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Colour preference - a comparative study

The eyes are the most important source of sensory information. When things go wrong with the visual system it can have a profound effect on everything we do. For some people changing the colour of their world produces interesting and surprising results.

Choice of colour, or colour preference, is deeply rooted in psychology and evolution. Red is often associated with danger (fire, poisonous berries) and so is the combination of yellow and black seen on wasps and venomous snakes. It may not be a coincidence that the natural colours of fields and forests and the blue of the sky and the sea are calming.

Colour preference can also be affected by pathological conditions like cataract. The French impressionist Monet was deeply disturbed by the effect cataract had on his colour perception. Macular degeneration and systemic disorders which affect cone function are also likely to have an effect. Complicated neurological disorders like dyslexia and associated conditions, migraine and epilepsy have been shown to be affected by looking through a coloured material[1].

Hazards of colour

The colour of light is an indication of wavelength and in some cases an associated danger. Blue light and ultraviolet (UV) are implicated in cataract formation and macular degeneration[2,3,4,5]. These shorter wavelengths are not dealt with easily by the eye, UV causes the lens to fluoresce and blue light is focused in front of the retina, contributing to a veiling luminance and reduced contrast sensitivity[6].

Infrared (IR) can cause cataracts in blast furnace workers[7]. It may be the heat in IR which increases the prevalence of a predisposition to cataract in people with brown eyes over the age of 45[8], the iris acting as a heat sink on top of the lens[9].

When light is intense in the orange/yellow part of the spectrum, to which the eye is most sensitive, it can lead to disability glare. Although filters will not necessarily increase contrast thresholds[8], they will save the retina from being unnecessarily bleached, with implications in terms of dark adaptation and long-term dysfunction of the macular[5].

The ability to distinguish between wavelengths in the electro magnetic spectrum is useful in industry, where colour coding is used to convey information quickly[10]. This can be a disadvantage in some professions[11] for about 8% of the male population who are colour-blind. For that 8% it has been proposed that a red tinted lens improves hue discrimination by increasing the relative brightness of red[12].

Understanding the physical effects of tinted lenses is important when it comes to the final dispensing[13], but the usefulness of tints is not fully understood[14].

In the Hospital Eye Service tints may be seen as clinically necessary for well-established reasons like albinism, aniridia and trabeculectomy damage, or symptomatic age related macular degeneration, cataracts and aphakia .

On the NHS examination claim forms, tints have to be justified in a way which other parts of the prescription are not. In neither situation is there clear guidance about the frequency of prescribing and which colour is best and why. When there is a lack of professional consensus, funding authorities will tend to be the final arbiter.

Given the potential of tinting to relieve symptoms and prevent disease, there needs to be a convenient way of measuring colour preference in general practice.

The Colorimeter

Anecdotally, some practitioners believe that tints should never be prescribed and have little value in the treatment of dyslexia and migraine. This may have contributed to the scepticism of early work with coloured overlays and reading disability[15]. The Colorimeter has established for the first time that individuals can have distinct and precise colour preferences[16,17].

A screening test for colour preference

The Colorimeter provides an exhaustive test for colour preference but is necessarily time-consuming and does not fit easily into a routine sight test. It is also suggested that the colour of the overlay does not produce the same effect when dispensed in spectacles[1], but it has been suggested, in a preliminary study, that contact lenses can improve reading in dyslexia[18].

Subjectively, the effect of tints seems stronger when worn compared with being held at a distance over the printed page, perhaps because the peripheral field is involved.

Although the Colorimeter confirms that tinted lenses have an effect, it may be necessary to measure colour preference in a different way when prescribing specifically for spectacles. It may not be necessary to define colour preference so precisely when considering the broader use of therapeutic tints.

Hypothesis

If a sample of say six colours, evenly spaced across the spectrum were chosen, it might be possible to establish that colour choice from this limited range could still be a basis for prescribing. To test this hypothesis, two groups of subjects were chosen from elite sport.

Subjects

1. All England Netball Association Panel Umpires
   - Screened at Nottingham University on September 6, 1998
   - N = 33
   - Average age = 44.3

2. British National Smallbore Rifle Association Junior Squad
   - Screened at Chesterfield on May 25, 1997 and Aldersley April 21, 2000
   - N = 51
   - Average age = 20.5

The umpires were tested in an indoor sports hall with no outside windows, the shooters mainly in a large room in a sports centre which was open to the daylight. A smaller group of the shooters were also tested outside.

