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Rapid Detection of Changes in the Optic Disc: Stereochronoscopy

II. Evaluation Technique, Influence of Some Physiologic Factors, and Follow-Up of a Case of Choked Disc

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Summary. A simple device for viewing stereochronoscopic (Sc) picture pairs under any azimuth is described. The influence of pulse, irradiation, time, and ocular pressure on disc configuration of some healthy and affected subjects is investigated. To test the sensitivity of Sc as compared to that of conventional stereoscopy (St), a case of choked disc in which pictures of both kinds had been taken was followed up. This material also served to test 10 observers as to their ability to detect St and Sc effects in fundus pictures. Despite good stereo vision in all observers as tested by the Titmus charts, considerable differences were found in the analysis of fundus pictures. Detailed instruction resulted in improved results. Two cases of glaucoma simplex incipiens are presented in which a change of disc configuration could be detected by Sc while ocular pressure and visual field remained normal in one case and did not change in the other.

Zusammenfassung. Es wird eine einfache Vorrichtung zur Betrachtung stereochronoskopischer Bildpaare (Sc) unter verschiedenem Azimut beschrieben. Der Einfluß von Puls, intensiver Lichteinwirkung, Zeit und Augendruck auf die Papillenkonfiguration einiger Gesunder und Kranker wird untersucht. Um die Empfindlichkeit von Sc im Vergleich zu derjenigen bei gewöhnlicher Stereoskopie (St) zu bestimmen, wurde ein Fall von Stauungspapille verfolgt, wobei Aufnahmen beider Art gemacht wurden. Dieses Material diente auch zum Testen von 10 Beobachtern bezüglich ihrer Fähigkeit, St- und Sc-Effekte in Fundusbildern aufzufinden. Obgleich alle Beobachter bei der Prüfung mit den Titmus-Tafeln sehr gutes Stereo-Sehvermögen aufwiesen, traten bei der Beurteilung von Fundusbildern beträchtliche Unterschiede zutage. Durch eingehende Instruktion war eine Verbesserung der Ergebnisse zu erzielen.

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Es werden zwei Fälle von glaucoma simplex incipiens vorgelegt, bei denen durch Sc eine Veränderung der Papillenkonfiguration nachgewiesen werden konnte, während Augendruck und Gesichtsfeld im einen noch normal waren und im zweiten sich nicht änderten.

1. Introduction

In a preceding paper (I) (Goldmann and Lotmar, 1977) we explained the principle of stereochronoscopy (Sc)[1], which was first mentioned by Schirmer (1974) for temporal changes in fundus configuration: Two successive photographic pictures of an object taken from exactly the same 'standpoint' are combined to form a stereo pair; when the object has changed between the exposures, stereo effects will appear. Meanwhile we have learned that the principle of stereochronoscopy is not at all new: Harmer (1892) conceived it and proposed its use for the detection of star movements. Meanwhile Schirmer (1976) has specified his method more closely.

We anticipated that this method would be of special interest for the follow-up of disc configuration changes in glaucoma simplex. The theory of the method and estimates of its sensitivity were given. In the present paper we describe our method of evaluating Sc pictures and investigate some factors liable to cause disc changes in healthy eyes (pulse, irradiation, pressure, and time). Finally, some results in cases of choked disc and glaucoma simplex are given.

2. Viewing Device (Sc scanner)

In contrast to conventional stereoscopy (St) where a rotation of the individual pictures through 90° causes any stereo effects to vanish, we have to expect, in principle, the presence of such effects under every azimuthal position in Sc pairs (not arising from the same structure elements of course). An exception is the case where all elements of the object have changed in only one direction parallel to the xy, i.e., frontal plane. For Sc pairs the viewing device should therefore allow rotation of both pictures simultaneously in the same sense, so that binocular inspection is possible under all azimuths without readjustment.

Figure 1 shows a simple device built to achieve this end. The pictures are used in a circular form 55 mm in diameter as is customary in fundus photography. They are fixed to the rotating discs by slightly elastic rings. The discs are slide-coupled to their axles so that adjustment for azimuthal image fusion at the beginning is easily possible. Owing to the rigid coupling of the disc axles *inter se,* this adjustment is preserved during rotation. Center distance is 64 mm, so the pictures may be observed directly or by means of a conventional stereoscope.

1 In our first paper we unfortunately used the symbols C and S with two different meanings: C for 'Center' and S for 'Superior' positions within the pupil, but also S for 'stereo' and SC for 'stereochrono.' To eliminate these ambiguities in the present paper we now adopt St for 'stereo' and Sc for 'stereochrono' reserving C and S for 'Center' and 'Superior', respectively, as before

