

A System for Precision Ophthalmic Tinting

Manual for the
Intuitive Colorimeter Mk.2
and Precision Tints

by
Professor Arnold Wilkins

BSc DPhil CPsychol FBPsS

Visual Perception Unit
University of Essex
Colchester, UK

Cerium Visual Technologies
Tenterden, Kent, UK

6th Edition, 2002

Table of contents

1. GENERAL SAFETY REMINDERS	3
2. INSTRUMENT CLASSIFICATION AND DATA.....	3
3. BACKGROUND.....	4
Ophthalmic tinting	4
Intuitive Colorimeter Mk. 2	4
How it works.....	6
Advantages	7
4. INSTALLATION OF THE COLORIMETER.....	7
5. SIDE-EFFECTS OF COLORIMETRY	8
6. EVALUATION OF PRECISION TINTING	8
7. EXAMINATION PROCEDURE	8
Introduction.....	8
i. Selecting an appropriate chromaticity	9
<i>Introduction</i>	9
ii. Selecting a suitable combination of coloured trial lenses	12
8. REFERENCES	16
9. MAINTENANCE	17
Cleaning.....	17
Lamp Replacement - Filter Assembly.....	17
Lamp Replacement - Standard comparison Port.....	17
10. SUMMARY OF TEST PROCEDURE.....	18

1. GENERAL SAFETY REMINDERS

Read this manual carefully before operating the machine for the first time.

Plug the machine into an earthed (grounded) 220-240 volt outlet only. **NOTE.** Grounding reliability can only be achieved when the instrument is connected to an equivalent receptacle marked *Hospital Grade* or *Hospital Only*. Use only a power supply with specifications:- Power Box Model SW173MA0003F01, Max. Power 33W, Voltage 15V, Max. Current 2.2A, as supplied with the unit. The power box must be connected to an electrical outlet using only a certified 3 core, 18SWG, SJT cord set with a hospital grade plug. The user should not touch the patient and the output connector of the power supply at the same time.

The Instrument is not suitable for use in the presence of flammable anaesthetic mixtures with air oxygen or nitrous oxide.

All machine covers must be in place when operating the machine. Any alteration, removal, or damage to these parts may cause a safety hazard.



This sign on the instrument and in the manual indicates a potential hazard. Read the manual for details.

2. INSTRUMENT CLASSIFICATION AND DATA

The instrument is electrically classified as Class 1, Type B, to IP10, and continuous rated. The type B symbol  shown here and marked on the equipment means this equipment complies with UL2601.1 and CSA C22.2 601.1 in providing protection against electric shocks, particularly regarding leakage currents.

Supply current 240vAC. Frequency 50-60Hz. Rated power input for the voltage range 0.8A.

Temperature Range -10° - $+70^{\circ}\text{C}$. Operating Temperature Range 0° - $+30^{\circ}\text{C}$. Humidity Range 20-80%.

There should be no interference with other equipment. If any is experienced move the instrument further away.

Store and transport in upright position.

Recognized accessories include the computer spreadsheet on CD, as supplied. The markings on the instrument are used with the computer spreadsheet to give an appropriate specification of lens color and transmission.

Local regulations should be considered when disposing of this product. When disposing of fluorescent lamps it is usual to break the tubes, taking care to avoid:

- The risk of cuts from flying glass. The pressure in the lamps is very low and, if broken carelessly can give rise to an implosion.

- The risk of inhalation of the fluorescent powder. The powder itself is not especially toxic but it will be contaminated with mercury and it is not advisable to inhale any type of dust. Those carrying out the work should wear suitable protection for exposed parts of the body especially for the eyes, hands and arms.

A suitable mask will guard against unnecessary inhalation of dust. The work should be carried out outdoors or in a well-ventilated area.

Compact fluorescent lamps may be broken, as above, or left intact, in which case they should be returned to their packaging or wrapped in several layers of newspaper.

Cerium Visual Technologies Ltd. will make available on request all information, circuit diagrams etc., required by the users' technically qualified personnel to repair those parts classified by the manufacturer as repairable.

3. BACKGROUND

The Intuitive Colorimeter enables an ophthalmic tint to be chosen according to a patient's subjective assessment of its effects on perception and visual comfort. A precise tint can be selected rapidly and efficiently. Precision Tints can reduce visual stress and perceptual distortion (Wilkins *et al.*, 1994).

The Colorimeter has undergone open and double-masked clinical trials (Maclachlan *et al.*, 1994; Wilkins *et al.*, 1994; Wilkins, 1995; Lightstone *et al.*, 1999; Wilkins *et al.*, 2002, Evans *et al.*, 2002).

This manual describes procedures derived from ten years' experience.

Ophthalmic tinting

Most modern spectacle lenses are made from plastic, usually a resin (allyl-diglycol-carbonate, CR39). Lenses made from this resin can be dyed by immersing them in hot organic dyes. Although this technology has been used for cosmetic tinting, there is now evidence that coloured glasses have therapeutic potential. There are published clinical trials to show that tinted glasses can be of value in dyslexia (Wilkins *et al.*, 1994; Evans *et al.*, 1999), photosensitive epilepsy (Wilkins *et al.*, 1999) and migraine (Wilkins *et al.*, 2002; Evans *et al.*, 2002). There is anecdotal evidence that they may also be of value in multiple sclerosis and other disorders of the central nervous system that involve vision. Individuals differ with respect to the tint that they find therapeutic, and it seems that, at least in some individuals, the tint needs to be precisely determined if the benefits are to be optimized.