Screening set

The colour preference testing set consisted of six coloured lenses and a control neutral density filter, mounted in a lorgnette (**Figure 1**).

Figure 1 Colour preference set
Photo by coutesy of Norville Optical

The light transmission factor is about 65% for each set of lenses (**Figure 2**). The precise wavelength may not be important but should be about the middle of the range generally accepted to be the colour indicated.

Method

Each lorgnette was presented at random. Subjects

Wavelength guide (nm) (Mid range values)	Colour						
	Pink	Orange	Yellow	Green	Blue	Violet	Grey
Jalie [9]	640	610	580	540	480	420	Neutral
Fincham and Freeman [19]	640	606	584	545	482	420	Neutral
Freeman MH[20]	629	605	568	520	470	408	Neutral

Figure 2
The colours used and wavelength guide

Group	Reason
Blue, Green	Mutually exclusive
Yellow, Orange	
Grey, no preference	Indicates no tint preference
Pink, Lilac	Least chosen colours

Figure 7
Tint group for analysis

were asked to say if they liked the feel of the lens or hated it, or something in-between. They were asked to look as some distant object in the prevailing ambient light (ideally relevant to their sport, like a target in shooting). The instructions were as open as possible to encourage the subject not to base their choice on pre-conceptions.

In the consulting room conditions can be standardised. A high contrast, internally illuminated test chart, is a suitable target with the room illumination turned up as high as possible. Fluorescent light with its spiky emissions[21] and UV content is a good simulation of indoor lighting which can cause problems.

The favoured tints were placed in one group and the least favoured in another. Preference was judged on three levels: Strong, medium and weak

The choice was then narrowed by forcing a choice between pairs of filters. The subject was asked to say if it was better with the first filter or the second. The first choice was retained and compared with the next one in the favoured group. When a preference for a group of tints has been expressed, it is very rare for the subject not to be able to decide which of the remaining favoured tints is the best.

If there was no colour preference, there were two further divisions:

- All colours chosen, this indicated no preference and a good tolerance of colour distortion.
- None of the tints chosen, indicated an intolerance of colour distortion.

Recording results

The reference number for each lorgnette shown in **Figure 4**, is recorded on the data sheet **(Figure 3)**.

Colour preference		
Best	Worst	No preference

Figure 3
Colour preference data sheet

The **Figures 4** and **5** show some summary tables of the results. **Figure 4** shows the colour-coding system and the frequency with which colours were chosen as the best and worst in netball panel umpires and rifle shooters at Aldersley.

		Frequency			
		Shooters		Umpires	
No.	Colour	Best	Worst	Best	Worst
1	Green	2	2	9	1
2	Yellow	14	3	2	18
3	Blue	3	5	8	2
4	Orange	4	2	2	9
5	Grey	0	7	3	2
6	Pink	2	2	5	1
7	Violet	0	3	3	2
	none	6	1	-	-

Figure 4
Colour choice in netball umpires and rifle shooters

Indoors					
Green 3	Yellow 10	Blue 2	Tan 2	Grey 6	Pink 3

Outdoors			
Yellow 7	Blue 3	Tan 2	Grey 3

Figure 5
The comparison of colour choice indoors and outdoors in the Chesterfield Shooters.

Analysis of results

With the colours considered separately, there was insufficient data to analyse the result so the groups were amalgamated. In the data for the panel umpires, two groups of tints were found to be mutually exclusive **(Figure 6)**.

Group 1	Group 2
Grey Blue Green	Orange Yellow

Figure 6
Mutually exclusive tint groups

In only one instance were two tints from the same group chosen as best and worst choice.

Using this evidence the colours were grouped as shown in **Figure 7** for the reason indicated.

Intense concentration needs good contrast

Netball requires fast reactions from the umpire

Many athletes have a definite colour preference

The Chi Squared Test compares the expected frequency of results if the choices were purely random, to the recorded results. The null hypothesis is that there is no difference in choice of colour between netball referees and the National Small Bore Rifle Association**(Figure 8)**.