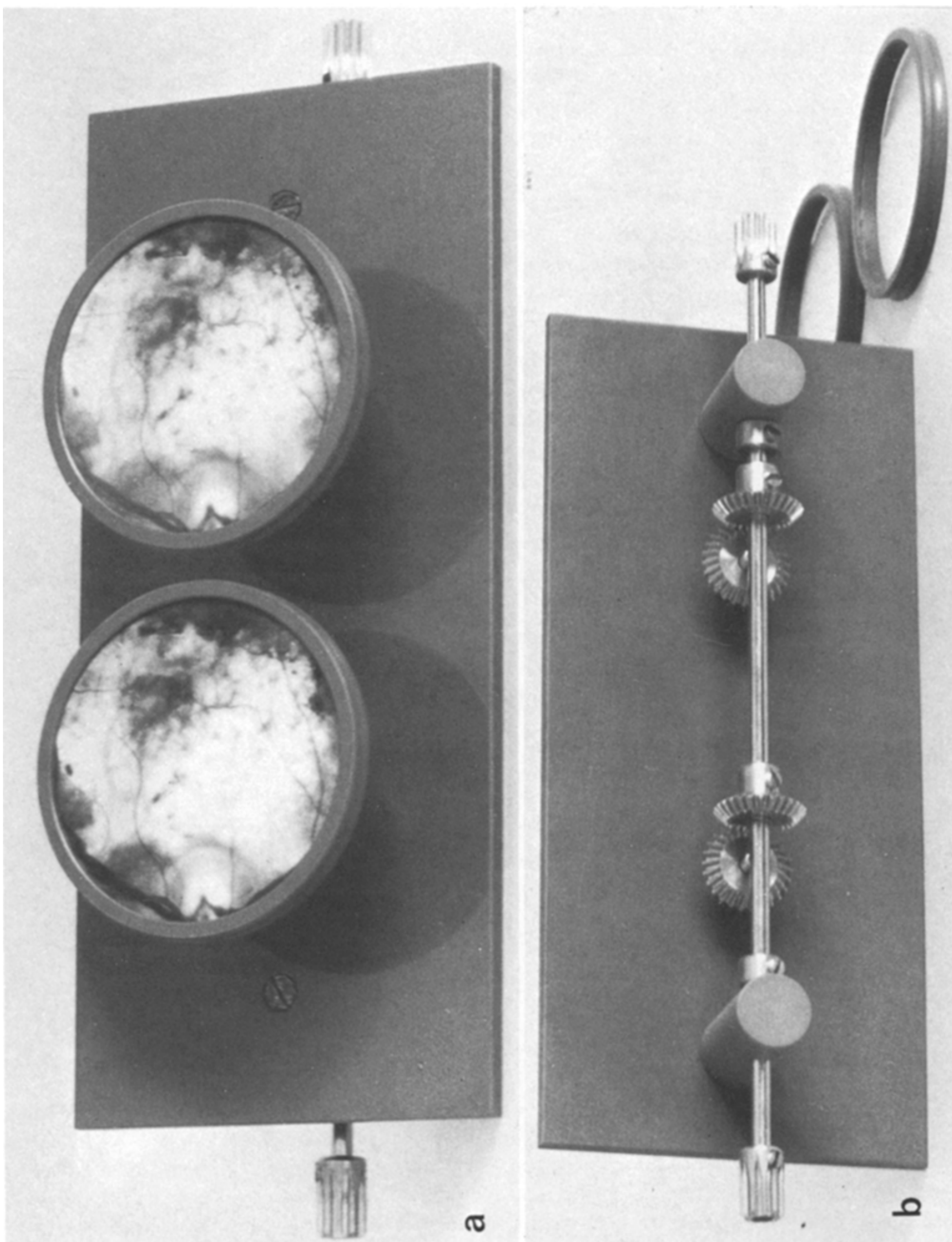

Fig. 1. Scanning device for stereo-chronoscopic picture pairs. **(a)** front view, **(b)** back view, with rings taken off. Pictures can be adjusted azimuthally and rotated simultaneously

The fundus pictures were taken at 3.75x magnification (Robot additional lens 1.5x) and magnified 3x. Overall magnification was therefore 11.2x. The picture-taking procedure has been described in I. Ilford Pan F film was used so that the pictures would not have too much contrast.

Pictures intended to form rotatable stereo pairs must be cut out with a circular stamp so that their centers of rotation are occupied by corresponding points of the two pictures. If this condition is not met, the observed stereo picture will float up and down within the frame during rotation, a movement that may easily mimic a stereo effect, even when no such effect is really present. At still higher levels of relative decentering, difficulties in fusion may occur under certain azimuths.

We have found that 'free-hand stereoscopy,' that is, fusion without any optical aid, is best suited for evaluation, in complete accord with earlier results. This method is accessible to everybody, although some practice is of course needed. Myopes in general find it easier than emmetropes and hyperopes.[2] Moreover, it is important for evaluation that exact azimuthal correlation be achieved between the two parts of a stereo pair. Adjustment is correct when the plane of the rim of the image appears to be parallel to the rings limiting the field.

In cases of small disparity it is often difficult to decide whether an apparent depth difference is truly stereoscopic or is produced only by other effects like crossover of vessels or luminance differences simulating hills and valleys. We have tried to facilitate the decision by superimposing grids of different patterns on the pictures, hoping that true depth differences might be perceived more easily when the details in question were brought near an element of the grid. However, it turned out that no definite improvement in depth discrimination could be achieved by this device, so we do not give constructional details.

