Brit. J. Ophthal. (1975) **59**, 545

Use of random-dot stereograms in the clinical assessment of strabismic patients

J. P. FRISBY, J. MEIN*, A. SAYE, AND A. STANWORTH*
*From the Department of Psychology, University of Sheffield, and the *Hallamshire Hospital, Sheffield*

Random-dot stereograms (Julesz, 1971) have been used in recent years to study anomalies in stereopsis (Benton and Hecaen, 1970; Carmon and Bechtoldt, 1969; Richards, 1973). Their special advantage for this purpose is that they provide a very pure test of stereopsis, because they present disparity information in the absence of all other clues to depth and lend themselves to unfakeable test procedures, so facilitating the collection of reliable measures. Despite this advantage their use in orthoptic and ophthalmic clinics has not been widespread, probably because there has been no systematic clinical trial of their usefulness before that of Reinecke and Simons (1974). They used random-dot stereograms to screen for amblyopia and amblyopia-related visual dysfunctions in young children. They found that, with the exception of some microtropic patients and one esophoric/esotropic patient, no patient with a constant horizontal or vertical tropia could obtain a random-dot stereoscopic percept with their stimuli; moreover, those microtropic patients who passed the test did so only when shown stimuli with a disparity of at least 8′, all the patients appreciating a disparity of less than 4′ being normal or near normal (most had an intermittent exotropia).

We too have examined the abilities of various categories of strabismic patients to fuse random-dot stereograms. Our approach was similar to that of Reinecke and Simons in that we have compared results from random-dot stereograms with standard clinical orthoptic measures. The study we report here, however, differs from that of Reinecke and Simons in three major respects: two different types of random-dot stereograms were used (Figs 1 and 2), the disparity except in pilot studies was always 12′ (which is greater than either disparity used in their study), and strabismic patients were selected for examination only if their clinical records mentioned that some degree of stereopsis was present.

An initial pilot study revealed that there was no simple correspondence between the performance of strabismic patients on the widely-used Wirt (or Titmus) stereotest and on our random-dot stereograms. Some patients could demonstrate a stereoacuity of better than 13′ on the Wirt test and yet prove incapable of fusing random-dot stereograms with disparities in the range 7′ to 1°24′.

We followed-up this pilot finding with experiments which presented two different kinds of random-dot stereogram to patients attending an orthoptic clinic. One kind of random-dot stereogram was of the usual type (Fig. 1). The second kind, however, was novel in that it contained prominent uniocularly-identifiable features. Its central square-shaped area of disparate elements was thus enclosed in each field of view by an outline square which possessed the same disparity as the elements it contained (Fig. 2). The rationale underlying the use of this latter 'contoured' kind of stereogram was as follows.

Random-dot stereograms are complex stimuli which contain many ambiguities concerning which element in the left field is to be fused with which element in the right. An enormous number of possibilities exists in principle, but in practice the binocular combination process produces a fusion of the two fields in which relatively dense surfaces are preferred to 'lace-like' patterns in which individual elements are scattered in a multitude of different depth planes (Julesz, 1971). The Wirt test figures, on the other hand, are relatively simple stereograms which incorporate little ambiguity. Each Wirt figure is made up of only four circular elements enclosed in a frame, the observer's task being to identify which of the four is standing out in depth. This distinction between random-dot stereograms and Wirt test figures in terms of their complexity and ambiguity might have been the cause of the asymmetry in stereo-ability observed with them in pilot work. We attempted to investigate this possibility by seeing if demarcation of the disparate area in a random-dot stereogram would facilitate stereopsis for patients who would otherwise fail to obtain it with these stimuli. Demarcation of the disparate area, it can be argued, makes a random-dot stereogram more like a Wirt test figure

Address for reprints: Dr J. P. Frisby, Department of Psychology, University of Sheffield, Sheffield S10 2TN

