

**The Effect of Coloured Lenses on the Visual Evoked Response
in Children with Photophobia**

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Abstract

Background: Some children with photophobia or headaches have fewer symptoms when wearing coloured lenses. Although subjective reports of improved perception exist, few objective correlates of these effects have been established.

Methods: In a pilot study, 10 children who wore Intuitive Colorimeter® lenses, and claimed benefit, were tested. Steady-state potentials were measured in response to low contrast patterns modulating at a frequency of 12Hz. Four viewing conditions were compared: (1) no lens; (2) Colorimeter lens; (3) lens of complementary colour; and (4) spectrally neutral lens with matched photopic transmission.

Results: Two asymptomatic children showed little or no difference between the lens and no lens conditions. When all the symptomatic children were tested together, a similar result was found. When the children were divided into two groups depending on their symptoms, an interaction emerged. Children with visuoperceptual distortions but no headaches showed the largest amplitude VEP response in the no lens condition, whereas those children whose symptoms included severe headaches or migraine showed the largest amplitude VEP response when wearing their prescribed Colorimeter lens.

Conclusions: The results suggest that it is possible to measure objective correlates of the beneficial subjective perceptual effects of coloured lenses, at least in some children who have a history of migraine or severe headaches.

Keywords: asthenopia, Meares-Irlen syndrome, migraine, visual evoked potentials, coloured lenses, photophobia

Introduction

Irlen (1983, 1991) introduced the use of ophthalmic tints to treat a disorder of visual perception now termed “Meares-Irlen syndrome”^{1,2,3}. Anecdotal reports of the success of her tinted lenses were met with scepticism justified by the lack of scientific evidence. Recently, however, Wilkins and co-workers^{4,5} developed an alternative method of prescribing coloured glasses. The method has the advantage that colours are searched systematically and comprehensively and an optimal tint is provided with minimal absorbance of light. Central to the method is a simple optical device (*Intuitive Colorimeter*) that optimises the tint while the eyes are colour-adapted. The hue and saturation are alternately adjusted so as to reduce perceptual distortions to a minimum with coloured light of an optimum chromaticity. Tinted trial lenses can be selected that match the chromaticity of the optimal coloured light and provide a spectral match to that obtained when the lenses are worn under conventional (CIE type F3) fluorescent lighting. In a double-masked trial, patients reported fewer episodes of headaches and eye-strain when they were wearing a tint of the optimal colour as compared to a sub-optimal tint of similar but not identical colour⁶. The coloured filters have also been shown to increase reading speed in individuals with a range of neurological disorders^{7,8}.

Comment:

Wilkins⁹ has advanced a theory that coloured glasses reduce pattern glare to which individuals with migraine are particularly susceptible as the result of a cortical hyperexcitability. Children who find coloured overlays and glasses of benefit are more likely to have a family history of migraine¹⁰.

Although the above studies go some way towards a scientific justification for treatment with coloured glasses, an objective physiological index of their benefit is clearly desirable, given the uncertainty and controversy that still surrounds their use. The question arises as to whether the individuals who report benefit from coloured glasses have abnormal visual evoked potentials, and, if so, whether any abnormalities they may exhibit are reduced when the appropriately prescribed coloured glasses are worn. That such differences exist is suggested by reports that the visual evoked potential is sometimes abnormal in migraine¹¹, and that the visual cortex is hyperexcitable in migraine

Here we report the results of a study in which we examined the steady state visual evoked response while children wore: 1) no lens; 2) the coloured lens they had been prescribed using the Intuitive Colorimeter; 3) a lens with spectrally uniform density and similar photopic transmission; and 4) a lens of a colour complementary to that of the child’s prescribed lens. The evoked potential was measured in response to patterns that repeatedly increased or decreased in contrast relative to a steady background. We predicted that the VEP response would be closer to normal while the children were wearing the prescribed lens.

Methods

Participants

Thirteen children who had previously been prescribed coloured lenses to relieve symptoms of headaches or asthenopia were tested in this study. The participants were a heterogeneous sample of individuals who responded to press coverage concerning the use of coloured lenses for treatment of reading difficulty. Three of these participants were not included in the final analysis because they failed to provide enough VEP data. The tests were stopped in two of these cases because the children found the stimulus uncomfortable to view in the no lens condition. These two children were the youngest tested (9 and 11 years). The third child omitted from the analysis failed to complete all conditions due to technical problems.

