A Hospital-Based Cross-Sectional Study to Estimate the Prevalence and Sex Distribution of Colour Vision Deficiency among School Going Children Attending a Tertiary Eye Care Center in Kolkata City, West Bengal, India

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ABSTRACT

BACKGROUND

Colour vision is a function of three types of cone pigments present in the retina. Colour vision deficiency is an important disorder of vision that may pose a handicap to the performance of an affected individual. The prevalence of colour blindness varies in different geographical areas. The identification and estimation of the prevalence of colour vision deficiency in school-going children will help to educate and guide the caregivers to help the children in selecting their profession. This study was done to estimate the prevalence, sex distribution, and types of colour vision deficiency among school-going children of 5 to 15 years.

METHODS

A cross-sectional observational study was done among 500 students to evaluate the colour vision during the period from 1st January 2018 to 30th June 2019 at the Regional Institute of Ophthalmology, Kolkata. Ishihara's pseudo isochromatic colour vision chart 38th edition was used to assess the school children for colour vision status. The children who were found to be colour blind were further classified into degree and types of colour vision deficiency.

RESULTS

A total of 500 students (250 male & 250 female) of surrounding schools, in the age group of 5 years to 15 years, were screened. 480 students (96 %) had normal colour vision while 20 (4 %) students were found to have defective colour vision. Prevalence (4 %) for colour blindness was found to be higher in males (3.6 %) than females (0.4 %). It was observed that out of 20 (4 %) colour-blind subjects 3.6 % were protanopes and 0.4 % were deuteranopes.

CONCLUSIONS

The present study shows the prevalence of colour blindness found to be quite low (4 %) and more common in males (3.6 %) in comparison to females (0.4 %). Protanomaly (3.6 %) was more common than deuteranomaly (0.4 %).

KEYWORDS

Colour Blindness, Protanomaly, Deuteranomaly, School Children

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DOI: 10.18410/jebmh/2021/541

How to Cite This Article:
Saha R, Sarkar I, Chatterjee T, et al. A hospital-based cross-sectional study to estimate the prevalence and sex distribution of colour vision deficiency among school going children attending a tertiary eye care center in Kolkata city, West Bengal, India. J Evid Based Med Healthc 2021;8(32):2962-2967. DOI: 10.18410/jebmh/2021/541

Submission 25-02-2021,
Peer Review 03-03-2021,
Acceptance 24-06-2021,
Published 09-08-2021.

BACKGROUND

Colour vision deficiency (CVD) or colour blindness, is the inability or decreased ability to distinguish different colours under normal lighting conditions.[1] Light with a wavelength of approximately 380 – 740 nm causes a photochemical reaction on the human retina which leads to colour vision. Because all colours are a result of admixture in different proportion of 3 primary colours: Red (723 – 647 nm), green (575 – 492 nm), blue (492 – 450 nm).[2] It is one of the important disorders of vision[3, 4] The incidence of CVD varies according to race and geography.[4,5] However, most colour-blind cases remain undetected due to the lack of proper screening.[6]

Colour vision deficiency may be congenital or acquired. Alterations of the three (Red, Green, Blue) cone pigments are responsible for colour vision defects. Ocular or neurological disease, some metabolic disorders, drug toxicity and exposure to certain solvent[6,7] are important causes of acquired colour vision defect. Acquired blue-yellow colour vision deficiency is commonly seen in central serous chorio-retinopathy, macular oedema, shallow retinal detachment while optic nerve disorders like optic neuritis, Leber's hereditary optic neuropathy and compressive optic neuropathy manifest as relative red green deficiency. Blue colour perception defect may be seen in cataracts due to the physical absorption of blue rays by the increased amber-coloured pigments in the nucleus. Some drugs may lead to transient changes in colour vision like phosphodiesterase type 5 inhibitors such as sildenafil, digoxin, ethambutol, and anti-malarial drugs.