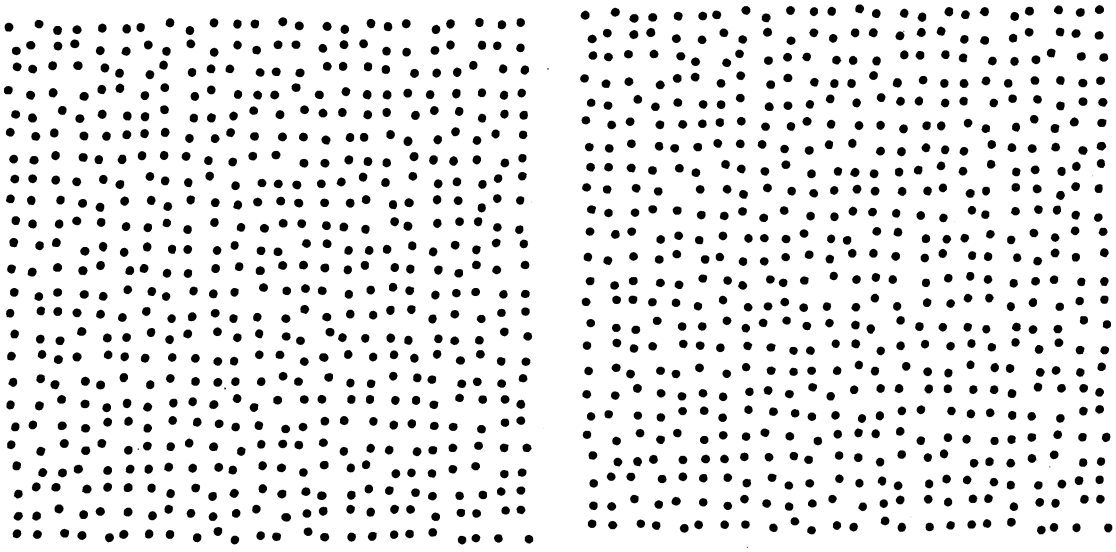

FIG. 1 *Non-contoured stereogram used in experiment. For the experiments, stereograms subtended a visual angle of 10° 30′. Brightness of the dots (as measured with an SEI spot photometer) was < about 3·4 cd m⁻² while that of the ground was about 34·3 cd m⁻²*

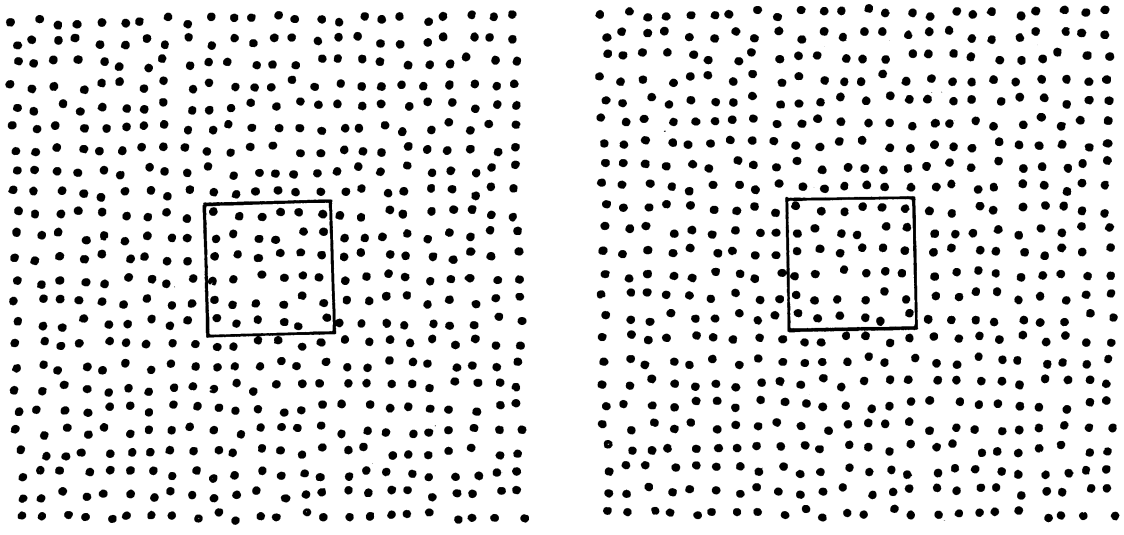

FIG. 2 *Contoured stereogram used in the experiment*

in that the stereogram is greatly simplified and resolution of the inherent ambiguity is likely, therefore, to be considerably aided.

