SENSORY DEFICITS IN VISUAL AGNOSIA

BY

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In recent years, Bay (1950, 1953) has repeatedly claimed that the so-called "higher" perceptual disorders are secondary to sensory impairment, to general intellectual loss, to language disturbance, or to a combination of these three factors. He denies strongly that agnosia in its classical sense of a circumscribed defect of recognition, specific to a single sense modality, in reality exists. Bay maintains that abnormal alterations in visual function (*pathologischer Funktionswandel*) may be present in cases conventionally held to display symptoms of agnosia and may play an important role in the genesis of this disorder. Although these sensory deficits may escape detection on routine examination of the visual fields, it is argued that they are measurable by means of a special test of local adaptation. This test has been fully described by Bay (1950, 1953). His results indicate first, that alterations in adaptation rate are prominent in most patients with clinical signs of agnosia; and secondly that such visual deficits may occur in perimetrically normal areas of the visual field. In general, Bay reports that significant alterations in visual efficiency are present in all cases of "agnosia" in which there is neither disorder of language nor significant global deterioration.

These contentions have been critically examined at a symposium of German neurologists held in 1951. The consensus of opinion cannot be said to favour Bay's interpretation. Thus it was argued by both Jung (1951) and Scheller (1951) that visual impairment together with non-specific intellectual loss could hardly explain the diversity of visual-agnosic syndromes and their relative specificity in terms of content (object agnosia, alexia, spatial agnosia, etc.). Faust (1951, 1955) has drawn a distinction between genuine and "pseudo-agnosic" symptoms; only the latter, he believes, are to be explained in terms of sensory loss in the manner proposed by Bay. It is also noteworthy that Russell (1951) has reported accelerated visual adaptation in the absence of visual agnosia; and Jaffe (1955)

has more recently described accelerated tactile adaptation without astereognosis. It would therefore appear that although sensory defects of the kind proposed by Bay may well occur in many cases of brain lesion, their relation to the classical agnosias is decidedly conjectural.

It should also be pointed out that there are certain methodological defects in the test procedure as reported by Bay (1953). In the first place, the effects of unilateral visual inattention (extinction) do not appear to have been given adequate consideration despite Bay's use of the condition of double simultaneous stimulation. In the second place, Bay's method of assessing the degree of adaptation defect in a particular patient by subtracting the value given from the mean value for an appropriate control group is far from satisfactory. It will readily be seen that this method would permit some "abnormality" to be recorded in about 50% of a healthy population. In the third place, Bay's method, which places stress on chromatic adaptation, is open to the objection that disturbances in colour recognition are commonly unrelated to other varieties of agnosia.

Despite these and other objections to Bay's methods, his views concerning agnosia have gained some measure of acceptance (cf. Critchley, 1953). Apart from purely theoretical issues, however, careful examination of more elementary visual processes in the manner suggested by Bay would appear a most valuable precaution in the analysis of cases presenting "higher" visual disabilities. An investigation has therefore been undertaken to assess the extent and significance of visual deficit in a series of 30 cases of brain lesion. These comprise (a) cases lacking both visual field defects (as conventionally ascertained) and signs of perceptual disorder (12 cases); (b) cases with field defects but without perceptual disorder (10 cases); (c) cases with field defects and various types of perceptual disorder ("agnosia") (eight cases). These patients were tested on a variety of visual discrimination tasks using systematic psychophysical procedures, and the results evaluated with reference to the thresholds given by a large control group of healthy

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subjects. It is hoped first, to determine the incidence and magnitude of visual deficits in cases of cerebral lesion; and secondly, to assess their possible significance in relation to the "higher" disorders of visual perception.

Apparatus

An apparatus was constructed to enable discrimination on a variety of visual tests to be assessed quantitatively at representative points in the visual field. This apparatus allows all variables not directly related to the differences between the tests, *e.g.*, background luminance, to be held constant.

An hemisphere made of plaster and of 1 m. radius is set vertically in a room which can be fully screened from daylight (Fig. 1). The smooth inside of the hemisphere is coated with special matt white diffusing paint according to a formula developed by the G.E.C. Ltd. to reflect light of all wave lengths approximately equally. A large corrected field lens is mounted behind a circular aperture of 6.3 cm. diameter let into the centre of the interior surface of the hemisphere. The interior is illuminated by two 4 ft. 40 w. "natural Osram" fluorescent tubes suspended vertically one to each side, at about 2½ ft. from the rim. These tubes are supplied with 230 v. A.C. from a constant voltage transformer. The luminance of the central part of the hemisphere is always maintained at a level of 34.7 ft. L. $\pm$ 5%.

Test stimuli are presented from the centre of the surface of the hemisphere, *i.e.*, through the lens or from close to it. The subject can be instructed to fixate on either the stimuli themselves (to test central vision) or on any point of the interior surface of the hemisphere which may be indicated by fixing a small black mark at the required position. For standard testing, small 2 v. torch bulbs are imbedded into the plaster at 5°, 15°, and 35° along the four diagonals running up and to the left, down and to the left, down and to the right, and up and to the right from the centre of the field lens, and serve as fixation lights. These bulbs are only faintly

illuminated when required, and only their filaments can then be seen to glow through 2 mm. apertures in the white paint. Similarly, neon "indicator" lamps are positioned, one each, at 2.5° from the centre of the field lens along each of the four diagonals, so that their top ends lie flush with the interior surface of the hemisphere. Pieces of diffusing paper are attached to the top ends of the neon bulbs and have small black crosses painted at their centres.