Intuitive Colorimeter Mk. 2

The Intuitive Colorimeter Mk. 2 is a new apparatus for mixing coloured light. Colours exist in three subjective dimensions: hue (colour) , saturation (depth or strength of colour)  and brightness . Many shades can be produced by mixing primary colours in various amounts, but it can be difficult and time consuming to mix lights to match a particular shade. Hue, saturation and brightness all change when one of the lights is

varied. The way in which the lights interact to produce a given colour is not obvious. The Intuitive Colorimeter overcomes these problems and enables colour and saturation to be varied separately without an associated change in luminance.

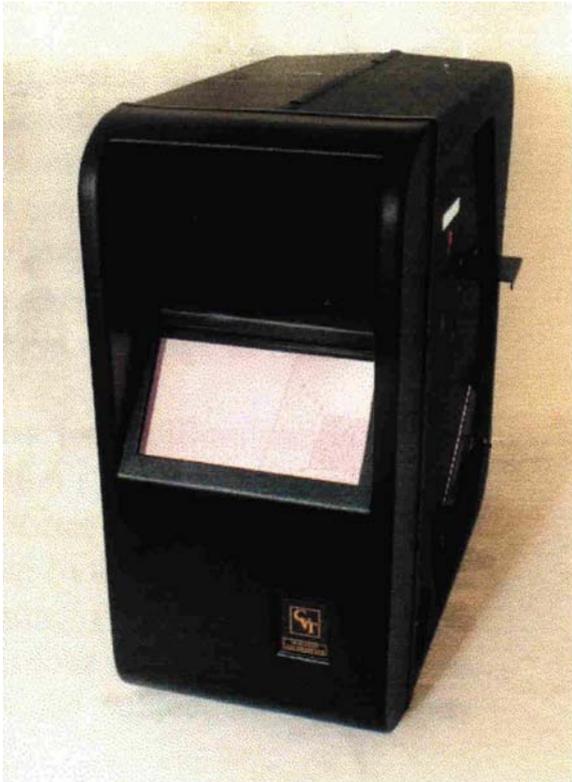


Figure 1. The Intuitive Colorimeter Mk. 2.
Patient's view.

The Intuitive Colorimeter Mk 2 is shown in Figure 1. It is designed to be placed on a table. The examiner sits beside the patient, on the patient's right, operating the controls on the right side of the instrument. The controls can also be operated by the patient. One control () changes the hue, another () changes the saturation, and two more alter the luminance, ( , ). The luminance controls (attenuators) change the luminance of the

viewing surface without altering the colour. They are operated by pulling out one or both of the attenuator slides. One attenuator control (upper slide, Figure 2) reduces the luminance by half (), and one reduces the luminance by three-quarters (), i.e. to one quarter of the unattenuated value. Operating the two together reduces the luminance to one eighth the unattenuated value.

The main viewing window on the front of the instrument has a sliding cover which can be raised to reveal an inner surface on which visual material such as text or the Test Plate (in the information pack) can be placed. The material can be inserted by lifting the hinged section of the side panel and sliding the material in through the slot, the lower margin resting on the lip at the bottom. Suitable visual material is included with the Colorimeter (see Test Plate), but practitioners may wish to use readable text as well, such as the patient's school reader or the Wilkins Rate of Reading Test (Wilkins *et al.*, 1996). *Please note that any material used must have a matt surface.*

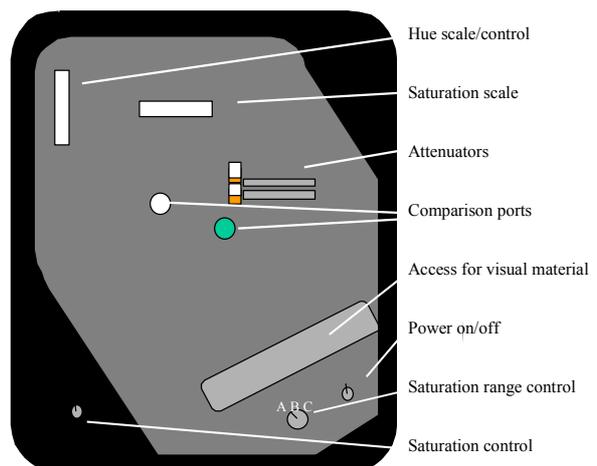


Figure 2. View of the right hand side panel of the Intuitive Colorimeter Mk. 2, showing the controls

The patient selects a hue and saturation that provides for the best perception of the text. Details of the appropriate procedure for selecting the hue and saturation are given in the next section.

The standard white comparison port shows the light from a "white" (halophosphate) fluorescent

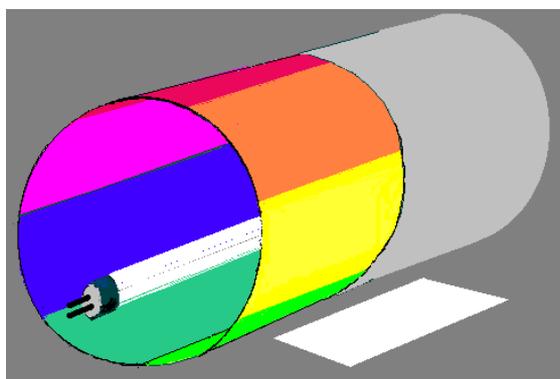


Figure 3. Basic mechanism showing filters on the circumference of a cylinder, coloured filters (left) and uniform grey filter (right).

lamp (CIE type F3). These lamps have a chromaticity that is yellower than daylight. A "white" fluorescent lamp was chosen because: (i) it is a light source that is commonly used for lighting offices and schools; (ii) its spectral power distribution is easily controlled; (iii) it has a chromaticity midway between that of daylight and incandescent light.

