the spectral transmittance curve was described as K by Israel & Verriest, 1972).

According to the purpose, we used the perimeter in the common way, the background luminance being set at 10 $cd.m^{-2}$, the test object increment luminance without selective filter being the same for the neutral filters setting 1, but the neutral filters setting being 4 when the selective filters were used. Moreover, we used object areas giving similar extents to the peripheral achromatic isopters, namely size I (0.275 mm^2) for green and yellow, size II (1.1 mm^2) for red and size III (4.4 mm^2) for blue (but size II for blue when measuring the blind spot).

To measure the extent of the peripheral isopters, the object was moved centripetally at a speed decreasing from $10°.s^{-1}$ at the extreme periphery to $1°.s^{-1}$ near the fixation point. The 12 chosen meridians are listed in Table 1 (they are those commonly used in pathology and avoid the lateral bowl slits), they were investigated in counterclockwise order beginning at the 275° meridian. The patient answered as soon as he perceived the object (for

Table 1. Means (*M*) and standard deviations (*S*) of the normal kinetic achromatic (achr.) and chromatic (chr.) threshold eccentricities for the test objects and experimental conditions specified in the text. The values are here given in Goldmann perimeter chart millimeters from the fixation point (0.833 mm = 1°). $N = 20$

			Down	Temporal			Up			Nasal			Down
			275°	315°	345°	15°	45°	85°	95°	135°	165°	195°	225°	265°
Green	achr.	*M*	47	53	59	61	51	41	39	39	39	39	41	45
		S	6.2	10	13	10	8.3	2.0	2.3	4.5	4.4	5.4	5.4	5.7
	chr.	*M*	7	8	8	8	8	7	7	7	7	7	7	7
		S	1.3	1.2	1.1	1.3	1.4	1.4	1.5	1.4	1.3	1.6	1.4	1.2
Red	achr.	*M*	31	39	46	48	40	31	29	30	30	28	29	30
		S	2.9	4.3	5.1	7.1	6.9	3.0	3.4	3.3	3.6	3.2	2.9	2.7
	chr.	*M*	9	10	10	10	10	9	9	9	9	9	9	9
		S	1.1	1.0	0.8	1.2	0.9	0.2	0.8	0.9	1.1	0.9	1.2	0.7
Blue	achr.	*M*	57	72	77	71	53	41	42	46	50	49	48	54
		S	7.5	9.1	7.3	7.1	5.7	5.3	5.6	5.5	5.4	5.3	4.5	5.4
	chr.	*M*	41	55	62	54	37	27	29	32	35	33	34	40
		S	8.5	13	12	12	8.8	4.8	5.2	5.8	6.9	7 4	6.5	7.2
Yellow	achr.	*M*	64	78	85	78	60	46	48	52	56	57	54	61
		S	5.6	7.3	5.6	5.8	7.6	3.2	4.4	4.6	4.5	5.2	3.8	5.3
	chr.	*M*	22	24	27	25	20	17	16	18	21	21	21	22
		S	12	12	14	15	10	7.2	7 4	7.5	9.9	10	9.6	11

the determination of the achromatic isopter) or as soon as he was sure of its colour (for the determination of the chromatic isopter).

To measure the extent of the blind spot, the object was slowly moved vertically up and down from the point lying at 15° eccentricity on the horizontal temporal meridian, and then horizontally nasally and temporally from a point lying on the record sheet 3 mm vertically beneath the first departure point. For this experiment only achromatic perception was required.

We used different groups of observers, each of them being checked as normal as concerns visual acuity, correction, intracular pressure, biomicroscopical features and colour vision (Ishihara, Tritan Plate, AO HRR and Panel D-15 under a C illuminant at 100 lx). For the peripheral isopters we used groups of 20 subjects of ages ranging between 10 and 40 years, the mean age being 23.5 years; for the blind spot we used groups of 25 subjects of ages between 12 and 50 years, the mean age being 29.3 years and the eventual presbyopia being corrected when measuring the blind spot.

Taking into account not only the instrumental and cartographic deformations, but also the fact that the measurements of the blind spot were made along eccentric straight lines, the means and standard deviations listed in Tables 1 and 2 are expressed not in degrees, but in mm on the Goldmann perimeter record sheets (1 mm corresponding to 0.833 degree along the meridians). The distributions are approximately gaussian and not skewed, so that the modes generally correspond to the means and the standard deviations are meaningful, although aberrant values were occasionally found, especially for the chromatic isopters.

Table 2 Spreads, means (*M*) and standard deviations (*S*) of the normal kinetic dimentions of Mariotte's blind spot for the test objects and experimental conditions specified in the text Values in millimeters on the Goldmann perimeter chart. $N = 25$

		Vertical		Horizontal	
		Up	Down	Up	Down
Green achr	spread	3-7	7-14	2-8	3-10
	M	5 3	10.0	5 3	7 0
	S	1 1	1 9	1.3	1 4
Red achr.	spread	3-10	7-14	4-7	4-14
	M	6 4	10.8	5 4	7 4
	S	2 4	2 5	1 1	2.3
Blue achr	spread	3-7	7-14	2-8	3-10
	M	5 3	10.0	5 3	7 0
	S	1 1	1 9	1.3	1 4
Yellow achr	spread	2-6	7-12	2-7	3-10
	M	4 0	8 9	5 0	6.0
	S	1 0	1 5	1 1	1 6

As concerns the peripheral isopters, from the clinical point of view Fig. 1 is perhaps more interesting than Table 1 as it gives in degrees the total spreads of the eccentricities of achromatic and chromatic perception. For what concerns the blind spots, the spreads are relatively enormous and we restricted ourselves to indicating them in Table 2.

The conclusions that can be drawn from these data are that the chosen selective filters and test sizes give larger mean isopters (and accordingly smaller blind spots) for blue and yellow than for green and red. On the other hand the mean achromatic peripheral isopter is somewhat larger for yellow than for blue and somewhat larger for green than for red, while the mean chromatic peripheral isopter is, on the contrary, distinctly larger for blue than for yellow and somewhat larger for red than for green. This shows that it would be practically impossible to find colour objects that should be equivalent for both achromatic and chromatic perception, all the more since our previous works showed that there is a central scotoma for lights of shorter wavelengths. Although the chromatic isopters for our red and green objects are rather small and although the spreads are relatively very large, especially, of course, at more peripheral levels and for chromatic perception but also for the blind spot, it appears that this simple method could be fruitfully applied to pathological cases.

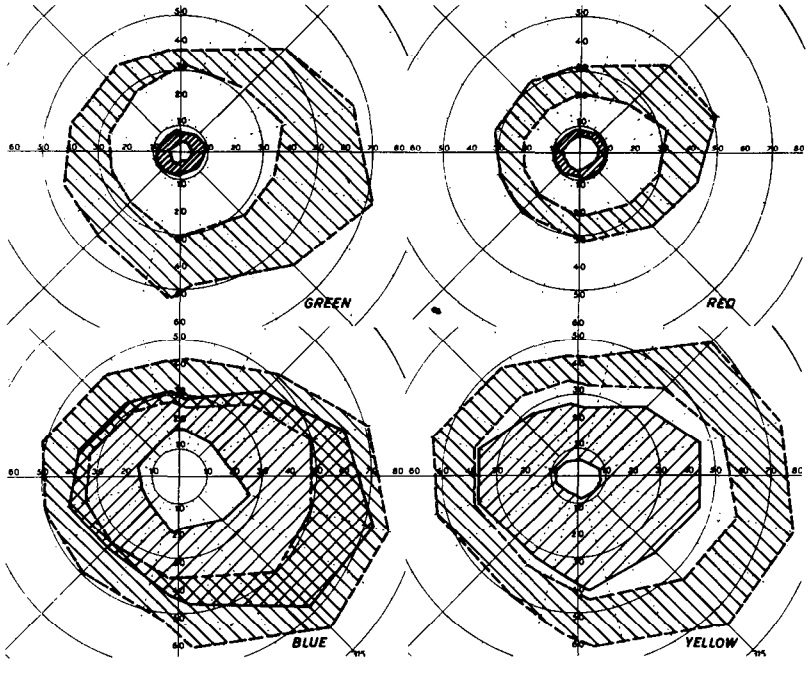

Fig 1. Spreads of the normal achromatic (--) and chromatic (—) isopters for the test objects and experimental conditions specified in the text The values are here given in degrees $N = 20$.

The data concerning the peripheral isopters were already published in Spanish by Israel & Golan (1971).

SUMMARY

The author presents a statistical series of normal cases in which kinetic perimetry has been performed (Goldmann). Four colours were used: red, green, blue and yellow. Normal isopters and the blind spot were examined in 160 eyes (chromatic and achromatic thresholds) The ages varied from 10 to 40 years.

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HIGH LUMINANCE CHROMATIC GOLDMANN PERIMETER*

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In no previous colour perimetric studies have chromatic stimuli always been at fully photopic luminance levels nor have they ever been photometrically equated. The modification we have made to the instrument makes both these objectives possible.

A Xenon Arc lamp was installed as the primary source and a quartz-iodine lamp in separate housing was used for background illumination. Both sources can be dismantled within 30 minutes and the instrument again used for its original purposes. Figure 1 shows the arrangement for the primary source (A) which is mounted above and behind the bowl of the perimeter. The image of the Xenon arc is projected into the pantograph system by means of 2 front surface mirrors (B), a focusing lens (C) and a quartz right-angle prism (D). Maximum available luminance of the achromatic target in the bowl is 10,000 apostilbs, and the colour temperature is 6,000K.

The secondary source (E) with an initial colour temperature of 3000K can be altered using daylight filters to equal the colour temperature of the primary source The maximum luminance under these conditions can be as high as 450 apostilbs. The energy distributions of both sources can be modified by filters to provide complete control over colour and luminance values of both target and background.

Several modes of testing are possible white target on white background (at varying correlated colour temperatures, up to 6000K), coloured on white, coloured on coloured and coloured on complementary background. In all modes of presentation the luminance of target and the background illumination are monitored.

Systematic studies of retinal thresholds for various modes of tests are in progress. A number of chromatic stimuli of differing sizes and varying bowl-adaptation levels are being used to establish norms for normal and colour defective subjects and also to find diagnostically the most effective means of detecting the earliest losses in retinal sensitivity in glaucomatous subjects.