A specially designed head rest is mounted on a supporting platform in such a way that the whole of it can rotate about a vertical axis, and part of it (including the chin and brow rests) can rotate about a horizontal axis. The point of intersection of these axes is also the exact centre of the hemisphere, *i.e.*, at 1 m. from every point of the interior surface. Either one of the subject's eyes can without difficulty be accurately positioned at this point, since the height of his chair and the deviation of the chin and brow rests from the horizontal and vertical axes are all adjustable. The head rest can be turned and tilted (without the eye shifting from its required position in relation to the field lens) so that the forehead is square to the optical axis for all fixation points. This eliminates that component of ocular fatigue which arises when fixation is maintained by ocular deviations away from the central position of the eyes in the head.

To ensure that fixation is maintained on the required point, a small hole ($\frac{1}{8}$ in. diameter) is drilled through the plaster of the hemisphere at eye level from the ground and at 20° from the centre of the interior surface. Through this the subject's fixation can be observed. A standard procedure is adopted for the different tests with regard to the few instances when a shift from the fixation point is observed, but in practice it is found that if the subjects are promptly checked and warned not to "cheat", steady fixation is maintained after the first test or so.

An optical system, the position of which relative to the hemisphere is roughly indicated (not to scale) in Fig. 1,

permits various light stimuli to be presented through the field lens. At the same time it fills the field lens, which is seen in Maxwellian view (cf. Leibowitz, 1954), with light. The details of the optical system are illustrated in Fig. 2.

Two channels of light are taken from one source, a vertical 2 ft. 40 w. "natural Osram" fluorescent tube, and are recombined in a mixing cube. The light of the background channel merely passes through wedge filters which permit an exact subjective match to be made between the brightness of the field lens and of the interior of the hemisphere. Cuts

FIG. 1.—Hemisphere and light source.

FIG. 2.—Enlarged view of optical system.

- 1 = shutter
- 2 = flicker sector
- 3 = filter holder
- 4 = cut holder
- 5 = flicker motor
- 6 = tachometer

any desired shape or size, and filters of any kind can be inserted into the cut and filter holders positioned along the axis of the stimulus channel. The images of the cuts are seen in the plane of the interior surface of the hemisphere. An electrically operated shutter can be set for stimulus exposures of 1 sec. or longer as required.

In order to minimize the 100 cycle component in the output of the 2 ft. 40 w. fluorescent source, the tube is supplied through a rectifier unit and the output voltage smoothed by means of an electrolytic capacitor. The associated control gear of the lamp unit is retained with the addition of a variable resistor and reversing switch. The residual ripple constitutes 8.5% of the total light output of this source which has a luminance of 3,162 ft. L. $\pm$ 2%. The range variation at one session is normally $\pm$ 0.5%, and control of the source luminance is achieved by use of the variable resistor on the output side of the constant voltage supply to regulate the current passed to the tube. Blackening of the tube is prevented by frequently reversing the direction of the current.

Visual Discrimination Tests and Control Performance

The particular tests used in this study comprised brightness discrimination (B.D.), flicker fusion (F.F.), acuity for small objects (Ac.), local adaptation (L.A.), tachistoscopic acuity (T.A.), and apparent movement perception (A.M.). A control group of 48 normal individuals, drawn from the staff of the National Hospital, was used in standardizing the tests. Its composition is fully described elsewhere (Ettlinger, 1955). The mean age of this group was 34.7 years, with a range of 17 to 61 years. Each control subject was tested with both eyes separately and on all the tests, each patient with one eye only. Three points along the diagonal meridian of each quadrant (2.5°, 15°, and 35° for B.D., F.F., and L.A.; 5°, 15°, and 35° for Ac., T.A., and A.M.) were selected for standard testing, with the addition of

central vision for B.D., F.F., and A.M. The order of testing eyes, quadrants, and points within quadrants was systematically varied for both control subjects and patients to balance practice effects. The sequence of the administration of the different tests was randomly varied. The interval of time between test sessions varied for all subjects from 24 hours to a few weeks. A standard rest period of two minutes is allowed in between the testing of successive quadrants.

In presenting the results for the control group, the findings for the right and left eyes are combined, as are those for the four quadrants tested. This procedure has been adopted because no significant differences were found between results analysed separately for eyes and quadrants, *i.e.*, between upper and lower, right and left, or nasal and temporal quadrants. The thresholds obtained for 48 control subjects using two eyes on each test are also combined because no systematic relationship between performance with the first and second eye could be detected for a random sample of eight of the control group on any test.

The background luminance of the hemisphere and field lens is held constant at 34.7 ft. L., but the dimensions of the various test objects presented in the different discrimination tasks are summarized for each test separately below.

The procedure and control results may now be reported for each test.