When the attenuators are in, the luminance of the Colorimeter viewing surface is at its maximum: about 25 candelas per square metre. The luminance recommended for office work varies considerably from one country to another but is generally between 60 cd.m⁻² and 100 cd.m⁻² (Mills and Borg, 1993). The Colorimeter luminance thus

allows for lenses that transmit about 30% of the light, the most common value (mode in a sample of 1000 lenses; Wilkins, 1997).

How it works

A beam of white light from a series of fluorescent lamps passes through a cylindrical filter assembly (shown in Figure 3) and into a box with matt white inner surfaces (shown in cross section in Figure 4). The filter assembly is divided into seven sectors, each made up of a different filter so as to transmit light of a different colour. Each sector transmits a coloured light equidistant from its neighbour and evenly positioned around colour space (CIE 1976 uniform chromaticity scale diagram). The coloured light is mixed as it is reflected and scattered from the inner surfaces of the box. Text is mounted on one surface of this box and viewed through a window in the front.

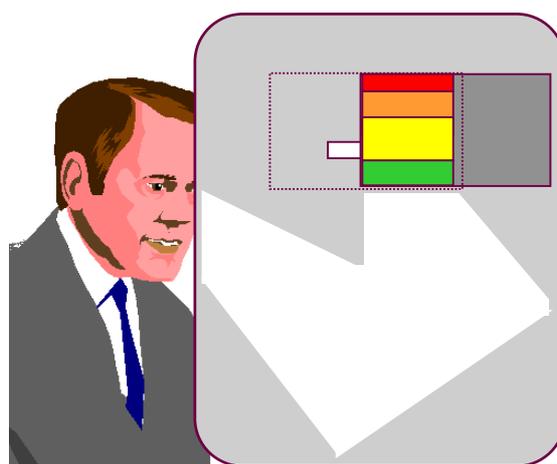


Figure 4. Cross section showing position of cylinder at maximum saturation, and (in dotted outline) at minimum saturation.

When the filter cylinder is in its start position (shown by the dotted lines in Figure 4) there is no

"colour" present. When the filter cylinder is moved along its axle, the saturation of the colour in the viewing chamber will increase, until one or more coloured filters fully cover the aperture when the saturation is at maximum. When a single filter sector covers the lamps and aperture the resulting hue will flood the viewing chamber. When a filter is combined with one of its neighbours either side the resulting hue will be a mixture of the two and will depend on the area of one filter covering the aperture in comparison with the other. By rotating the filter cylinder, combinations of all seven colours result in a continuously variable hue range. Although the colours obtained result from an additive mixture of light from some combination of one or two coloured filters and a neutral filter, the resulting spectral power distribution is remarkably similar to that from Precision Ophthalmic tints when these are worn under conventional fluorescent lighting (Wilkins and Sihra, 2000).

Advantages

The Intuitive Colorimeter Mk. 2 has several advantages for assessing the subjective effects of coloured light: (i) colour (UCS 1976 hue angle, h_{uv}) and depth of colour (saturation, s_{uv}) can be varied separately and therefore intuitatively; (ii) the variation is continuous rather than discrete; (iii) no coloured surfaces are visible within the Colorimeter, so it is unnecessary to consider colour constancy mechanisms at this stage; (iv) the perceptual effects of colour can be studied while the patient's eyes are colour-adapted; (v) the assessment is quick and efficient; (vi) the spectral power distribution is very similar to that for lenses.

4. INSTALLATION OF THE COLORIMETER

The Colorimeter should stand on a table or similar horizontal surface.

The front viewing window should be above the front edge of the table at a level at which a seated patient can see the textual material. The examiner should be able to sit on the right hand side of the patient and reach the controls on the right side panel of the Colorimeter. One end of the power lead should be plugged into the socket at the rear of the Colorimeter and the other end into a grounded electricity outlet.



The Colorimeter should only be connected to the electricity supply via the 15v DC transformer lead supplied with the instrument.

5. SIDE-EFFECTS OF COLORIMETRY



Clients should be informed that examination with the Colorimeter entails a small risk of headache or nausea. Those with photosensitive epilepsy should be examined in the presence of a carer who knows what steps to take in the event of a seizure. The risk of a seizure during colorimetry is, however, small (Wilkins *et al.*, 1999). If any side effects occur, details should be sent to Colorimeter Reports, Visual Perception Unit, University of Essex, Colchester, CO4 3SQ, United Kingdom.

6. EVALUATION OF PRECISION TINTING

The Medical Research Council is evaluating the effectiveness of precision tinting. Patients should be encouraged to send their comments to Colorimeter Reports, Visual Perception Unit, University of Essex, Colchester, CO4 3SQ, United Kingdom.

7. EXAMINATION PROCEDURE

Introduction

There are many potential causes of visual discomfort and perceptual distortions, and tinted lenses will not help everyone with these symptoms. Before using the Colorimeter, patients should undergo a full optometric examination. In particular, the optometrist should look for any binocular vision or accommodative problems. If any clinically significant anomalies are detected, they should be treated, before considering tinted lenses.