Figure 2 shows the results of a 21 year old male emmetrope for red, green, blue and white targets all photometrically equated to 1000 apostilbs

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** Visiting professor at that time

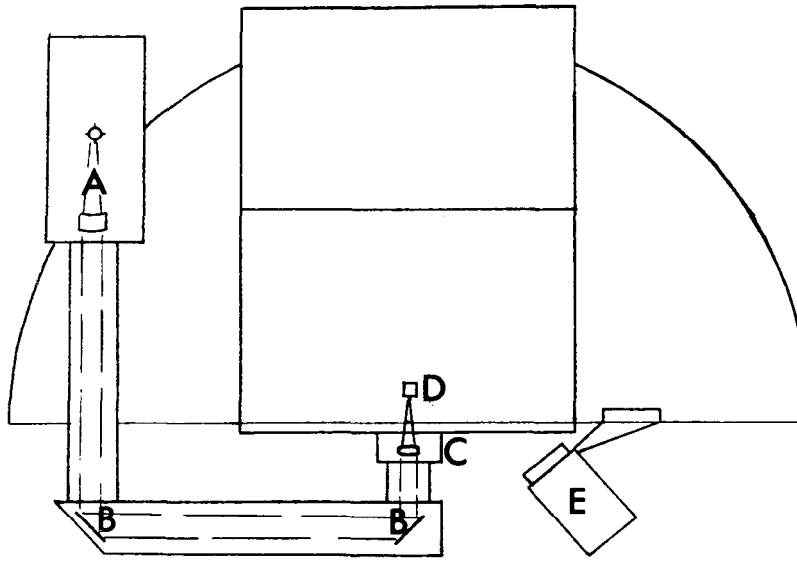

Fig 1 Modifications to the Goldmann Perimeter.

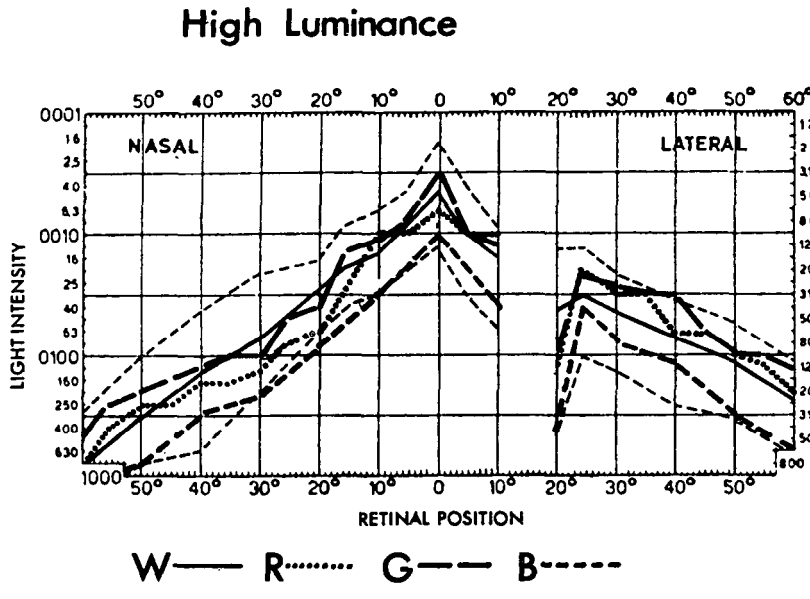

Fig 2 Retinal threshold gradients for 3 chromatic stimuli (R, G, B) and white (W) from one observer

with an achromatic background of 31.5 apostilbs. Note that the target size was maintained at ¼ mm^2 (i.e., size I) for all colours and that the chromatic gradients are not essentially different from the limits established for a comparable situation in the non-modified perimeter (Lakowski & Aspinall, 1969) where only an achromatic target (2600K) was used. These gradients differ from those of Verriest & Israel (1965), but correspond to those predicted by Magis, et al. (1974). A more extensive account of the modifications made to the instrument and further results will appear elsewhere (Lakowski, Wright & Oliver, 1977).

SUMMARY

A modification to the Goldmann projection perimeter is described in which a high luminance coloured target is produced The modification employs a 150 watt Xenon Arc lamp to provide a 1000 apostilb target in each of white, red, green, and blue An additional Quartz-Iodide lamp provides an independent background illumination in the four conditions, at 31.5 apostilbs. Thus the perimeter may be used for: white target on white background, coloured target on white background, coloured target on coloured background, and with additional filter, coloured target on complimentary coloured background, all at 1000/31.5 asb

Results have been collected for each of the above conditions and are presented for a young normal male emmetrope, a young protanopic male emmetrope, and an older deuteranomalous myope.

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LASER LIGHT IN STATIC PERIMETRY
(a preliminary report)

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In recent years we have employed laser light in kinetic perimetry We believe that the advantages obtained are

1) an earlier and more distinct evidence of defects,
2) a clearer indication of the evolution of the disease.

For instance, we report here one of the examined cases (see Fig. 1.).

Whereas these were the results obtained in kinetic perimetry, we are beginning to employ laser light in static perimetry. Our apparatus consists of a laser source fitted to a Goldmann perimeter. The laser is of the continious, helium-neon type, whose characteristics are· λ 632 mm; band width: 0.01 mm, spread: 1 milliradian; beam width: 0.8 mm; power 0.5 mW.

The target is strictly monochromatic and coherent. In static perimetry coherence becomes particularly important, so that we in the present report have devoted our attention to this particular point. Coherence gives rise to speckles, caused by interference. When a laser beam is projected on a diffused reflecting surface, the spot of light will be seen to have a shimmering, granular appearance. This is caused by the spatial coherence of laser light The reflected beam usually consists of a large specular component, coupled with other components due to random irregularities in the diffusing surface.

On the focal plane of an observing optical system, such as the eye, these components are seen as rapidly changing and randomly distributed interference spots It must be noted that the laser beam was not influenced by filters nor by diaphrams, and that enlarged photographs of the same spot at several moments also show modified spatial dispositions of the granulations (Fig. 2 and 3)

Thus a laser spot does not look uniform neither spatially nor temporally there are in this spot maxima and minima of light, continuously changing in space and time. These structures cause inhibition mechanisms, in the retinal horizontal and amacrine cells. A speckling effect is produced on the retina by laser light diffused by the spot on the screen. The resulting inhibition is similar to that produced by a windmill spinning light in physiological experiments this caused an increase in the response threshold, thus an increase of the number of quanta necessary to reach it. All this is justified by the basic theory saying that in order to detect some pathological photoreceptors, the best way consists in fractionning the stimulus as much as possible, i e., in having the greatest number of stimulus (photons) per surface unit.

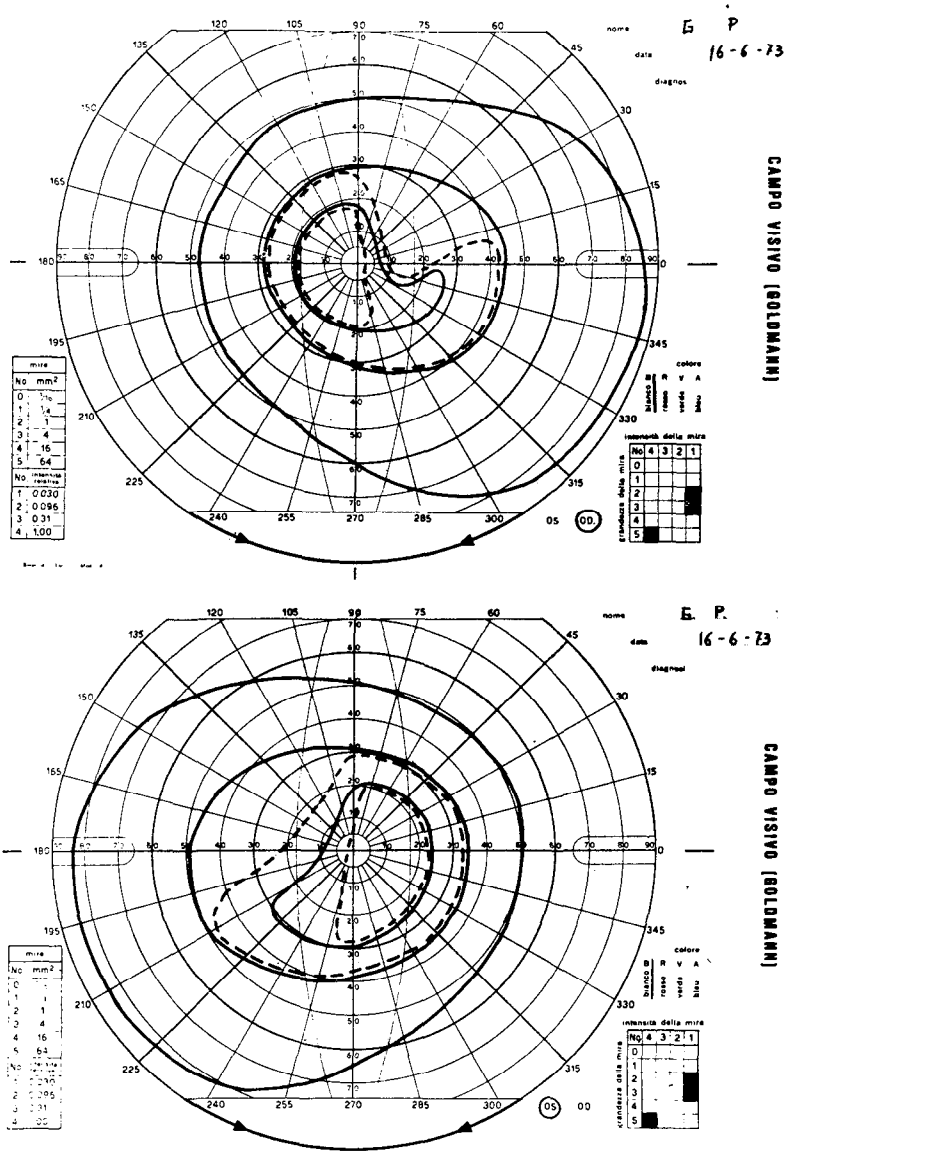

Fig 1 G.B. Chiasmal syndrom.
Visual field (white light = continuous line, laser light = broken line)
R.E White light: upper temporal quandrantopic defect (inner isopter).
Laser light: defect already visible in middle isopter, with increase to hemianopic defect in inner isopter.
L.E. White light: upper temporal quandranopic defect progressing to hemianopic defect in the inner isopter.
Laser light: extensive upper and lower temporal defect in middle isopted with increase to hemianopic defect in the inner isopter.

