CLINICAL

Computer-Based Analysis of Visual Fields:

Age-Related Norms for the Central Visual Field

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Abstract

This paper will fulfill two purposes:

A. To describe ways, means, and advantages of using computers to analyse two-dimensional clinical data (e.g. photographs, charts) so that the reader will have a clearer understanding of these methods and perhaps start considering applying them in practice.

B. To present the results from a study of the central visual fields of 129 normal patients aged 10 to 70 years. These results are presented as average central fields for individual age groups (15, 25, 35, 45, 55, 65 years) so that the reader may compare a given patient's central field data to a norm for that patient's age group.

Abrégé

Ce travail se propose deux objectifs:

a) une description des procédés et des avantages d'utiliser un ordinateur dans l'analyse des données cliniques à deux dimensions (photographie-tabler, figures) afin que le lecteur apprécie d'avantage la technique et considère son emploi dans sa practique.

b) de rapporter les résultats d'une enquête du champ visuel central sur un échantillon de 129 personnes reparties entre les âges de 10 à 70 ans. Ces données sont présentées en fonction d'une moyenne du champ visuel par groupe d'âge (15, 23, 35, 45, 55, 65) permettant une comparaison d'aucun individu à une norme pour son âge.

Part A: Analysing Two-Dimensional Figures

Hardware

One of the best devices for converting data on a chart into data which the computer can handle is a digitizing table. This is shown in Fig. 1. Each point (e.g. points A, B, C, and D in Fig. 2) must be represented in terms of X and Y coordinates. To do this, the figure to be analysed is taped to the surface of the digitizing table. A moveable cursor, consisting of an X-shaped reference mark, a receiving coil, and a pushbutton switch, is lined up with the point to be 'digitized' (e.g. point B in Fig. 2), and the button is depressed.

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Fig. 1 View of digitizing pad (Summagraphics BIT PAD ONE) and microcomputer (Commodore PET). Digitizing pad is sitting on the extendable writing surface of the desk.

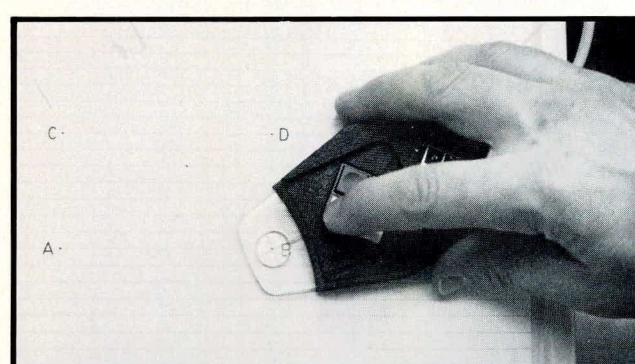


Fig. 2 A sheet of graph paper has been taped to surface of digitizing table and cursor placed on it. Four points on the paper will be digitized. Note X-shaped reference mark with circle around it: the circle contains a fine copper wire which is the sensor. There are four push-buttons on the cursor. The computer knows which button has been pressed, and it is possible to program different functions for each button.

Measuring an Area

Fig. 3 shows the X and Y coordinates for the four points shown in Fig. 2 as they appear on the computer display. The coordinates are given in 1/10 mm units: thus point A is 108.9 mm from the left hand edge, and 82.5 mm above the bottom edge of the digitizing table. Coordinates for B are (1920,832). If the line AB had been placed exactly parallel to the bottom edge of the digitizing table, then there would be no difference in the Y values for points A and B: as it is, there is a difference of 0.7 mm. This slight misalignment of the figure on the digitizing table is of no practical importance, as the computer is programmed to calculate distances (like the distance AB) based on the formulae of analytic geometry: only the point coordinates are required. Thus the distance AB would be calculated correctly regardless of the orientation of the line AB on the digitizing table. The same is true for calculation of the area of the rectangle ABDC (which is 3704.3 mm^2). (For more information concerning hardware, see Appendix A.)

