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THRESHOLD TESTS*

BY

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PART ONE

THE routine determination of the approximate thresholds for light differences and colours often shows striking results. It may prove of diagnostic value. We should all practise it for a time, and compare notes. Though the subject has occasionally been broached, and its probable diagnostic importance pointed out, I believe it is still comparatively untrodden ground.

Obviously only a rapid, but accurate, procedure can become quite popular among our best and busiest workers. I have tried to supply one, and as it seems to answer the purpose, I venture to bring it before you. It is easily contested on scientific grounds; its main object is practical.

The Principle

A brief account of my last experiments will, I think, describe the principle sufficiently to enable others to carry out the test on similar lines with the outfit now obtainable.

On pieces of white blotting paper I produced spots of black, red, green, blue, and yellow in dilutions equalling $1/512$, $1/256$, $1/128$, $1/64$, $1/32$, $1/16$, $1/8$, $1/4$, $1/2$ and 1. Each successive spot thus was double the intensity of the previous one. After trying many dyes and fabrics, I settled on the excellent waterproof inks of Winsor & Newton, commercially known as Indian ink, vermilion, emerald, ultramarine, yellow. The dilutions were made in distilled water. They were dropped from a pipette of 1 mm. drop surface, and from a height of 100 mm. The fifty cards were fastened, in the above order both of colour and dilution, on each grey page of a photograph album. The value of each card was noted in a corner.

The Test

Correction of error and accommodation being sometimes called for, the test is performed after this has been done, with the trial

* Read at the Oxford Ophthalmological Congress, 1917.

frame still in place. The patient must sit so that a good source of daylight strikes the pages of the album obliquely, coming from behind and one side, and the cards are successively presented in the above order before each eye separately. The patient is shown only one card at a time, the other being covered with the hand. It is well to give the album a few rolling movements each time, to let the light strike the spots at various angles, thus dodging the reflections. At each card the surgeon asks: "blank or spot?" The black series, coming first, gives a rapid clue in cases where the light sense is diminished. The palest black spot recognized is noted as the nearest to the threshold for differences of light intensity. Where this threshold is at fault with no scotoma, those who have a good photometer should use it and help decide whether the light threshold is also at fault in all cases. If this is the case—and I think there is little doubt about it—the test with the black series becomes a direct test of the light sense.

With the colour series the same process is performed until the patient answers "spot," when the surgeon must immediately say: "any colour?" The palest spot evoking a colour sensation, though misnamed, is noted as the nearest to the threshold for that colour. In testing for red and green it is often a good plan, after having exposed each card successively on two opposing pages, and no colour has been perceived, to uncover both, testing for scotoma.

For red I find the threshold for light differences and that for colour coincide invariably, as has been pointed out; but they often vary for the other colours, and "spot" is announced one or two cards before colour sensation is evoked. I think there is little doubt that these colour thresholds will frequently prove to be the only pathological sign, when colour vision and field are normal.

With the above set of cards, and a fairly large number of observations, I found as an average, seldom varying to any marked degree in normal eyes: black, $1/512$; red, $1/256$; green, $1/32$; blue, $1/512$; yellow, $1/256$. I also found that with both eyes exposed the thresholds are about twice as keen; that ordinary variations of daylight do not matter; that reflections do, and the light should be well chosen and uniformly adhered to; that the ordinary artificial lights should be avoided, though electric light with suitable bulbs may prove equally good, and yield the same figures.

Rapidity is not only possible, but essential, especially where the colour dots are concerned, in order to avoid the element of after-images creeping in, with the confusion that would result. To go through each set rapidly and urge the patient to prompt attention and quick reply, and to pause between each set while noting the number, will eliminate this complication. After very little use, the album test does not take two minutes.