However, we noted that even considerable differences in density or contrast between both pictures of a stereo pair do not seem to influence the decision 'stereo or no stereo.' This facilitates, of course, the technical side, since it is not easy to make copies of two film negatives differing in density and/or contrast look exactly alike.

3. Influence of Physiologic Factors

a) Pulse

Bynke and Krakau (1961) described pulsation of the disc in cases of choked disc. It was therefore of interest to see whether Sc would detect configuration changes due to pulsation in normal and choked disc. For this we took series of disc pictures using the flashes provided for angiography, setting the flash frequency slightly below or above pulse frequency. In this manner one obtains disc pictures at different pulse phases that can then be paired in any order. Within series of this kind taken on 5 healthy subjects and in one case of choked disc we found no influence of pulse phase on disc configuration

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[2] If you are not able to get fusion of the pictures 'freehand,' resort to your trial lens case and put two 8–10 diopter prisms into the trial frame, base out. A piece of cardboard 10 cm long between the glasses, obstructing one of the two pictures for each eye, will further help in image fusion. Wear your short distance spectacles or put equivalent lenses into the trial frame

when examined by Sc, even in a case where pulsation of the main vein was observed biomicroscopically. However, looking for pulse phenomena should be continued, especially in cases of pulsus celer.

b) Irradiation

In these same series another effect was noted in two healthy subjects, namely a slight and gradual change of the disc with an increasing number of flashes. In a case of 18 flashes delivered within 3 min a slight but distinct stereo effect was found. The reason for this was suspected to be hyperemia caused by the irradiation. Since so many flashes will not usually be fired in Sc investigations and no Sc effects were found in pictures only a few flashes apart, it was of interest to see whether a few flashes would cause visible hyperemia if given a limited time to develop. Some experiments along these lines showed that up to 5 consecutive flashes (intervals of 1 s) produced no visible Sc effect 10 s after the last flash. In taking pictures of the disc for Sc, 5 flashes seem therefore safe with regard to artifacts. We intend to investigate this point further.

c) Time

Here the task was to find the minimum time interval during which a change of disc configuration producing a positive Sc effect would occur in the course of normal physiologic aging. Within the period of about one year during which our picture-taking device was available we found no Sc effects on healthy subjects (ages from 29 to 68 years). However, a number of disc pictures taken by conventional technique reaching back over 4 years were available. This material was used in the following way:

In Part I it has been explained that stereo effects in disc pictures can have two different causes: displacement of the point where the camera axis strikes the pupil, the disc being at the same place for both pictures, or displacement of the disc within the frame between the taking of the pictures. It was shown that the tolerances to be adhered to so that no stereo effect should show up were 0.27 mm of displacement (case 1) and 2°, or one-third disc diameter (case 2), if it is assumed that the depth of the disc is 0.5 mm at most.

For pictures taken at great temporal intervals it is not too difficult to locate the disc at the same position with the help of a fixation mark for the other eye, but it is hardly possible to know the location of the camera axis with an uncertainty of 0.27 mm when the first picture has been taken in the conventional manner, that is, without an auxiliary lens as described in Part I. Despite this, we can decide with some confidence whether or not a change in disc configuration has occurred between the taking of both pictures. If the combined pair appears flat under all azimuths of the Sc scanner, surely nothing has changed. If stereo effects show up, but all disappear under one and the same azimuth, *probably* nothing has changed, because the effect is likely to be ascribed to camera-axis displacement. If stereo effects are observed under every azimuth, Sc is present and a change is certain, even when normal St due to camera displacement is possibly superimposed. Note that the strength of the observed stereo effects may of course vary greatly during rotation.

Table 1. Search for changes of disc configuration with time in healthy eyes

Subject	Age	Interval (months)	Result
S.D.	29	54.5	St
B.P.	46	50	St
E.G.	48	34	0
C.S.	30	34	St
F.F.	52	12.5	0
N.W.	54	12.5	St
S.H.	52	12.5	0

We followed up disc development with age in 7 healthy subjects (only one eye each). Table 1 summarizes our results. In no case was an unambigous Sc effect found. Conventional stereo effects, in this context, probably arise from camera or disc misalignment, as explained above. So we conclude from this admittedly scarce material that for periods of up to four years at least, a change of the disc configuration in healthy eyes of subjects 30 to 50 years old is rather unlikely.

d) Ocular Pressure

It has been known for a long time that glaucomatous excavations can disappear when ocular pressure in glaucoma simplex is drastically lowered, e.g., by cyclodialysis. Shaffer and Hetherington (1969) saw the disappearance of excavations after pressure-lowering operations in juvenile glaucoma. Therefore the question arose whether Sc would reveal a configuration change of the disc when ocular pressure was reduced in cases of ocular hypertension.

We chose patients with a relatively high ocular pressure who had, however, not been treated, because here a considerable reduction of pressure could be expected on administration of Diamox. Pressure was measured and a first picture o.u. of the disc taken, then 250 mg of Diamox were given; two hours later pressure was again measured and another picture taken. Results are given in Table 2. A slight Sc effect was observed in one case out of eight.

