34. The pseudoisochromatic plates of E.N. Yustova

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Abstract

The new pseudoisochromatic plates of Yustova have been tested in various illuminants for a well characterized panel of colour-defective observers. Under the same conditions, colorimetric measurements were made of the target and ground patches of each plate. In a subset of plates (1,5 and 9) the chromaticities of target and ground did not lie on the intended confusion lines and these were the plates that were diagnostically unsatisfactory. The most successful plates (e.g. 7 and 8) are those whose chromaticities lie close to the intended confusion line. There is clear value in making concurrent spectroradiometric measurements when field testing colour tests.

Introduction

The pseudoisochromatic plates of E.N. Yustova (Alekseeva and Yustova, 1978) were described to the International Research Group at its Dresden meeting (Yustova ***et*** al., 1986). A production version of the test has recently been introduced and is offered as a replacement for the Rabkin pseudoisochromatic plates, which are widely used in the former Soviet Union but have been out of print for many years. Since the principle of the Yustova plates most closely resembles that of the HRR plates (Hardy ***et al.***, 1954), themselves long out of print, we have made a preliminary examination of the new Russian plates. Each plate consists of a mosaic of patches, 9 mm square, with 2 mm gaps. The target is defined by a subset of patches that form three sides of a square (Fig. 1). The examinee must indicate the orientation of the gap in the square. The examiner is thus free to present a given plate repeatedly in random orientations, and it would be difficult for a candidate to learn specific responses for particular plates, as he might in the case of the Ishihara or Rabkin tests. In this property the Yustova plates resemble those of Schaaff (1925; illustrated in Oblath, 1929) and those of Ishihara and Okuma (1975).

The plates are colorimetrically based, in that the target and background are in each case intended to lie on the confusion line of one type of dichromat. There are four protan plates, four deutan plates and three tritan. Within each subset the chromaticity difference between target and background is intended to

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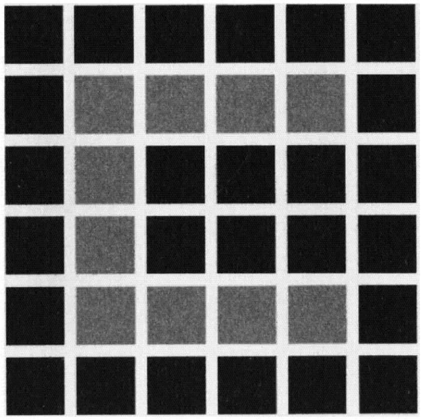

Fig. 1. **The achromatic demonstration plate of the Yustova test. The coloured test plates have the same geometry.**

increase in successive plates. (According to the test manual, these chromaticity differences have been adjusted to correspond to fixed numbers of threshold units, on the basis of discrimination measurements with a Maxwell disc.) Like the HRR plates, the Yustova plates are intended to detect and classify daltonians entirely on the basis of chromatic difference thresholds. And like Hardy ***et al***. (1954), the authors of the present plates introduce a classification scheme corresponding to their graded plates. Thus plates 1–3 correspond to 'protodeficits' of the first, second and third degrees, while failure on plate 4 is intended to indicate protanopia. Plates 5–7 correspond to 'deutodeficits' of the first, second and third degree, while failure on plate 8 indicates deuteranopia.

A particular feature of the Yustova plates is that the target and background are designed to be equated not only in colour for the corresponding dichromat but also in lightness. Having made this equation, the authors of the plates took the daring step of foregoing the luminance noise that has been a feature of most pseudoisochromatic plates since their invention by Stilling in 1877 (see Regan ***et al***., 1994). An effective (but not commercially available) plate without luminance noise has been designed by Birch (1975), but here spatial noise is introduced.

Methods

We tested the Yustova plates on a panel of 31 colour-defective observers who had been classified in detail by means of the Nagel anomaloscope (Model I; Schmidt & Haensch) and the computerized test of Regan ***et al***. (1994). Since the plates are promoted as being colorimetrically based and yet the recommended illumination is specified only as 'fluorescent light or natural daylight', we tried more than one illuminant. All subjects were tested using the Macbeth easel daylight lamp that is typically used for clinical colour testing in the West; most subjects were also tested in natural northern daylight (in Cambridge in the period July–October) and under white fluorescent lighting (GE F58Wl35).

The test manual calls for a rather high level of illumination of 500-1000 lux. This range is higher than provided either by our Macbeth easel lamp (330 lux) or by our normal office fluorescent lighting or by natural daylight when the subject sat with his back to a north-facing window (350-500 lux). We therefore equipped our testing room with additional lighting to give 750 lux of illumination from fluorescent lamps. Of the conditions we explored, these are the ones that best match those called for by the test manual.