Some Clinical Examples

		Black.	Red.	Green.	Blue.	Yellow.
1 Lightning damage to macula, left eye...	R.	512	512	64	512	256
	L.	128	32	16	128	32
2 Toxic Amblyopia (tobacco)	R.	16	0	0	4	0
	L.	64	1	0	64	8
3 Choroiditis (Disseminated), left eye ...	R.	512	256	64	512	256
	L.	64	64	16	64	256
4 Choroiditis (Tuberculous), left eye ...	R.	512	256	64	512	256
	L.	16	16	16	64	16
5 Retinitis (Haemorrhagic), right eye ...	R.	64	16	16	16	1
	L.	512	256	32	512	256
6 Retinitis (Pigmentosa)	R.	8	16	8	64	16
	L.	64	32	16	64	16
7 Neuritis (Albuminuric), left eye ...	R.	256	256	64	128	256
	L.	256	32	16	32	16
8 Neuritis (Sympathetic), right eye ...	R.	128	64	16	32	32
	L.	—	—	—	—	—
9 Atrophy (Primary), both eyes	R.	256	64	32	256	64
	L.	256	16	4	64	16
10 Atrophy (Secondary), both eyes ...	R.	512	128	4	64	32
	L.	128	16	0	2	4
11 Glaucoma (Chronic), both eyes ...	R.	512	256	32	128	256
	L.	256	128	32	256	256
12 Glaucoma (Chronic) both eyes ...	R.	256	256	32	512	256
	L.	256	256	32	512	128
13 Threatened Glaucoma, both eyes ...	R.	128	128	32	256	128
	L.	128	128	64	256	128
Normal Average		512	256	32	512	256

While all too scanty to draw conclusions from, these figures, being noted with the same test objects, bear comparison with the average normal figures, and often speak for themselves. One is struck, for instance, by the singularly marked effect on yellow in case 5; its absence from case 3, while it is present in case 4; by the reduced light sense, as compared with the colour sense, in cases 11 to 13 of glaucoma: by the reverse condition in cases 9 and 10 of optic atrophy, in which the light sense is only affected very late, as shown in case 10, left eye, Other figures corroborate in a forcible manner what has been pointed out before.

Tobacco amblyopia is diagnosed with great rapidity with the red and green cards, the patient at once seeing the colour on the opposite page, while missing it on the one he is looking at. No doubt the same will be found in other forms of central scotoma.

Dr. Sinclair's Clinical Examples

My colleague and friend, Walter W. Sinclair, of Ipswich, has taken interest in this subject, and with a duplicate set of my test cards, abridged by one-half, he has collected the following cases, which I thankfully acknowledge and add here with his kind permission.

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		Black	Red	Green	Blue	Yellow
1 Large haemorrhage near y. s. in myopia, R.E. ...	R. L.	64 256	4 16	16 64	1 256	1=red 64
2 Toxic amblyopia (tobacco) ...	R. L.	16 64	0 4	0 0	4 4	1=red 1=red
3 Detached retina (right eye) ...	R. L.	64 64	64 64	16 16	256 256	64 16
4 Detached retina, about ten years' duration	L.	64	4	16	16	1=pink
5 Former albuminuric retinitis of pregnancy	R.	64	64	64	64	4=orange
6 Recent active albuminuric retinitis of pregnancy ...	R. L.	64 256	16 16	16 4	64 64	4=orange 4=red
7 Same case some months later	R. L.	256 256	16 64	16 64	64 256	4 4
8 Renal retinitis (? Trench nephritis)	R. L.	256 256	64 64	64 64	64 256	256 64
9 Thrombosis retinal vein, albuminuria. Left eye ...	R. L.	256 64	64 64	64 64	256 256	64 64
10 Diabetic retinitis ...	R. L.	16 16	4 4	16 16	64 64	64 16
11 Optic neuritis (cerebral tumour) right eye	R.	256	64	64	256	64
12 Retro-ocular neuritis, recovered several years ago. Right eye	R. L.	64 256	16 64	16 64	16 256	4 256
13 Slight optic atrophy, L.E., years after concussion, V. 6/9, F.V. full white	R. L.	256 64	64 16	64 { 4=bluey 1=slate	256 16	64 4
14 Arterio-sclerosis, discs normal, both eyes		256	64	64	256	64
15 Very early chronic glaucoma, R.E.	R.	16	64	64	16	64
16 Chronic glaucoma ...	R. L.	256 256	16 16	64 64	256 256	16 16
17 Chronic glaucoma, both eyes	R. L.	64 64	16 16	16 16	16 16	16 4
18 Chronic glaucoma ...	R. L.	64 256	16 64	16 64	64 256	16 64
19 Chronic glaucoma, slight cupping in both, right defect in field, left full	R. L.	64 64	16 64	16 64	64 256	16 64
20 Pigmentary degeneration of retina, night-blindness (family case)		256	64	64	64	16
21 Right eye very rigid sclera, rainbows, V. 6/6, F.V. full, no cupping after several years (eserin). Left eye blind (glaucoma)	R.	256	64	64	256	64
22 Retro-ocular neuritis, recovery, left eye normal.						
1 month ...	R.	4	4	1	4	1
2 months, V. 6/9 ...	R.	64	16	16	64	16
3 months, V. 6/6 ...	R.	64	16	16	256	64
23 Trench nephritis, retinal haemorrhages, left eye	L.	256	64	64	256	64=drab 16=yellow

