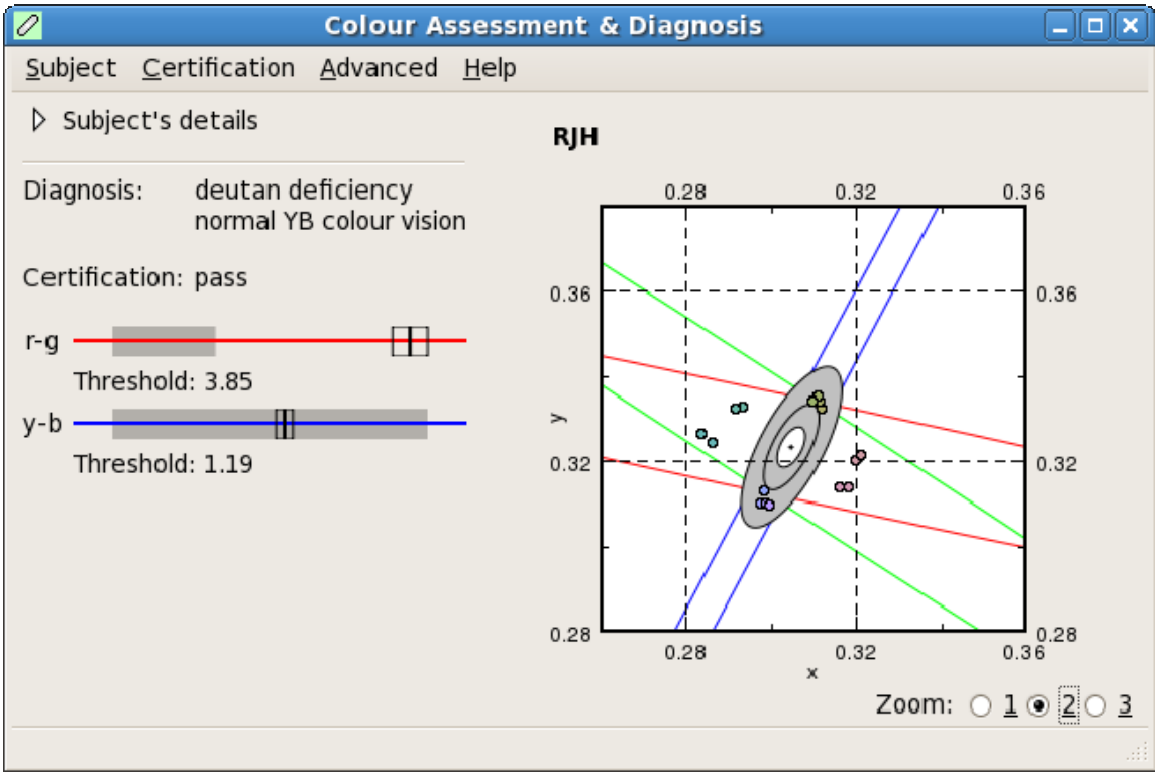
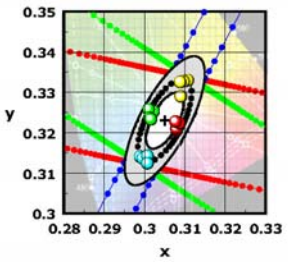
The **CAD (C**olour **A**ssessment **& D**iagnosis**)** test



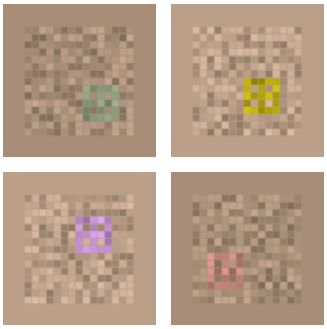
What one needs to know about CAD

1. What does the CAD test measure?
2. How does one use the CAD test?
3. What are the MENU options?
4. What are the possible outcomes of the “definitive” CAD test?
5. How does one interpret the information displayed in the CAD window?
6. Notes on Windows / displays set up
7. How does one calibrate the visual display?
8. Notes on CIE – (x,y) chromaticity chart
9. Trouble shooting hints



1. **What does the CAD test measure?**

The CAD test measures the size of the red/green (RG) and /or yellow/blue (YB) signals needed to just see a colour-defined target moving diagonally across a square made of checks that vary randomly in luminance every 50 to 80 ms. A “chromaticity chart” (CIE 1931 (x,y) - chromaticity diagram) is used for convenience



and the colour signal strength is measured as the distance away from the "neutral" grey background for each of the colours examined. The test employs four slightly different colours for each of the four colour direction investigated (i.e., red, green, yellow and blue) giving a total of 16 colours.
This approach provides statistical robustness and also allows accurate, automatic classification of the subject's colour vision status (see section 4).