For some patients, there are circumscribed regions of colour space within which perceptual distortions abate, and visual discomfort is reduced (Wilkins *et al.*, 1992a,b; Maclachlan *et al.*, 1993). The procedure described below is aimed at locating these regions without inducing discomfort, and then refining the measurements under conditions of colour adaptation. The measurements are initially made at a constant luminance (V_λ) similar to that which a person might experience under normal conditions of office lighting when wearing tinted glasses that absorb about half the light. In Step 11 the measurements are checked at lower luminance levels.

The absence of coloured surfaces in the Colorimeter should ensure that the chromaticity co-ordinates for maximum comfort and clarity are independent of the particular spectral power distribution and related colour constancy mechanisms. The assessment is carried out under

binocular viewing conditions unless there are indications that the optimal tint may differ in the two eyes and the patient is prepared to countenance wearing spectacles with differently coloured lenses. Once appropriately coloured lenses have been selected, the colour can be altered in each eye by small amounts if this improves perceptual clarity reliably, but binocular function should be checked with any prescription for coloured lenses that are different in the two eyes.

The examination procedure has two parts: (1) selection of an appropriate chromaticity in the Colorimeter and (2) selection of a suitable combination of coloured trial lenses.

i. Selecting an appropriate chromaticity

Introduction

The following procedure for the use of the Colorimeter is designed to minimise the likelihood of adverse symptoms from exposure to colour. Patients who benefit from certain colours can show adverse symptoms when exposed to other colours. The procedure exposes the patient briefly to a wide range of colours under conditions of adaptation to white light. Aversive colours are subsequently avoided during the second stage when measurements are made under conditions of adaptation to coloured light. The colours are changed in the Colorimeter in two ways. First, the practitioner can adjust the instrument, requiring the patient to report which of two successive settings is the best. This is similar to a crossed-cylinder technique. Adults may prefer to adjust the controls. Generally speaking, patients can

manipulate the saturation control for themselves, but need help in assessing the effects of changes in hue: variation of the hue control is usually best left to the examiner.

When you read these instructions for the first time, it would be helpful to practise with the Colorimeter.

1. *Prepare Colorimeter.* Sit on the patient's right. Place the Test Plate on the viewing platform by lifting the side panel and sliding the Test Plate through the access, see Figure 2. Ensure both attenuators are off (pushed in). Adjust the hue wheel () until hue reads 0 degrees on the hue scale. Adjust the saturation control until the saturation () reads 0 on the saturation scale. Turn the Colorimeter on at the power switch on the right of the right-hand side panel. **Turn off the room lights.**

2. *Obtain a description* of perceptual distortions and/or visual discomfort. Ask the patient to look at the text on the Test Plate in the Colorimeter. Make sure the patient is at a comfortable viewing distance with the eyes close to the viewing aperture. Ask the patient to report any perceptual distortions. For example, do the letters move (e.g. wobble, shimmer); do they distort in any other way; do they blur; do coloured halos appear around the letters; what exactly happens? Use the description given by the patient to refer to the perceptual distortion subsequently. Record this description on the appropriate panel on the Colorimeter Record Form. If the patient does not report perceptual distortion, use the subjective feeling of "eye comfort" as a substitute in subsequent testing.

3. *Explain* that you are going to shine different colours on the text. Some may make it better, some worse, and some may have no effect. Ensure that the patient understands that the colours that will be the best ones may not be the same as those of any overlay that they have previously chosen.

4. *Increase then decrease saturation.* Set the saturation range control on the side panel to 'A'. This setting prevents strong saturation of any colour. Ask the patient to compare the text as you activate the saturation control switch (press right and hold). This increases the saturation slowly to a level of approximately 25. Leave the control at this level for about 5 seconds and then reactivate the saturation control switch (press left and hold). This reduces the saturation back to 0. The slow speed enables the patient to compare intermediate degrees of saturation: occasionally these are more beneficial than the higher levels. When the saturation has returned to 0, ask which was better, the coloured or the white. Note the response on the Fan Chart of the Colorimeter Record Form by entering a number in the appropriate position in the fan. Use the response code shown in the attached box. i.e. Enter +1 if perception improves a little, +2 if there is a considerable improvement, -1 if it gets a little worse, -2 if it gets a lot worse, and 0 (not =) if there is no appreciable change. For example, if at hue=0 the patient reports that the perceptual distortions improve a little at saturation = 25, enter +1 half way along the arm that leads to the 0 on the chart. If the perception improves and then gets worse as saturation increases further, make a note.

5. *Increase hue angle.* With the saturation at 0, move the hue to 30 degrees. Repeat Step 4. Do so

again with the hue at 60 degrees, and so on, advancing hue by 30 degrees until the Fan Chart is complete. Note that you can repeat 0 degrees to check for consistency: 0 degrees was the first trial, and the patient may take a little time to realize what is required.

6. *Note the uncomfortable colours.* There may be hue angles where perception gets worse and the perceptual distortions are uncomfortable. Hereafter make sure the hue control is not brought within 20 degrees of any uncomfortable settings. The patient may experience pain, and the test may have to be stopped.



Do not allow the patient to come within 20 degrees of any uncomfortable hue.