Sinclair used five cards for each colour, 1/256, 1/64, 1/16, 1/4, and 1, finding the normal average: black 1/256, red 1/64, green 1/64, blue 1/256, yellow 1/64. Making all due allowances the result approaches mine. Had he used the full set I think it probable that his result would have been: black 1/512, red 1/128,

green 1/64, blue 1/512, yellow 1/128. He also emphasizes that our clinical evidence is scanty. We ask you to look upon our clinical quotations therefore as examples only.

Though Sinclair quite justly points out that we may not say very much on the subject of clinical diagnosis, or even evidence just yet in favour of this test, I am most interested in studying his cases. He intended me only to select from them, but they all contain matter for reflection. His remarkable results with yellow in cases 5, 6, 7, are noteworthy, and though, from the point of view of differential diagnosis, there is nothing we can formulate, yet these

FIG. 1.

cases, together with my case 5, may go to show that in some forms of retinitis the threshold for yellow is affected, while in others it is not. His results with yellow are news to me. I never heard it in my student days, nor do I recall ever having heard it mentioned. In case 14 of arterio-sclerosis the thresholds are normal. I have seen and painted cases of this nature which gave an ophthalmoscopic picture exactly like albuminuric retinitis. A point of differential diagnosis might be looked for here. The reduction of the light sense in his glaucoma cases is again as striking as in mine; especially interesting is its very early onset in case 15. I think this sign should be carefully followed up. It seems very likely that it will prove at least a valuable aid as a premonitory symptom of glaucoma, where no other cause, retinal or choroidal, accounts for its presence, or where optic atrophy forms the alternative diagnosis.

A Venture at a Universal Standard

At the last meeting of the Oxford Congress I had the honour to say a few words on this subject, and it was considered desirable to make this test accessible to all who wished to try it. To make it universal the expression of the thresholds would need to be as generally intelligible in fractions as are the formulae V. 6/6, etc. It must be possible at all future times to reproduce the same test objects. I have the assurance of Messrs. John Weiss & Son that

FIG. 2.

FIG. 3.

this can be done. That this firm has actually carried out my ideas and placed them on the market, in spite of these times so strenuous to all surgical instrument makers, is an achievement for which I cannot express my thanks too warmly here; to the firm in general, and to Mr. Voigt in particular for his personal activity, and all who have worked for me. It is, for instance, no small task to produce each part of every test by hand. The objects themselves

cannot be printed, each one is done by hand. I cannot warn sufficiently against using copies. Mutual understanding would at once be made impossible, and confusion would result.

In order that they might standardize the test, I submitted to the makers a complete series of my test objects of the types shown in Figs. 1—3. The best pigments for purity and luminosity were then definitely settled upon; discs in black and colours in full intensity were constructed of the type of Fig. 1, their principle being, that when rapidly revolved on the table, Fig. 4, the eight arcs of different

FIG. 4.

lengths would blend with the background in the ratio, from periphery to centre, of $1/256$, $1/128$, etc., to $1/2$, while the innermost, being a complete circle, would stand for $1/1$. From the intensity of each circle produced by the discs while revolved, the dots for the album test, Fig. 2, were matched by experts, and can in future always be matched again. It was soon found unnecessary to extend the album series beyond limits of dilutions which the most sensitive retinae could detect; thus, while all five series of spots end in 1, or full strength, they do not all begin with the same degree of dilution.