Brightness Discrimination Tests.—The just-not-noticeable difference in brightness between the test object and the background is determined by the method of serial groups. The luminance of the test object can be decreased from the standard incremental value (measured against an unfilled

Test	Nature of Test Object	Angular Size of Test Object	Incremental Luminance of Test Object	Duration of Exposure
B.D.	Central circular disc	1.5°	Variable	1.5 sec.
F.F.	Central circular disc	1.5°	199.5 ft. L. (light phase)	1.5 sec.
Ac.	Central modified Landolt rings	Variable	199.5 ft. L.	1.5 sec.
L.A.	Central circular disc	1.5°	199.5 ft. L.	—
T.A.	2 pairs of neon lamps, round field lens	Each lamp 53 min.	58.9 ft. L.	Variable
A.M.	4 neon lamps round field lens	Each lamp 53 min.	58.9 ft. L.	5 sec.

field lens) of 199.5 ft. L. by the insertion into the stimulus channel of one of a series of neutral density filters. These are graded in steps of 0.25 log. units of density.

At each level of luminance the subject is given 10 "presentations", *i.e.*, the shutter is operated 10 times, but in only five of these, at random, is the disc of light actually exposed. The luminance level of the last group of the series (from easy to difficult) in which eight out of 10 responses are correct is recorded as the threshold value. A response "yes" to no exposure is counted incorrect just as is "no" to a faint presentation. No account is taken of errors in groups containing eight correct responses or of correct answers in unsuccessful groups. A period of one to two seconds is allowed between successive presentations and some provisions are made for practice at discrimination on the first quadrant of each test session.

The results at brightness discrimination in central vision and at angular separations of 2.5°, 15°, and 35° from the visual axis for the middle 80% of the control group are presented in Table I. Ten per cent of all the values obtained have been excluded from each extreme end of this and every other distribution of control data. N refers to the total number of control values from which the "normal" range of any category of response is derived. As explained above the results for right and left eyes and different quadrants have been combined. In addition, the normal ranges of performance were determined for the following categories of response

("normal" in this context represents the results for the middle 80% of a control group):—

(1) Sum of thresholds at three points in one quadrant (N = 383); (2) difference between sums of thresholds at three points in the right and left quadrants (combining upper and lower quadrants when N = 191); (3) difference between thresholds at right and left points, comparing 2.5°, 15°, and 35° each separately (N = 192, 192, 191).

Flicker Fusion Tests.—Two ascending and two descending thresholds are obtained, using the method of minimal changes, for the phenomenal fusion of a flickering disc of light. Each presentation of flicker has a duration of 1.5 sec. with intervals of one to two seconds in between successive presentations.

A metal disc having four sectors is driven by a constant speed motor through a "ball and disc" type of gear box and is mounted as illustrated in Fig. 2 so that it interrupts the stimulus light beam close to its narrowest cross-section. The blades of this disc give a 1 : 1 light-dark ratio, where the dark phase is the background luminance of the field lens. A Smith's hand tachometer (Model A.T.H.7) is locked to the sector shaft and thus gives a direct reading of its rate of rotation.

The normal ranges of the mean c.f.f.s in central vision and in the peripheral field are presented in Table I. In addition, the normal ranges of the deviations of the individual flicker thresholds from their mean at any point were ascertained. This measure reflects the normal variability of performance at flicker fusion at one position in the visual field. The normal ranges for further categories of response were also determined, as for brightness discrimination, except that no sums of thresholds at three points in one quadrant were taken. This additional category of response has been omitted because change of fusion frequency in relation to the eccentricity of the test object was not uniform in the same direction for all subjects as is reported elsewhere (Ettlinger, 1956).

Acuity for Small Objects Test.—In order to determine the acuity for small objects progressively

TABLE I
NORMAL (80%) RANGES OF PERFORMANCE BY CONTROL GROUP ON TESTS OF BRIGHTNESS DISCRIMINATION, FLICKER FUSION, ACUITY FOR SMALL OBJECTS, LOCAL ADAPTATION AND TACHISTOSCOPIC ACUITY

	N*	B.D. ($\Delta I/I$, fractional differences)	F.F. (Mean C.f.f.s in c.p.s.)	Ac. (Angular Sizes in Min. and Sec. of Arc)	L.A. (Middle Times in Sec.)	T.A. (Duration of Flashes in msec.)
Central vision	96	0.0057—0.018	72.5—42.5			
2.5°	384	0.0102—0.032	60.5—40.0		120—11	
5°	384			1' 4"—2' 9"		1.5—5.4
15°	384	0.032—0.057	63.5—35.5	8' 35"—17' 10"	30—5	5.4—14.5
35°	383	0.057—0.181	61.5—32.5	34' 20"—137' 20"	20—4	14.5—80.0

* N refers to the number of thresholds on which any range is based.

smaller "modified" Landolt rings are presented by the method of serial groups from the centre of the field lens. The gap in the ring faces twice in each direction (in random order) in each group, and testing is continued until the direction of the gap cannot be correctly discriminated in six out of the eight trials allowed for any one size of gap.

The modified Landolt rings are prepared from thin copper foil and are then attached to glass slides. Since the image of any cut has dimensions about three times greater than those of the cut itself owing to the characteristics of the optical system, modified Landolt rings were developed in which the angular size of the rings is maintained constant (at 2.3° outer, 1.5° inner diameter) for variations in the magnitude of the gap ranging from 1 min. 4 sec. to 68 min. 40 sec. Unfortunately certain disadvantages are inherent in this design.

Small differently coloured marks can be attached to the surface of the hemisphere close to the lens in the four directions, *e.g.*, red to the left, blue to the right, etc., to assist those patients who have right/left disorientation.