2. How to use the CAD test?

First, one must decide what one wishes to establish by carrying out the CAD test. There are three major options:

- Screen for normal RG and YB colour vision (Advanced Menu option ~ 80s).
  This option is in the Advanced Menu. A pass requires 100% correct response for each colour presented to the eye and indicates normal RG & YB colour vision.

- Establish pass / fail outcome as required for certification within selected occupational environment (~ 40s)
  This option is in the Certification Menu. A pass requires 100% correct response for each colour presented to the eye and indicates adequate RG colour vision to pass minimum requirements within the selected occupation. By selecting the check box, YB colour vision can also be investigated.

- Quantify the severity of colour vision loss and/or classify the class of colour deficiency (~ 12 minutes)
  This is the "definitive" CAD test found in the Advanced Menu. If this option is selected, none of the other tests are needed. The output quantifies the subject's RG and YB colour vision in SN units, provides certification outcome and classifies the class of colour deficiency involved.

All the tests follow the same basic procedure. Position the subject's eye at display height and at a distance of ~1.4 meters (allowable range: 1.3 to 1.5m). This corresponds to ~55" with a range of 51" to 59". The illumination in the room should be arranged such that no light from any room lights, etc falls directly on the display. Room lights and the laptop screen should be placed outside the field of view of the subject. The ambient illumination level on the display surface should not exceed 1 lux. The display should be turned on for at least 10 minutes before the test is started to allow for the monitor to warm up and for its output to become stable. One can best achieve these conditions by placing a small desk lamp away from the subject and pointing it towards the ceiling to avoid direct light falling on the display surface.

During this test, the subject will see a coloured target moving diagonally across a central square in one of four possible directions (i.e., ending top-right, top-left, bottom-right, or bottom-left). The **response box** provided has **four buttons** laid out to form a square and a central button that is not used in the CAD test. The subject's task is to press the appropriate button (i.e., top-right, top-left, bottom-right or bottom-left) to indicate the corresponding end point and hence the direction of movement. When unsure, the subject

has to make the best guess. For best results, the subject should be instructed to maintain fixation on the centre of the square and not to track the moving target.

If, for any reason, one needs to repeat the same presentation, this can be done by the experimenter (but not the subject) by pressing **<Alt> R** on the keyboard or by clicking the **R**epresent widget in the measurement window. This is often useful when starting the test, if the subject fails to look at the centre of the display. The response buttons window (which indicates to the experimenter the button pressed by the subject) can be open during the test, but the measurement window (which contains the **R**epresent widget) must be the active window in order for the **<Alt> R** shortcut to work.

An option that allows the applicant to "**Learn**" how to carry out the test is provided. It is recommended that **one starts with this option** which takes less than one minute to complete. **Every subject**, including all colour deficient observes, will be able to see the moving object and to carry out the "**Learn**" option with no difficulty. A 100% score on the learn option means that the subject understands the testing procedure.

3. What are the MENU options?

Subject **C**ertification **A**dvanced **H**elp

The MENU options are as shown in the top diagram. Detailed, on-screen instructions are provided with each option, but the brief explanations below can help to save time and select the option you need. One must always start with the **S**ubject option to either enter a new subject or to import the subject's earlier results:

Subject

Enter, **I**mport, **E**dit subject's details. The subject's details must be entered before any colour vision assessment is done

Certification

Phase 1 (fast procedure, duration ~ 40s). Select this option if all that is needed is to know whether the applicant passes the minimum RG colour vision requirements for the selected occupational environment. This option does not screen for normal RG colour vision, nor does it quantify the severity of RG colour vision loss.