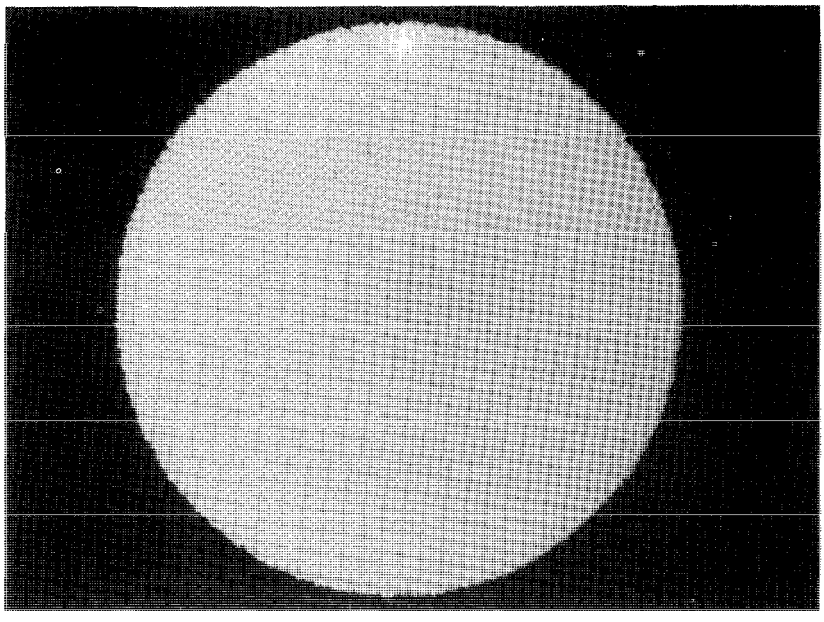

Fig. 2

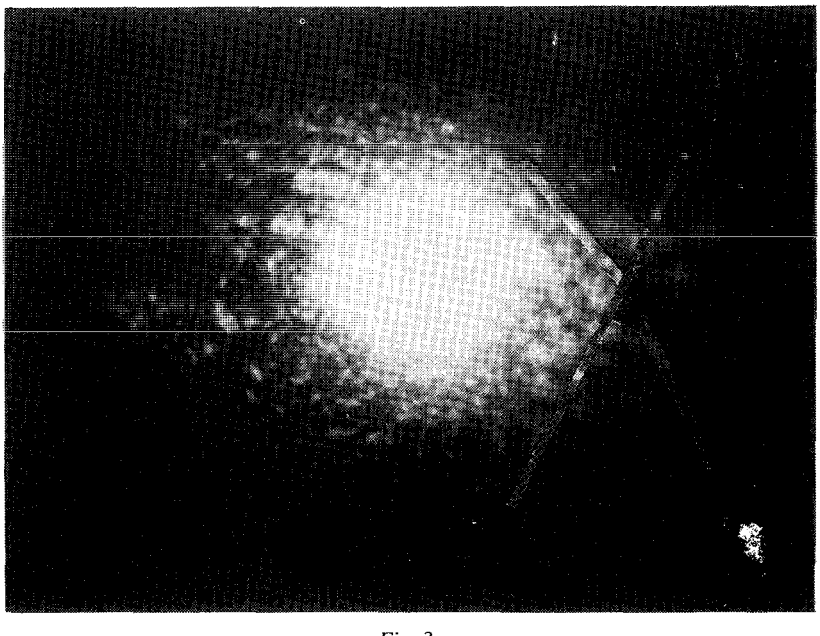

Fig. 3

Our technique of static perimetry using laser light consists of:

1) detection by kinetic perimetry of the area to be studied subsequently by static perimetry;
2) static profile by means of white light,
3) statement of equivalent thresholds for white and laser light in an unimpaired area of the field,
4) measurement of a static profile using laser light

The results obtained up to now are promising, although the number of cases is still not sufficient in order to allow a statistic evaluation.

SUMMARY

An apparatus consisting of a Goldmann perimeter fitted with a laser generator is described The physical and mathematical characteristics of a laser light are discussed with reference to the possible advantages of perimetry using laser light sharper definition and earlier detection of defects.

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COLOR PERIMETRY IN CHIASMAL LESIONS

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Sensoric functions in clinical perimetry may be assessed in different ways either by means of threshold perception of white and colored simuli (Traquair, 1939, Bair, 1940, Harrington, 1971) or by sensation of supra-threshold stimuli regarding brightness and contour (Chamlin, 1949; Dannheim, this volume), or saturation of colors (Chamlin, 1949; Dannheim, this volume, Frisén, 1973). Color differentiation is based on perception (chromatic threshold) (Alexander, 1956; Weiss et al., 1973) as well as sensation.

A test with circularly moving white and colored supraluminal stimuli of 10-120′ was performed with a Tübingen and a modified Rodenstock Perimeter in approx. 100 patients which had been referred with the suspicion of a chiasmal lesion or a definite pituitary tumor, and was compared with static and kinetic perimetry. For this report 65 of these visual fields have been selected, which either had changes in static and kinetic perimetry or areas, in which the subjective appearance of supraliminal stimuli was definitely disturbed. Only patients with steady fixation and good cooperation were included in the study since this is a necessary condition for obtaining valuable results.

A few typical findings will be demonstrated in detail. The areas of the visual field in which a white or colored stimulus appeared pale, blurred and faded will show up hatched in all figures (Fig. 1-6).

The different degrees of disorders found by static and kinetic threshold perimetry are compared in Table 1 with the results of supra-threshold perimetry for all 65 patients. Changes in threshold perimetry were in all cases accompanied by those in supra-threshold perimetry The group of 12 patients without disorders in static and kinetic threshold perimetry but definite changes in sensation of supraluminal stimuli are cases which would have been missed by conventional perimetry, even though the chiasmal lesion has since been proven surgically in 5 of them.

The right column shows the value of a simple confrontation test for desaturation of pigment colors as opposed to spectral colors in projection perimetry (Frisén, 1973). The confrontation test was frequently falsely negative in discrete changes of threshold and in cases with a sector-shaped desaturation effect.

The upper half of Table 2 shows that in the majority of patients saturation of colors was subjectively more affected than sensation of white

stimuli. The lower half gives the distribution of the desaturation effect over the spectrum, reflecting a preference for red.

A sample of 40 subjects without disorders of the optical pathways was tested for desaturation effects without positive results even along the upper vertical meridian (Bair, 1940; Ehlers, 1976).

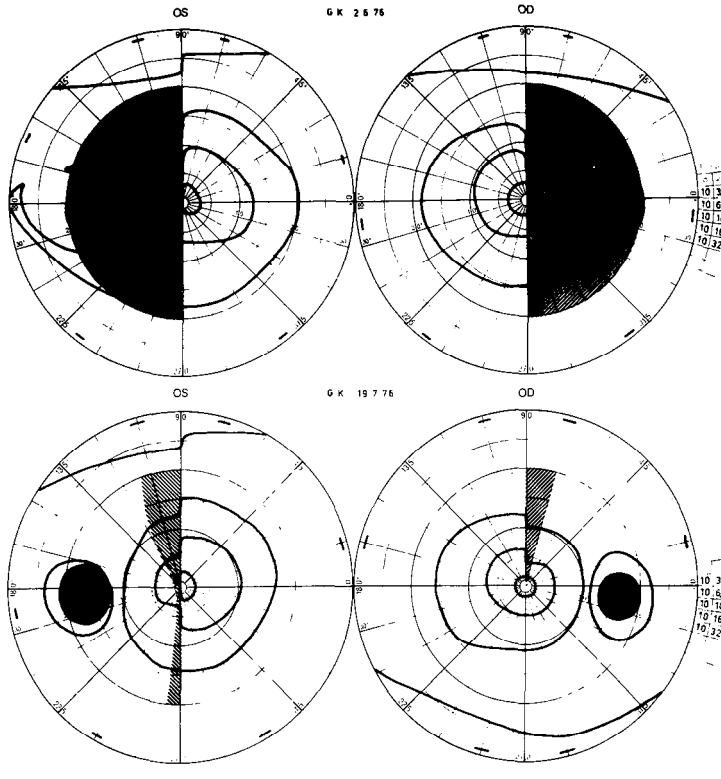


Fig. 1 Preoperative fields (above) and postoperative fields (below) after removal of a pituitary tumor The isopters reveal for the right eye discrete, for the left eye definite bitemporal changes before as well as after surgery The sensoric disturbance for supraluminal stimuli has preoperatively a bitemporal hemiopic distribution with homogeneous accentuation of the left eye and sector-shaped accentuation of the right eye Postoperatively only a sector-shaped disturbance for supraluminal stimuli is present

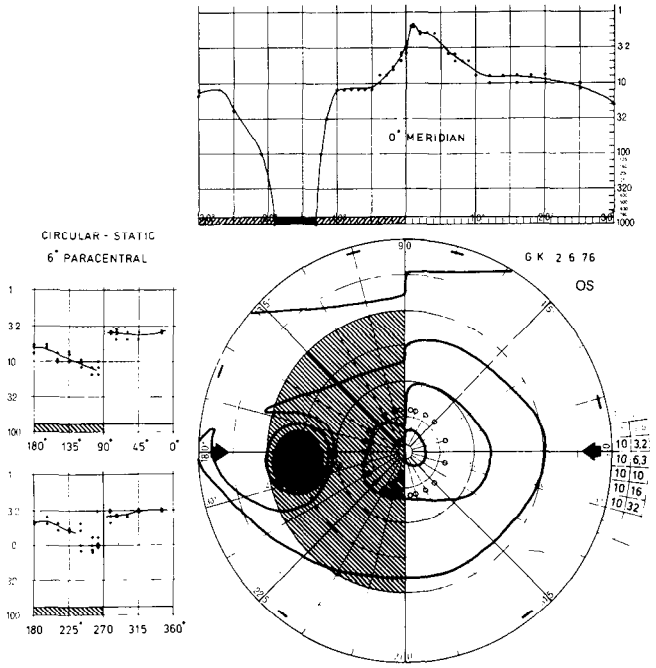


Fig 2 Kinetic, meridional- and circular-static perimetry of the left eye of the same patient as Fig 1 prior to surgery All three methods have similar diagnostic value. The hemiopic disorder for supraliminal stimuli, however, is a definite hint for the nature of the lesion.