Figure 8
Summary of Chi Squared Test results and method

Colours	Netball	Shooting	Row Totals	
Green/Blue	18	8	26	
Yellow/Tan	4	28	32	n=84
Pink/Lilac	8	4	12	
Grey/None	3	11	14	
	33	51	Column Totals	

Frequencies compared: choice of blue/green in netball, against blue/green in shooting, yellow/tan in netball against yellow/tan in shooting etc

Frequencies

Actual	18.00	8.00	4.00	28.00	8.00	4.00	3.00	11.00
Expected	10.21	15.79	12.57	19.43	19.43	7.29	5.50	8.50
X Sp	5.93	3.84	5.84	3.78	3.78	1.48	1.14	0.74

Sum X Sqd 25.04 DF=3
Probability P=0.0005 Null Hypothesis rejected

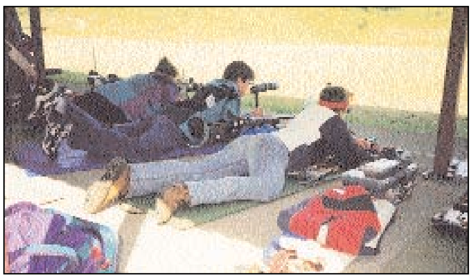
Lighting conditions

The results in **Figure 5** (favourite colour indoors versus outdoors) suggest that colour preference is not greatly affected by lighting conditions, but this was a young group and does not take age or pathology into account **(Figure 9)**. This was a small sample and not all those who were tested indoors repeated the test outdoors.

Colours choice	Indoors N=26	%	Outdoors N=26	%
Green Blue Grey	11	42	6	40
Yellow Orange	12	46	9	60
Pink	3	11	-	-

Figure 9
Effect of illumination on colour preference indoors vs outdoors

Shooters have to deal with varying light conditions



Contrast sensitivity is the first victim of macular degeneration

Discussion

The range of response varied from very strong feelings (immediate removal of the head from behind lorgnette or saying this makes me feel sick) to complete indifference. Very strong feelings against one tint were often balanced by a strong liking for another tint in the same subject.

The Chi Squared Test (p=0.0005 is highly significant) seems to confirm that colour choice is quite specific and not random.

The results suggest that the groups as a whole were different and that individuals within the groups also have different choices. Physiology and the known physical properties of light may help to explain this.

Tint prescription

The tint that is prescribed needs to take into account colour preference, which may be a summation of psychological, neurological and physiological characteristics, as well as its physical properties.

Blue/green and yellow/orange

These groups were almost mutually exclusive. Of all negative responses, the greatest was to yellow and orange and this was very often in blue-eyed subjects.

Yellow

A yellow filter increases the contrast between that colour and the surrounding colours, this concentrates light in the area of the spectrum to which the eye is most sensitive. If an individual is already light-sensitive then the experience is heightened looking through a yellow or orange filter.

Someone who is not light-sensitive would appreciate the contrast-enhancing elimination of the blue/ultraviolet (UV) end of the spectrum.

Blue versus yellow

In particularly light-sensitive individuals the light scattering effect of blue light is outweighed by the relief they get from the elimination of peak sensitivity wavelengths in the yellow and orange.

If, however, there are media changes which increase the scattering effect of blue and UV then preference may change. In light-sensitive people this would be towards a longer wavelength like green, which absorbs blue and UV but still subdues the effect of yellow and orange. Someone who is less light-sensitive but still has some clouding of the media might choose orange (the effect of a brown tint) which will reduce general light levels and eliminate blue and UV.

It could be concluded from this that a best choice of blue and a worst choice of yellow is diagnostic of clinically significant light sensitivity in a (young) healthy eye.

Looking at the frequency of choice of blue and yellow shows that the characteristics of the two groups are very different **(Figure 10)**.

No.	Colour	Best	Worst	Best	Worst
2	Yellow	14	3	2	18
3	Blue	3	5	8	2

The yellow contrast-enhancing filter is likely to be favoured in a visually demanding sport like shooting, but it also implies that shooters do not tend to be light-sensitive. In the older group, the umpires, the tendency is completely reversed. Perhaps this is an ageing effect due to benign media opacities or perhaps umpires self select because of the mainly indoor nature of netball and a natural sensitivity to light

Figure 10
Choice of yellow and blue

Blue/grey

If there is a strong preference for blue, its prescription for outdoor use should be avoided because:

- It is likely to transmit the more dangerous high energy part of the spectrum (short wavelength blue and UV). The eye's lack of sensitivity to this part of the spectrum adds to the danger
- The darkening effect of blue would allow the pupils to dilate and increase exposure

In young, light-sensitive children, a suitable alternative would be neutral grey or green, with a UV block, if there is a high transmission factor, say LT 60 and above.