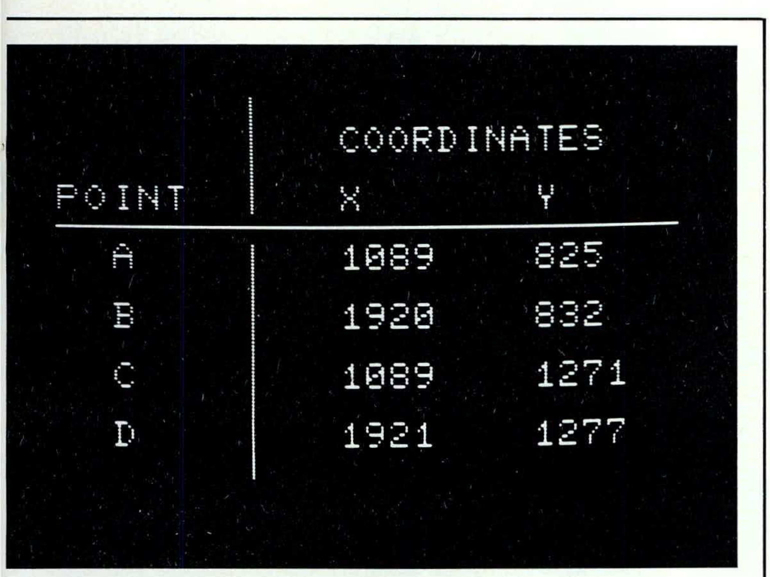
Measuring Visual Field Area

Analysis of visual field charts presents two fundamental problems:

1. Are there any marked abnormalities in the *shape* of the isopters (an isopter is the locus of points at which a specific stimulus is seen)? Are there quadrants or larger portions of the field missing, or anomalies of the blind spot?
2. Are the isopters of normal *size*?

The first question is usually answered by observation of the field chart and will not be dealt with in this report. However, computer-based analysis may be used for this purpose.

The second question prompts reference to normal visual field data: difficulties sometimes arise here because (a) the patient's isopter occasionally wanders inside and outside the limits of the normal chart, or (b) no normal data are available for the patient's age group (the size of the visual field is known to decrease with age).



POINT	COORDINATES X	Y
A	1089	825
B	1920	832
C	1089	1271
D	1921	1277

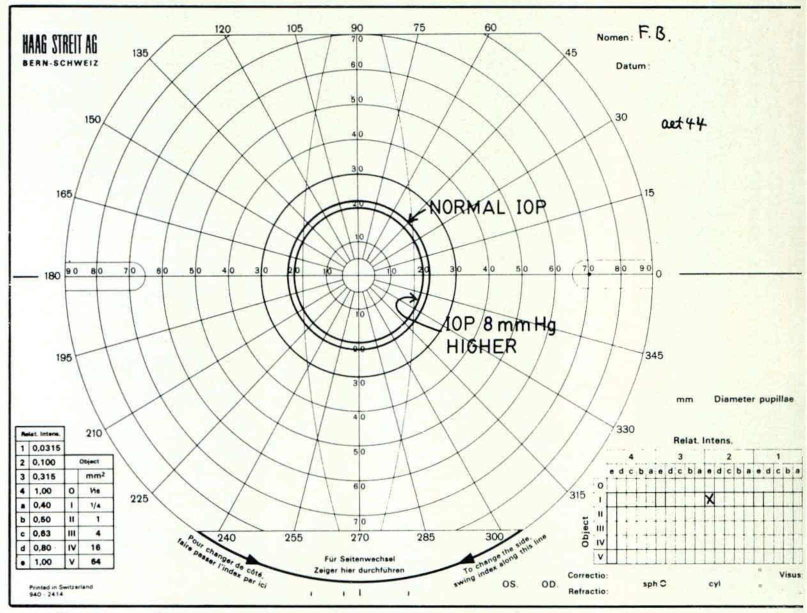


Fig. 4 Outer isopter represents normal I_2 isopter for a 44 year old patient with normal intraocular pressure. Inner isopter represents reduction in field size in an ocular hypertensive whose intraocular pressure has increased 8 mmHg due to provocative testing with topical steroid. The inner isopter has an area 20% smaller than the outer isopter.

There is a subtler problem in estimating the size of isopters: while the practitioner may do a good job of estimating the *length* of lines (or radii), it is very difficult to establish by inspection the *area* of a figure. This is further complicated when the figure is irregular.