The normal ranges of performance are given in Table I. The normal ranges for additional categories of response were also determined, as for brightness discrimination.

Local Adaptation Test.—In the test of local adaptation three values for the time of subjective disappearance of a disc of light after its exposure are recorded for each position of the visual field tested. Taking one quadrant at a time, the positions along it are tested once each in rotation and then for the second and third times again in rotation.

The subject is given standard instructions part of which read: "If the bright central disc appears to you to fade from view into the background I want you to press this key here. If the disc does not appear to fade from view into the background within a certain time, I shall switch it off. You should avoid blinking more frequently than is necessary, and you should *not* press the key if the disc has disappeared from view only during a blink. On the other hand, you *should* press the key if the bright central disc has appeared to fade from view into the background *even for a moment only* and then has reappeared." An electrical clock is started synchronously with the exposure of the disc and stopped by the subject when he presses the key.

The maximum exposure time is 120 sec., and a response category of 120+ is recorded if the subject has failed to press the key within this interval. In order to ensure that the prolonged local adaptation times manifested by some patients are not the result of inadequate comprehension of instructions

but are genuinely visual phenomena, the disc can be silently obscured. Such checks are only made after the disc has been exposed for 120 sec., and the threshold value is discounted if the subject has failed to press the key within 5 sec. of the obscuration.

In computing the normal ranges of performance (Table I) account has been taken of only the middle one of the three values recorded at any position in the field of vision. The normal ranges of variability at local adaptation were ascertained by including the deviations of the two remaining readings from the middle time at each position in one frequency distribution. In addition, the normal ranges for other categories of response were also determined, as for brightness discrimination.

Tachistoscopic Acuity Test.—Tachistoscopic acuity is evaluated by flashing one of two pairs of neon lamps on for progressively shorter durations until the stimulus pair cannot be identified correctly in eight out of the 10 trials allowed for any one duration of flash.

The 240 v. neon indicator lamps positioned at 2.5° along the four diagonal meridians from the centre of the field lens are employed. They are wired for this test in pairs, the bulbs at the diagonally opposite corners of the square being connected together. Each pair is presented five times (in random order) in each group of 10 trials. Their light has an orange red appearance.

The neon tube circuit is completed by means of a pair of high speed relay contacts, and the current pulse for the operating coil of this relay is drawn from a capacitor charged to a suitable potential. Variation of the flash duration is achieved by selecting the appropriate one of five capacitors giving times ranging from 1.5 to 80 msec. In the course of the investigation all flash durations have varied by approximately $\pm 5\%$, and a further disadvantage relates to the relatively large angular size of the test pairs.

The normal ranges of performance are shown in Table I. The normal ranges for additional categories of response were also determined, as for brightness discrimination.

Apparent Movement Perception Test.—The four neon lamps at 2.5° from the centre of the field lens are illuminated in anti-clockwise rotation in order to test apparent movement perception. The standard parameters of stimulation, *i.e.*, exposures lasting 160 msec. and intervals between exposures of 40 msec., are such as have been found to give optimal perception of apparent movement with a small pilot group. Only one presentation, lasting 5 sec., is made under the standard conditions at each position in the visual field, and the subject is then

immediately questioned about his experience. Answers are sought according to five categories of experience, but leading questions are avoided and the subject is not pressed to answer if he is uncertain.

The four neon lamps are supplied through contacts on an electrically driven cam operated switch, and variation of the motor speed will adjust the period of the complete stimulus cycle (from 0.6 to 2.0 sec.). On the other hand, movement of the wedge-shaped operating cam in relation to the switch contacts allows the on-off ratio of the lamps to be altered (from 0.46 to 1.16, *i.e.*, so that successive flashes may overlap).

The relative frequencies of two out of the five categories of response for the control group are presented in Table II, where N refers to the number of positive responses on which any percentage is based.

TABLE II
CONTROL RESULTS ON TEST OF APPARENT MOVEMENT PERCEPTION (% INCIDENCE OF ALTERNATIVE RESPONSES)

	N	Movement	No Movement		
Central	94	91.5	8.5		
5°	384	95.3	4.7		
15°	384	99.7	0.3		
35°	383	94.0	6.0		
	N	Square Shape	Circle	Others	No Shape
Central	86	79.1	18.6	0.0	2.3
5°	367	62.1	30.8	4.1	3.0
15°	376	22.6	66.2	9.1	2.1
35°	355	9.9	56.1	8.5	25.5

The response category of "movement" includes any impression of movement, whatsoever its nature. The most common alternative report was to the effect that the lights merely flashed on and off successively. When a response of "no movement" was given, the temporal parameters of stimulation were varied over the ranges described above. In about one half of these cases the perception of movement could then be evoked, but no systematic trend became evident implicating either shorter or longer durations of illumination or of intervals between illuminations as more effective in promoting the perception of movement than the standard conditions. Mere repetition of presentations to one retinal position may, therefore, exert a facilitating effect, independently, within certain limits, of the temporal parameters of stimulation. At all positions some responses of "no shape" probably reflect uncertainty rather than a positive absence of perceived shape.

In about 10% of all responses a phenomenal

change in the display occurred during the 5 sec. presentation. In such cases only the predominating appearance was included in the results analysis. A number of subjects also spontaneously reported a diminution in the apparent size of the display at 35° by comparison with its appearance at 15° and 5°. Information concerning the other categories of response is given by Ettlinger (1955).