Table 2. Influence of short-time pressure variation on disc configuration

Subject		Age	c/d ratio	Pressure (mm)		Effect
				initial	after Diamox	
F.O.	od	52	0.5–0.6	30	21	just discernible
	os		0.5–0.6	30	20	uncertain
R.A.	od	56	0.7	28	17	0
	os		0.5	19	13	uncertain
B.A.	od	77	0.5–0.6	35	24	0
	os		0.6	31	21	0
M.P.	od	40	0.8	38(35)	22	0
	os		0.6–0.7	31(30)	22	0

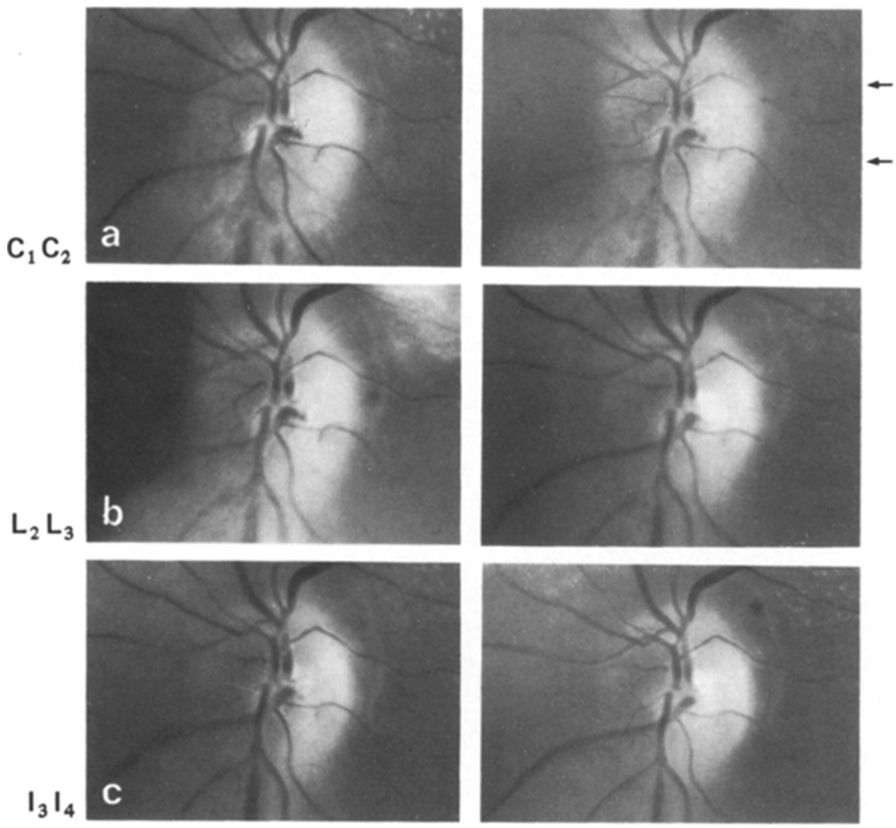

Fig. 2. Sc pairs at intervals of 1 week each in a case of choked disc. Patient A.G., age 63, os. *Arrows* point to vessels showing increased depth effect when pictures are rotated through 90°

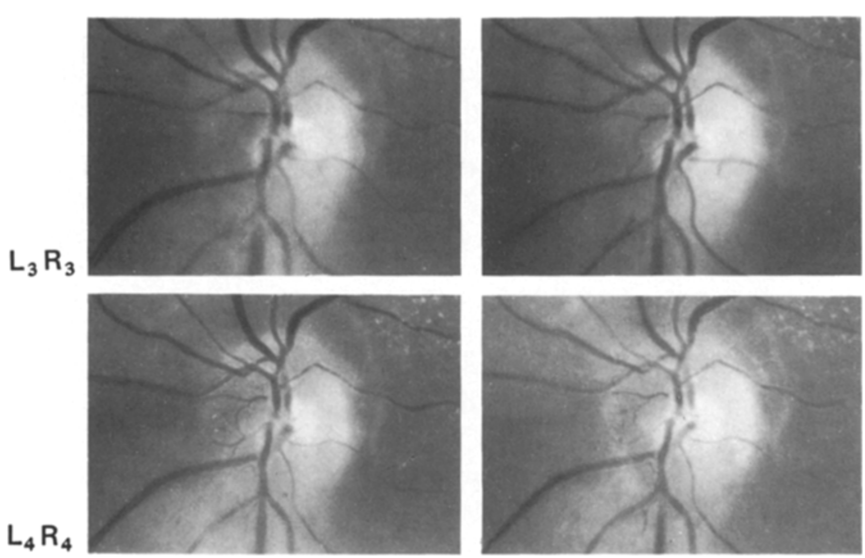

Fig. 3. Conventional St pairs of same case as Figure 4, taken when pictures I_3 and I_4 were made, respectively

4. Follow-Up of a Case of Choked Disc

To test our method we followed up one typical case of choked disc over an interval of 4 months, taking not only C but also L, R, S, and I pictures with our auxiliary lens (for the meaning of the symbols see Part I). The patient was seen and photographed at intervals of 6, 13, 20, 27, 41, and 134 days from first admission to the Clinic. All Sc pairs produced positive effects of change, irrespective of whether C, L, R, S, or I pairs were used. Figure 2 shows the first three pairs of consecutive intervals. Depth effects are seen mainly on the large short vessel parts at the center.