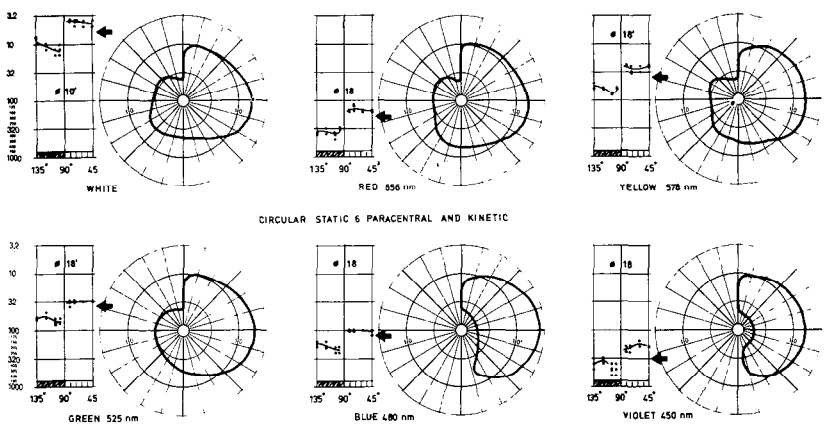


Fig 3 Composite graph of kinetic and circular-static perimetry for white and colored stimuli The comparable isopters look similar except the ones for blue and violet, which show a sparing of the center The severity of the sensoric disorder along the upper vertical meridian as demonstrated by circular-static perimetry is of the same degree for white and all colors The disturbance for supraluminal stimuli, hemiopic for all colors, was subjectively most pronounced for red

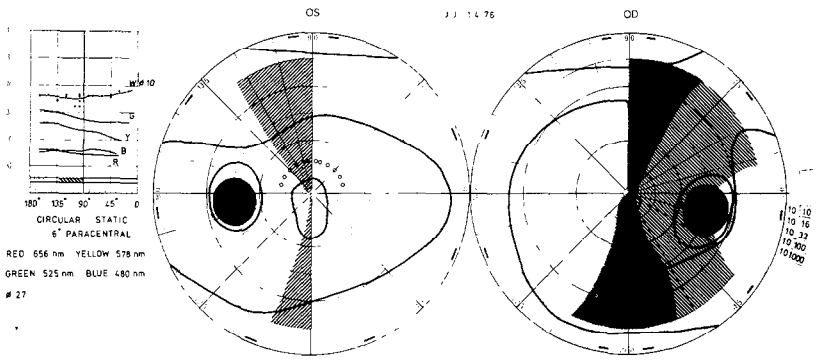


Fig 4 The asymmetric fields in chiasmal syndrome, with definite changes for the right, but no significant alterations for the left eye, as apparent in kinetic and circular-static perimetry for white and colored stimuli Supraluminal stimuli reveal the sector-shaped disorder also for the left eye.

Table 1.

DISTURBANCE OF PERCEPTION + severe (+) discrete – absent	DISTURBANCE OF SENSATION sector homog		CONFRT. TEST pos.	 neg
+ +		7	3	2
21		14	7	2
+/(+)		4	1	2
8		4	2	1
+ –		4	-	4
6		2	-	-
(+)/(+)		8	1	4
10		2	2	-
(+)/–		6	1	5
8		2	-	2
– –		7	-	6
12		5	4	1
65 TOTAL				

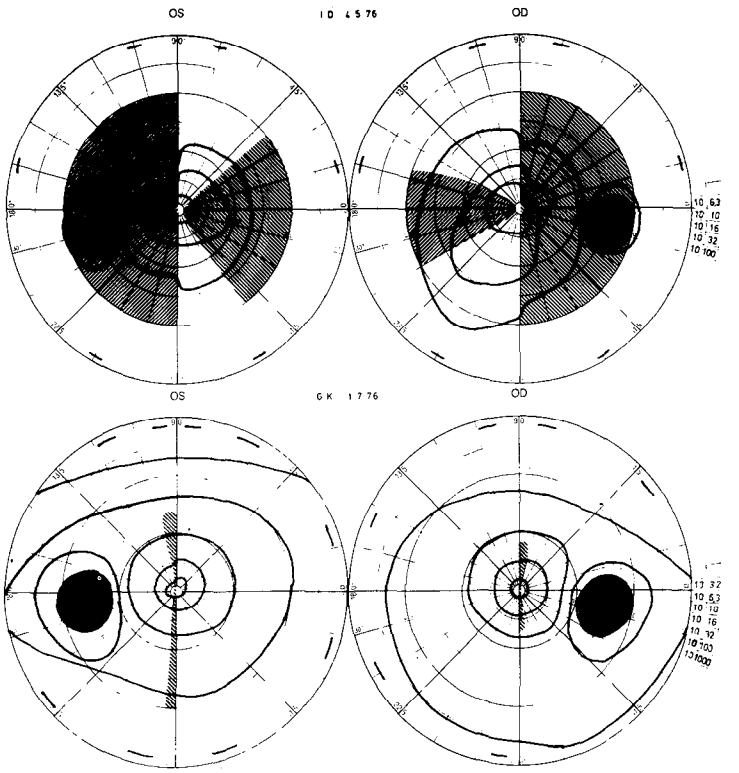


Fig. 5 Fields of two different patients with typically distributed changes for supraluminal stimuli

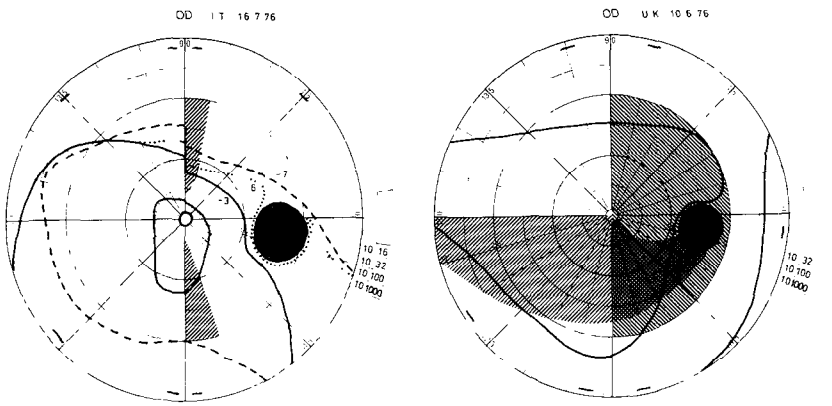
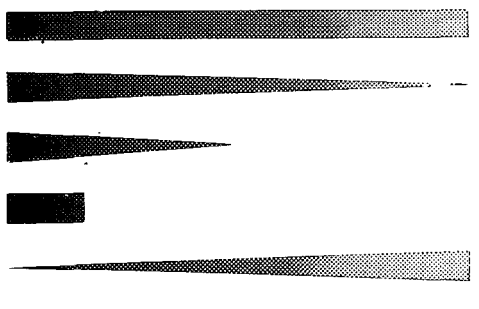


Fig 6 The sensoric disorder for supraluminal stimuli in chiasmal syndrone superimposed on a refraction-sectoma (left) and an old nerve-fiber change following retrobulbar neuritis (right)

Table 2.

	NR OF PAT
COLOR SATURATION MORE DISTURBED THAN BRIGHTNESS OF WHITE	34
COLOR SATURATION EQUAL OR LESS DISTURBED THAN BRIGHTNESS OF WHITE	19
SPECTRAL DISTRIBUTION OF DESATURATION	
	16 20 10 10 2
RED YELLOW GREEN BLUE VIOLET	

SUMMARY

The value of static and kinetic perimetry with white and colored stimuli in chiasmal syndrome seems to be similar. The presentation of evenly moving supraluminal stimuli may reveal discrete sensoric pathology earlier than conventional perimetry. Red is often superior to other colors, spectral colors are superior to pigment colors.

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AN OUTLINE OF THE CLINICAL INTEREST OF THE SPECTRAL INCREMENT THRESHOLDS ON A WHITE BACKGROUND IN ACQUIRED OCULAR DISEASES

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After having calibrated the Tübingen perimeter in view of increment threshold colour perimetry on white backgrounds (Verriest, Padmos & Greve, 1974), and after having described the results obtained in different age groups of normal subjects (Verriest & Kandemir, 1974; Verriest & Uvijls, 1977), we applied exactly the same technique to 120 pathological eyes, the only new feature being that, in order to plot more easily the individual results for the coloured objects in spectral sensitivity curves, we designed special wavelength vs. log sensitivity graphs, whereby each neutral density filters setting for each wavelength is immediately converted in the corresponding log watt. $m^{-2}.sr^{-1}$ value, moreover, the normal sensitivity range for each combination of wavelength, age group, background luminance (3.16 or 10.0 $cd.m^{-2}$) and eccentricity (0°, 6°, 20°, 50° and 45° nasally), is indicated by means of a thicker line.

Before analyzing the results obtained in pathology, it must first be emphasized that such increment threshold spectral sensitivity curves are never smooth because all curves from normal subjects are characterized at all eccentricities by peaks for our 451, 528 and 600 nm filters; these peaks

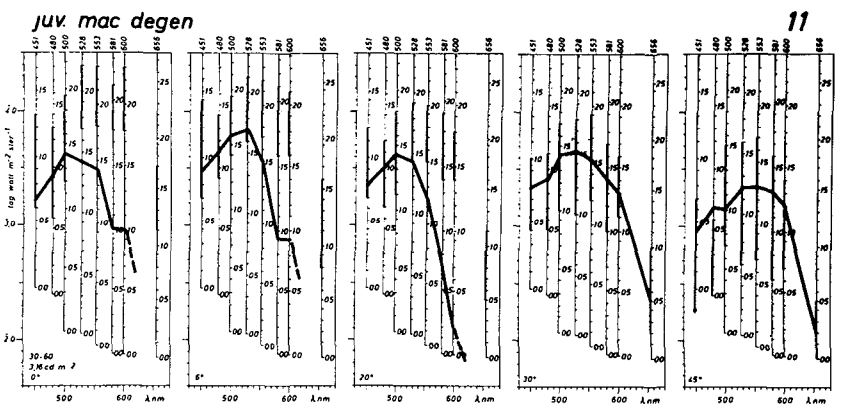

Fig 1 Juvenile macular degeneration Unevenly changed spectral sensitivity curves resulting in scotopisation at 0°, 6° and 20° of eccentricity

can be attributed to the blue, the green and the red retinal mechanisms or to their interactions, as shown by the results obtained in the congenital colour vision deficiencies.