Congenital colour defects are non-pathological, incurable, and constant.[8] It is commonly an X-linked recessive disorder affecting 8 % of males and 0.5 % of females.[3] Red-green colour blindness, and other X-linked recessive inherited disorder, occurs predominantly in males and female usually acts as a carrier. Congenital CVD is divided into two types, dyschromatopsia and achromatopsia. Dyschromatopsia is again classified into three types: Protanomalous, deuteranomalous, and tritanomalous. In 1798, John Dalton discovered colour blindness.[9] Trichromatic theory of Young Helm Holtz[10] postulates the existence of three kinds of cones, each cone containing different photopigments that are maximally sensitive to one of three primary colours: Red, green and blue. The sensation of any given colour is determined by the relative frequency of the impulse from each of the three-cone systems. The genetics of colour vision deficiency are as follows:

Protanopia is caused by the complete absence of red retinal photoreceptors while the absence of green retinal photoreceptors causes deuteranopia. Protanomaly or red weakness is characterized by anomalous red cones (Long-wavelength L cones) whereas deuteranomaly or green weakness is characterized by anomalous green cones (Medium wavelength M cones). These subjects are regarded as anomalous trichromats and though they recognize colour in the red-green region, the colour saturation is weakened. There is another type of CVD, tritanopia which is caused by a missense mutation of the gene on chromosome 7. This gene encodes the short wavelength S or blue retinal cone pigment. People affected by tritan colour blindness confuse blue with green and yellow with a violet colour. Unlike the red-green CVD, tritan defects are found in both males and females equally as it is an autosomal dominant trait and are very rare. Another CVD, achromatopsia, or total colour blindness is characterized by reduced visual acuity, photophobia, and reduced or complete loss of colour discrimination. It has an autosomal recessive inheritance and the associated genes are present on chromosomes 1,8,10, and 12.

Currently, there is no treatment for inherited /congenital colour blindness. The prevalence of colour vision deficiency varies according to races, tribes, and ethnic groups. However, a high proportion of school children, their teachers, and parents are unaware of their colour vision status and it may pose a difficulty in their future life.[11] Taking these aspects into account, our study was done to detect the prevalence of colour blindness in school children in Kolkata so that they can be educated properly and guided in choosing their profession in the future. This study will also be helpful to the colour-blind students to know their disability and to adjust appropriately for the learning process. The tests which are used in screening and detection of colour vision deficiency are as follows Ishihara's pseudo-isochromatic colour vision charts, Nagel anomaloscope test, Farnsworth-Munsell hundred 100 hue test, and Holmgren wools.

Objectives

This study was done to estimate the prevalence, types, and sex distribution of colour vision deficiency among school-going children (5 - 15 years.).

METHODS

This cross-sectional study was conducted at the Regional Institute of Ophthalmology (RIO), Medical College, Kolkata from January 2018 to June 2019. The study was initiated after obtaining approval from the Institutional Ethical Committee, RIO, Kolkata, and conformed to the Declaration of Helsinki.

A total of 500 students (250 boys and 250 girls) in the age group of 5 to 15 years were included in this study after taking approval from the school principal. The required sample size was calculated using the statistical formula for single population proportion with confidence interval 95 %, margin of error 2 %, and population proportion of defective colour vision as 4.2 % [12] from previous studies. Hence the final sample size was ≥ 385. Students with ocular pathology, trauma, and previous ocular surgery were excluded from the study. Informed consent was taken from each student's caregiver. In each school from grade 1st to grade 10th, all students were called according to their roll number and complete history taking, examination of vision, refraction, and detailed anterior and posterior segment examination of the eye were performed to rule out other pathologies / ocular disease. Refractive corrections were given and each eye was tested for colour vision separately for colour

blindness using Ishihara's pseudo isochromatic colour vision chart 2008 edition (38 plates), held at 40 cm distance in an adequately lighted room. Students were asked to recognize the number and the figure on a chart within 3 - 5 seconds and write the number seen in a plate and again, the other eye closed, and the test was repeated. The students were evaluated according to the interpretation obtained from the chart in the back of Ishihara book whether as normal colour vision or which type of colour deficient. Both partial and complete colour blindness were included in the study. Students having mono ocular / different colour blindness between two eyes were also excluded from the study.

Statistical Analysis

The data obtained was arranged in tables, bars, and charts and descriptive statistics was used. Data were analyzed by epi info software version 7 (USA). A chi-square ($\chi 2$) test of independence was performed to examine the relationship between gender and colour-blindness and $P < .05$ was considered as statistically significant. The relation between gender and colour-blindness was significant, $\chi 2$ (1, N = 500) = 13.3333. P = .000261.