Table 1 presents a summary of the clinical details of subjects included in the study. The aetiology is heterogeneous, but all children had a history of visuo-perceptual distortion, reduced by colour. Two children who did not wear lenses and had no history of any headaches or other visual symptoms were also tested as asymptomatic controls.

- Table 1 about here -

VEP Recording and Analysis. Three standard gold cup electrodes were placed on midline sites according to the International 10-20 system¹³. One electrode was placed at O_z (near the occipital pole) and was referenced to a second electrode placed at C_z (the vertex of the head). A floating ground was placed on the participant's forehead. Data were collected and analysed using a VENUS system (Neuroscientific Corp.). A differential amplifier with low and high corner frequencies set at 1 and 100 Hz respectively was used to amplify the signal by 20,000. The amplified EEG, synchronized to the temporal modulation of the stimulus, was then digitized and stored on computer for later analysis. A discrete Fourier transform was used to calculate amplitude (microvolts) and phase (degrees) of the relevant frequency components of the VEP. The component of interest was the fundamental component (at the stimulus frequency). A multivariate noise estimate was obtained by dividing the one-minute EEG record into 6 epochs, each containing 10 s of data. This epoch duration is considered sufficiently long that successive blocks can be treated as independent for the purpose of the analyses¹⁴.

Stimuli

Stimuli were presented on a Princeton Graphics colour display (Ultrasynch RGB monitor) with a surrounding mask to give a 16cm square screen size. The system was set up with only the red and green guns connected, with the red/green ratio adjusted to produce a yellow hue (CIE UCS chromaticity 0.18, 0.55). The isolated-check stimuli used were modulated from 0% to 16% contrast against a uniform field that had a fixed luminance of 60 cd/m². Contrast is here

defined by the Weber contrast: $C=(L_c-L_b)/L_b$, where L_c is the maximum (or minimum) luminance of the bright (or dark) checks, and L_b is the luminance of the background. Contributions from the ON and OFF subdivisions of the visual system were considered separately by modulating the isolated checks either above (*positive* contrast) or below (*negative* contrast) the background luminance¹⁸, resulting in the appearance and disappearance of bright and dark checks respectively.

Participants viewed the isolated check stimuli monocularly, through their right eye, at a viewing distance of 1.14 m. At this distance, the display subtended a visual angle of 8 degrees square. The check size used was 0.25 degrees square and temporal frequency was 12 Hz. Monocular viewing was used to reduce the unpleasantness of the stimuli.

Lenses

Each participant was tested in four lens conditions: In one condition the child wore the coloured lens they had been prescribed. In another condition the child wore a plano lens of complementary colour. If the prescribed lenses included a refractive correction then clear spherical, or cylindrical trial lenses were added so as to provide the same correction. In another condition the child wore a lens of neutral density and photopic transmission similar to that of the prescribed lens, together with any refractive trial lenses required. In the final condition no absorbtive lenses were worn and the child wore either no lenses or the necessary refractive trial lenses. The order of condition was randomised across participants. Asymptomatic controls were tested using a yellow and a blue tint of density similar to that of lenses those used by other participants.

Results

Asymptomatic Participants

- Figure 1 about here -

The two asymptomatic control children showed no differences when tested with or without lenses (Figure 1a-d), except in one condition. The amplitude of the response in the no-lens condition was significantly different from the blue-lens condition (Figure 1b: $F(3,20)=4.41$, $p=0.016$). It is clear from Figure 1b that the amplitude of the response was greater in the no-lens condition than in the other conditions, and that this reached significance in the blue-lens condition.

Overall results for children who wore lenses:

- Figure 2 about here -

A similar pattern of results was seen when all the children who wore lenses were considered as a group (Figure 2 a & b). There were no significant differences in the amplitude or phase responses between the different lens conditions using either bright or dark targets.

Results for children who wore lenses grouped by symptoms

The symptoms of the children who had been prescribed lenses were used to divide children into two groups: those with a history of migraine or severe headaches and a family history of migraine (n=6), and those with visuoperceptual distortions as their main symptom, with no history of headaches (n=4). Group VEP responses were then tested to identify if there were any between-group differences.

A 2x2x4 MANOVA with migraine versus no migraine, bright versus dark target, and lens condition as factors, and amplitude and phase as dependent variables was run. This produced no significant three-way interactions. There was also no significant interaction between lens and target. There was a significant interaction between migraine and target for both amplitude ($F(1,464) = 4.86, p = 0.03$) and phase ($F(1,464) = 11.4, p = 0.01$). This is due to the larger amplitude response and increased phase lag found for the bright target in the group with migraine (Table 2).