In Part I it was explained that a Sc pair is well suited to detect changes in an object, but does not detect the direction in which the change has occurred. In the case of the disc, specifically, it cannot be decided from a Sc picture alone whether a manifest change corresponds to a protrusion, a recession, or to a lateral displacement of vessels. We tried to apply the procedure proposed in Section 5 of Part I to the present case of choked disc, but the results were not decisive compared to the unambigous results obtained by dioptric measurements on the ophthalmoscope. However, we found that by making use of the St pairs at our disposal it was generally possible to detect the sign of a change.

However, identification of change from a Sc pair is often more conclusive than that which can be derived from the corresponding St pictures (at least when they are compared only qualitatively). Figure 3 shows two St pairs taken at the same time as the left and right parts of Fig. 2c, respectively. While the two St pairs are nearly indistinguishable regarding depth effect, the Sc effect in Fig. 2c is obvious.

5. Other Cases

As regards incipient glaucoma simplex, we have found so far two cases yielding a positive Sc effect.

Case 1. The patient (R.A.) was referred to the Clinic because of excavation of the disc o.u. in March 1976 (c/d: od 0.7, os 0.5). Pressure was 30 mm Hg od, 16 mm os. No visual-field defects were found, but therapy with Eppy was initiated. Fundus pictures were taken with the help of the auxiliary lens. The patient was seen again in November 1976 and in March 1977. Pressure and field had not changed during this period. However, a stereo effect is seen in both the C_1C_2 and the C_2C_3 pairs of the left eye (Fig. 4), the change having occurred in the same sense for both intervals. Inspection with the Sc scanner showed that no detectable stereo effect was left when the pictures were rotated through 90°. This meant that configuration had varied in one direction only, the horizontal. The well-known phenomenon of lateral vessel-tree displacement came to mind.

For comparison, a conventional LR pair taken with a stereo angle of 7° is shown in Figure 4d. It can be seen that the strength of the stereo effect in Figure 4c is quite similar to that of 4d. In the right eye virtually no stereo effect could be detected.

Case 2. This patient (M.P.) was first seen on January 4, 1977, and again on September 7, 1977. While C-images of the left eye taken at these dates showed no stereo effect whatsoever, those of the right eye gave a distinct Sc effect, as shown in Figure 5.