Advantages of Measuring Area of Visual Field

(i) Area changes with the square of the radius

The area of the visual field is roughly a function of the *square* of its component radii: small, consistent changes in the position of data points on the isopter will have large effects on the area of the isopter. For example, Hart and Becker[1] employed computer-based visual field analysis to assess the effect of temporarily increased intraocular pressure. They found that an intraocular pressure increase of 8 mmHg produced a decrease in visual field area of approximately 20%. Such a change is shown in Fig. 4. For the purpose of this demonstration, the isopter is shown as round. If this patient had an initial isopter radius of 22.5° (26.4 mm on the chart), this would correspond to a visual field area (on the chart) of 2189 mm^2. If this field were to be reduced by 20% (to 1751 mm^2), this would correspond to an isopter radius of 20° (23.6 mm on the chart). Thus a small change in radius produces a much larger change in area of the field.

Fig. 3 Computer display showing X and Y coordinates obtained for the four points in Fig. 2.

(ii) Variability of points on the isopter

Most clinicians will agree that patients show some variability in the location of individual points on the isopter. Data supplied by Werner and Drance[2] indicate that variability of 5° or less in any point on the isopter is probably not clinically significant. Since this variability can occur on either side of a given isopter point, it is quite likely that it would not have a marked effect on the area of isopters plotted on different occasions, because there are usually at least 12 points on each isopter: some will be inside the first isopter points and others will be outside the first isopter points. If an *area* is computed for each isopter, this will effectively average out these differences.

Targets for Central Field Testing

Central fields are tested with the tangent screen or the perimeter. These procedures will yield equivalent visual field dimensions, provided that equivalent test stimuli are used: for the tangent screen, this would be a 1 mm white pin at 1 m, with a screen illuminance of 10 to 15 foot-candles (100-160 lux); for the perimeter, the test stimulus I_2 would be used. In other words, the 1/1000 W tangent screen isopter should match the I_2 perimeter isopter. (For more information concerning test targets, see Appendix B.)

Analysing a Field Chart

To measure the area (in terms of square millimeters on the chart) of an isopter, the chart is taped to the digitizing pad and the data points are digitized using the cursor. This arrangement is shown in Fig. 5. The field chart to be analysed is for the normal right eye of a 70 year old patient. It is necessary to let the computer know how many points are on the isopter: for routine analysis of fields, 12 points are used. The fixation point is also digitized, so that the area of the field may be measured sector by sector. The first three sectors of the innermost isopter are shown in Fig. 5. After all data points have been input, the computer displays for each isopter the area of each of the 12 sectors on the chart, the sum of the sector areas for each of the 4 quadrants, and the sum of the areas of all 4 quadrants. If desired, the blind spot may be analysed similarly, and its area subtracted from the total, although most studies of visual field area do not do this. The total areas of the three isopters shown in Fig. 5 (not subtracting the blind spot areas) are 2215, 5830 and 14833 mm^2 for the I_2, I_3, and III_3 isopters respectively.

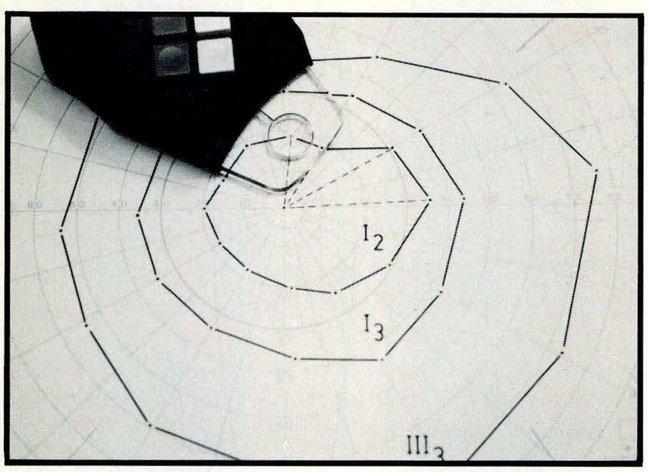


Fig. 5 Field chart on digitizing table with cursor lined up with first data point on the I_2 isopter. This isopter is equivalent to a 1/1000 W tangent screen isopter.