7. *Adjust saturation.* Set the hue control to the angle where perception was most improved. If there was more than one setting at which perception/comfort improved, select one of the better settings. If in doubt about an improvement set the hue control to an angle 180 degrees from that at which distortion/discomfort was worst. Turn the saturation range control to 'B'. This allows strong saturations to be obtained. Adjust or ask the patient to adjust the saturation by activating the saturation control switch **away from them and hold to increase** saturation, **towards them and hold to decrease**, until the saturation level gives maximum clarity/comfort. Tell the patient to imagine they are tuning a radio. To tune a radio you go past the position of strongest signal until reception gets worse; you then come back in the opposite direction, until reception again gets worse. It is the same for the "tuning" of colour. **Stress that it is important to find the least**

saturated setting (weakest colour) that is comfortable. (Otherwise the lenses will be too dark). If the patient is young or has difficulty making this adjustment, help by supplying two alternative settings in immediate succession, asking "Which is best, number one, or number two?". You can enter the settings in the columns headed 1st and 2nd on the Colorimeter Record Form, and indicate which was preferred with a ✓.

Repeat the above at each of the good settings identified in the Fan Chart Column 1 of the columns headed 2AFC. Note whether the patient adjusted saturation for him/herself (P), or whether the examiner adjusted the controls (E). Now present each of the 'good' settings in turn and find which is best. Do this by asking the patient to look at a setting for a few seconds. Say "This is setting number 1". Then ask them to close their eyes while you adjust the controls to a second setting. Ask them to open their eyes and say "This is setting number 2". Ask them which setting was best. They may find it helpful if you repeat the first setting. You can note the second setting in Column 2, and then check which of the settings, 1 or 2, was preferred.

8. *Adjust hue at best saturation.* Leave the saturation control at the best setting identified in the previous step. Mark this setting on the Target Chart. Compare the hue with a hue 20 degrees above and below. Show the two settings in succession, having the patient close their eyes while the setting is adjusted, as described in Step 7. Ask the patient to choose which is better. Maximize clarity/comfort using steps that are initially 20 degrees in either direction, the size of step being increased to 30 degrees if no

differences are apparent, and reduced to 10 degrees if a clear difference is seen.

If, for example, the initial hue setting is 120 degrees, try comparing 120 with 140. If 140 is preferred, next compare 140 with 160. Continue moving the comparison as appropriate so as to "home in" on the best setting. Repeat the measurements to check for consistency. If the patient is consistent on several trials with 20 degrees separation, try 10 degrees separation.

Note the revised setting of hue angle by plotting it in the Target Chart or by recording the two-alternative forced choices in the 1st and 2nd columns.

9. *Minimize saturation.* Leave the hue at this setting. Ask the patient to adjust the saturation once again, as for Step 7. **Emphasize that we are trying to find the minimum saturation that is beneficial.**

10. *Check for consistency.* Try other neighbouring hues and saturations to check the patient's consistency. Poor consistency may mean that the patient is tiring, or simply that the symptoms are not affected reliably by colour. Check for tiredness by repeating earlier steps after a rest.

11. *Compare lower luminance levels.* Compare the chosen colour with no attenuator and with the 50% attenuator. Pull out the 50% attenuator slide marked  and ask the patient if the lower brightness is better, worse or about the same. Ideally the reduction in brightness will not make much difference. Which is preferred?

The darkness of a lens varies with colour. Enter the values of hue and saturation in the spreadsheet supplied on the CD. The computer will specify the transmission of the matching lenses. It will also specify the attenuator setting necessary to provide the luminance that will be obtained when the spectacles are worn under normal office lighting. If the patient has chosen this setting, no further adjustment is likely to be necessary.

If the program indicates that the 50% attenuator is necessary to match the darkness of the lenses, and yet the patient has chosen no attenuator, point out to the patient that stronger colours require darker lenses; i.e. a compromise is necessary between brightness and saturation. Try decreasing the saturation slightly on the spreadsheet to see whether the program still indicates the 50% attenuator setting.

If the program indicates that no attenuator is necessary to match the darkness of the lenses, and yet the patient has chosen the 50% attenuator, try increasing the saturation slightly to see whether the preference for dimmer light exists with stronger colours. If the preference for dimmer light is maintained even at maximum saturation it will be worthwhile trying trial lenses that are more strongly saturated than those indicated by the program, and perhaps also grey lenses in addition.

12. *Replace the test chart with a reading passage from the Wilkins Rate of Reading Test.* You can use the speed with which the passage is read to assess the effect of the tint on reading, using alternative passages under different Colorimeter settings, as described in the instructions for the *Wilkins Rate of Reading Test*.

13. *Check final setting.* Ask the patient whether the final setting is at least as good as the best one the patient has thus far observed. It should be, unless untoward adaptation has been taking place. If the patient thinks one of the earlier settings was preferable, try and find it. Bear in mind that the patient may have become tired, and the earlier setting may not now seem as good as it was. The procedure can be quite stressful for some people.

14. *Annotate.* Write in the values of the best setting in the box on the lower right hand side of the record form.

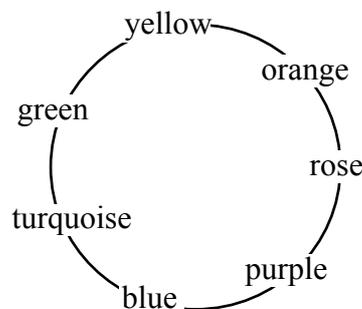


Figure 6. A circle of colours

ii. Selecting a suitable combination of coloured trial lenses

Introduction

It is possible to match any Colorimeter setting with a stack of trial lenses so that the colour appearance is identical, allowing for differences in brightness. This can be done using lenses from only two dyes, and the dyes are always neighbours in the circle of colours shown in Figure 6.

