

Establishing the statistical limits of “normal” chromatic sensitivity

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Novel methods developed to assess chromatic sensitivity often yield statistically significant, inter-subject differences that can, in principle, be attributed to either congenital or acquired colour deficiencies(1, 2). The high sensitivity of such techniques can be used to monitor changes in colour vision in the same subject, a clear benefit when monitoring the progress of disease or the effects of treatment. The advantage of improved test sensitivity is however less useful in detecting “abnormal” colour vision, largely because of the large variance within the “normal” population and the lack of test-specific, statistical data to describe the parameters of the normal population. The variation in chromatic sensitivity in normal trichromats can be large. In addition to small differences in the wavelength tuning of photopigment genes, other factors such as differences in the optical density of cone photoreceptors or / and variation in post-receptoral amplification of cone signals can also cause significant changes in chromatic sensitivity(3). Colour vision is currently assessed using a wide range of tests. In the absence of an internationally recognized standard procedure for examination of colour vision, clinical assessment relies on the use of a battery of tests that can produce inconsistent results for a number of different reasons(4).

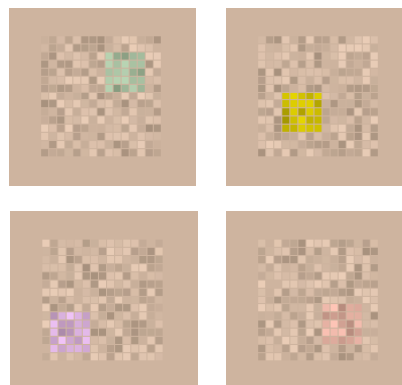
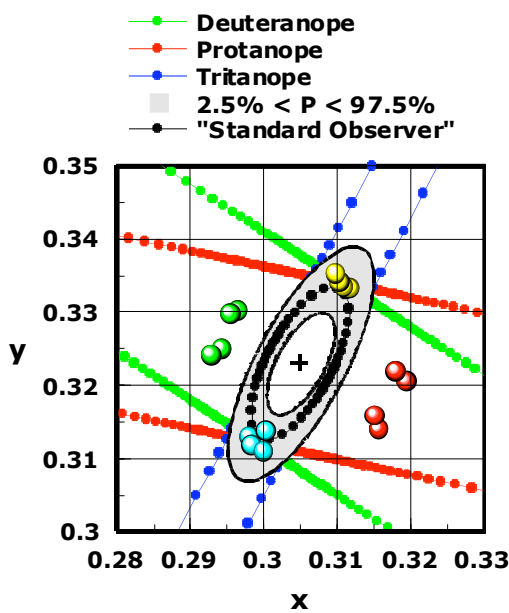


Fig. 1. The large colored discs show typical CAD test results for a subject with minimum deuteranomaly that passes the Ishihara test. The results are plotted in the CIE – (x,y) 1931 chromaticity chart. The black cross at the centre of the diagram

plots the chromaticity of the white background i.e., 0.305, 0.323. The dotted black ellipse represents the median values computed from the distribution of r-g and y-b thresholds in 230 normal trichromats. The corresponding 2.5% and the 97.5% statistical limits were used to plot the innermost and outermost ellipses. Thresholds that fall within the grey region are taken to reflect “normal” chromatic

discrimination sensitivity. The red, green and blue lines denote “colour confusion bands” based on data measured in protanopes, deuteranopes and tritanopes. The distribution of the eight data points in the r-g direction changes significantly in minimal protanomaly and this makes it possible to classify accurately the class of deficiency involved. The inserts show the appearance of the moving colored stimulus during the test. The subject’s task is to press one of four buttons placed at the corners of a square box to indicate the direction of motion of the colored stimulus. The CAD test employs four-alternative, interleaved staircases with a chance probability of 1/16. The subject’s task was to discriminate the direction of motion of a colour-defined stimulus buried in dynamic luminance contrast noise, a technique that isolates the use of colour signals(5, 6). <http://www.city.ac.uk/avrc/colourtest.html>

The principal aim of this study was to exploit the use the CIE-(x,y) 1931 system and to extend the work of MacAdam (7) by assessing the variability in red-green (r-g) and yellow-blue (y-b) chromatic discrimination sensitivity within normal trichromats using a new Colour Assessment and Diagnosis (CAD) test(8)

The data describing the statistical parameters of the normal population were used to produce a template that allows immediate classification of normal and deficient colour vision (Fig. 1). 250 colour deficient observers were also examined in order to assess the usefulness of the new template. The median values for r-g and y-b discrimination can be used to express all data in “*standard normal*” CAD units. The data for the 230 normal trichromats and the 250 colour deficient observers (plotted in CAD units) are shown in Fig. 2. Section B shows the usefulness of the CAD test in separating unambiguously the subjects with minimal deficiency from the cluster of normal trichromats. Full comparison of CAD data and results obtained using the Ishihara and Nagel anomaloscope tests will also be presented.

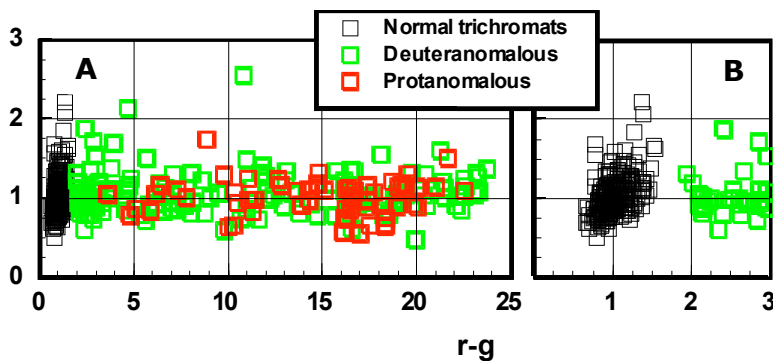


Fig. 2. The graph (section A) shows yellow-blue thresholds plotted against the corresponding red-green thresholds in 230 normal trichromats (black symbols) and 250 colour deficient observers (green and red symbols). The results are expressed in CAD units (i.e., median threshold values

computed from measurements taken in 230 normal trichromats). The distribution of r-g thresholds in the range 0 to 3 units is shown expanded in section B to illustrate the clear separation between the cluster of points that define the “normal trichromats” and subjects with minimal deuteranomaly.

The CAD test detects minimum deficiencies and quantifies the severity of colour vision loss by evaluating both r-g and y-b thresholds in an internationally recognized colour system. When expressed in standard normal units the results are easy to understand and provide an immediate indication of the severity of colour vision loss. The test has proved particularly useful in assessing changes in chromatic sensitivity in subjects with diseases of the retina and the optic nerve and in specifying minimum colour vision requirements in occupational environments. The studies carried out so far suggest that the new test and the establishment of the standard normal CAD observer provide an accurate means of detecting and classifying deficiency, of assessing the severity of r-g and y-b colour vision loss (whether congenital or acquired) and of monitoring small changes in colour vision either in disease or treatment.

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