Material and methods

A total of 27 strabismic patients aged between 8 and 18 years were shown the contoured and non-contoured stereograms described above. All were outpatients attending an orthoptic clinic who had been selected for the experiment because they were known to have some clinical record of stereopsis (that is, they could see at least the 'fly' stimulus of the Wirt test), and they were expected to be co-operative in a testing situation.

The stereograms, which always contained a disparity of 12′, were projected through polarizing filters on to a vertical aluminized screen situated 167 cm in front of the subject's rigidly-fixed headrest. Polarized filters were mounted on the headrest in such a way that the disparity incorporated in the stereograms was crossed—that is, the disparate square, if fused correctly—would appear to lie in front of the screen. The non-contoured and contoured stereograms were shown successively to each subject, the non-contoured kind always first. On each

presentation, subjects were asked to look carefully at the centre of the stereogram and report if any part of it appeared to 'stick out' in front of the rest. An attempt was made in making this inquiry, and indeed throughout the experiment, to put the subject at his ease and to encourage him to describe fully his percepts at any given moment. Moreover, any reports of depth experiences were followed by further requests for clarification if these initial reports were either not clear or not full. For instance, in the case of the contoured stereogram, if the subject described a 'square shape sticking out' but did not also state that the elements within this square were also 'sticking out', he was asked whether this was in fact the case. These full verbal reports were not taken simply at their face value, but were checked by asking the subject to set a pointer to lie in the apparent depth plane of the disparate square, if this had been correctly reported. This pointer was mounted in a toy railway truck which could be moved by the subject *via* a pulley system along a track lying on a table top between the base of the headrest and the screen. The length of the pointer was such that its tip could be positioned immediately underneath the lower edge of the square-in depth. This toy train arrangement was used to make the task more interesting for the younger subjects. Average depth settings for successfully fused stereograms were about 20 cm. The experimental session lasted about 15 minutes.

Results

The subjects differed markedly in their ability to fuse the random-dot stereograms and it proved possible to classify them into the following three groups:

Group 1: Normal stereopsis obtained with both non-contoured and contoured stereograms (N=11).

Group 2: Normal stereopsis obtained only with the contoured stereogram (N=10).

Group 3: Normal stereopsis obtained with neither kind of stereogram (N=6).

Three subjects who failed to fuse the non-contoured stereogram satisfactorily and who in the contoured stereogram could see only the outline square in depth, and not its enclosed elements, were assigned to Group 3.

The clinical records of the subjects were examined by an experienced orthoptist (JM) who had no prior knowledge of the subjects' performance on the random-dot stereograms. The Table presents a summary of items drawn from her assessment which seemed to discriminate between the subject groupings found with the random-dot stereograms. These items were:

1. Original and present diagnoses
2. Wirt stereoacuity
3. Anomalies in ocular movement (as revealed when tested in the nine cardinal directions of gaze)
4. Prism fusion ranges.

No clear differences between the groups were found when size of deviation, visual acuity, or degree of anisometropia were examined. These details are, therefore, excluded from the Table.

Further details about the four discriminatory items are given below.

1. ORIGINAL AND PRESENT DIAGNOSES

Of the 11 patients in Group 1, seven (cases 1, 2, 3, 6, 7, 10, and 11 in the Table) presented with intermittent squints. Of the remaining four only one (no. 4) had a constant manifest squint requiring surgery, two had microtropias (nos 8 and 9), and the other one (no. 5) presented with aniso-amblyopia. Eight out of 11 patients in this group therefore apparently retained bifoveal binocular single vision for at least part of the time on initial presentation. Five out of 11 patients (nos 1, 2, 3, 4, and 5) now maintain constant bifoveal binocular single vision, two (nos 6 and 7) show intermittent squints but exercise normal binocular vision almost constantly and four (nos 8, 9, 10, and 11) show microtropias but anomalous binocular function.