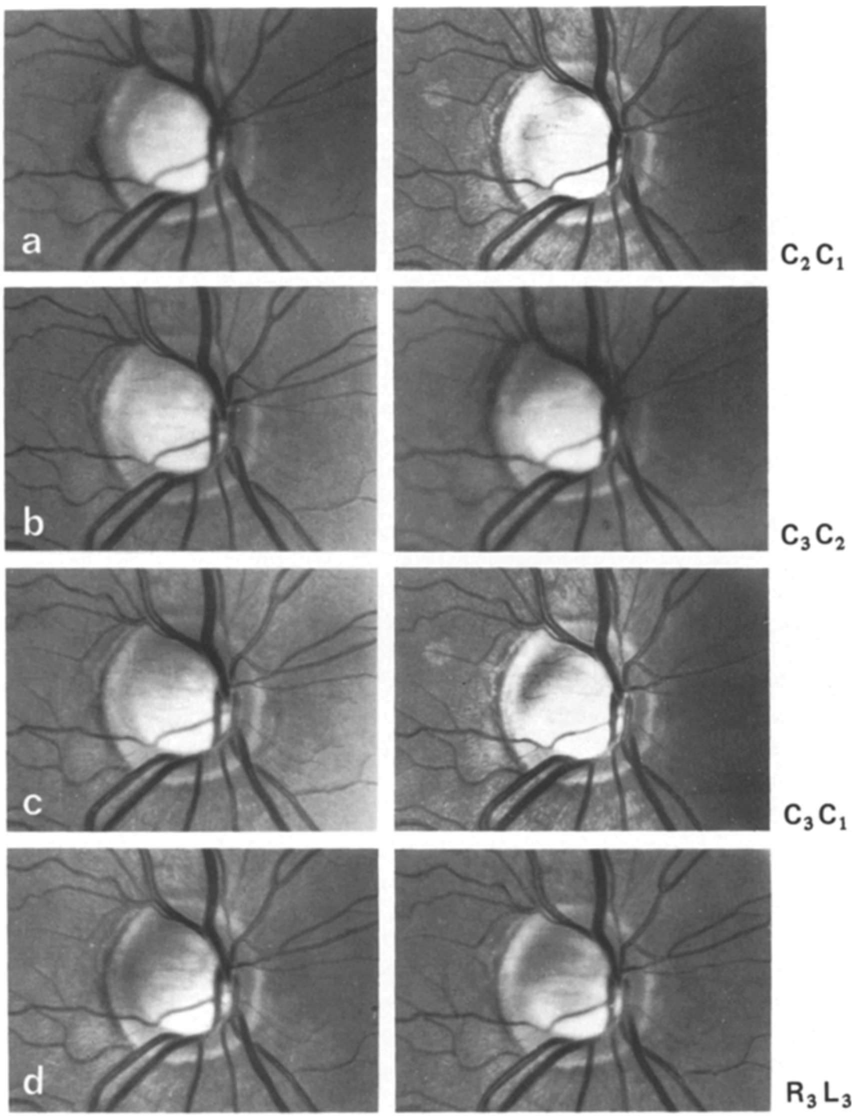

Fig. 4. Sc pairs of a case of incipient glaucoma simplex. Time interval for (**a**) is 8 months, for (**b**) 4 months, and for (**c**) 12 months. (**d**) is a conventional St pair of the same case, for comparison. Patient R.A., age 56, os. To avoid moon crater effect, pictures are shown upside down

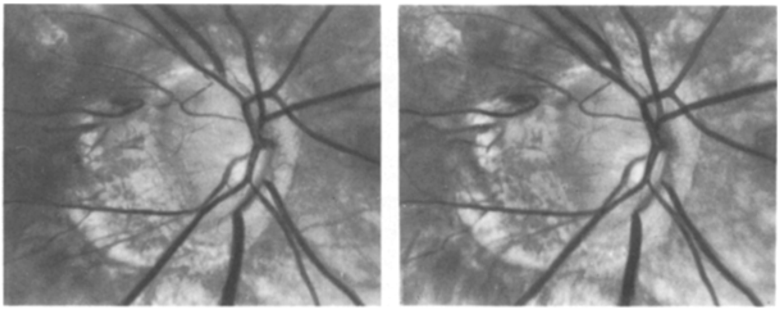

Fig. 5. Another case of a positive Sc effect in glauc.chron. Patient M.P., age 40, od; time interval of 8 months. Diagnosis: Glauc.simpl.inc.ou.Myopia magna. *4.1.77: od:* Vis. −14.0 sph ⊃ −3.0 cyl 0°: 0.5–0.6. Vis.f.: nasal step with I/2. Fundus: conus myop., c/d 0.8. T: 24–28 appl (*diurnal curve*). *os:* Vis. −10.0 sph ⊃ −2.0 cyl 0°: 1.0. Vis.f.normal. Fundus: small conus, c/d 0.4–0.5. T: 21–25 appl. *7.9.77: od:* obj.id. Vis.f.: perhaps nasal step more pronounced. T: 18–28. *os:* as formerly

In this instance we are especially sure that the effect was caused by real changes in the disc and not by any artifacts. First, our photographer already had an experience of nearly one year in our technique when the first pictures were taken, and correct centering of the camera is indicated by the zero result on the left eye. Second, additional proof to the same effect was obtained as follows: at both dates not only one but 3 pictures were taken of each eye, thus yielding 4 triplets, and in none of these could any stereo effect be detected. Third, the effect found in the right eye (Fig. 5) was a true Sc effect, that is, there existed no azimuthal position of the Sc scanner where no stereo effect was left.

In two other cases of disc excavation no unambigous Sc effects were found over periods of 1/2 and 1 year, respectively.

We saw one case of chorioretinal degeneration of the posterior pole reaching from the macula up to the disc. Several pictures were taken on two occasions 6 weeks apart, the disc being located at the border of the field in this instance. Stereo effects within the disc were observed in some of the pairs, but the results were erratic and prompted an investigation summarized in the Appendix, since in effect it should have been included in Part I. Its results led us to think that a change within the disc was rather doubtful, but could not absolutely be excluded. This case will be followed up further.

6. Testing of Observers

With the material described in Section 4 plus some pictures of excavations, we tested 10 observers of different training as to their ability to detect stereo effects of variable strength, to discriminate between true St effects and those that are mimicked by light and shadow (as e.g., in nonstereo moonscape pictures, see Fig. 6), and to distinguish Sc effects from St. A selected series of stereo pairs was handed to each subject along with the Sc scanner and a stereoscope of 4.5 dpt power. Oral and written explanations about the generation and properties of Sc pairs were given. The subjects were asked to

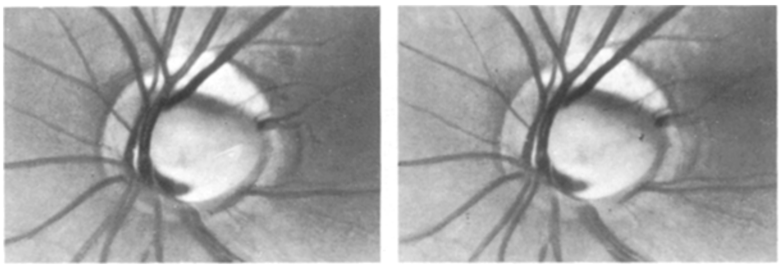

Fig. 6. Two identical pictures of a case of excavated disc showing 'moon crater effect.' When the page is turned upside down, excavation appears to be a protrusion

look for St and Sc effects within the area of the disc and to write down the result on a prepared list for every pair presented. The individual pictures were randomly numbered. The sample contained, in random order, 7 conventional St pairs, 11 Sc pairs, and 4 pairs of identical pictures (2 copies of the same frame, marked by different numbers). All observers had normal stereo discrimination as tested by the Titmus stereo tests. Six of them were ophthalmologists of long standing. The subjects were asked to mark what they saw by 0 (none), St, or Sc.