Using a PhotoResearch 650 spectroradiometer, we measured the chromaticities of target and ground patches of each plate in each of the three illuminants used for testing. All measurements were repeated with a Minolta Chroma Meter. The chromaticities obtained with the Chroma Meter showed small systematic shifts from those measured with the PhotoResearch instrument, but the vectors defined by the chromaticities of target and ground were very similar.

Results

Test performance

Table 1 summarizes the performance of our subjects. One deuteranomalous trichromat passed all plates in all illuminants; and three protanomalous subjects passed all plates in natural daylight. Otherwise, the test successfully detected red–green defectives (including all dichromats) in all illuminants used. However, it was plate 9, nominally a tritan plate, that caught most red–green defectives, whereas plates 1 and 5, intended to detect mild protans and mild deutans respectively, were failed only by one elderly deuteranope. Deuteranopes were usually identified as such (by plate 8), but all the protanopes passed the 'protanope' plate (no. 4) in at least one illumination. Anomalous trichromats were not well classified, often failing both the second protan and the second deutan plates. No protanomalous trichromats were misclassified as dichromats, but some deuteranomalous subjects were classified as deuteranopes, in that they failed plate 8. A patient suffering from a complete acquired tritanopia (subject DC in the study of Regan ***et al***., 1994) passed all the plates, including the three graded tritan plates.

Colorimetric measurements

The foregoing test results can more readily be understood by reference to our concurrent colorimetric measurements (Fig. 2). In the case of the protan plates 2, 3, and 4, the colorimetric measurements suggest that the designers' intentions

Table 1. Performance of colour-defective subjects on individual plates of the Yustova test.

	Plate											
	Protan				Deutan				Tritan			
	1	2	3	4	5	6	7	8	9	10	11	Nagel
Subject												
WL									xxx			PA
BJ									/ / x			PA
JI		xxx				xx /			xxx			PA
RJ									xxx			PA
TR		x /										PA
LC		xx	/ x			xx			xx			PA
LL									x /			PA
WS		xxx	x / /	xx /		x / /			xxx			P
WM						xx			xx			P
HT		xxx		xx /		xxx			/ xx			P
McCA		x										DA
MC		xx				xx	x /		xx			DA
PD		xx				xx			xx			DA
BM						x / /			x / x			DA
KB		x							x			DA
KS		xx /				xx /	x / /	xx /	xxx			DA
MD		xx /				x / /	xxx	xx /	/ xx			DA
HC		xxx				xx /	/ / x	xxx	xxx			DA
SR												DA
SJ		x				x			x			DA
OD		xx /				x / /	/ / x	xxx	xxx			DA
HI		xxx				xx /	xxx	xxx	xxx			DA
WC		x				x	x	x	x			D
LW		xx				x /	xx	xx	xx			D
BK	x/ /	xxx			xx /	xx /	xxx	xxx	xxx	/ xx	/ x /	D
KM		/ x						/ x	xx			D
VS		xxx				xx /	xxx	xxx	xxx			D
BB		xx				xx	x/	xx	xx			D
BS								xx /	/ xx			D
CD												T
CL			x				x		x			Cone dystrophy

An empty cell indicates that the subject passed that plate in all illuminants tried for that subject. Cells containing symbols indicate plates that were failed under at least one illuminant. In these cases the first symbol in the cell refers to the Macbeth illuminant (used in all cases), the second to natural daylight, and the third to fluorescent light. x indicates failure and / indicates a pass. In the case of the congenital red–green defectives the rightmost column shows the diagnosis according to the Nagel anomaloscope (PA protanomalous; P protanopic; DA deuteranomalous; D deuteranopic). T indicates a case of acquired total tritanopia.