In Group 2 there was a much higher proportion of constant manifest squints on presentation (five patients out of 10: nos 12, 14, 18, 19, and 20). Only one patient (no. 13) presented with an intermittent squint and therefore maintained bifoveal binocular single vision for at least some of the time. The remaining four patients (nos 15, 16, 17, and 21) all presented with microtropias with consequent anomalous binocular vision. The present diagnoses are also less good in Group 2. Thus constant bifoveal binocular single vision is present in only one patient (no. 12), another (no. 13) has an intermittent squint but maintains normal binocular vision nearly all the time, one patient (no. 21) has a manifest eso-/exo-deviation and all the remaining six have microtropias (nos 15, 16, 17, 18, 19, and 20).

Summarizing these clinical assessments of Groups 1, and 2, it is evident that the major difference between them is that there is a much higher proportion of subjects in Group 1 than in Group 2 who experience bifoveal binocular single vision for at least part of the time. This difference is highly significant when original diagnoses are considered (Group 1—eight subjects out of 11; Group 2—one subject out of 10; Fisher's exact test, $P=0.006$) and it almost achieves significance on the present diagnoses (Group 1—seven subjects out of 11; Group 2—two subjects out of 10; Fisher's exact test, $P=0.056$).

In Group 3, five out of the six patients presented with constant manifest squints (nos 23, 24, 25, 26, and 27), with the remaining patient (no 22) showing microtropia. The results of treatment in this group are that five patients have small-angle residual deviations with some degree of anomalous binocular

Table *Summary of data taken from clinical records*

Group	Case no.	Sex	Age (years)	Original diagnosis	Present diagnosis	Wirt	Ocular movement anomaly		Prism fusion range
							Vertical	Horizontal	
1	1	F	12	Intermittent exotropia	Exophoria*	40″	2	0	0
	2	F	14	Intermittent exotropia	Exophoria	2′ 20″	1	0	1
	3	F	9	Fully accommodative	Esophoria	40″	1	0	0
	4	M	11	Manifest esotropia	Esophoria*	2′ 20″	1	0	1
	5	M	8	Aniso-amblyopia	Aniso-amblyopia[1]	50″	0	0	1
	6	M	9	Fully accommodative	Fully accommodative	50″	1	0	1
	7	F	9	Intermittent exotropia	Intermittent exotropia	40″	1	0	1
	8	F	12	Microtropia	Microtropia	6′ 40″	0	0	1
	9	M	9	Microtropia	Microtropia	2′ 20″	1	0	0
	10	M	10	Convergence excess	Microtropia	1′ 40″	0	0	1
	11	M	11	Fully accommodative	Microtropia	40″	0	0	1
2	12	F	12	Manifest esotropia	Esophoria*	2′ 20″	2	2	1
	13	M	9	Convergence excess	Fully accommodative	6′ 40″	1	0	1
	14	F	18	Manifest esotropia	Microtropia*	2′ 20″	0	2	1
	15	M	10	Microtropia	Microtropia	2′ 20″	0	0	1
	16	F	9	Microtropia	Microtropia	3′ 20″	0	1	2
	17	F	8	Microtropia	Microtropia	1′ 40″	1	2	0
	18	M	8	Manifest esotropia	Microtropia	6′ 40″	0	1	1
	19	F	13	Manifest exotropia	Microtropia*	3′ 20″	1	0	2
	20	M	12	Manifest esotropia	Microtropia*	6′ 40″	1	0	0
	21	M	9	Microtropia	Manifest eso./exo.	3′ 20″	0	1	0
3	22	F	11	Microtropia	Microtropia	Gross	2	1	2
	23	M	9	Manifest esotropia	Manifest esotropia*	3′ 20″	2	0	2
	24	M	9	Manifest esotropia	Microtropia*	Gross	1	2	1
	25	F	13	Manifest esotropia	Microtropia*	2′ 20″	2	0	2
	26	F	13	Manifest esotropia	Microtropia*	Gross	0	0	1
	27	F	13	Manifest esotropia	Microtropia*	Gross	2	0	2