When we look at the tracings from our 120 pathological cases, we class them immediately in two groups: on the one hand the cases in which the curves are either normal or evenly lowered, i.e., about the same amount for all seen wavelengths, and on the other the cases in which the spectral sensitivity curves are unevenly modified, i.e., evidently different amounts for the different seen wavelengths.

We recognized three types of uneven changes: (1) a stronger sensitivity loss for the longer wavelengths that reaches full scotopisation in juvenile macular degeneration (Fig. 1) and in generalized cone dysfunction, and is

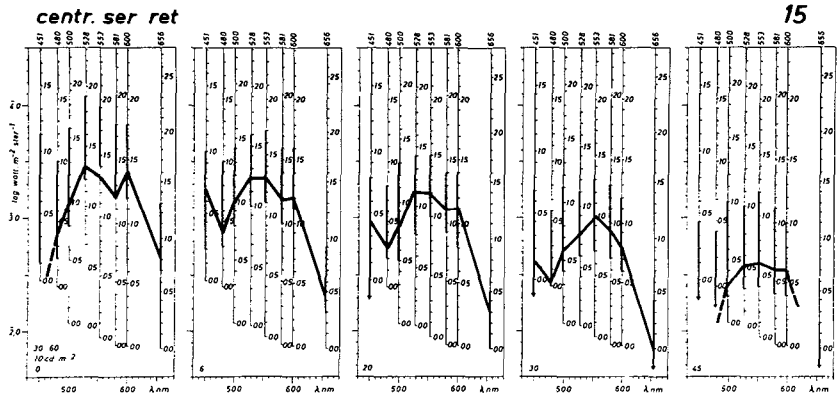

Fig 2 Central serous (chorio)retinopathy. Unevenly changed spectral sensitivity curve at 0°: lowered sensitivities for 451 and 553 nm.

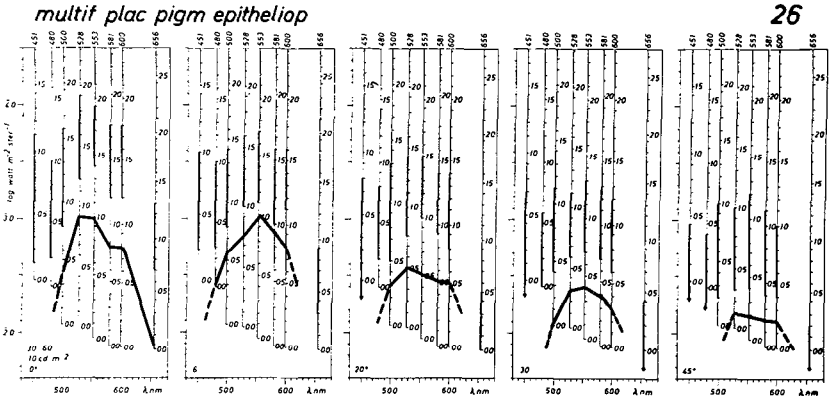

Fig. 3 Multifocal placoid pigment epitheliopathy. Evenly lowered spectral sensitivity curves at all tested eccentricities.

less pronounced in cystic macular degeneration and in myopia gravis; (2) inversely, a stronger sensitivity loss for the shortest wavelengths, as stated in some cases of pigmentary retinopathy, but especially in central serous retinopathy, where it is associated to a sensitivity loss to some intermediate wavelengths, in such a way that the 451 nm peak disappears and that the 600 nm peak becomes more evident (Fig. 2); (3) an enhancement of the sensitivity for the shortest wavelength, 451 nm, that we stated in some instances of optic nerve disease (retrobulbar neuritis, optic atrophy, nicotinic intoxication).

We found either normal or, more frequently, evenly lowered curves in all or in most of the examined cases of preretinal fibrosis, pigmentary retinopathy, senile macular degeneration, Fuchs' spot, secondary macular edema, chorioretinitis, diabetic retinopathy, macular lesions by synthetic antimalarial drugs, papillar edema, closed-angle glaucoma, neuritis retro-bulbaris, and optic atrophy.

The interest of our kind of colour perimetry lies not only in the statement of evenly or unevenly lowered curves, but also in the comparison of the extent of this disturbance as compared with that suggested by the ophthalmoscopic, bio-microscopic, fluo-angiographic and electro-retinographic examinations: although these methods suggested that the pathological process was restricted to the posterior pole, all our curves were abnormal, even at 45°, in 1 of our 7 cases of juvenile macular degeneration, in 4 of our 7 cases of central serous retinopathy, in 7 of our 8 cases of other macular edema's, and also in most cases of preretinal fibrosis, senile macular degeneration and choriocapillaritis (Fig. 3). Inversely, among our 7 cases of 'electroretinographical' generalized cone dysfunction, there are 3 cases where scotopisation does not extend in more than 20° eccentricity.

Finally, as concerns the detection accuracy of our methods in ocular pathology, we stated that, when the sensitivity for the white object is normal, the coloured objects are at least partially abnormal in about half of the instances. Moreover, our curves are also at least partially abnormal in more than two thirds of the cases wherein visual acuity is at least 10/10, and in more than four-fifths of the cases wherein colour discrimination is clinically normal.

In conclusion, the determination of the spectral sensitivity curves by means of that of the static achromatic thresholds for the monochromatic objects of the Tübingen perimeter is a relatively quick and very sensitive method, which is extremely useful for the differential diagnosis of the cone dystrophies with other diseases and for the differentiation of the congenital and acquired colour vision defects, but which can also be useful for the assessment of the kind and of the extent of the functional disturbances in other ophthalmic diseases.

We must thank Dr. J.J. De Laey for providing all cases with full diagnosis and for discussing our results.

SUMMARY

Energetical increment thresholds were measured in 120 pathological eyes at 5 eccentricities by means of 8 interference filters incorporated to a calibrated Tübingen perimeter. When compared to that of normal eyes, the age factor being considered, the so obtained spectral sensitivity curves can be either not evenly lowered (especially in the cone dystrophies) or evenly lowered. The method allows to estimate the relative sufferings of the retinal mechanisms; it is quick, more sensitive than white perimetry and often very useful for clinical diagnosis and prognosis.

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INVESTIGATION OF RETINITIS PIGMENTOSA BY USE OF SPECIFIC QUANTITATIVE PERIMETRY

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A slowly progressive deterioration of vision which is a characteristic of retinitis pigmentosa, affects the receptor mechanisms at different rates. In the early stages there is a reduction of the rod function. Less clearly charted is the involvement of the cone functions.

The routine perimetric examinations with the white test objects are inadequate to distinguish between the different retinal mechanisms (Sloan 1950). By methods combining static perimetry with the two-colour-threshold technique of Stiles the receptor mechanisms can be separately studied and quantitatively evaluated. Such methods were described simultaneously by Greve, Verduin & Ledeboer and by Hansen in 1973. The purpose of this

Table 1 Visual acuity and colour vision registered in 8 patients with retinitis pigmentosa

Tests	Case 1	2	3	4	5	6	7	8
Age, sex	12 F	18 F	27 M	17 F	36 M	26 M	37 M	28 M
Visual acuity	0 5	0 5	0 6	0 2	0 3	0.3	0 9	0 8
F D-15	N-	T	N-	IR	T	T/IR	T	T
F-II	–		–				–	
100 Hue	116 T		249 T		693 IR		493 T	
Ishihara (10-17)	8		–		–			8
H R R (r g)	13		5		1	–		13
,, (b.y)	5		–		–	–		1
Tissue paper contrasts	failed B, RP		-		–		–	failed V
Anomaloscope (r g screw)	45-47	47-48	50-52	0-73	35-60	47-57	47-50	43-46

N: normal, T: tritan, IR: irregular, B: blue, RP: red-purple, V: violet
No reading is indicated by

study is to report the results obtained on patients with retinitis pigmentosa using techniques of specific quantitative perimetry.

MATERIAL

8 patients, 5 males and 3 females, were examined. The diagnosis of retinitis pigmentosa had been verified by clinical examinations including ERG (case 1 and 3) and EOG (case 2, 4 and 7). In the two oldest patients (case 5 and 7) very slight posterior lens opacities were found. In the other patients clear ocular media were noticed. Visual acuity and the results of the colour vision tests are given in Table 1.

METHODS

Spectral sensitivity curves and perimetric profiles were registered in the Goldmann perimeter during chromatic adaptation. Near monochromatic object lights were used. Further details were described earlier (Hansen 1974, 1975). Colour vision examinations were performed with the AO-H.R.R. test containing 14 charts for red-green deficiencies and 6 charts for blue-yellow deficiencies. With the Farnsworth's D-15 test normal performance (N), tritan pattern (T) and irregular confusions (IR) were recorded. With the 100 Hue test error scores were recorded as well. The charts 10-17 of the Ishihara test (11th ed.), the Farnsworth's tritan chart (F-II) and the tissue paper contrast charts of the Velhagen-Stilling test (21st ed.) and the Cohn's test (1905) were used. Case 8 was examined with a new series of tissue paper

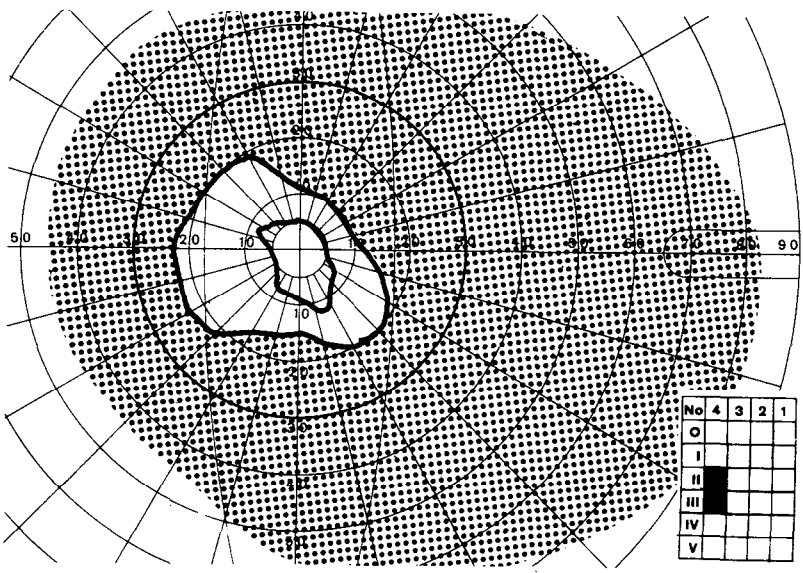

Fig. 1. The right visual field of case 1.