Test-Retest Correlations

The rank test-retest correlations were calculated on all the tests excepting apparent movement perception for a group of eight control subjects selected at random. Applying one-tailed tests of significance and adopting the conventional 5% level of confidence, these test-retest correlations proved significant in every instance with the exception of acuity for small objects.

Selection of Cases

A group of 30 patients has been studied. Of these only one (Case 23) was selected for the presence of visual perceptual disorder and was referred by Dr. C. A. Pallis for examination (Pallis, 1955). The remainder comprised 22 cases of cerebral disease and five cases of brain injury. Two cases presented visual deficits associated with optic atrophy. With one exception (Case 30)* no case with severe intellectual deterioration was included, although there were minor degrees of impairment in several. These were not, however, thought to be sufficient to disturb cooperation on the tests.

The cases were divided into three groups on the basis of the presence of visual field defects and/or evidence of higher perceptual disorder. Group A comprises 12 cases lacking both field defects and evidence of perceptual disorder; group B comprises 10 cases with various types of field defect but without evidence of perceptual loss other than that directly attributable to the field defects; group C comprises eight cases in which both field defects and various types of higher perceptual disorder were in evidence. The salient data in the individual cases in each group are summarized in Tables III, IV and V.

No pupillary abnormalities were present in the eye tested of any patient apart from Case 17, and disturbance of eye movements during fixation was observed only in Case 24. Reasonable allowance for various other clinical features such as dysphasia (Cases 1, 2, and 25) and right/left disorientation was made by slight alterations of procedure, but tests were abandoned in all instances in preference to the

* Case 30 has been included because he demonstrates that sensory thresholds can be determined for patients of extremely defective intelligence.

introduction of any significant departure from the standard procedures. Results of clinical tests of central visual acuity were available in every case and are given in detail elsewhere (Ettlinger, 1955). No exceptional values were reported.

Procedure and Treatment of Results

In general the patient's more "effective" eye (by reference to clinical tests of acuity or perimetry) was selected for testing, but where vision seemed to be essentially the same in the two eyes the choice was made by a random procedure. An exception to this rule was made in one case of optic atrophy (Case 19) when the eye with least effective vision was chosen for tests of both perception and sensory efficiency.

Although thresholds were obtained for some patients at positions in the visual field additional to the standard points used with the control group, *e.g.*, for the vertical and horizontal meridians, these data have been neglected in computing two overall measures of visual sensory performance for each patient, the "efficiency index" and the "variability index". Details of the method of calculating these indices are given by Ettlinger (1955). In outline, however, the patient's performance is compared with the appropriate normal range, taking the threshold obtained at each of the standard positions in the visual field separately, as also certain additional categories of response.*

If performance at any point or according to any additional category of response falls within the normal range it is allotted a "transformed" score of zero; if it falls outside the normal range in the direction of less efficient performance or of greater variability between successive discriminations, it is allotted a transformed score of -1 ; if it falls outside the normal range in the direction of more efficient performance or of less variability between successive discriminations it is allotted a transformed score of $+1$. The algebraic sums of these transformed scores, taking scores relating to efficiency and variability separately, are found either for one test at a time or for all tests in combination.†

In order to eliminate the positive or negative

signs of the algebraic sums of transformed scores, and to allow for the varying numbers of transformed scores on which these sums may be based, a mathematical conversion to indices is effected. Thus a positive algebraic sum of transformed scores is added to the total of transformed scores on which it is based and the resulting value is expressed as a ratio of this total, times 100; if the sum of transformed scores is negative, it is subtracted from the total number of transformed scores on which it is based, and the difference is expressed as a ratio of this total, times 100. An index of 100 then represents the level of performance relating to the middle 80% of the control data, and values greater or smaller than 100 are related to more or less efficient or consistent levels of performance respectively. However, owing to a scoring bias which affects all the patients' results equally, efficiency indices greater than 100 in value are slightly less probable than values below 100.*

In computing efficiency indices, a transformed score of -1 is allotted both for performance relating to a totally blind area of the visual field and for a threshold determination falling just outside the normal range of performance. Account is, however, taken of the difference between these two kinds of result in charting each patient's performance at different sites in the visual field with a graphical technique described elsewhere (Ettlinger, 1955).

Results

The efficiency indices on the individual tests and on all the tests in combination for the 30 patients are given in Tables III, IV, and V. It will be seen from Table III that the mean overall efficiency index for the 12 cases with perimetrically normal fields is found to be 82. This signifies that there is some overall impairment of sensory efficiency relative to the standard of the control subjects despite the lack of field defects as conventionally determined. It is improbable that the sensory impairment of patients in Group A is related to the slightly greater mean age (38.2 yr.) in this group than in the control group. The effect of the scoring bias may also be discounted since the mean efficiency index for 11 of the 12 patients tested at brightness discrimination is still only 89, although the bias is negligible in this test. These scores on brightness discrimination (which may be shown to be significantly lower than control values at the 1% level

* These have been mentioned in the description of the sensory tests. There are four scores in each test (excluding flicker fusion and apparent movement) for the sums of three thresholds in one quadrant. Comparisons between performance in the left and right half-fields are always allotted two scores, whether quadrants or individual sites are contrasted. In the test of apparent movement perception only "movement" and "shape" responses are compared with control data. One measure of variability is taken for each threshold, where applicable, for computing variability indices.