Table 3 contains the results of this test. The following scale was used for evaluation:

a) –	Every St or Sc marked St	1 point
b) –	Every Sc recognized as such	2 points
c) –	Every identical pair recognized	1 point
d) –	Every St or Sc marked 0	0
e) –	Every St marked Sc	0
f) –	Every identical pair marked St or Sc	−1 point

Table 3. Performance in the evaluation of a series of stereo pairs

Observer	Performance %	Number of errors	Performance for St = Sc (%)	Number of errors
o N.P.	79	0	87	0
L.W.	79	0	91	0
o G.H.	73	4	87	1
L.T.	64	1	73	1
o K.F.	51	2	64	2
o K.U.	45	2	64	2
D.R.	39	6	50	3
S.E.	36	2	54	2
o E.G.	33	5	41	2
o P.J.-M.	27	3	50	1
Mean	52.6	2.5	66.1	1.4

With 7 St, 11 Sc, and 4 identical pairs the maximum attainable score is 33 points. The number of errors, that is, the sum of pairs falling under specifications e) and f) of

the scale, corresponding to a manifestly erroneous diagnosis, is also shown. Ophthalmologists are marked o in Table 3. It can be seen that this has little to do with performance.

If a less rigorous scale is applied in that no discrimination between St and Sc is asked for and one point is scored for recognition of either of them, better results are achieved (an increase of 14% as a mean), as is shown in the fourth and fifth columns of Table 3. Such a scale would be fully legitimate when, by an appropriate picture-taking technique, conventional St effects were virtually eliminated. In this case all stereo effects showing up in the picture pairs are indeed to be interpreted as Sc effects.

From Table 3, it becomes evident that normal stereo discrimination in a subject as tested by the Titmus Tests is by no means a sufficient criterion for high performance in the evaluation of fundus stereo pictures of usual quality. Nevertheless, relatively good results in 3 out of 10 observers seem to imply that such people are not too rare, but should be selected by the procedure described.

We have, however, tried to improve the results of some of the less successful subjects by presenting to them once more all the pairs of choked disc that they had not optimally identified. After inviting them to direct their attention mainly to the large, short vessels at the center and the two thinner vessels marked by arrows in Figure 2, they showed a definite improvement, as shown in Table 4. This probably means that expertise may be gained by training, even if no senior expert is available. Model series of St and Sc disc pictures with explanations will be of help in this process.

Table 4. Improvement of evaluation results by additional instruction (second run)

Observer	Number of pairs	Score first run	Score second run	max. attainable
o K.F.	10	2	16	18
D.R.	11	−3	4	15
o E.G.	12	−2	13	18

Discussion

From the experience gained until now, the following conclusions can be drawn:
a) Three to four exposures made in rapid succession with the Zeiss fundus camera do not alter the disc configuration.
b) A normal disc in normal fundus does not vary in configuration during a period of 3 to 4 years. This result must, however, be regarded as preliminary and should be tested on groups of different age to determine the limits more accurately. In any case, variations of disc configuration within a few months are not normal.
c) To establish a disc variation it is sufficient to take a well-defined axial (C) picture both at the start and the end of the chosen time interval. If it is not clear from other knowledge in which direction a stated change has occurred (in contrast to incipient glaucoma), it is necessary to take, in addition, conventional St pairs at the start and end of a sufficient time interval. Comparison of these pairs (L_1R_1 and L_2R_2) will indicate in principle the direction of the change, although sensitivity, at least when only direct qualitative inspection is used, is markedly inferior to that of the corres-

ponding Sc pair $C_1 C_2$, or for that matter, $L_1 L_2$ and $R_1 R_2$. Moreover, it should be noted that 'no depth differences between the St pairs but a visible effect in the Sc pair' may also mean that only, or mainly, lateral displacements of contours have occurred during the time interval in question. We know indeed that variations of just this kind are characteristic for glaucoma (nasal displacement of vessels).

d) Rapid pressure variations of as much as 10 mm may in rare cases influence disc configuration. Therefore Sc pictures should preferably be taken at approximately the same pressure level.

Our knowledge about a possible influence of fundus changes outside the disc on the surface configuration of the latter is still rudimentary. Therefore what has been said above is valid, for the time being, only if no changes outside the disc have occurred.

From what has been said if follows that $C_1 C_2$ pictures, which because of their simplicity and rapidity can easily be taken routinely in every case, may provide especially valuable information in two areas regarding glaucoma:

(1) Differentiation between ocular hyptertension and early glaucoma simplex. In the former case no variation in disc configuration should be expected within a period of less than 2 years. However, this is a preliminary figure; a better-founded value may arise with increasing experience.

(2) Is pressure reduction by drugs in a given case of glaucoma simplex sufficient, i.e., is the administered medicament sufficiently effective? If so, the disc configuration examined at approximately equal pressure levels should not change in an abnormally short time during treatment.