Protan plates

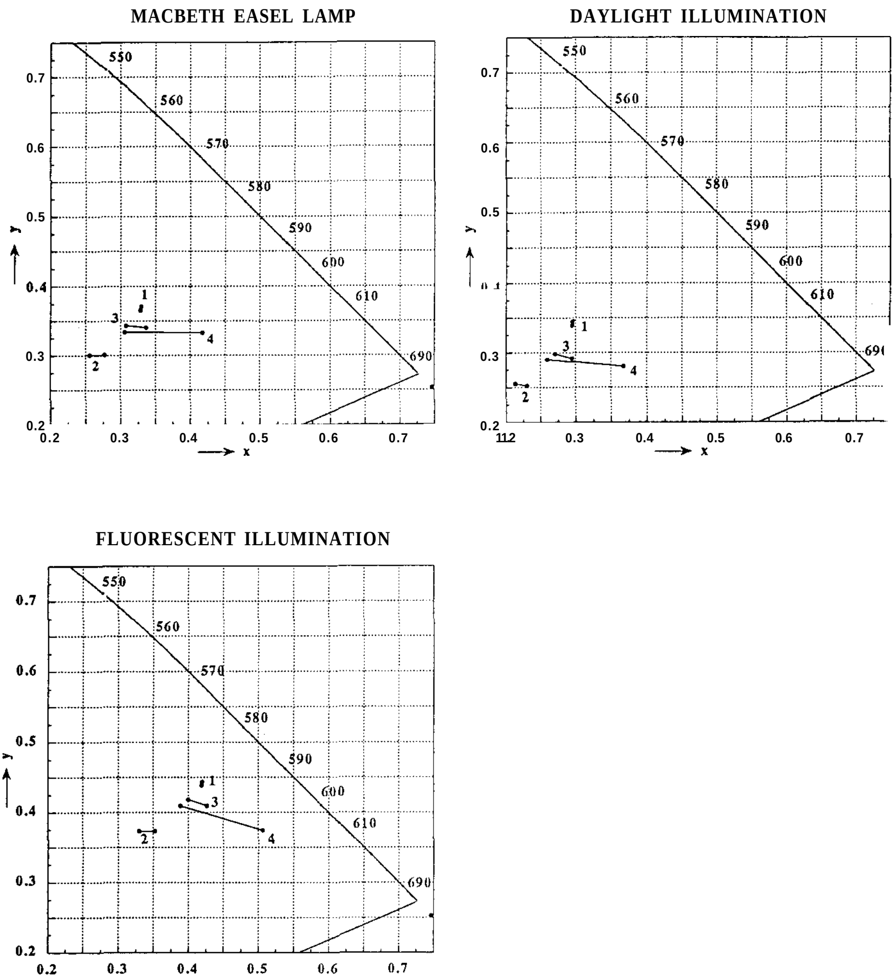

Fig. 2. The chromaticities of target and ground for the four protan plates of the Yustova test, plotted in the 1931 CIE diagram. Measurements are shown for three different illuminants. The protan copunctal point is shown at the bottom right of each diagram. The numbers by the data points indicate plate number.

are reasonably well incorporated into the production version of the test: in all the illuminations tried, the chromaticity differences in these three plates lie approximately along protan lines. In the case of the deutan plates 6, 7, and 8 the pattern of chromaticities depends on the illuminant: under a Macbeth easel