- Table 2 about here -

There was also a significant interaction between migraine and lens for amplitude only ($F(3,464) = 6.1, p = 0.000$). This is due to an interaction between the prescribed lens and other lens conditions: In the prescribed lens condition the children with no migraine have lower amplitude responses than in other conditions, whereas the children with migraine have higher amplitude responses (Table 3).

- Table 3 about here -

There were main effects for each factor. The main effect for target was found only for the phase response ($F(1,464) = 39.3, p = 0.000$) where bright targets were found to produce a phase lag while there was a small phase lead for the dark targets (Bright targets: mean = -36.65 degrees, SD = 59.68; Dark targets: mean = 0.80 degrees, SD = 58.43). The main effect for lens was also found only in the phase response ($F(3, 464) = 3.74, p = 0.11$) where the no lens condition has a smaller phase lag than other lens conditions (no lens: mean = -1.45

degrees, SD = 54.43; own lens: mean = -22.01 degrees, SD = 57.44; comp lens: mean = -22.16 degrees, SD = 71.75; ND lens: mean = -26.09 degrees, SD = 60.32). The main effect for symptoms was found in the amplitude response ($F(1,464) = 8.8, p = 0.003$) where the children with migraine show higher amplitude responses across targets and lens conditions than the children with no migraine (no migraine: mean = 1.88 microvolts, SD = 1.07; migraine: mean = 2.19 microvolts, SD = 1.17).

- Figure 3 about here -

Figure 3 a-d shows the amplitude and phase response for the bright and dark targets for each lens condition for children with and without migraine as a symptom. Comparison of the amplitude responses for the bright checks shows that there is an interaction between the symptom groups. Planned comparisons were used to test for between-group differences. These demonstrated that there are significant differences in amplitude between the no lens condition and both the prescribed lens (two-tailed t-test: $t=3.4, df= 45, p = 0.001$) and neutral density (two-tailed t-test: $t=2.72, df = 45, p = 0.009$) conditions in the group with no history of headaches. In the group with migraine, there are significant difference between the prescribed lens and both the no lens (two-tailed t-test: $t = -2.67, df = 57, p = 0.01$) and neutral density (two-tailed t-test: $t = 3.03, df = 56, p = 0.004$) conditions. The children with no migraine show the largest amplitude of response in the no lens condition, while the children with migraine show the largest amplitude when wearing their own lenses. The pattern of results is similar for the dark target, but the differences in this condition do not reach significance.

Discussion

In this study, an objective measure, the VEP, was used to investigate physiological correlates of the subjective reports of benefits from the use of coloured lenses. In the two asymptomatic control children tested, there were only small differences in VEP response between the lens and no-lens conditions. In the condition where there were differences, these were attributable to the larger amplitude of response in the no-lens condition. This difference could be the result of the difference in luminance between the no-lens condition and the remaining conditions, due to the absorption of the various filters. Thus, when there is no lens, the overall luminance of the target is greatest, leading to the largest amplitude of response. This pattern of response was found in one of the two asymptomatic subjects. In the other subject, all lens conditions produced similar amplitudes of VEP responses.

The overall group results for all the children who wore lenses were found to show a similar pattern to that of one of the two controls, in that there were no significant differences in response across lens conditions.

Children who were prescribed lenses could be divided into two groups on the basis of their symptomatology. Four children from the lens wearing group had no history of headaches, while the other six children in this group all had history of severe headaches or migraine, and a family history of migraine. The children were therefore divided into these two groups to determine if there were between group differences in the VEP response.

The results showed an interaction between the lens conditions and symptomatology that was significant for the bright target. Children with no history of migraine (subjects 1-4) showed the same pattern of response as one of the asymptomatic children in that the amplitude of the VEP response was largest for the no lens condition. The remaining six children (Subjects 5-10) again showed differences between the coloured lenses and the no lens conditions. In these children, however, the VEP responses were *larger* for their prescribed lens when compared to either the no lens or the neutral density lens conditions. This suggests that these children were gaining some visual benefit from their prescribed lens in comparison to either no lens or a lens with similar overall absorption but no colour specificity, and in this respect at least, the response differs from that obtained in the controls.