† One "transformed" score is also allotted for performance on a test of real movement perception in central vision, and this is included in the algebraic sums of "transformed" scores for all the tests in combination.

* Owing to the significant excess of positive transformed scores at L.A. (see below), algebraic sums of transformed scores derived by a different method are incorporated into the overall efficiency indices. Thus both positive and negative transformed scores are treated as negative, but the negative total is reduced by a constant factor to allow for the 20% expectation of both positive and negative transformed scores.

TABLE III

EFFICIENCY INDICES FOR INDIVIDUAL TESTS AND FOR TESTS IN COMBINATION IN CASES WITHOUT FIELD DEFECTS OR PERCEPTUAL LOSS (GROUP A)

Case	Sex	Age	Diagnosis	Efficiency Indices (normal = 100)						Overall
				B.D.	F.F.	Ac.	L.A.	T.A.	A.M.	
1	M	33	Left temporo-parietal subdural haematoma	100 (19)*	69 (15)	95 (19)	111 (18)	89 (18)	100 (26)	93 (116)
2	M	52	Left temporo-parietal lesion of unknown aetiology	95 (19)	107 (15)	89 (19)	78 (18)	67 (18)	75 (23)	85 (113)
3	M	19	Left temporal lobe E.E.G. focus; excision	84 (19)	91 (15)	94 (18)	111 (18)	122 (18)	0 (13)	85 (101)
4	F	31	Right temporal lobectomy	74 (19)	38 (15)	79 (19)	139 (18)	44 (18)	84 (25)	88 (115)
5	M	57	Left fronto-parietal parasagittal G.S.W.	95 (19)	98 (15)	100 (18)	111 (18)	67 (18)	60 (20)	85 (109)
6	F	43	Left frontal angioma	79 (19)	25 (15)	72 (18)	167 (18)	50 (18)	92 (25)	65 (114)
7	F	37	Left fronto-parietal parasagittal glioma; partial excision	100 (19)	98 (15)	100 (19)	167 (18)	50 (18)	87 (23)	82 (113)
8	M	38	Left frontal lesion of unknown aetiology	95 (19)	47 (15)	89 (19)	106 (18)	111 (18)	100 (26)	92 (116)
9	(L-handed) M	35	Right mid-fronto-parietal G.S.W.	95 (19)	93 (15)	89 (19)	83 (18)	44 (18)	96 (26)	89 (116)
10	(L-handed) M	46	Right frontal glioma	96 (19)	111 (15)	115 (18)	156 (18)	100 (18)	85 (26)	90 (116)
11	M	45	Right frontal lesion of unknown aetiology; focal epilepsy	100 (19)	16 (15)	100 (19)	167 (18)	78 (18)	84 (25)	74 (114)
12	(L-handed) M	22	Severe contusional midbrain injury	58 (19)	20 (15)	100 (19)	100 (18)	40 (18)	84 (26)	72 (113)

* Values in brackets refer to the number of "transformed" scores on which any index is based.

TABLE IV

EFFICIENCY INDICES FOR INDIVIDUAL TESTS AND FOR ALL TESTS IN COMBINATION IN CASES WITH FIELD DEFECTS BUT WITHOUT PERCEPTUAL LOSS (GROUP B)

Case	Sex	Age	Diagnosis	Field Defects	Efficiency Indices (normal = 100)					
					B.D.	F.F.	Ac.	L.A.	T.A.	A.M.
13	M	27	Left occipito-parietal parasagittal G.S.W.	Partial R. homonymous hemianopia	26 (19)*	43 (15)	26 (19)	89 (18)	6 (18)	83 (24)
14	F	13	Right occipital lesion of unknown aetiology	Concentric constriction more marked to left	63 (19)	40 (51)	42 (19)	— (18)	47 (23)	65 (23)
15	F	43	Right parieto-occipital neoplasm	L. homonymous hemianopia	42 (19)	14 (14)	37 (19)	50 (18)	39 (18)	65 (20)
16	F	45	Right mid-parietal meningo- glioma; excision	L. homonymous lower quadrantic defect	47 (19)	17 (15)	67 (18)	94 (18)	— (18)	88 (25)
17	M	30	Right mid-fronto-parietal G.S.W.	L. homonymous lower quadrantic defect	61 (19)	67 (15)	58 (19)	75 (18)	17 (18)	92 (24)
18	M	26	Cerebral lesion of unknown aetiology; epilepsy	Inconstant defects	58 (19)	36 (15)	37 (19)	83 (18)	50 (18)	83 (23)
19	M	27	Suprasellar meningioma; right subtotal frontal lobectomy	Bitemporal constriction	21 (19)	13 (15)	47 (19)	167 (18)	17 (18)	50 (18)
20	M	61	Optic atrophy related to pituitary adenoma	Right eye blind, concentric constriction more marked to L. in L. eye	11 (19)	7 (14)	26 (19)	67 (18)	53 (18)	38 (19)
21	M	18	Right temporal lobectomy	Left homonymous upper quadrantic defect	58 (19)	95 (14)	74 (19)	83 (18)	67 (18)	67 (21)
22	M	30	Right temporal lobectomy	Partial left homonymous hemianopia	42 (19)	63 (15)	63 (19)	78 (18)	11 (18)	30 (21)

* Values in brackets refer to the number of "transformed" scores on which any index is based.

of confidence) also exclude the effect of the abnormal results at flicker fusion and local adaptation in cases with frontal pathology (see below).