For example, a yellowy green is produced with a combination of yellow and green trial lenses, and a red with a combination of rose and orange lenses. There are five pairs of lenses of each colour, apart from rose and purple which have six pairs. The pairs are labelled by letter starting with A for the least saturated. The deposition of dye doubles from one pair to the next; for example Trial lens B has half as much dye as Trial lens C and twice as much as trial lens A.

This means that the saturation of colour can be increased by very small steps by combining the lenses, placing one lens on top of another. Table 1 shows all the possible combinations of lenses A-E in order of increasing dye deposition.

With the exception of Rose and Purple, there are 32 steps for each colour (numbered 0-31 in Table 1), one for each combination of trial lenses. Rose and Purple have six lenses and therefore 64 possible combinations, 32 including lens F in addition to those lenses shown in Table 1.

The combinations of lenses that approximately match any Colorimeter setting can be obtained using the computer spreadsheet supplied on CD.

1. Find the combination of lenses specified by the program. Identify these trial lenses and place them together in a stack. Check that the colour of the stack matches the Colorimeter setting by placing the stack over the Standard White Comparison port, and compare the colour with that of the Colour Comparison port. Adjust the stack if necessary, by adding or removing lenses of either colour

2. Compare the effect of the lenses with that of the Colorimeter. Set the saturation range control on the side panel to 'C' and decrease the saturation to the maximum extent. This brings the leading edge of the coloured filter assembly towards the left hand side of the scale. When it is at this position, the white is as bright as the patient is likely to encounter under conventional lighting conditions (about 150 cd.m⁻²). When the leading edge is at a scale reading of 45, the luminance is similar to that recommended for office lighting, i.e. about 70 cd.m⁻².

Make up a duplicate stack of trial lenses, and place one stack in each side of the lens holder supplied, one stack for each eye. Have the patient hold the lenses over their eyes and view the text in the Colorimeter. Ask the patient if the appearance is as good as it was previously. It should be. If it is not, the lenses need adjustment.

You can adjust the saturation by separating the trial lenses of one stack into the lenses of each colour. Then reduce/increase the strength of each colour by the same number of steps, according to Table 1. For example, if the lens specification was Rose E2, Orange C3, you could reduce the Rose E by one step to Rose A+B+C+D and the Orange C by one step to Orange A+B, giving a stack with similar hue but reduced saturation.

3. Try out the lenses under a range of lighting conditions, and viewing distances. The patient should be given the opportunity of comparing the lenses under fluorescent light, natural daylight (if at all possible), and under the light from a tungsten filament lamp. The lighting should also be made as similar as possible to that which the patient typically has to read under. For example, if the patient has to

read music in an orchestra pit, a low wattage filament lamp should be used in a darkened room. Adjust the lenses in the stack if necessary.

4. *Check the ultraviolet filters.* Add one ultraviolet filter to each stack and then remove them from the stacks to check that these filters do not make matters worse. Provided the filters do not have detrimental effects, leave them in the stack. (The purpose of the ultraviolet filters is to reduce exposure to potentially harmful radiation should the glasses be worn outdoors in strong sun.)

5. *Issue a prescription and order the lenses.* It is most important to enter the specification of the trial lenses clearly and correctly. Enter the name of the main colour. Then follow the name with the letter and number of each lens of that colour (e.g. TURQUOISE: A5 + C3). Then do the same for the subsidiary colour:

TURQUOISE: A5 + C3 | BLUE: D2.

Enter Yes in the box “UV BLOCKER” unless the ultraviolet filters have detrimental effects on perception or the program indicates that UV blocking dye is unnecessary. Please note that it is essential that the prescription and ordering details are given in this format. The tinting procedure uses dyes identical to those used for the trial lenses and the spectral transmission of the spectacle lenses is therefore guaranteed. Other dyes should not be used.

6. *Verify the chromaticity of the spectacle lenses.* When the spectacle lenses are received, the chromaticity can be verified by placing the lenses over the standard white comparison port when the Colorimeter is at the appropriate setting. The colour

of the two comparison ports should be similar, although the brightness may differ.

The spectacle lenses will be provided with two leaflets. One leaflet, to be retained by the practitioner, gives the spectral transmission, and various numerical indices required under British Standard 2724 for the assessment of sunglasses. The second leaflet gives advice to patients concerning: (i) use of their glasses as sun glasses (based on the degree of ultraviolet and blue light absorption), and (ii) the extent of likely interference with the perception of traffic signals. This advice is offered because many patients find their glasses comfortable to wear for activities other than reading. Patients need to be given guidance concerning the advisability of wearing their glasses when driving. In general it is inadvisable to wear any filter in front of the eyes when driving at night. The glasses also come with a small card, which can be useful for children to show to their teachers. It explains that the glasses are necessary to correct a medical condition and are not conventional sunglasses.

Table 1. Steps of dye deposition achieved with combinations of coloured trial lenses.