In one of our cases (patient R.A.) the configuration *has* changed: either ocular pressure, despite seemingly normal values, was not sufficiently reduced, or the hypotonicum Eppy was not an appropriate medicament, possibly because it simultaneously influenced disc circulation unfavourably.

All these results have to be consolidated by further investigations. The same applies to the correlation between a variation of disc configuration and that of the visual field. We intend to report on these points in future work.

Acknowledgements. Our thanks go to Mrs. R. Doebeli, who took all the fundus pictures used. Equipment as described in Part I and in the present paper is obtainable from K. Meyer, Feinmechanische Werkstätte, Könizstraße 229, CH-3098 Liebefeld-Bern, Switzerland.

Appendix

Generation of Stereo Effects by Variation of Eye to Camera Distance

In our discussion of tolerances in Part I, one factor of possible influence has been omitted: distance between the camera and the cornea. For an object on axis, that is, centred within the image, variation of this distance does not affect the angle under which the object is seen. Two pictures taken at different distances will therefore show no stereo effect. This is, however, not true for off-axis objects, where the angle variation may easily amount to values that are no longer negligible. Such a case arises for example when fundus pictures are centred more or less on the macula, and the disc (near the border of the field) is examined for Sc effects. Even when the cornea reflex has been

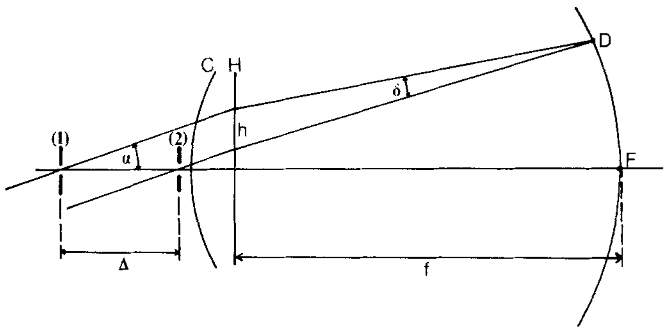

Fig. 7. Influence of camera-to-cornea distance on stereopis of off-axis fundus parts. *C* cornea, *D* center of disc, *H* principal plane, *F* focal length of eye

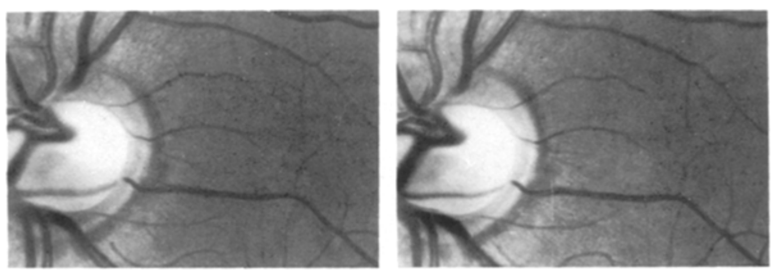

Fig. 8. Stereo effect on off-axis object (disc) generated by varying the camera-to-cornea distance while the camera remains centred on the cornea

correctly centred and the disc brought to the same position for both pictures, a variation of the camera-to-cornea distance may produce stereo effects that have nothing to do with true Sc. The situation is exemplified by Figure 7, where the disc lies off-axis by an angle α. When the distance of the camera is changed by Δ, displacing its entrance pupil from position (1) to (2), the angle of the principal ray starting from the disc center varies by δ. From the figure we obtain in first approximation $h/\Delta = \tan \alpha$ and $h/f = \tan \delta$, or $\delta \cong \alpha\Delta/f$. For $f = 16.7$ mm, $\Delta = 5$ mm, and $\alpha = 10^\circ 50'$ (corresponding to the border of the field when the Robot with lens 1.5x is used) the result is $\delta = 3^\circ 14'$. Keeping the estimates made in Part I in mind, we have to expect easily detectable stereo effects within the disc in this case. Figure 8 shows that such effects are indeed found under the conditions mentioned.

A distance variation of as much as 5 mm is, however, not usual for a well-trained fundus photographer. We have made an attempt to obtain a crude statistical value for this variation in the following way: a piece of paper was fastened to the camera table by adhesive tape. The photographer was told to adjust the camera on a dilated eye in the usual manner, whereupon the position of the camera in the direction of its axis was marked on the paper by use of a ruler in contact with the height adjustment knob.

This procedure was repeated 5 times on one eye, and 4 eyes were tried. From these 20 marks it was concluded that, at least for our photographer, the distance variation is mostly within 2.5 mm for a given eye, although higher values may occasionally occur. However a limit for the angle δ was derived in Part I (see Fig. 5, where the corresponding angle is β), namely $55'$. When this value is used together with $\Delta = 2.5$ mm as found above, we obtain,

$$\alpha = \frac{\delta f}{\Delta} = 55' \cdot \frac{16 \cdot 7}{2.5} = 6^\circ\ 08'$$

which means that for the usual adjustment technique a central area of about 12° diameter will as a rule show no detectable stereo effects arising as artifacts solely from variation of distance between the camera and the eye under investigation.
Conclusion: The region of interest in regard to Sc effects should be centred within the image.

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