Phase 2. Tick Phase 2 "*check box*" (located in Phase 1 window) if you wish to bypass Phase 1 and proceed directly to Phase 2. This option measures the full set of RG thresholds and takes about 6 minutes. The option produces certification outcome, RG diagnosis (i.e., classification of the class of RG colour deficiency involved) and an accurate measure of the severity of RG colour vision loss. The RG threshold (and its standard deviation) is expressed in Standard Normal (SN) units and the results are plotted graphically within the distribution of RG thresholds measured within normal trichromats. By ticking the corresponding icons in either Phase 1 or Phase 2 one can also screen for normal YB colour vision (a rapid procedure that takes ~ 40s), or measure the full set of YB thresholds (which takes ~ 5 to 6 minutes). The latter produces an accurate measure of YB colour vision loss (in SNU) and makes possible the graphical representation of the subject's YB data within the distribution of YB thresholds measured within normal trichromats (see top diagram).

Advanced **MENU** window
The advanced menu options allow screening for normal RG and YB colour vision or the full assessment of both RG and YB colour vision (i.e., the "*definitive*" CAD test). The advanced MENU window also provides options that are designed specifically to examine protan, deutan or tritan subjects and provide more detailed description of their colour vision loss.

Help MENU window
This window provides information on how to use the CAD test

4. What are the possible outcomes of the definitive CAD test?
The definitive CAD test produces one of a number of outcomes that describes the subject's colour vision:

- **Normal colour vision**
- **Deutan** like (green) colour deficiency
- **Protan** like (red) colour deficiency
- **Tritan** like (blue) colour deficiency
- **Acquired deficiency** involves loss of either YB and / or RG chromatic sensitivity.

5. How to interpret the information displayed in the CAD window?
The top figure shows a screen dump of the CAD window following the completion of the definitive CAD test option. Subject's details and the results of diagnosis are shown with the certification outcome. The r-g and y-b horizontal bars contain shaded regions which indicate the range for RG and YB thresholds expected for subjects with normal colour vision. Each bold vertical line that is flanked by two thinner lines indicates the subject's measured threshold. The thinner flanking lines indicate the corresponding ±standard error. The number given below each bar shows the subject's **actual threshold** in SN units (see top diagram).

6. How does one calibrate the visual display?
The laptop is provided with the monitor calibration data installed for the monitor supplied. In order to ensure the integrity of the data, the CAD test **will not** work with any uncalibrated monitor. If the software cannot find a calibrated monitor connected to the laptop, a message will be displayed informing you of this. Should this happen whilst a calibrated monitor is connected, check the connection cables and reboot Windows.

Windows has been configured with the laptop display as "primary" and the additional monitor as "secondary" with the desktop extended onto the secondary monitor. If for any reason, Windows reconfigures the displays set up, you will need to use the Intel Display Control Facility (normally available through the icon on the bottom right hand side of the screen or via the control panel) to configure the displays appropriately.

7. How does one calibrate the visual display?

The visual display (i.e., ViewSonic E70fSB CRT monitor) has already been adjusted for optimum geometry, luminance and contrast limits. The default RGB colour setting is 9300K. The optimum spatial resolution is 1024 x 768 pixels and frame rate is set at 75Hz. In order to secure stable luminance output, the monitor must be left turned on ~ 10 minutes before use.

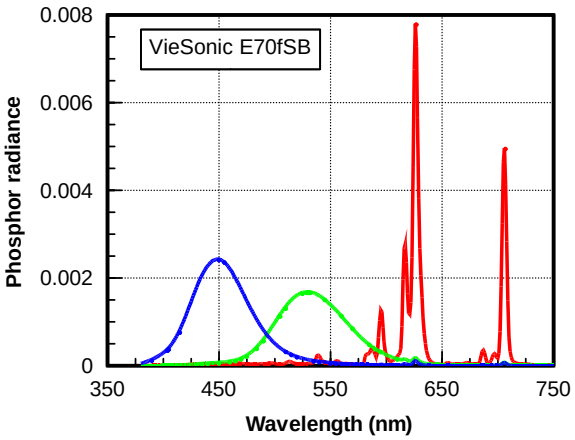


Figure 1. Typical spectral radiance distributions for the red, green and blue phosphors of the ViewSonic E70fSB display. The chromaticity co-ordinates of the phosphors are given below:

x_red:	0.6231
y_red:	0.3391
x_green:	0.2773
y_green:	0.5999
x_blue:	0.1514
y_blue:	0.0696