Step	Combination	Step	Combination
0	No lens	16	E
1	A	17	A+E
2	B	18	B+E
3	A+B	19	A+B+E
4	C	20	C+E
5	A+C	21	A+C+E
6	B+C	22	B+C+E
7	A+B+C	23	A+B+C+E
8	D	24	D+E
9	A+D	25	A+D+E
10	B+D	26	B+D+E
11	A+B+D	27	A+B+D+E
12	C+D	28	C+D+E
13	A+C+D	29	A+C+D+E
14	B+C+D	30	B+C+D+E
15	A+B+C+D	31	A+B+C+D+E

8. REFERENCES

- Evans, B.J.W., Lightstone, A., Eperjesi, F., Duffy, J., Speedwell, L., Patel, R. and Wilkins, A.J. (1999). A review of the management of 323 consecutive patients seen in a learning difficulties clinic. *Ophthalmic and Physiological Optics*, **19**(6), 454-466.
- Evans, B.J.W., Patel, R., Wilkins, A.J. (2002). Optometric function in visually sensitive migraine before and after treatment with tinted spectacles. *Ophthalmic and Physiological Optics*, **22**, 130-142.
- Lightstone, A., Lightstone, T, Wilkins, A.J. (1999). Both coloured overlays and coloured lenses can improve reading fluency, but their optimal chromaticities differ. *Ophthalmic and Physiological Optics*, **19**(4), 279-285.
- Maclachlan, A., Yale, S. and Wilkins, A.J. (1993). Open trial of subjective precision tinting: follow-up of 55 patients. *Ophthalmic and Physiological Optics*, **13**, 175-178.
- Mills, E. and Borg, N. (1993) Trends in recommended lighting levels: an international comparison. In *Proceedings of the 2nd European Conference on Energy-Efficient Lighting*, Arnhem, The Netherlands, September 26-29.
- Wilkins, A.J., Milroy, R., Nimmo-Smith, I., Wright, A., Tyrrell, R., Holland, K., Martin, J., Bald, J., Yale, S., Miles, T., and Noakes, T. (1992a). Preliminary observations concerning treatment of visual discomfort and associated perceptual distortion. *Ophthalmic and Physiological Optics*, **12**, 257-263.
- Wilkins, A.J., Nimmo-Smith, I. and Jansons, J. (1992b). A colorimeter for the intuitive manipulation of hue and saturation and its role in the study of perceptual distortion. *Ophthalmic and Physiological Optics*, **12**, 381-385.
- Wilkins, A.J., Evans, B.J.W., Brown, J.A., Busby, A.E., Wingfield, A.E., Jeanes, R.J. and Bald, J. (1994). Double-masked placebo-controlled trial of precision spectral filters in children who use coloured overlays. *Ophthalmic and Physiological Optics*, **14**(4), 365-370.
- Wilkins, A.J. (1995). *Visual Stress*. Oxford University Press. 194 pp.
- Wilkins, A.J. , Jeanes, R.J., Pumfrey, P.D. and Laskier, M. (1996). Rate of Reading Test: its reliability, and its validity in the assessment of the effects of coloured overlays. *Ophthalmic and Physiological Optics*, **16**, 491-497.
- Wilkins, A.J. (1997). A system for precision ophthalmic tinting and its role in the treatment of visual stress. In C.M.Dickinson, I.J. Murray and D. Carden (Eds), *John Dalton's Colour Vision Legacy*. London: Taylor and Francis, pp. 695-708.
- Wilkins, A.J., Baker, A., Amin, D. Smith, S., Bradford, J. Boniface, S., Zaiwalla, Z., Besag, F.M.C., Binnie, C.D. and Fish, D. (1999). Treatment of photosensitive epilepsy using coloured filters. *Seizure*, **8**, 444-449.
- Wilkins, A.J. and Sihra, N. (2000). A colorizer for use in determining an optimal ophthalmic tint. *Color Research and Application*, **26**(3), 246-253.
- Wilkins, A.J., Patel, R. Adjajian, R., Evans, B.J.W. (2002). Tinted spectacles and visually sensitive migraine. *Cephalalgia* (in press).

9. MAINTENANCE

Cleaning



Switch off power and disconnect power lead before cleaning. The external surfaces of the Colorimeter may be cleaned using a cloth moistened with water and with dilute disinfectant or mild detergent, if necessary.

Lamp Replacement - Filter Assembly

1. Disconnect Colorimeter from electricity supply.

Pull out plug from rear of instrument.

2. Remove rear panel from Colorimeter.

Pull out the plastic lugs using a blade. Remove the bolts using an Allen key. Pull the panel outwards to release the Velcro tape.

3. Remove fluorescent lamp assembly.

At the top of the instrument is the cylindrical filter assembly. In the centre of this is the aluminum fluorescent lamp assembly connected to the chassis by a black cable. **Do not remove this cable.** Grasp the lamp assembly by both sides between thumb and forefinger and pull. The assembly will slide out. Remove it from the filter assembly completely.

4. Remove the clear lamp assembly cover.

The three lamps are covered by a clear U.V. filter in an aluminum frame. The frame is held by four small lugs and has a light snap fit. Remove the frame and filter by pulling outwards away from the lamps.

5. Remove the lamps.

The lamps are now accessible and can be removed by rotating each in turn and pulling out.

Note It is recommended that all three lamps be replaced at the same time.

6. Replace the lamps.

7. Replace the frame and filter.

Press onto the lamp assembly.

8. Replace the lamp assembly.

Locate the lamp assembly runners in the slides and push fully home.

9. Replace rear panel.

10. Reconnect power supply.

Lamp Replacement - Standard comparison Port

1. Disconnect power supply.

Pull out plug from rear of instrument.

2. Remove front panel.

The front panel is connected to the remainder of the instrument by plastic lugs. Remove these and pull panel outwards.

Note the viewing chamber door is not attached to the front panel. Remove this and place to one side.

3. Remove fluorescent lamp.

The fluorescent lamp is accessed to the left of the hue scale wheel at the top of the instrument. Remove the lamp by rotating and lifting out.

4. Fit new lamp.

5. Replace viewing chamber door and front panel.

Place viewing chamber door in position over aperture and replace front panel, using lugs.