*Surgical treatment given
[1]No microtropia
Microtropia—small angle convergent deviation of $< 5°$ with evidence of binocular vision
Ocular movement anomaly: 0 = no evidence, 1 = some evidence (at least one report in the subject's case record), 2 = clear evidence (repeated consistent observations).
Prism fusion range: 0 = Good ($> 30^{\Delta}$BO, $> 8^{\Delta}$BI), 1 = Fair (20^{Δ}–29^{Δ}BO, 4^{Δ}–7^{Δ}BI), 2 = Poor ($< 20^{\Delta}$BO, $< 4^{\Delta}$BI)

vision (nos 22, 24, 25, 26, and 27) while one retains a constant manifest squint (although of reduced angle). Bifoveal binocular single vision was not present in any of the patients of this group at the time of the original diagnosis nor was it achieved as a result of treatment.

2. STEREOACUITIES

Group 1 had a median stereoacuity of 50″ which was significantly better than the 3′ 20″ of Group 2 (Mann-Whitney $U = 16{\cdot}5$, $N_1 = 11$, $N_2 = 10$, $P < 0{\cdot}01$, one-tailed). Group 3 subjects were too few in number to warrant significance tests but the Table shows that most of them (four out of six) possessed only gross stereoscopic ability on the Wirt test (that is, they were successful with the fly figure which introduces the Wirt test but not with any of the stereoacuity test patterns). Thus the Group 3 Wirt scores were broadly in keeping with the fact that Group 3 subjects were incapable of fusing either the non-contoured or contoured stereograms. (It is perhaps worth noting in this connexion that the two Group 3 subjects with better than gross stereoacuity on the Wirt test were at least able to see the outline square in depth in the contoured stereogram, although not the elements enclosed within this square.)

3. ANOMALIES IN OCULAR MOVEMENTS

This assessment ascertained whether or not the subject had a history of horizontal and/or vertical ocular movement anomalies in either or both eyes.

The evidence from each subject's records concerning each direction of movement was rated on a three-point scale: 0=no evidence, 1=some evidence (at least one report in the subject's case record), and 2=clear evidence (repeated observations of a consistent kind). The Table shows the results of this assessment; whereas Groups 1 and 2 are very similar in terms of their histories of vertical ocular movement anomalies, they are very different when it comes to horizontal movement anomalies. Thus none of the 11 subjects of Group 1 had any record whatsoever of horizontal anomalies whereas six of the 10 subjects of Group 2 showed at least some evidence of this disorder. This difference between Groups 1 and 2 is significant (Fisher's exact test, $P=0{\cdot}003$).

4. PRISM FUSION RANGES

The Table also includes a summary of the results from tests conducted with a prism bar at 1/3 m. The fusion ranges so obtained were rated on a three-point scale as follows: 0=Good ($>30^{\Delta}$BO, $>8^{\Delta}$BI); 1=Fair (20^{Δ}–29^{Δ}BO, 4^{Δ}–7^{Δ}BI); 2=Poor ($<20^{\Delta}$BO, $<4^{\Delta}$BI). The Table shows that no patients in Group 1 had a Poor rating whereas three in Group 2 had (a non-significant difference). Group 3 patients, however, present a more uniform pattern in that four (out of six) had Poor ratings and none had a Good one.

Discussion

The principal finding of the experiment was that the 27 subjects fell neatly into three groups on the basis of their random-dot stereoability. We shall attempt here some interpretation of this classification.

The clinical histories of Groups 1 and 2 indicate that Group 1 subjects in general had never completely lost normal bifoveal binocular single vision, whereas this applied only to one subject in Group 2. The likelihood is therefore that for Group 2 subjects the presence of a constant deviation for a period of time has led to an impairment in their stereopsis or in a failure to develop it in the normal way. The same argument can be applied to Group 3 subjects, except that in their case the generally more severe nature of their diagnoses seems to have produced a more serious result. This is reflected in the fact that four out of six subjects in this latter group could obtain only gross stereopsis with the Wirt test.