The relative frequencies of the negative transformed scores relating to thresholds taken in the half-field of vision on the same and on the opposite side to a unilateral lesion were also compared in this group of cases. Performance on all the tests excepting only local adaptation was found to be very slightly more depressed in the half-field contralateral to the lesion than in the ipsilateral half-field. Statistical analysis, however, failed to

demonstrate that this difference in performance between the two half-fields on all the tests is significant at the conventional 5% level of confidence.

The results in Group B are presented in Table IV. As expected, visual discrimination is more severely impaired in this group than in Group A, the mean overall efficiency index being only 54. On the other hand, the presence of perceptual disorder additional to field defects is not associated with a significant further loss of visual efficiency. Thus the mean overall efficiency index of the eight patients in Group C (Table V) is 51, only three points below

TABLE V
EFFICIENCY INDICES FOR INDIVIDUAL TESTS AND FOR ALL TESTS IN COMBINATION IN CASES WITH FIELD DEFECTS AND PERCEPTUAL LOSS (GROUP C)

Case	Sex	Age	Diagnosis	Field Defects	Perceptual Disorders	Efficiency Indices (normal = 100)						
						B.D.	F.F.	Ac.	L.A.	T.A.	A.M.	Overall
23	M	52	Bilateral occipital infarcts	Bilateral paracentral scotoma in upper quadrants; L. upper quadrant defect	Prosopagnosia, achromatopsia, topographical loss	42 (19)*	38 (14)	26 (19)	94 (18)	22 (18)	41 (17)	36 (106)
24	M	63	Occlusion of basilar artery	R. homonymous hemianopia	Visual alexia	32 (19)	53 (15)	11 (18)	100 (18)	28 (18)	27 (15)	33 (103)
25	M	53	Cortical atrophy	L. lower quadrant defect in L. eye	Simultanagnosia, visual constructive defects	37 (19)	67 (15)	100 (1)	89 (18)		87 (23)	74 (76)
26	M	49	Supratentorial meningioma	Concentric constriction more marked to L.	Visual constructive defect	37 (19)	33 (15)	26 (19)	11 (18)	11 (18)	50 (20)	32 (110)
27	M	49	R. parietal cystic glioma	L. homonymous attention hemianopia	Unilateral visual neglect, visual-spatial agnosia, topographical loss	74 (19)	89 (15)	32 (19)	100 (18)	22 (18)	75 (24)	65 (113)
28	M	61	R. parietal angioma	L. homonymous hemianopia	Unilateral visual neglect, visual-spatial agnosia	21 (19)	67 (15)	26 (19)	67 (18)	44 (18)	67 (21)	47 (110)
29	F	51	R. occipitoparietal glioma	Partial L. homonymous hemianopia	Visual-spatial agnosia, topographical loss	47 (19)	47 (15)	58 (19)	67 (18)	44 (18)	71 (21)	59 (110)
30	M	49	Cortical atrophy	R. homonymous hemianopia	Multiple defects of visual perception, dementia	11 (19)	77 (15)		83 (18)			61 (52)

* Values in brackets refer to the number of "transformed" scores on which any index is based.

the mean value for Group B. Individual results for patients in this group, and their significance in relation to the origins of agnosia, are discussed below.

The results given by all patients on all tests are analysed in order to determine the relative sensitivity of the different tests as indicators of visual loss. The mean efficiency indices of all patients and of Groups A, B, and C separately on each test are given in Table VI. It will be seen that tachistoscopic

TABLE VI
SENSITIVITY OF TESTS AS INDICATORS OF VISUAL DEFECT FOR ALL PATIENTS AND FOR GROUPS A, B, AND C SEPARATELY

	Mean Efficiency Indices (normal = 100)			
	All Cases	Group A	Group B	Group C
(1) Tachistoscopic acuity	46	72	32	29
(2) Flicker fusion	56	67	40	59
(3) Brightness discrimination	59	89	43	38
(4) Acuity for small objects	65	85	48	30
(5) Apparent movement perception	69	82	68	60
(6) Local adaptation	100	125	87	76

acuity appears the most, and local adaptation the least, sensitive indicator of defect in visual discrimination when all 30 patients are combined. In the cases of Group A, however, the lowest score is found on the test of flicker fusion. This alteration in the order of sensitivity of the tests is probably the result of a predominance of cases with frontal pathology in Group A (see below). The most striking finding in the cases of Group C is the

depression of performance on three tests (T.A., Ac, and B.D.) in combination relative to the scores on the remaining three tests. Such a difference is not seen in either Group A or B, and it is most marked on the tests of acuity for small objects and brightness discrimination. For the scores on these two tests are relatively high in Groups A and B, whereas the mean efficiency index at tachistoscopic acuity is uniformly low for all 30 patients.