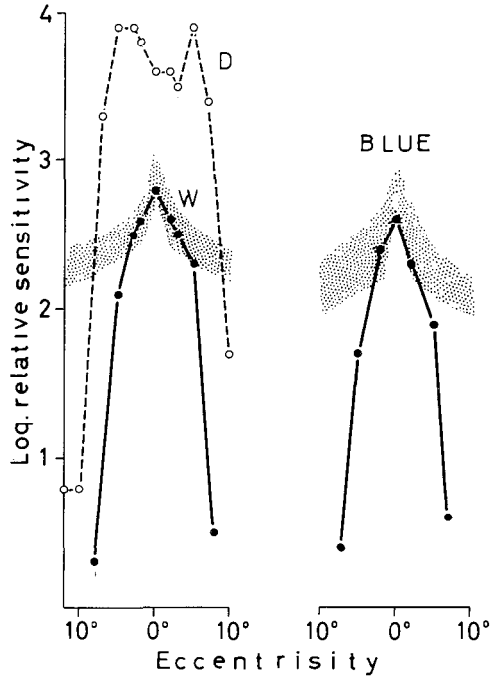

Fig 2 Static perimetry performed in case 1 during total dark adaption (D), in standard white illumination (W) and in blue light. Object II (white), III (λ_{max} = 515 nm) and IV (λ_{max} = 617,5 nm) were used in the white, the dark and the blue backgrounds respectively Shaded area indicates the normal variation (± 1 s.d.).

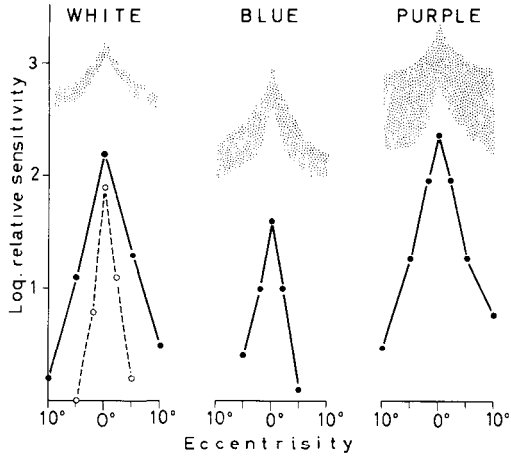

Fig 3 Static perimetry curves of case 2 in standard white and coloured backgrounds. Object IV and II (stippled line) were used in white and object IV with maximal transmission at λ = 617,5 nm and at λ = 562,5 nm in the blue and purple light respectively Shaded area indicates the normal variation (± 1 s.d).

contrast charts. The anomaloscope examinations were performed with the Nagel anomaloscope, type I. Mean normal value of the red-green screw is at 40 and that of the yellow screw at 16.

RESULTS

Case 1 having visual field defects of medium severity (Fig. 1) showed some recidual rod response near the fixation point (Fig. 2). Static perimetry in standard white illumination indicates that there is a good cone function centrally, and the high central sensitivity level in blue light indicates that there is a red receptor functioning.

Case 2 with a rather smaller field showed clearly reduced threshold sensitivity by static perimetry (Fig. 3). The sensitivity level is relatively more reduced in the blue than in the purple light indicating a weak red receptor function. Spectral sensitivity curves registered against white, blue, purple and yellow backgrounds confirm that the red receptor mechanism is present though not very distinct. No blue receptor response could be demonstrated (Fig. 4).

Case 3 also with a small central field (Fig. 5), has response patterns indicating the presence of all the cone mechanisms though at reduced levels (Fig. 6). Even a weak blue receptor mechanism could be traced.

Case 4 is characterized by a great difference between the isopters (Fig. 7). The spectral sensitivity curves registered against coloured backgrounds demonstrate only one receptor mechanism, i.e. the red sensitive one (though covering a broad range of the spectrum), (Fig. 8). This is consistent with the anomaloscope examinations where settings between 0/18 and 73/12 were accepted. No blue receptor response was demonstrated. This patient probably has a combined congenital and acquired colour vision defect.

Case 5 with a small central field (Fig. 9) has a severe colour vision defect. The spectral sensitivity curves obtained on coloured backgrounds (Fig. 10) present little distinction between the red and green sensitive mechanisms. No blue sensitive mechanism could be demonstrated.

Case 6 having extreme tube vision, could only indicate the threshold level at 0° by static perimetry. In Fig. 11 a distinct green receptor mechanism is demonstrated while the red receptor mechanism is indistinct. No blue receptor mechanism could be traced.

Case 7 with a medium visual field loss (Fig. 12) had nearly identical perimetric profiles on standard white and dark backgrounds (Fig. 13) demonstrating complete loss of rod function. The registration on blue and purple backgrounds indicate a reduction of the red and the green sensitive mechanisms to approximately the same extent. Fig. 14 shows typical pattern for both the receptors at a reduced level. Against a yellow background (which in this case was adjusted to half the usual level of intensity) only a weak green receptor response and no blue receptor response could be recorded Nor in the paracentral region could any blue sensitive mechanism be traced.

Case 8 having a moderate reduction of the visual fields (Fig. 15) was

examined with a special technique in order to bring forward the blue receptor response with a minimum of influence from the other receptors. Monochromatic yellow light produced by a low pressure Na-lamp illuminated the sphere. Against this background the patient was unable to identify any short wave-length stimuli which were, however, distinctly seen by normal persons (Fig 16).

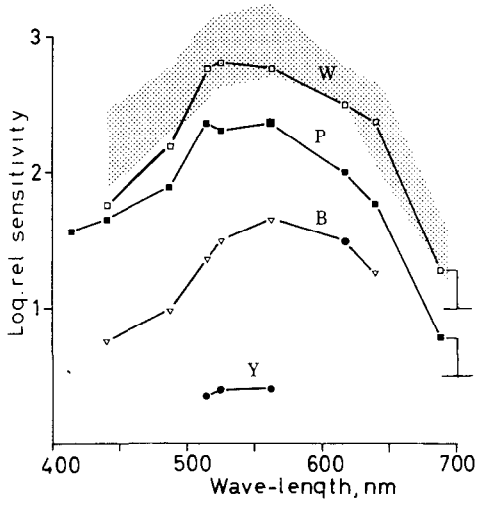

Fig 4 Spectral sensitivity curves obtained in case 2 in white (W), purple (P), blue (B) and yellow (Y) lights respectively Shaded area indicates the normal response in purple light (± 1 s d) being valid also for the Figures 6, 8, 10 and 11.

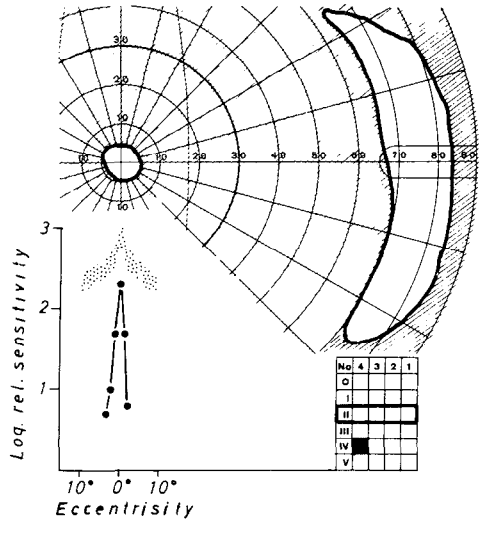

Fig 5 The right visual field of case 3.

DISCUSSION

In addition to the early loss of rod function our cases demonstrate that also the blue sensitive receptors are lacking or considerably reduced in their function. This is not surprising as more often the blue-yellow than the

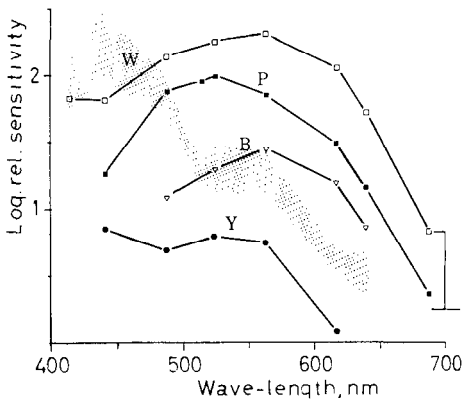

Fig. 6. Spectral sensitivity curves obtained in case 3 in white (W), purple (P), blue (B) and yellow (Y) lights Shaded area indicates the normal response in yellow light (± 1 s.d) being valid also for the Figures 4, 8, 10 and 11.

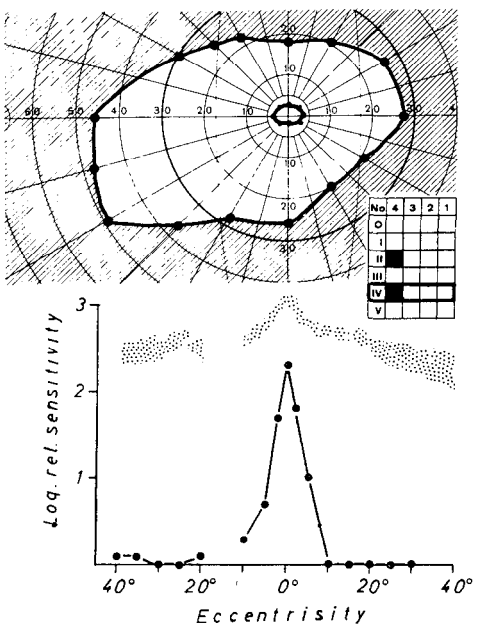

Fig 7. The left visual field of case 4

red-green discrimination is affected in typical retinitis pigmentosa (Verriest 1974). In our material tritan colour vision defects were registered in 7 patients. One patient had a red-green defect which might have been of congenital type even though the patient is a female. But also in this patient the blue receptor response was lacking. Blue receptor function may be preserved in retinal diseases which sometimes may be confused with retinitis pigmentosa. Therefore, for the purpose of differential diagnosis, registration of the blue receptor function is of importance. Perimetry with the eye adapted to the pure yellow illumination of the Na-lamp and the use of object lights corresponding to the peak sensitivity of the blue sensitive mechanisme has proved to be a simple and efficient technique.

A common finding in our patients with small visual fields was the weak and indistinct red receptor response. A deviation of the Rayleigh equation in the direction of protanomaly which was found parallel to this indicates in the same way a weakened red receptor function. Though at a reduced level the green receptor character was more distinctly recognized.