The question which arises, therefore, is what is the nature of the stereopsis deficiency which allows Group 2 subjects to see our random-dot stereograms successfully *only* when a contour is added? In order to discuss this question and the probable benefit which could be conveyed by the contour for these subjects, a digression into the fusional problems presented by random-dot stereograms is required.

Julesz (1971, p. 216) has pointed out that fusing random-dot stereograms of the kind used here, which possessed fairly large disparities, would require a vergence shift on the part of the observer during the fusional process. Consider the stereogram of Fig. 1 as it appeared in the present experiment. The observer would begin by fixing the screen on which the stereogram was projected and, providing he was capable of experiencing binocular vision, he would immediately secure fusion of the background elements of the stereogram because corresponding background elements in each field of view would fall on corresponding points on the two retinae. The elements comprising the central square, however, could not be fused while fixation was maintained on the plane of the screen. This is because corresponding elements in the left and right images of the central square possessed a disparity of 12′, which would cause them to fall outside the disparity limits for establishing binocular fusion. The evidence for this argument comes from Fender and Julesz (1967) who studied Panum's fusional areas for random-dot stereograms using stabilized image techniques. They found that left and right images have to be aligned within about 6′ disparity before fusion can take place. A vergence shift will therefore be required to bring the images of the central square to within this disparity. Note that the fusion of the background elements would not be disturbed by this vergence shift because Julesz and Fender have also shown that, once fusion of a random-dot stereogram has been established, left and right images can undergo horizontal misalignments of about 2° before fusion is lost.

The important point made in the above discussion is that random-dot stereograms with disparities greater than about 6′ require a vergence shift before they can be fused. The stereograms used in the present experiment had disparities of 12′ and so they would require just such a vergence shift. The suggestion which immediately presents itself concerning the facilitating role of the contour for the Group 2 subjects is that it helped them produce this necessary shift. Note that the contours of the outline square were uniocularly identifiable in each field, unlike the edges of the 'hidden square' in the noncontoured stereogram which appear only *after* binocular fusion has been obtained. This property of uniocular identifiability could have made the execution of appropriate vergence movements much easier in the contoured stereogram task. This suggestion is supported by the work of Westheimer (1971) who showed that the kind of uniocular features possessed by the square would indeed be adequate for initiating and driving vergence movements.

If this vergence suggestion is valid, the particular disability characterizing the Group 2 subjects was a weakness in their vergence mechanisms, a weakness which probably had its origin in the period in their clinical history during which bifoveal binocular single vision was absent. The disability might reside in one or more parts of the vergence control pathway. It might, for instance, lie in the disparity-detecting cells which are probably used to control, initiate, and guide these movements (Blakemore, 1970). Alternatively it may be located in the motor mechanisms themselves. In the latter case, it might be that subjects with the disability find it difficult to produce integrated vergence shifts voluntarily or spontaneously (which is exactly what an uncontoured random-dot stereogram with a large disparity requires), but that they can do so under stimulus control (that is, when, as in the contoured random-dot stereogram, there is an adequate stimulus to trigger the vergence movements directly).

Some qualitative observations made by various Group 2 subjects confirm this vergence interpretation of their random-dot performance. They reported while viewing the non-contoured stereogram that, although they could not see a square-shaped area of elements standing out in a single depth plane, none the less *some* elements in the central area did appear to stand out on their own, each in a different depth plane. This suggests that these subjects were fusing the two halves of the stereogram in an unusual manner, perhaps because they had become locked into an imperfect fusion of the two fields from which they could not 'escape' because of the inability to control their vergence movements appropriately. Such imperfect fusions would, of course, be possible because of the inherent ambiguity of random-dot stereograms (see page 545).