Deutan plates

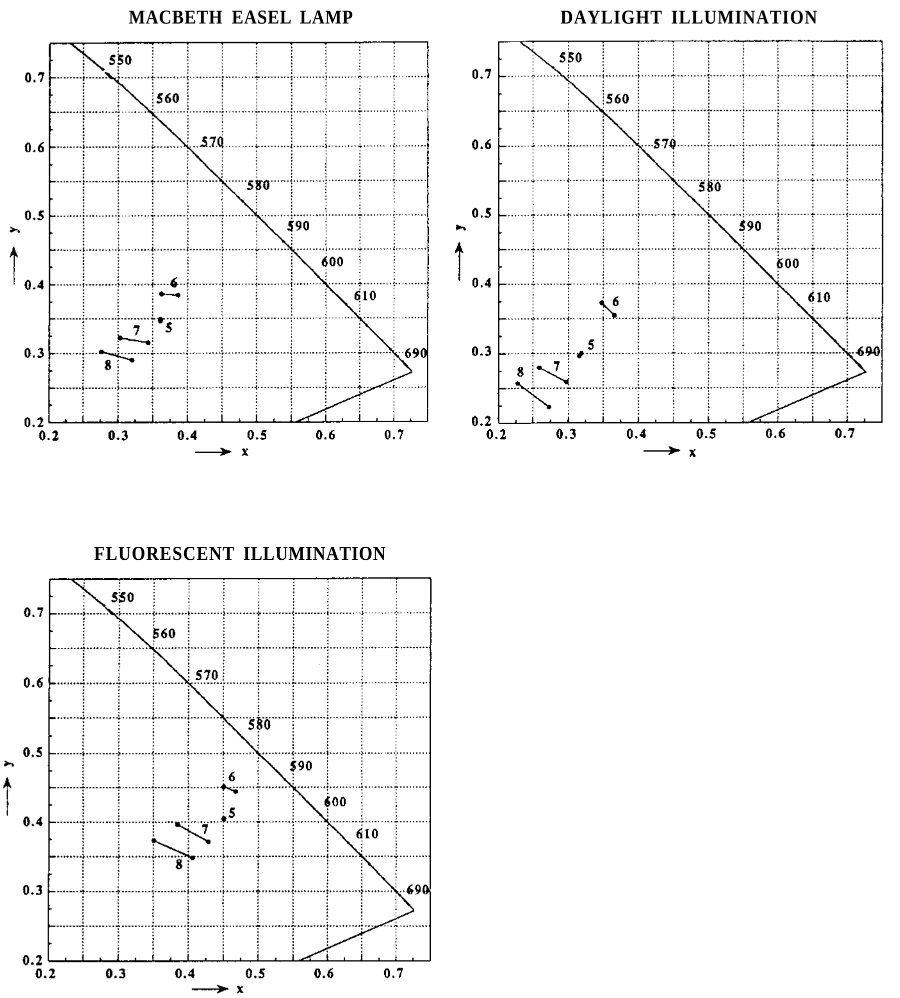

Fig. **3.** The chromaticities of target and ground for the four deutan plates, plotted in the 1931 CIE diagram. Measurements are shown for three different illuminants.

lamp the confusion lines are predominantly protan – this is especially true for plate 6, which many protans fail. In true daylight, the chromaticity differences lie much more nearly along deutan lines, whereas the fluorescent lamps give a pattern of chromaticities that is less clearly deutan or protan.

The lack of diagnostic power of the mild protan and mild deutan plates (1 and 5), so manifest in Table 1, is easily understood from Figure 2: in neither plate do

Tritan plates

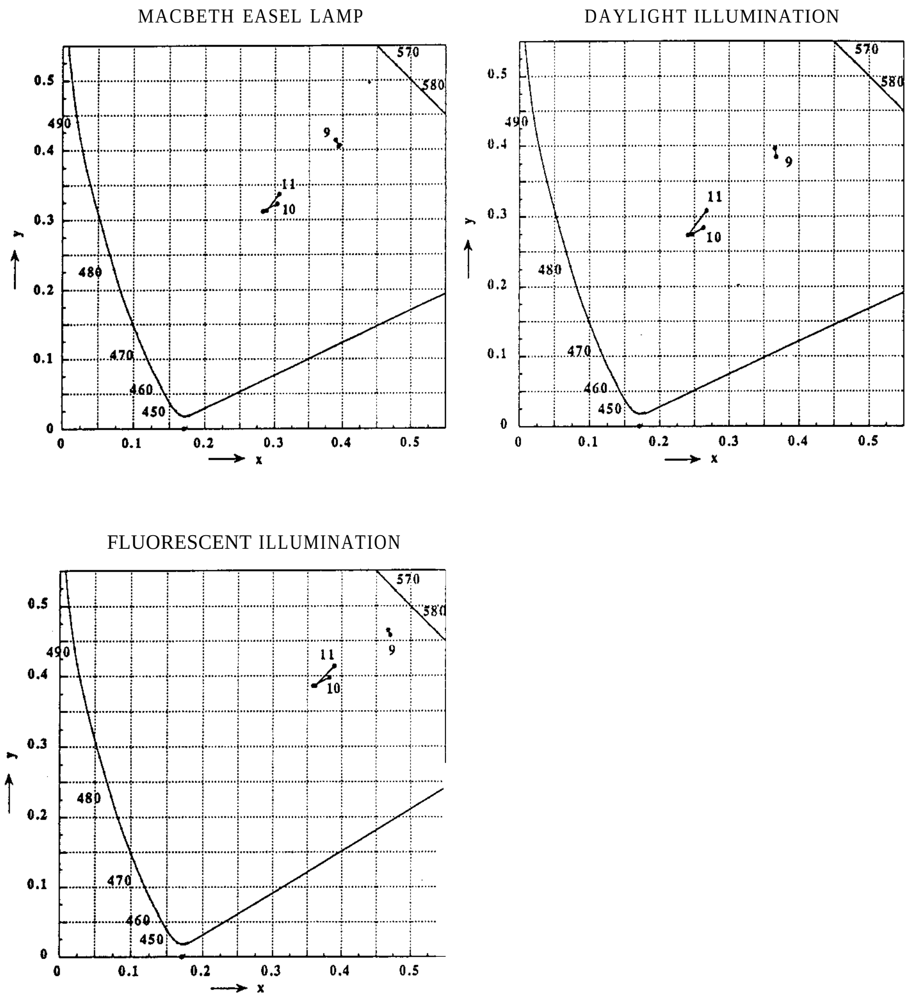

Fig. 4. The chromaticities of target and ground for the three tritan plates, plotted in the 1931 CIE diagram. Measurements are shown for three different illuminants.