Therefore, in the advanced cases of retinitis pigmentosa not only greatly limited fields but also a limitation of the spectral sensitivity range seems to be the case.

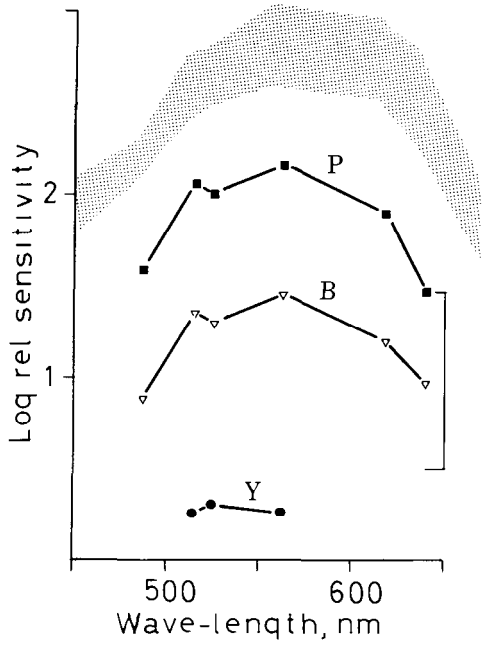

Fig. 8 Spectral sensitivity curves in case 4 in purple (P), blue (B) and yellow (Y) lights Shaded area indicates the normal response in blue light (± 1 s d) being valid also for the Figures 4, 6, 10 and 11.

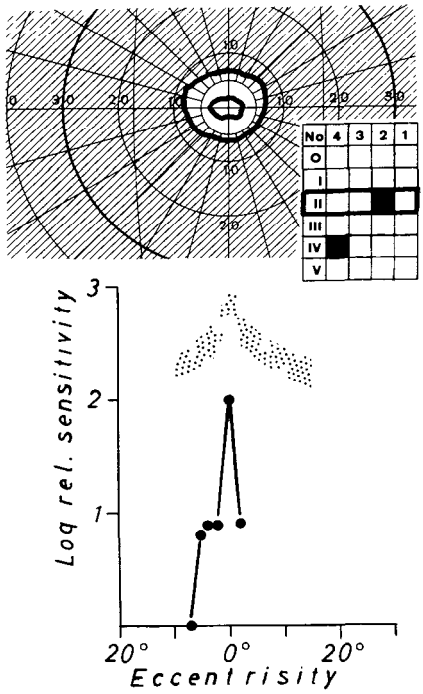

Fig. 9. The left visual field of case 5.

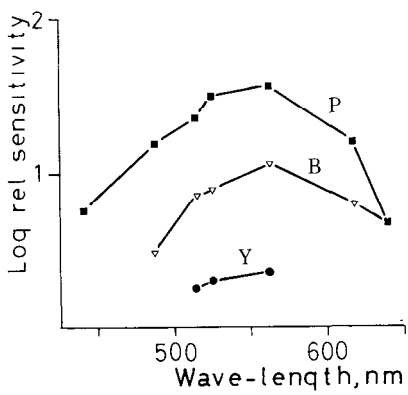

Fig 10 Spectral sensitivity in case 5 in purple (P), blue (B) and yellow (Y) lights.

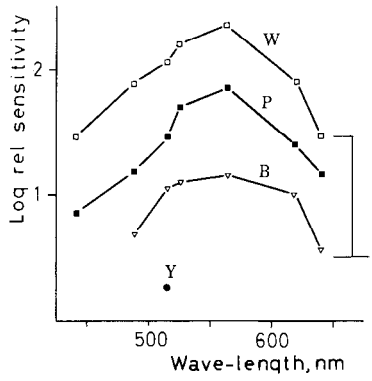

Fig. 11. Spectral sensitivity in case 6 in white (W), purple (P), blue (B) and yellow (Y) lights.

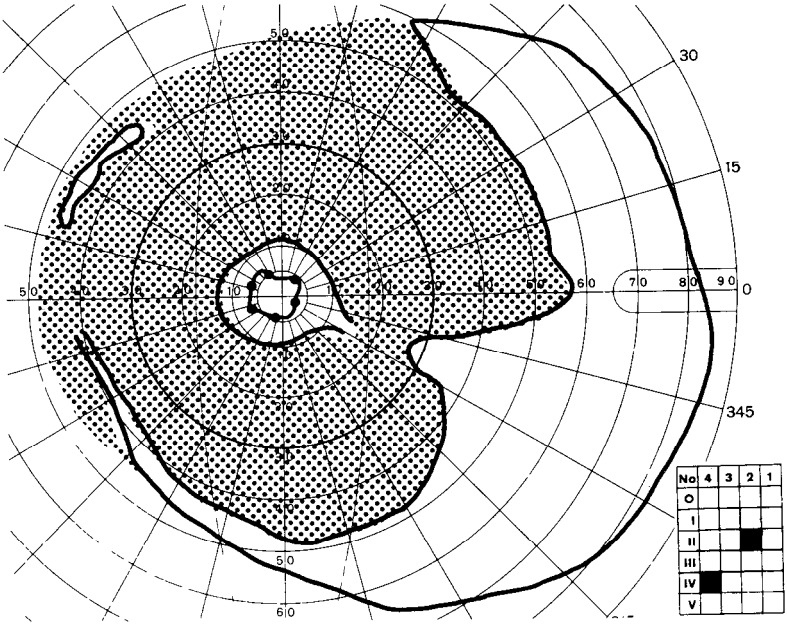

Fig. 12. The right visual field of case 7

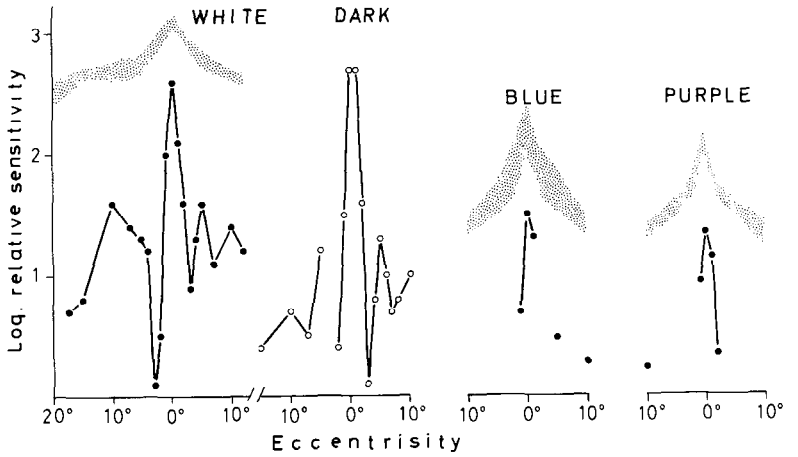

Fig. 13. Static perimetry performed in case 7 Object IV (white), III (λ_{max} = 515 nm), IV (λ_{max} = 582 nm) and IV (λ_{max} = 552 nm) were used in the white, the dark, the blue and the purple backgrounds respectively. Shaded area indicates the normal variation (± 1 s.d).

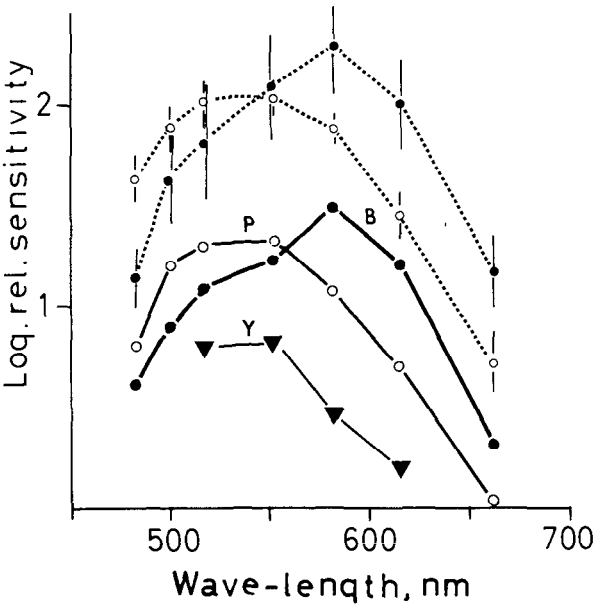

Fig. 14 Spectral sensitivity curves of case 7 in blue (B) and purple (P) lights and in yellow light of reduced intensity (Y). Stippled lines indicate the normal response pattern in blue and purple lights (± 1 s d)

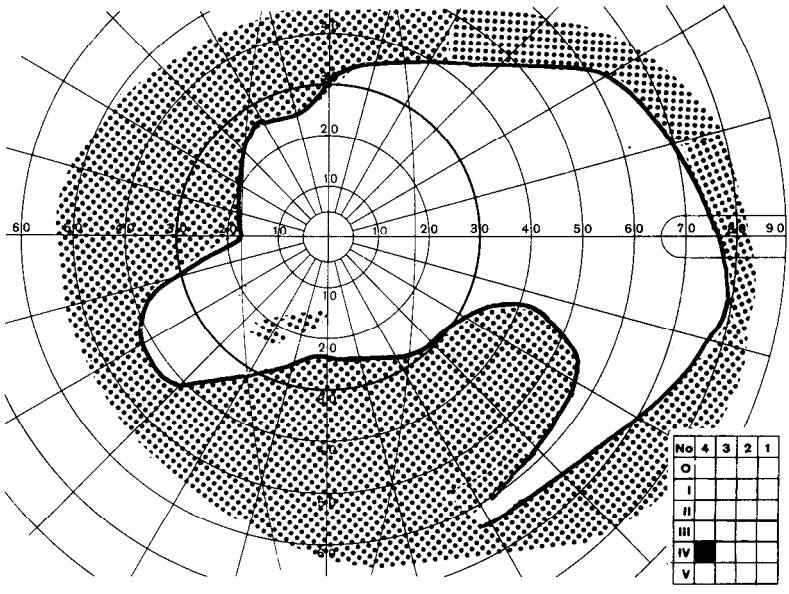

Fig. 15. The right visual field of case 8.