That the Group 2 subjects could do as well as they did on the Wirt test while failing to fuse the non-contoured stereogram is, of course, compatible with regarding them as subjects with vergence difficulties. The Wirt test contains many prominent contours which could guide vergence movements in just the same manner as the outline square might have done in the contoured stereogram. (Caution is necessary, however, when making detailed comparisons between performance on the Wirt and performance on our stereograms since an important difference exists between the two testing situations: the Wirt is usually placed in the hands of the patient and viewed at reading distance, whereas our stereograms were projected at some distance from the patient.)

Normal subjects also benefit from the inclusion of prominent contours in random-dot stereograms if the disparities are very large and therefore require large vergence shifts. Thus Saye and Frisby (1975) have shown that contours shorten the stereopsis perception time for stereograms with a disparity of $> 1°$ but that they do not do so for similar stereograms with a disparity of only $5'$. This result is easily explicable in terms of vergence, with the contour facilitating the large vergence shift required for the high disparity stimulus but with no benefit conveyed for the low disparity stimulus because no such shift is needed.

On initial consideration, it might appear that our vergence explanation of the subject groupings would predict less good prism fusional ranges in Group 2 than in Group 1 as this range measure provides an index of vergence capability. In fact, the two groups were not significantly different in this respect, although the presence of three subjects in Group 2 with poor fusional ranges (nos 16, 19, and 21) contrasts with the absence of subjects in Group 1 with this assessment and is therefore suggestive. However, two considerations must be borne in mind when assessing the prism fusional range scores in connexion with the present subject groupings:

1. The disparity incorporated in the random-dot stereograms was only $12'$. This represents a vergence shift equivalent to that required for a prism of considerably less than 1^{Δ}. It is generally recognized that it is impossible in the clinical testing situation to detect reliably fusional movements to prisms of less than about 2^{Δ}. Accordingly, even if Group 2 had in fact possessed significantly poorer prism fusion range scores, they might still have had sufficient fusional reserves to deal with the very slight vergence shift required by the present stereograms. In short, the prism fusional ranges scores are rather too crude to be directly relevant to the present stimuli.
2. Inability to produce appropriate vergence movements to the uncontoured stereograms, the defining characteristic of Group 2 subjects as far as our vergence explanation is concerned, need not *necessarily* be associated with a poor fusional range as measured with a prism bar, regardless of the question of sensitivity. This is because the uncontoured stereogram presents quite a different fusional task from that provided by the prism bar. In the latter case, there are many prominent uniocularly visible contours in the field of view which can guide an appropriate vergence movement (indeed, the prism task is similar to the *contoured* stereogram situation in this respect). But in the former case, there are *no* stimulus features which can trigger the required vergence movements. Consequently, even a good fusional range score as measured with a prism bar need not imply the capacity to fuse the uncon-

toured type of random-dot stereogram. If we consider the possibility discussed earlier, that the Group 2 subjects possessed a limitation in producing integrated vergence shifts voluntarily or spontaneously in the absence of direct stimulus control, then the prism fusional task could be unhelpful in understanding the nature of their difficulties.

A very marked difference between Groups 1 and 2 concerned ocular movement anomalies. Group 1 contained no subjects with horizontal ocular movement anomaly but there were six out of 10 subjects with this movement in Group 2. In discussing this result, it must be emphasized that the limitations or overactions in ocular movement recorded were minimal and there was no evidence to suggest that any of them were related to paralytic squint. In no case were they symptom-producing, nor did they give rise to a compensatory head posture. Two of the three patients in Group 2 who had clear evidence of horizontal anomaly had acquired this limitation after surgery (nos 12 and 14) but even with this finding they should have had no difficulty in maintaining binocular single vision of a centrally-placed stimulus once they had obtained fusion.