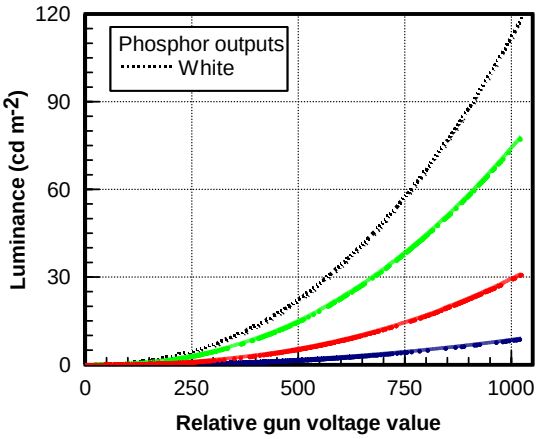


Figure 2. Luminance output of display phosphors plotted as a function of the relative gun voltage value. The dotted line plots the luminance output of all three guns together which produce the "white" light calibration. Provided the monitor is allowed to warm up for ~ 10 minutes before the test is started, the luminance output remains steady and any small fluctuations do not affect significantly the outcome of the CAD test.

Calibration of the spectral power distribution of display phosphors is required and this was done before the monitor was supplied to you. **You will not need to repeat this calibration**. The spectral radiance output of each display phosphor is shown in Fig. 1 together with the corresponding CIE – (x,y) 1931 chromaticity co-ordinates of each phosphor. In addition, the luminance output of each phosphor has also been calibrated for each possible drive voltage value. Typical data are shown in Fig. 2.

The CRT monitor will require luminance recalibration depending on the amount of usage, etc. If the monitor is not moved frequently and the various menu adjustments are kept unchanged, recalibration may only be needed once every six months or every year. Three options are provided for luminance calibration:

7.1 Manual calibration

If you use this option to recalibrate the monitor you will need a good luminance meter which must be positioned to capture light from the centre of the display (as shown in the photograph below). Run the luminance calibration program provided which will allow you to set up a calibration area at the centre of the screen. The RGB values for the uniform background are set to match approximately the luminance of the screen during the CAD test. This is important and therefore the screen calibration must be carried out with the background luminance set approximately to 24 cd/m^2 (i.e., the default value employed in the CAD test). You can choose any step size for use in the calibration and the program will interpolate all intermediate voltage steps to produce the full calibration. A step size of 4 is adequate for calibration. Allow monitor warm up (usually ~ 15 minutes) before you start the calibration. Follow the instructions in the program to calibrate the luminance of the red, green and blue phosphors.

7.2 Automatic calibration using LMT photometer (via RS232 interface)

The position of the photometer is the same as for manual calibration. Connect the photometer to the laptop through an RS232 cable and select this option in the program. A step size of 4 is again adequate for calibration. Follow the instructions in the program to start the automatic calibration procedure. The program controls automatically the range settings of the photometer and selects the optimum range. When the program completes the calibration procedure, click apply to save the luminance calibration.

7.3 Automatic calibration using *i1Display2* colorimeter (via USB interface)

The *i1D2* colorimeter supplied by CO Ltd has been calibrated against the LMT luminance photometer. The installation program provided with each colorimeter head will copy the calibration data to your laptop. Make sure this is done before you run the Lumcal calibration program. You will be asked to position the *i1D2* head in the centre of the display. Follow the instructions on the screen to ensure that the colorimeter is positioned as closely as possible to the centre of the screen. Allow enough time for the readings from the colorimeter to be taken and for its measured position to be indicated graphically on the screen. When this is done, proceed with the automatic calibration. The *i1D2* is slower than the LMT luminance meter and the full calibration may take ~ 20 minutes to complete. A step size of 8 is preferable when using the *i1D2*. When the program completes the calibration procedure, click apply to save the luminance calibration.