the chromaticities lie along the required confusion line. The tritan plates 10 and 11 are the least satisfactory of the set, being read easily by a complete tritanope. Two factors contribute here. First, the chromaticities of target and ground lie along a yellow–blue line rather than a tritan line; and second, in both plates a clear lightness difference between target and ground is apparent to the normal eye (and to the spectroradiometer). Yet the luminous efficiency functions of congenital tritanopes do not differ systematically from those of normal observers (Wright, 1952). Plate 9, intended for detecting tritan defects of the mildest degree, exhibits small chromaticity differences that lie more in a protan or deutan direction (Fig. 2) and thus it is not remarkable that this plate serves well as a screening plate for red–green deficiencies. The user might do well to cross out the '9' on the back of this plate and substitute 'l'.

Discussion

It has proved instructive to test subjects on a new set of plates and concurrently to measure the chromaticities of the plates. The subjects behave rather lawfully when their passes and failures are compared to the colorimetric data. It seems unlikely that the chromaticity vectors in plates 1, 5, and 9 are those intended by the designers. It is possible that errors in reproduction have occurred between the hand-made prototypes and the sets now circulated. Even if reproduction of the chromaticities of the prototype were perfect, there would be a second reason to expect differences in the behaviour of the field-tested prototype and that of the production version: spectroradiometrically different stimuli that are perfectly metameric for a normal observer will not be metameric for anomalous trichromats. Thus data gathered on a prototype are valid for a production version of a colour test only if the stimuli are spectroradiometrically, and not merely colorimetrically, identical to the original.

Equation of lightnesses

By eschewing the use of luminance noise in their plates, Yustova and her colleagues deny themselves one of the hard-won devices of colour vision testing (Regan ***et al***., 1994). Even if lightnesses could be reproduced perfectly, we today have reason to doubt that lightness equations can be made a priori for all daltonians: both the long and middle wavelength photopigments are genetically polymorphic, varying in their spectral position (Merbs and Nathans, 1992; Winderickx ***et al***, 1992), and so there are good grounds for expecting the variations in psychophysical sensitivities that are in practice seen in populations of dichromats and anomalous trichromats (Alpern and Wake, 1977; Cavonius and Kammann, 1984; Jordan and Mollon, this volume). Lens and macular pigment are additional sources of variance. Yustova's idea of adjusting the lightnesses to compensate for the altered spectral sensitivities of daltonians is an excellent one, but the test might gain considerably by the addition of luminance noise centred on the mean match for each type of dichromat.

Anomalous trichromats

Yustova and her colleagues recognize that a standard colorimetric system, based on normal observers, cannot be applied to anomalous trichromats, whose colour matching functions differ from those of normals. The Yustova plates are explicitly intended only to detect impairments of colour discrimination. Clearly, however, in healthy young populations most of the subjects diagnosed as having protan or deutan deficits of the first, second or third kinds are likely to be anomalous trichromats. Insofar as the Yustova or HRR plates detect anomalous trichromats, they depend on the fact that the discrimination ellipse of the anomal is typically elongated in the direction of the confusion line of the corresponding dichromat. There does exist a subset of anomalous trichromats whose discrimination ellipses resemble those of normal individuals and whose spectral saturation function shows little loss at the wavelength of the neutral point of the corresponding dichromat (Chapanis, 1944; Regan et al., 1994). Members of this subgroup of anomalous trichromats with good discrimination are usually caught by the transformation plates of the Ishihara test. The latter plates work not by measuring chromatic thresholds but by a quite distinct and little recognized principle (Reffin et al., 1991): they measure the relative salience of the signals derived from the phylogenetically older and younger subsystems of colour vision. Those anomals who passed the Yustova plates in the present study are all known to fail the Ishihara.

Conclusions

Although the most sensitive plate is not the one intended by the designers, the Yustova test will serve adequately to screen for actual impairment of colour discrimination, while passing a small proportion of anomals who have good discrimination. Plates 7 and 8 are useful in distinguishing deutans from protans, and the Yustova test probably could be used to make this distinction as well as other plate tests in common use (Frey, 1958; Walls, 1959; Lakowski, 1966). Plates 1 and 5 are ineffective and should be omitted. Plate 9, intended as a tritan plate, can be usefully retained as a red–green screening plate. It is clear how the weaknesses of the test could be removed without sacrificing its strengths.

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