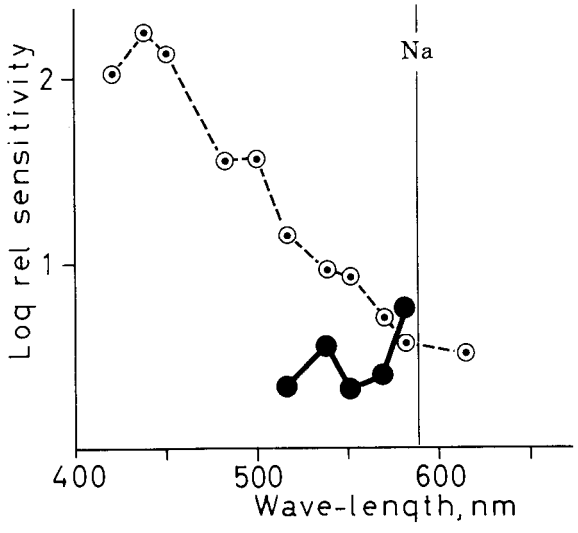

Fig. 16. Spectral sensitivity registered in case 8 against a background of monochromatic yellow light from a low pressure Na-lamp (λ = 589 nm, 1500 lx). The performance of a normal individual in the same age group is shown by stippled line. The measurements were done 4° paracentrally in the temporal field.

SUMMARY

A reduced light threshold sensitivity is commonly found in retinitis pigmentosa. By static perimetry applying the two-colour threshold technique of Stiles differentiated response patterns can be obtained. Retinitis pigmentosa patients in different stages were analyzed with this technique. Colour vision examinations were made parallel to this. The most typical finding is an early loss of the blue receptor mechanism which is consistent with the tritan type of colour vision deficiency being present in the same patients.

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THE RESULTS OF A COMPARISON OF THE HUNDRED HUE TEST AND STATIC COLOUR PERIMETRY IN DIABETIC RETINOPATHY
(short description of methods and results)

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(Bristol, England)

The use of angular resolution acuity as an absolute measurement in the assessment of retinal disease is open to criticism, Sloan. Perimetric exploration of retinal function can enhance the examination by the use of the static colour profile, and this could be of particular value to those diseases which exhibit colour loss an early manifestation of the retinal disorder. In 1968 Cullen demonstrated changes in the 100 hue at an early stage in diabetic retinopathy. In 1975 Maguire showed scotomatous changes by static perimetry in the exudative phase of a retinopathy.

Thus, there is data on hue and brightness in diabetic retinal disease but the information on brightness in relation to colour is still rather sparse. Added to this is a lack of information on normal static colour profiles.

Diabetics attend a special clinic. Each patient has had a full general opthalmological assessment followed by fundus photography and usually fluorescein angiography. Data is gathered on the duration of their disease and any familial trait. Blood group studies including HLA and bio-chemical studies, encompassing cholesterol lipids and vitamin B12 are performed in each case. Their colour vision is measured by the D15 and 100 hue and a newer pseudo-isocromatic plate, curently being developed in Bristol.

A selected number of patients has been studied with the Goldman perimeter to assess their deficit for red and green. The patients examined fell into three groups of 'normal' subjects.

(a) Patients without any disease or known ocular disease.
(b) Patients with congenital colour blindness
(c) Diabetics. The first group of diabetics was thought to be normal in every respect.

The third (c) group of patients consisted of those having minimal retinal changes and the third group had retinal changes which were known to be established and associated with a defect on the 100 hue.

It should be borne in mind that two different modalities of colour are being examined and the absence of satisfactory standards makes it difficult to postulate a percentage loss to validate the comparisons on a statistical basis. However, there appeared to be a general trend indicating that any defect

was more marked on the static profile than the 100 hue test.

Examination of the patients revealed a distinct correlation between the observed fundus changes and the defect in the colour vision and static perimetry. The red deficiency was more marked than had been anticipated and the depression was inconsistent with the recording of the 100 hue test. Depression of the red isopter was noteable throughout and was also noted in relation to white light. The profiles for green were better than had been expected after inspection of the 100 hue error in this region, specially 490-530 nm.

As all cases were examined under mesoptic conditions it was felt that no conclusion could be drawn as to any pseudo-isocromatic interval.

It could be argued that some of the changes were more consistent with a change related to age. Correction of the 100 hue error score did not substantiate this and the positive anatomical correlations would give more support to this being related to the duration or retinopathy type.

The small scotomatous changes demonstrated on static perimetry must cast doubt on the validity of isolated acuity readings. A series of assessments acuity, colour vision and static perimetry including colour, offer a better way of estimating the depth of retinal disfunction and, therefore, would provide a sounder basis on which to assess any response to treatment.

It is concluded that the static profiles offer a satisfactory way of examining patients at an early stage and may provide a better parameter for the estimation of benefit obtained by light coagulation or other therapeutic measures.

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SUMMARY OF SESSION VIII: COLOUR PERIMETRY

G. VERRIEST

The Research Group on Colour Perimetry of the International Perimetric Society states that there is strongly renewed interest in clinical perimetry by means of coloured objects, especially for the determination of the achromatic and chromatic increment thresholds on white or coloured backgrounds, and for the assessment of the subjective saturation in different parts of the visual field, as these methods proved to be very effective for the recognition and the follow-up of many diseases. However, the Group stresses that such methods imply severe photometric and colormetric controls, the comparison of the pathological cases with a sufficient number of normal cases of the same age range, and, when the retinal chromatic mechanisms are appreciated, a background of photopic level and colours of well chosen spectral distributions.

In this connection, a provisory agreement was made with both Prof. Goldmann and Prof. Harms, in order that both the Goldmann and the Tübingen apparatuses should be fitted, on request of the buyers and/or owners, with the same standardized test object and background selective filters (e.g. well placed narrow band interference filters with the appropriate cutting filters for the test object), with light sources providing a basis luminance higher than the actual ones, and with simple devices allowing to check easily radiance, luminances and spectral distribution. Accordingly, I will have a correspondence with all members of the Research Group and with the Standardization and Automation Groups in order to be able to propose to the constructor detailed instructions for the aim of this standardization. Prof. Enoch also approved this project.

CLOSING SPEECH

A. DUBOIS-POULSEN

(Paris, France)

The second International Visual Field Symposium has come to an end. Two years ago we met in Marseilles for the first symposium which took place on the occasion of the International Congress in Paris. It was a great event for all physiologists and practitioners interested in perimetrical questions; it was the first time they met. Many of them had never met the other perimetrologists and many worked in isolation. The visual field examination itself was not popular. It is a very time-consuming technique which, to be correctly performed, necessitates precise physiological knowledge and is, therefore, unattractive to many clinicians. Moreover, it seems to be a subjective examination and many people will always prefer what they call 'anatomical objectivity', being unaware that, in taking this standpoint, they deprive themselves of a good deal of knowledge. Among all the symposia organised on the occasion of the Congress, the Visual Field Symposium was thought to be the least interesting and until the last moment its achievement seemed very problematic. In truth it was a very great success for which we must be grateful to the Marseilles' team directed by Professor Jayle and to the dynamic Dr. Greve from Amsterdam whose faith moved mountains. Everyone thought that the first symposium was such a success, the atmosphere was so friendly and the various specialists were so pleased to get to know each other, that it was decided to create an International Perimetric Society and to meet every two years. Many problems were still under discussion and everyone hoped that these discussions could be continued. A series of Research Groups were created under the direction of the best authorities among our members. Professor Harms became Honorary President, Professor Aulhorn - President and the General Secretariat was entrusted to Dr. Greve, being the principal promoter.

It was this team that ensured the great success of this Second Symposium, demonstrating that the infant born in Marseilles was alive and had made a good start in life, and that the idea which seemed so disputable then had taken solid roots.

The success of this second meeting has been even greater than that of the first We are most grateful to the organisers: Prof Harms who received us in his beautiful university town of Tübingen. Professor Aulhorn who organised everything for our instruction and our pleasure with so much friendliness and in such a charming manner, Dr. Greve who assumed the thankless and

heavy task of the secretariat, collecting the papers and organization of the scientific programme. Everything went perfect: the organization of the sessions and the high standard of the papers read. The excursions were most interesting and beautiful in this early autumn season, the monastery of Bebenhausen leaves splendid memories in our minds and we greatly appreciated the concert which was given by Professor Harm's assistants. This afternoon's trip to the Swabian Hills and to the Castle of Lichtenstein was certainly interesting and enjoyable. All this has been possible because Tübingen is one of the International Temples of perimetry and because our hosts are its high priests.

What has this symposium given to us? Our Research Group Chairmen have presented their summaries of the sessions over which they presided. I should like to neglect the details and indicate the main features.

The character of this symposium is not the same as that of the previous one. In the first symposium technical aspects predominated and many considerations on methods of examinations were developed. Colour perimetry in particular has taken a new departure, for it was greatly facilitated by a new chromatic instrument which did not exist a few years ago. Automation raised hopes of quick and easy examinations. The second symposium has been more clinical and it seems that the application of perimetry to diagnosis has received more consideration.

The authors have been more interested in glaucoma, the great neurological syndromes and the central scotomata. It was stated that the perimetric examination should not be neglected in general pathology and circumstances have been described in which the perimetric examination was the only way to diagnosis. The perimetrologists have also recognized the necessity of speaking a common language and have begun a work of normalization which I should wish to see completed before the International Congress in Kyoto, where it should be put in practice. Automation has taken giant strides. Alternative solutions are offered and, as always, technical efforts have revealed new physiological principles of general interest. I was particularly interested in the instrumental attempts which have been made to determine the exact spot on the fundus which is under perimetric examination, and in the achievement of macular perimetry. For these reasons the printed proceedings of this symposium will form a most valuable book for our discipline.

I hope that the Third International Visual Field Symposium in Tokyo will cover a still wider field and that it will afford us highlights on the characteristics and peculiarities of peripheral vision about which so little is known.

Professor Matsuo has cordially invited us to his magnificent country. Japanese hospitality is proverbial and I have personally experienced it. The third meeting will undoubtedly be a great success. Today our most urgent duty is to express our gratitude to our guests. For a long time the Tübingen symposium, the work which has been performed and the atmosphere of friendship prevailing here will be the topic of our conversations. Now we are looking forward to 1978 which will be Japanese. As I have already begun to

study Japanese, I shall say to Professor Harms, to Professor Aulhorn and to Dr. Greve 'Aligato gozaïmashita', Danke schön, I hope to see you in Tokyo. 'Sayo nara', auf wieder sehn.

Professor Aulhorn has been re-elected President of our society. She will be our guide to Japan and personally I think, as all English people do, that it is a delightful experience to be ruled by a queen.