Differential analysis by site and laterality of lesion reveals only one significant difference of performance on the discrimination tests between appropriate sub-groupings of patients, when the presence of field defects is allowed for by taking a relative measure between the overall efficiency index and that relating to any specific test. Thus a significant increase in length of fading times on the local adaptation test is found in cases of exclusively frontal-lobe pathology. Nevertheless, prolongation of fading times is not entirely confined to frontal cases and may be demonstrated to be in excess of control results for all 30 patients in combination ($\chi^2 = 122, 1 \text{ d.f.}$). Patients with frontal lesions, moreover, tend towards low thresholds and small deviations of successive judgments on the flicker fusion test in comparison with the results given by patients with lesions elsewhere. This difference is, however, just below significance at the 5% level of confidence. The converse trend on the test of brightness discrimination, namely for frontal cases to score more highly than patients with temporal lobe lesions (but excluding cases with perimetric defects), also fails to prove statistically significant.

Discussion

We may now inquire what light our results throw upon the origin of agnosic disorders. As we have seen, some degree of sensory deficit has been established in 12 cases of cerebral lesion in the absence of visual field defects. Where field defects are present, moreover, an even greater sensory deficit, as established by our methods of examination, was ascertained in 10 cases. On the other hand, no significant increase in sensory deficit could be established in eight cases in which field defects were associated with higher perceptual disorders. It would therefore appear, on first inspection at least, that sensory deficits of the type adduced by Bay as responsible for visual agnosia do not play a significant role in the genesis of this disorder.

At the same time, it must be borne in mind that no true case of visual object agnosia in the classical sense of the term is included in our series. In the one case of "prosopagnosia" (Case 23), moreover, the overall efficiency index was undoubtedly low. This might be interpreted as evidence in support of Bay's view that defects in physiognomic recognition arise on a sensory basis. None the less, three patients in our series (Cases 19, 24, and 26) gave evidence of an even greater reduction in sensory efficiency without the least trace of prosopagnosia.* It is also noteworthy that one patient (Case 18) gave no evidence of visual agnosia at a time at which fluctuating alterations of sensory function were present over the entire visual field. Further, the combination of sensory defects and intellectual loss in certain of our patients (in particular Cases 19 and 20), was not found to give rise to agnosia in the manner suggested by Bay. It would therefore appear that impairment of visual discrimination, while present in many cases with disturbances in visual perception, is not in itself adequate to provoke the symptoms of agnosia.

The results in three cases presenting the syndrome of visual-spatial agnosia (as defined by McFie, Piercy, and Zangwill, 1950) do not suggest that sensory defects are of appreciable significance in its origin. The overall efficiency indices of three patients who presented this syndrome (Cases 27, 28, and 29) are respectively 65, 47, and 59. Although these values are low, they are certainly well above those given by several patients in Group B who had sustained field defects unaccompanied by spatial

loss. Moreover, no consistent relationship between any one pattern of sensory deficit and visual-spatial agnosia can be detected. It would therefore appear that there is no direct association between reduction of visual efficiency and disorders of spatial judgment.

It might still be argued that the various disorders of visual perception are attributable to intellectual deficit of a global character. This claim cannot be fully discussed in the present context, but intellectual testing (fully reported elsewhere) revealed no greater intellectual impairment in cases comprising Group C than in either Group A or B. It is therefore unlikely that higher disorders of perception are the expression of global intellectual loss.

In connexion with Bay's reliance on the method of local adaptation, it should perhaps be pointed out that successive fading times determined at the same position in the visual field commonly vary considerably, even in healthy subjects. Thus variations of up to 31 sec. between successive fading times are normal at 2.5°, and of up to 10 sec. at the 15° positions. Moreover, this method has been shown to discriminate the least successfully of our tests between healthy and brain-damaged individuals. Its reliability, as indicated by test-retest correlation, is also lower than that of any other test excepting acuity for small objects. It may therefore be suggested that future studies of the significance of sensory defects in agnosia should not be limited to the use of this test alone.

The level of the neurophysiological changes in the visual system underlying the sensory deficits established in this study provides an important problem for future investigation. Whether, for example, local adaptation is peripheral or cerebral in origin is not at present known with certainty. The extent to which the defects described in this paper are specific to the visual modality has also to be ascertained. All that can be said with confidence is that defects in visual discrimination are commonly encountered in cases of cerebral lesion and may be elicited in perimetrically normal areas of the visual field. We are thus able to confirm Bay's finding that bilateral visual discrimination defects may follow unilateral cerebral lesions. We cannot, however, find confirmation of his view that such defects play an appreciable part in the genesis of the visual agnosias.

Summary

An investigation of visual sensory discrimination in 30 cases of brain lesion is reported. The object was first to determine the incidence and magnitude of sensory deficits in cases of cerebral lesion; and secondly to assess their significance in relation to the visual agnosias.

* It can of course be held that the precise distribution of sensory loss in the visual fields has greater significance for agnosia than overall reduction in visual efficiency. Thus in the case under discussion, it might be argued that the combination of paracentral scotomata with sensory deficit in perimetrically normal areas of the peripheral field is sufficient to constrain prosopagnosia. This interpretation is not, however, supported by Pallis (1955) in his discussion of this case.

The cases fall into three groups on the basis of the presence of field defects and/or higher perceptual disorders. All patients were tested on a variety of visual discrimination tasks at representative points in the visual fields. Their results were evaluated with reference to the thresholds given by a large control group.

The presence of visual sensory deficits in perimetrically normal areas of the visual field, both ipsilateral and contralateral to the side of a unilateral lesion, was ascertained. The results did not, however, support the view that agnosic conditions are secondary to deficits of visual sensory discrimination.

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