Automatic CAD display recalibration using *i1Display2* colorimeter

8. Help notes with the CIE (x,y) - chromaticity chart and the classification of colour deficiency

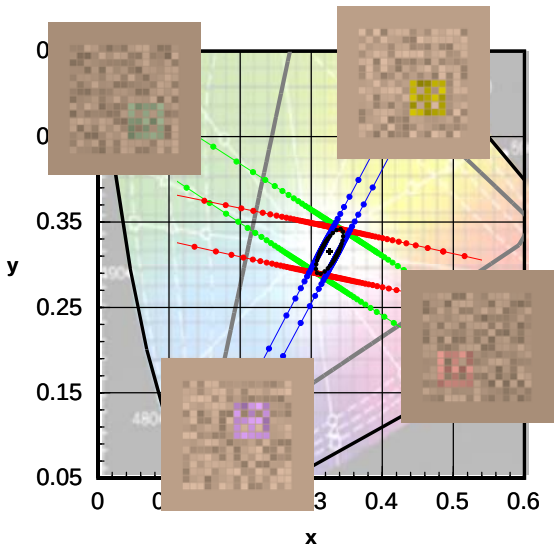
- **Normal colour vision** (i.e., an individual with three, distinct cone photoreceptors in the eye who exhibits RG and YB thresholds that fall within the normal range)

- **Deutan** like (green) colour deficiency when an individual lacks normal M-cones. Such subjects can exhibit reduced RG colour discrimination that results by substituting the normal M-cone pigment with a variant L-cone pigment.

- **Protan** like (red) colour deficiency when an individual lacks normal L-cones. Such subjects can exhibit reduced RG colour discrimination that results by substituting the normal L-cone pigment with a variant M-cone pigment. Protans also exhibit reduced sensitivity to long-wavelength (red) light.

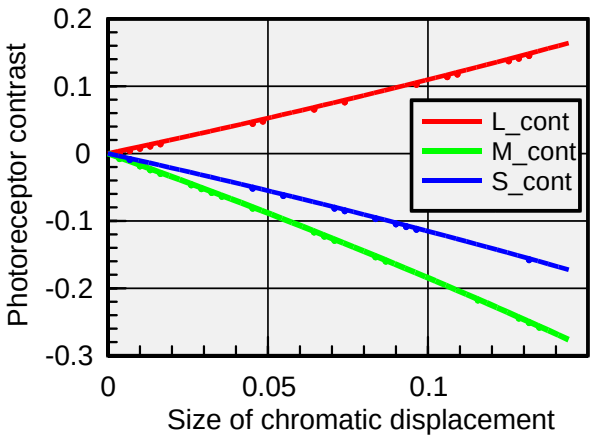
- **Tritan** like (blue) colour deficiency when an individual lacks normal S-cones. Congenital S-cone deficiencies are very rare (1 in ~ 15000).

- **Acquired deficiency** involves loss of either YB and/or RG chromatic sensitivity. Almost every case of acquired colour deficiency shows both RG and YB loss, although the relative amount of RG and YB loss depends on the disease involved and/or the cause of deficiency.



The figure on the left shows the **CIE - (1931) chromaticity chart**, together with the triangle that defines the maximum gamut of colours that can be reproduced on the visual display (grey continuous lines). A magnified version of the colour discrimination ellipse for the average normal trichromat is shown at the centre together with the corresponding "colour confusion bands" for deuteranopes (green), protanopes (red) and tritanopes (blue) colour deficient observers. The insets indicate the colour of the stimulus along the RG and YB directions.

Colour detection thresholds are measured in the CIE 1931 (x,y) - chromaticity diagram. For convenience, the colour signal strength for each colour direction examined is measured as the chromatic displacement (CD) of the test colour away from the "neutral"



grey background. Colours become more saturated with increasing distance away from the neutral grey point (as shown above on the left). The circle plots colours of equal chromatic displacement. The line shows how colours generated in the same direction of chromatic displacement become more saturated, but do not change in hue with increasing CD value. The graph above on the right shows how the corresponding cone contrasts change with increasing CD value when the chromatic displacement is towards the red region of the spectrum locus. Higher chromatic saturation corresponds to larger cone contrasts. In practice, the largest cone contrasts that can be generated are limited by the gamut of the phosphors of the display and the mean luminance of the background field.