While the testing was in progress, the children were asked if they were aware of any differences in the patterns they were seeing when wearing the coloured lenses or when the lenses were removed. In two cases (e.g. Subject 7 and ?) the child reported that the image would sometimes blur in the no-lens condition but this blurring was not seen when wearing a coloured lens. This might be helpful in explaining the findings. One possible reason that there was a change in the VEP response while wearing a coloured lens is that there was an effect on the accommodative response of the child. Variations in accommodation during the time that the child is viewing the VEP stimulus can result in variations in the latency of the VEP response ref. Variability in the phase response can result in a decrease in the amplitude of the response. If the coloured lenses reduce the amplitude of accommodative fluctuations, this could result both in an increase in the amplitude of the VEP response and perhaps also to a decrease in symptomatic headaches. Simmers et al.²⁰ have shown a reduction in accommodative fluctuations with a prescribed coloured lens but this was apparently dependent on luminance rather than chromaticity.

The above results suggest that while no clear objective VEP differences can be measured in all children who claim benefit from the use of coloured lenses, there are differences in the

VEP responses for at least some of this population. When the symptoms of the different groups are examined, it can be seen that the presence or absence of migraine is useful in categorizing the differences in VEP outcomes. Children with headaches and migraine appear to benefit from the prescribed lens in that this leads to an increase in the amplitude of the VEP response. In comparison, the children without a history of migraine and headaches showed a similar pattern of response to asymptomatic children in that the largest amplitude VEP response was found in response to the no lens condition. Although this result is limited by the small population tested, it does demonstrate that it is possible to find objective differences in VEP response when children are wearing their prescribed lenses—at least for children who experience migraine and headaches.

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ID	Sex	Age	Optometric Findings	Tint	Lens use	History
1	M	12	Slight hypermetropia in both eyes.	Green-Turquoise	3 months	Visuo-Perceptual (VP) distortions. Reading difficulty. Brother has migraine
2	F	11	Slight hypermetropia in both eyes, corrected	Blue-Turquoise	2 months	VP distortions
3	F	16	Slight myopia in both eyes, corrected.	Blue-Purple	13 months	VP distortions
4	F	15	No optometric problems	Yellow	6 months	VP distortions
5	M	11	Convergence insufficiency treated with exercises	Blue-Purple	9 months	Frequent migraine. Family history of migraine and epilepsy. VP distortions.
6	M	16	No refractive correction.	Green	4 months	Severe frequent headaches. Mother has migraine. VP distortions. Reading difficulty.
7	M	13	Slight astigmatism in both eyes, corrected.	Blue-Turquoise	18 months	Migraine. Mother has migraine. VP distortions.
8	M	15	No refractive correction.	Green-Turquoise	5 years	Headaches. Mother has migraine. VP distortions. Reading difficulty.
9	M	12	No refractive correction.	Blue-Turquoise	0 months	Migraine. Mother has migraine. VP distortions.
10	F	9	Marked deficiency in convergence and fusional reserves.	Blue-Purple, +1DP	15 months	Frequent migraine. Family history of migraine and epilepsy. VP distortion.
C1	F	13	Myopia in both eyes, corrected.	No lenses	N/A	No headaches or other visual symptoms
C2	F	15	No refractive error	No lenses	N/A	No headaches or other visual symptoms

	Bright Target		Dark Target	
	Amp (Microvolts)	Phase (Degrees)	Amp (Microvolts)	Phase (Degrees)
No Migraine	1.86	-25.28	1.91	-9.69
Mean (SD)	(1.20)	(60.98)	(.93)	(56.81)
Migraine	2.39	-44.23	1.99	7.78
Mean (SD)	(1.44)	(57.76)	(.78)	(58.64)

Table 2

Amp (Microvolts)	No Lens	Own Lens	Comp Lens	ND Lens
No Migraine	2.32	1.62	1.81	1.78
Mean (SD)	(1.06)	(0.97)	(1.19)	(0.95)
Migraine	2.07	2.59	2.15	1.94
Mean (SD)	(0.87)	(1.40)	(1.33)	(0.91)

Table 3

Figure Legends

Figure 1 (a-d): Plots of the amplitude and phase responses for two control subjects using bright (ON) and dark (OFF) check stimuli. Each graph shows the VEP response for four conditions: NL – no lens; YL – yellow lens; BL – blue lens and ND – neutral density lens.

Figure 2 (a-b): Plots of the amplitude and phase responses for all 10 lens wearers combined. Each graph shows the VEP response for four conditions: NL – no lens; OL – own, prescribed lens; CL – lens of a complementary colour; ND – neutral density lens.

Figure 3 (a-d) Plots of the amplitude and phase responses for the lens wearing subjects grouped by symptoms. Each graph shows the VEP response for four conditions: NL – no lens; OL – own, prescribed lens; CL – lens of a complementary colour; ND – neutral density lens.