The findings of this marked difference between Groups 1 and 2 was unexpected and it is difficult to relate it satisfactorily to their different performances with the random-dot stereograms. From one point of view it could be taken as evidence in favour of our vergence explanation of the Group 1/Group 2 separation in that it suggests that the two groups did indeed differ in terms of eye movement control. But it must be emphasized that the *gross conjugate* eye movements required in the ocular movement test are very different from the *slight vergence* movements required for fusion of the random-dot stimuli. It may be that the important common property shared by these two test situations is that they both involve a certain degree of *voluntary* control over eye movements. In the ocular movement test the patient has to direct his gaze deliberately to the point indicated in the field of view; and while attempting to fuse an uncontoured random-dot stereogram he has to scan the stimulus and create a vergence shift in the absence of any prominent feature. The contoured random-dot stereogram presents a contrasting task. There the presence of a contour in each field of view produces the required vergence shift directly, without any deliberate effort on the part of the subject. This speculation about voluntary control can thus make sense of the data but it would of course be unwise to draw any firm conclusions at this stage. Further evidence from a larger sample is clearly required and we are currently engaged on this task.

Groups 1 and 2 also differed in terms of their Wirt stereoacuity scores and so the question arises whether this factor alone can provide any basis for these groupings. First, it is important that considerable overlap was shown by the two groups (see the Table) and it would be incorrect to conclude that the two groups were clearly separated by the Wirt test. Secondly, it is difficult to see why inclusion of a contour in a random-dot stereogram should have helped subjects with relatively less good stereoacuity as measured on the Wirt test. In this connexion it was noted that the worst Wirt stereoacuity found in either Group 1 or Group 2 was 6′ 40″. This, despite the differences existing between the Wirt and random-dot stereogram test situations, suggests that all these subjects would probably have had no difficulty in coping with the 12′ disparity incorporated in the random-dot stereograms if stereoacuity was the critical factor. Thus it seems unlikely that the important underlying factor determining the Group 1/Group 2 separation was stereoacuity *per se* and it is more probable that the differing stereoacuities of the two groups was associated with the generally less severe clinical diagnoses for the Group 1 subjects as compared with the Group 2 subjects.

Finally the relevance of our findings for clinical practice needs to be assessed. The prime conclusion is that random-dot stereograms can discriminate between patient categories. In particular, the simple uncontoured stereogram is unlikely to be fused successfully by any patient who has lost bifoveal binocular single vision for any length of time. This conclusion confirms that drawn by Reinecke and Simons. The present investigation, however, goes further in showing that random-dot stereograms can be fused by many patients with this history *if* they are helped by the inclusion of a contour. We suggest that this fact may be very revealing in assessing the consequences for stereopsis in a patient with a history of disturbed binocular single vision.

Summary

Random-dot stereograms were shown to a sample of strabismic patients for whom there was clinical evidence of stereopsis. Two kinds of stereograms were used, one of the usual sort and the other having a contour surrounding the disparate area in each field of view. The patients tested could be clearly classified as belonging to one of three response groups. The first group could fuse both kinds of stereogram, the second could fuse only the contoured kind, and the third could not fuse either kind. This grouping was found to relate to the degree to which bifoveal binocular single vision had been absent in the clinical histories of these patients. The result is discussed in terms of the consequences for vergence and stereopsis of a period of absence of normal binocular function.

References

BENTON, A. L., and HECAEN, H. (1970) *Neurology (Minneap.)*, **20**, 1089
BLAKEMORE, C. (1970) *J. Physiol. (Lond.)*, **209**, 155
CARMON, A., and BECHTOLDT, H. P. (1969) *Neuropsychologia*, **7**, 29
FENDER, D., and JULESZ, B. (1967) *J. opt. Soc. Amer.*, **57**, 819
JULESZ, B. (1971) 'Foundations of Cyclopean Perception'. University of Chicago Press, Chicago
REINECKE, R. D., and SIMONS, K. (1974) *Amer. J. Ophthal.*, **78**, 714
RICHARDS, W. (1973) US Air Force Office of Science Research Report No. 73-0439, 1400 Wilson Boulevard, Washington, DC
SAYE, A., and FRISBY, J. P. (1975) (In press)
WESTHEIMER, G. (1971) *In* 'The Control of Eye Movements', eds P. Bach-y-rita, C. C. Collins, and J. E. Hyde, pp. 473–482. Academic Press, New York and London