Part B: Central Field Study

Population Studied

Patients aged 10-70 years were asked to participate in the study while they were seen in the Clinic of the University of Waterloo School of Optometry. All patients were free of systemic and ocular disease, and had best corrected acuities of 6/6.

Method

All visual field data were obtained using the same Goldmann perimeter, manufactured by Haag-Streit.

Instructions to Patient

Since patient instructions are an important determinant of successful field testing, it would be useful to mention here the instructions we used:

1. We will be testing *one eye at a time.*
2. This is a test of your *side vision*; you must resist the (natural) urge to look at the moving target. You must concentrate your attention on the tip of the silver pin you see in the center of the black hole in front of you.
3. This is a *threshold test*: we will be going from a condition where you are positive you *don't* see the target (spot of light) to a condition where you are positive you *do* see the target. We want you to let us know (push the response button) as soon as you *think* you see the spot. Don't wait until you are certain. You will probably be uncertain of your responses most of the time. That is normal.
4. We will be using a small, dim spot: it *is* hard to see, but that is part of the test.
5. We will always tell you what direction we are coming from (in terms of o'clock position) so you won't have to guess.

These instructions are given while the patient is seated in a semi-darkened room, facing the illuminated bowl of the perimeter. A trial case lens is used to give the patient an appropriate correction for the 1/3 m viewing distance of the perimeter. All patients were tested with their pupils and ciliary muscles in a normal state.

Results

Using the Goldmann perimeter target I_2 (target area = ¼ mm², intensity = 100 apostilbs — this target yields field results which are equivalent to those obtained with a 1 mm W pin at 1 m when the tangent screen illuminance is 10-15 foot-candles), right and left visual fields were determined for 129 normal patients. Their age distribution is shown in Table I.

X and Y coordinates were determined for each point around the I_2 isopters. As no significant difference ($p < .05$) was found between left and right visual fields, the left visual field data were pooled with the right visual field data by mathematically reversing the left visual field data.

Next, the isopter coordinates for each age group were averaged to produce the normal field plots shown in Fig. 6.

The outermost isopter is for the groups aged 15 and 25 years: the averaged data points for these two groups were coincident. The second isopter in is for the group aged 35, the next for age 45, and so on. At the 4 o'clock position, the average isopter points for the first three age groups are coincident.

The areas of the isopters are shown in Table II.

TABLE I

AGE DISTRIBUTION OF PATIENTS PARTICIPATING IN STUDY

Age Group	Range	Number of patients	Number of isopters
15	10-20	13	26
25	20-30	33	66
35	30-40	22	44
45	40-50	24	48
55	50-60	22	44
65	60-70	15	30
	TOTALS	129	258

TABLE II

AREA OF NORMAL CENTRAL FIELD
(Goldmann I_2 stimulus)

Age Group	Isopter area (mm²)	Per Cent. Reduction*
15	6728	0.0
25	6728	0.0
35	6125	8.9
45	5156	23.3
55	3376	49.8
65	2772	58.7

*relative to 15-25 yr. age group

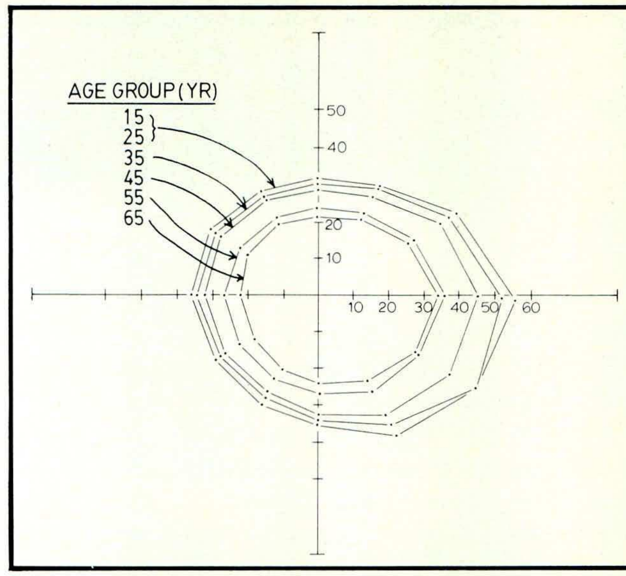


Fig. 6 **Normal central field isopters for different age groups. Test target was the Goldmann I_2 stimulus, which is equivalent to a 1 mm W pin at 1 m when the tangent screen illuminance is 10-15 foot-candles.**

Comments

1. The series of normal central isopters shown in Fig. 6 should provide a helpful age-related reference point for the practitioner who is evaluating the size of a central field for an individual patient.