I have suggested that, besides the album test, discs, and a good revolving apparatus, Fig. 4, be supplied. Some may prefer them. They must be revolved with sufficient rapidity for blending with the

background. The patient counts the circles seen, from the centre to the periphery. The value of the outermost is noted, as nearest the threshold. There should be complete harmony between this and the album test. Personally, I prefer the latter for consulting room. It suffices for all practical purposes; is rapid, handy, and inexpensive; it presents only one object at a time and eludes the element of suggestion through comparison, by which judgment is apt to become biased. Besides, if the test proves useful, it would perhaps be better to settle on one, at least for the purpose of expressing ourselves in fractions. Time and usage will decide.

It is hardly necessary to mention that neither of these two tests reaches the actual threshold. For determining this as nearly as possible I suggest the idea illustrated in the twin disc, Fig. 3. It obviously offers a wider scope, but requires more time and imposes on the patient a harder task than he is always able to grasp without considerable practice. Those who wish to explore the thresholds with more precision and, perhaps, aid to define their limits within figures less widely divergent than has been done up to the present, will find here a method of measuring them very accurately and expressing them in degrees of the circle. By a superimposed shutter, a scale and an arrow, as many degrees of black or colour can be gradually exposed on the disc as are required to provoke the threshold when revolved. With the black object the threshold for light differences can thus be measured with great precision. The colour thresholds offer a little more difficulty,—with the exception of red, which is always unmistakable—for the reason that in some instances the threshold for differences of light will allow a ring to be differentiated from the background which really does not evoke colour sensation till a little more of the test object is exposed. If any one could devise a simple method of changing the test objects and increasing or decreasing the number of degrees, so that they could be read and noted, or dictated, while the disc is revolving, this test would surpass all the others in delicacy, and be just as rapid as the album test, if not more so. The necessity of stopping the disc to make these frequent changes, and of obliging the patient to shut the eyes at each stopping place, lest he see the process and be prejudiced, runs away with much time. It is, nevertheless, with this disc that the finest observations can be made. With this I convinced myself that the thresholds in normal eyes were practically twice as keen when both eyes are exposed, and corroborated the statement that light and colour, in red, have the same threshold. Here too, apparently, ordinary variations in daylight do not matter. This might well be expected on the ground that thresholds are a question of differences between objects and their backgrounds. Variations of illumination affect both equally, and possibly do not upset the ratio between them. It

is very much more difficult to understand the surprising fact that dark and light shades of the same colour record identical thresholds. With a twin disc adapted for this purpose, I have found this to be uniformly the case in my own and other eyes, which I accepted as being normal.

The normal average

In standardizing these tests the makers submitted their results to me. In twelve cases, uncomplicated except for trifling errors of refraction, mostly hypermetropic, ten saw 1/128 and two 1/64 for black; all saw 1/64 for red; eleven saw 1/64 and one 1/32 for green; ten saw 1/128 and two 1/64 for blue; ten saw 1/32 and two 1/16 for yellow.

In 30 consecutive cases of my own, with various refractions and ages I found absolutely uniform results, in every case both eyes were exactly alike. My results were: Black 1/128, Red 1/64, Green 1/64, Blue 1/128, Yellow 1/32.

Owing to delay I have not received a sample of the Twin Discs, Fig. 3, which Messrs. Weiss are going to supply. But I have made many measurements of the actual thresholds before with my original model and do not expect to find any material variations when I come to test its reproductions. My findings of the true thresholds were as follows:

		Black		Red		Green		Blue		Yellow*	
				Light Colour		L.	C.	L.	C.	L.	C.
One Eye	...	9°		11°	11°	10°	14°	10°	12°	12°	13°
Both Eyes	...	4°		6°	6°	6°	8°	5°	7°	7°	8°

These are the averages of a fair number of observations, which were very uniform, and show that the thresholds for light and colour are only the same for red, and that the thresholds for both eyes open are about twice as keen as for each eye separately.

In aphakia, after cataract extraction, the thresholds are sometimes below normal, even though vision be of the very best.

(To be concluded.)

* Lately it appears more likely to me that the two thresholds for yellow coincide. I suggest investigating this physiological question very carefully, as I do not think it has been noted before.