6. Reconnect power supply.

10. SUMMARY OF TEST PROCEDURE

Obtain description of distortions
Explain procedure
Increase/decrease saturation, every 30 degrees, completing Fan Chart.
Optimise saturation of best settings.
Compare these settings by presenting two in succession. (Patient closes eyes when setting is changed.) Record response using “1 st ” and “2 nd ” columns.
At best setting optimise hue by comparing two neighbouring hues in succession. Record response using “1 st ” and “2 nd ” columns.
At revised hue, re-optimize saturation. Use Target chart.
Reduce saturation as much as possible.
Compare reduced luminances, in relation to program.
Select stack of matching coloured trial lenses.
Try the stack under various lighting conditions and decide on UV filter.
Revise stack, reducing saturation as much as tolerable.
Order lenses.

Appendix 1. Colorimeter Record Form. (The form may be photocopied.)

Colorimeter Record Form

Name: _____
 Date: _____
 Ref: _____ Examiner's initials: _____

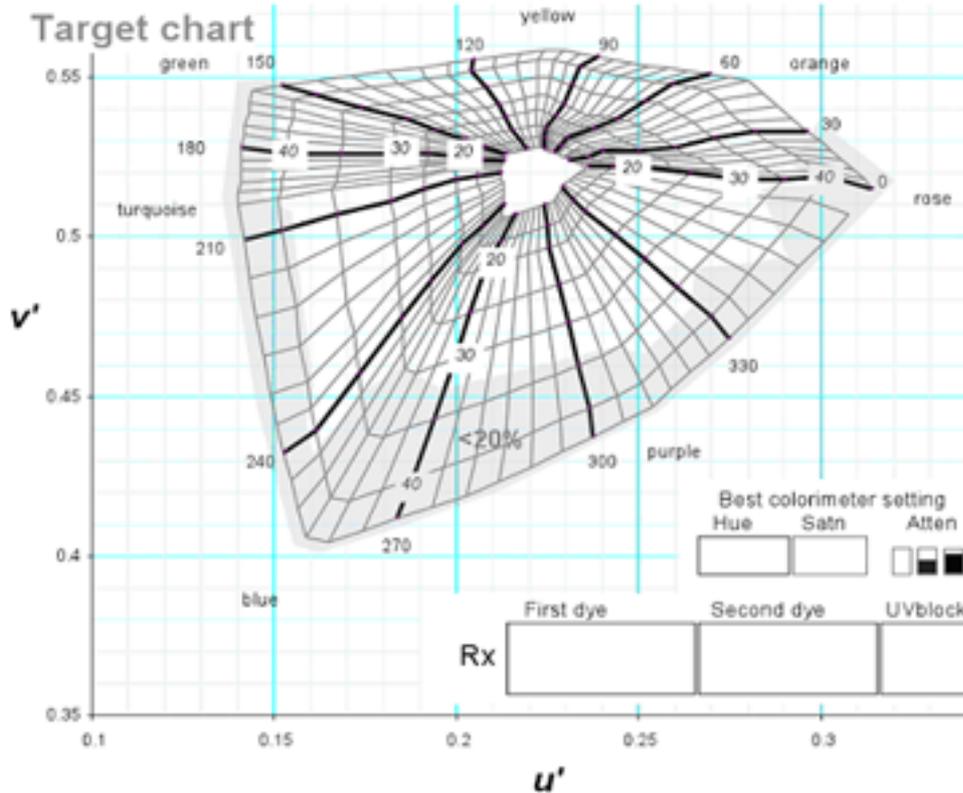
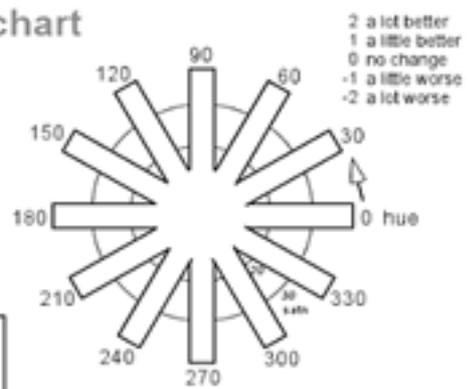
Address and telephone

Description of perceptual distortion

Notes

Consistency?
Suitability?

Fan chart



1 st		2 nd	
Hue	sat	Hue	sat
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Appendix 2. CIE 1976 u',v' chromaticity coordinates of the trial lenses, with photopic transmission (percent). Up to 5% error is inevitable.

	A	B	C	D	E	F
Rose	.216, .473 85%	.219, .472 83%	.233, .469 71%	.262, .463 54%	.308, .455 37%	.389, .464 22%
Orange	.214, .478 91%	.218, .484 86%	.227, .494 80%	.249, .512 67%	.290, .532 51%	
Yellow	.211, .486 93%	.211, .500 92%	.213, .519 90%	.216, .537 88%	.224, .550 84%	
Green	.206, .479 84%	.201, .487 80%	.187, .500 67%	.167, .515 51%	.138, .526 33%	
Turquoise	.206, .474 87%	.200, .473 80%	.190, .473 68%	.170, .472? 51%	.138, .472 32%	
Blue	.207, .470 86%	.203, .467 82%	.196, .457 71%	.180, .433 53%	.158, .384 31%	
Purple	.211, .472 90%	.213, .467 84%	.217, .460 74%	.226, .440 54%	.236, .406 35%	.267, .322 14%
Neutral	.211, .474 76%	.211, .473 50%	.214, .469 24%			
Ultra-violet	.210, .476 92%					