2. The size of the field appears to drop more markedly after the age of 45. This would suggest that the effects of aging (at least as indicated by changes in the size of the visual field) are not linear, but are less marked before age 45 and more marked thereafter.

3. Manipulating visual field charts as *data* may lead to better clinical decisions (in some cases) than simple subjective analysis of *shapes*.

Acknowledgments

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Perimetry and digitizing of isopters were performed by Diane Quinlan (UW Optometry Class of 1984), who was my research assistant during this project. Her meticulous work and enthusiasm were invaluable.

References

1. Hart, W.M., and B. Becker, Visual field changes in ocular hypertension, a computer-based analysis, *Arch Ophthalmol* 95:1176-1179, July 1977
2. Werner, E.B., and S.M. Drance, Early visual field disturbances in glaucoma, *Arch Ophthalmol* 95: 1173-1175, July 1977

Appendix A

Pushing the button starts a timer and releases a pulse of electrical current along a wire below the surface of the table, generating a strain wave through a mesh of wires just under the surface of the table. The receiving coil, simply a circle of fine copper wire in which the X-shaped reference mark is centered, senses the passing of the strain wave: this is used to time the delay required for the strain wave to reach the receiving coil. The timing information is converted by the microprocessor of the digitizing table into X and Y coordinates (accurate to 0.1 mm), which are then transmitted from the digitizing table to the computer. All of this happens virtually instantaneously.

Incidentally, the digitizing table (or pad, or graphics tablet as it is cometimes called) may be programmed to output X and Y coordinates in several different ways. For example, it is possible to have it provide a continuous stream of data points whenever the switch is pressed. It is also possible to have the X and Y coordinates produced as soon as the cursor is brought close to the surface of the pad. There is also a different cursor (like a ball-point pen) which can be used to replace the larger cursor shown in Figs. 1 and 2. The advantage of the larger cursor is that the four switches can be used to put labels on certain coordinates, so that (for example) four different figures could be analysed on the same chart: the computer will know which data points belong together because each will have an identifying label attached to it according to which button was pressed.

Appendix B

Equivalent Stimuli for Tangent Screen and Perimeter

Central visual fields may be tested (a) at the tangent screen, usually with a 1 mm white pin at a 1 m viewing distance, with a screen illuminance of 10 to 15 foot-candles (100-160 lux), or (b) at the perimeter, usually with Goldmann stimulus I_2.

In the Goldmann system, the target *size* is given by the Roman numeral (O to V), while the target *intensity* is given by the Arabic numeral (1 to 4). Goldmann target size I has an area of $\frac{1}{4}mm^2$ on the surface of the perimeter: this has an angular size of 5.82 minutes of arc at 1/3 m, which is a reasonable approximation to the angular size of a 1 mm pin at 1 m, which is 3.43 minutes of arc.

Goldmann intensity 2 = 100 apostilbs: this is the equivalent of 13 foot-candles (142 lux). The background intensity in the perimeter is 31.5 apostilbs, which is equivalent to 4 foot-candles (43 lux).

The contrast of the Goldmann target (compared to the tangent screen target) is somewhat reduced, owing to the illuminated background; however, the Goldmann target size is somewhat larger than the tangent screen target size (5.82 vs 3.43 minutes of arc). These two factors tend to counterbalance each other, as the size of the 1/1000 W tangent screen field usually differs very little from the 1_2 Goldmann perimeter field.

The target areas increase in size in steps of 0.6 log area, while the target intensities increase in steps of 0.5 log intensity. Thus, in Fig. 5, the I_3 stimulus is 0.5 log units brighter than the I_2 stimulus (i.e. 316 apostilbs vs 100 apostilbs), and the III_3 stimulus is 1.2 log area units larger than the I_3 stimulus (i.e. 4 mm^2 vs $\frac{1}{4}$ mm^2). In terms of tangent screen targets, the III_3 stimulus would be equivalent to a 6.7 mm pin at 1 m.