Pink and violet

These colours are at opposite ends of the spectrum and were only grouped together because as a pair they were the least popular, that in itself makes their choice, when it occurs, interesting.

Violet was the least chosen tint of all and it may be that the glare due to short wavelength transmission and the darkening effect, was too great even for light-sensitive subjects.

Pink

When the choice of tint was compared for light (blue/green irides) and dark (brown irides), the most popular tint for dark eyes was pink, which was not chosen by any of the umpires with light coloured eyes **(Figure 11)**.

This could suggest that vision in brown eyes, which are more prone to early lens changes, degrades as the pupil expands. The pupil in a blue eye might expand less because the eye is relatively more sensitive even in low light levels. Pink has the bright feel favoured by non light-sensitive subjects and is still a good UV and blue light absorber.

Pink/red has been shown to be useful in hue discrimination in colour blindness and early results in the author's unpublished research, points to migraine sufferers making this unusual choice. Pink might be the colour of choice when there are neurological problems as opposed to physical and physiological.

In colour deficiency a red tint has helped hue discrimination. This effect might be enhanced by relating the tint to the anomaly, a red tint for protanopes and a green for deuteranopes. It is possible that the choice will not be as simple as this (or the reverse, red for deuteranopes) or that the greatest effect is achieved by another colour or different colours in each eye.

	Light eyes	Dark eyes
Green	33.3	21.4
Blue	33.3	21.4
Pink	0	35.7

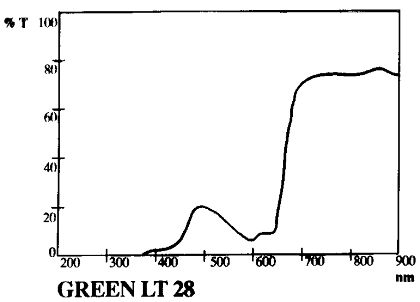
Figure 11
Tint preference, most preferred, for light and dark eyes In the panel umpires (%)

Green

The choice of green is interesting because it has good UV and blue light absorption, but has a peak of transmission quite close to yellow. It should also have good IR heat-absorbing properties. This combination of factors would maximise visual information while providing necessary protection from peak brightness in the yellow. The pupil would remain relatively constricted and heat effect minimised.

The transmission curve for a typical green tint illustrates the peak in the most visible part of the spectrum and absorption of the shorter blue and UV wavelengths **(Figure 12)**.

Figure 12
Transmission spectrum for a green tint, (IR absorption not measured)



Conclusion

The colour preference test provides a quick and convenient way of measuring colour preference, as well as giving an indication of light sensitivity. It enables an informed choice of tint to be made, which in turn helps to assess the need for further investigation.

The results indicate that there is a need to screen all children and adults who are in any way symptomatic or predisposed to light sensitivity. This includes children with reading difficulties and adults with pathologies which are known to cause photophobia. Light sensitivity may be an indication of a predisposition to long term macular problems in an eye which does not have natural pigment protection.

Future research

Several points follow from the results and discussion which could be the subject of future research

- Blue eyes may be prone to macular degeneration because of the lack of protection from a yellowing, sclerotic lens
- Brown eyes may be prone to cataract
- There may be a measurable effect on accommodation in a hardening lens which is greater in a brown eye than a blue eye
- Early cataract extraction leaves the macular even more susceptible to the effects of short wavelength and intense visible light
- Colour preference may influence the choice of tint in the enhancement of hue discrimination in colour deficiency
- Colour preference may be relatively unaffected by varying light conditions with reasonable colour rendering

The correct prescribing of tints is entirely within the province of general practice and a powerful tool in the relief of symptoms and visual enhancement. It also paves the way for future research and developments in the prevention of eye disease.

Light Sensitivity and Colour Preference test (LSCP) test available:
Lafayette Instrument,
Europe (Inc Campden Instruments),
4 Park Road, Sileby,
Loughborough, LE12 7TJ.
Telephone: 01509-817700

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About the author

Geraint Griffiths is a founder committee member of the Sports Vision Association and is also Editor the SVA Journal. He is a former British International high jumper and Clinical Director for Sport Vision Services.

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