The CAD test employs four slightly different colours for each of the four colour directions investigated (i.e., red, green, yellow and blue) giving a total of 16 colours. Data measured in 330 normal trichromats provide the statistical limits that define the median and the extremes of “normal” RG and YB colour vision. The median RG and YB thresholds define the standard normal (SN) CAD observer. The measured colour thresholds are expressed in SN units. This approach makes it easy to understand the results of the CAD test and to appreciate the severity of colour vision loss, i.e. an observer with a RG threshold of 2 SN units requires twice the colour signal strength needed by the median standard CAD observer. The use of a SN template also provides instant diagnosis of either normal or deficient colour vision (see top diagram). If the thresholds measured fall within the shaded area indicated on the graph, the subject has normal RG and YB colour vision.

9. Trouble shooting hints

a. The batteries in the wireless response buttons pad do not last very long.

*There is a switch underneath the keypad which can be switched to **off** when not in use to extend battery life.*

b. When the test (or the calibration program) is run, the program refuses to start, complaining that the display is either not calibrated (or that it cannot find a calibrated display).

The stimulus display monitor must be turned on and connected to the laptop before you start windows. Make sure everything is connected and switched on and then reboot windows.

c. There is a strange white stripe on the left hand side of the stimulus monitor.

Since Windows treats the external monitor as an extended desktop, one must ensure that items / windows on the primary display do not extend onto the external monitor. If necessary, use the mouse to drag the encroaching window fully onto the primary display.

d. Strange symbols are being displayed by the test program which look like a small box filled with numbers in the middle of some text.

The test program uses the full range of unicode characters. Most fonts supplied with windows XP supply only a limited range. The default fonts that are selected by windows when you change the display theme are not unicode fonts. To fix the problem, go into the windows control panel, select "Appearance and Themes" and then the "Display" control panel icon. Once the dialog is displayed, select the "Appearance" tab and click on the "Advanced" button. Then go through every possible setting of the" Item" widget and ensure that either no font is associated with this item or that the font is a unicode one (e.g., Arial Unicode MS). When all changes have been made click the "OK" button in both dialogs.

e. The stimulus display appears as a clone of the laptop display.

Click the Intel GMA driver icon (located at the bottom of the screen) and select the extended desk top mode. Choose the Notebook for ***the primary display*** *and apply this selection. The external monitor should be set for a resolution of 1024 x 768 at 75Hz.*

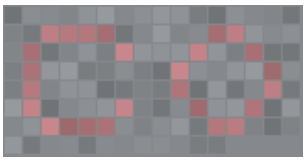
f. The CAD test fails to present the next stimulus after pressing any of the response buttons.

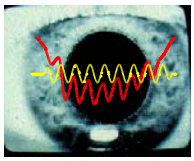
Ensure that the active window is the CAD test measurement option is the stimulus presentation window. This can be done by clicking the mouse when the pointer is within the area of the window.

Suggested instructions to be passed on to the subject before the test is carried out
It is recommended that the examiner reads the following instructions to the examinee. These instructions are also listed in the "*Learning mode*" pull down menu.

Instruct to subject to sit comfortably with the head in line with the centre of the display and approximately ~ 1.4 m (55") away from it. Hand the response buttons box to the examinee and ensure that it is properly oriented. Select and activate the "*Learning mode*" option and repeat the initial presentation of the moving stimulus (by clicking the repeat box in the Learning mode window) until the subject understands the use of the four response buttons. All subjects (including colour deficients) will be able to see the moving stimuli. The small, square stimulus can move in one of four possible directions (over the larger square formed by luminance noise), each corresponding to one of the four corner buttons on the response buttons box.

The motion direction, when instructing the subject, can be described as: *Top Right, Top Left, Bottom Right* and *Bottom left*. It is also useful to instruct the subject to look at the centre of the larger square and to press the appropriate button only after the audible "beep" (generated by the computer after each presentation to indicate the termination of the stimulus). The learning mode takes ~ 40s to complete. Scores of 100% throughout indicate that the subject understands the instructions and is ready to carry out the CAD test.





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