RESULTS

A total of 500 students (250 boys and 250 girls from randomly selected schools) were screened in this study in an age group of 5 to 15 years. After careful examination, it was noted that 96 % (480 students) were found to have a normal colour vision while only 4 % (20 students) were having defective colour vision. In our study, no case of total colour blindness was detected. Therefore, the estimated prevalence of colour vision deficiency was 4 %. Among the enrolled subjects, no students showed evidence of ocular pathology. Most of the CVD students were unaware of their defect.

No. of Students	Normal Colour Vision	Defective Colour Vision
500	480	20

Table 1. Prevalence of Normal/ Defective Colour Vision among School Going Children

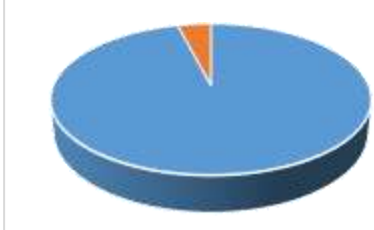

Figure 1. Prevalence of Normal/Defective Colour Vision

Protanomaly	Deuteranomaly	Tritanomaly	Total
18 (3.6 %)	2 (0.4 %)	0 (0)	**20 (4 %)**

Table 2. Types of Colour Vision Deficiency among School Going Children

Protanopia (3.6 %) was found to be more common than deuteranopia (0.4 %). Protan: deutan ratio in our study was 9 : 1.

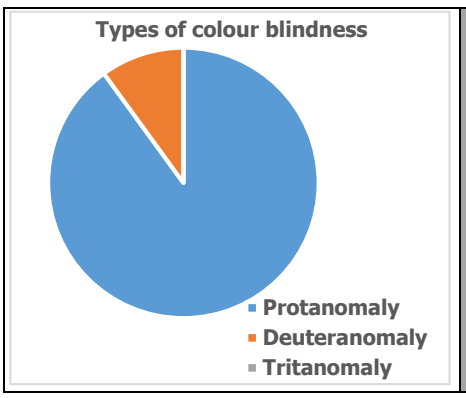

Figure 2. Distribution of Colour Vision Deficiency

CVD	Protanomaly	Deuteranomaly	Tritanomaly	Total
Male	16 (3.2 %)	2 (0.4 %)	0	18 (3.6 %)
Female	2 (0.4 %)	0	0	2 (0.4 %)
Total	**18 (3.6%)**	**2**	**0**	**20 (4%)**

Table 3. Sex Distribution of Colour Vision Deficiency among School Going Children

In this study, the gender-based differences in the prevalence of colour vision deficiency was found to be statistically significant ($P < .05$), with a higher prevalence among male (3.6 %) as compared to female (0.4 %) students. Male : female ratio was also 9 : 1 in our study. Among the 18 colour blind boys, 16 were protanopes and 2 were deuteranopes. Out of 2 colour blind girls, all were protanopes.

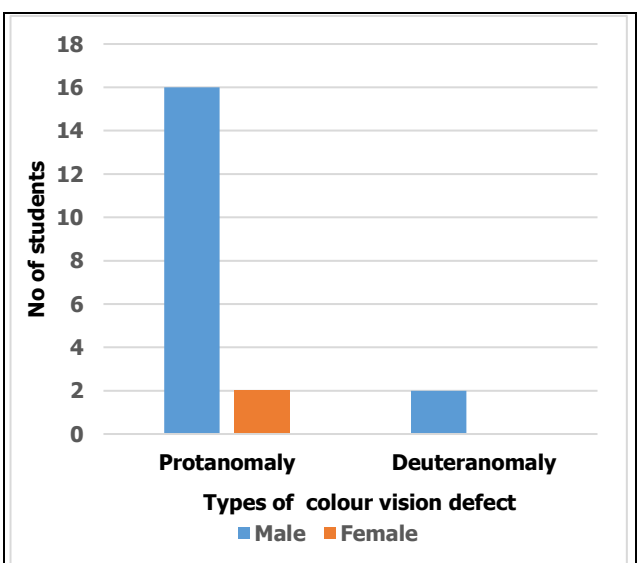

Figure 3. Sex Distribution of Colour Vision Defect

DISCUSSION

Colour vision can be described in terms of hue (determined by wavelength discrimination), lightness, and saturation. Those with colour vision defects have only defective colour discrimination to a greater or lesser degree. In CVD, discrimination is less accurate in the middle of the spectrum and deteriorates rapidly at the end of the spectrum.

Opponent ganglionic cell system is that when some of the ganglionic cells are excited by one colour type cone and inhibited by other types cone, whereas double opponent type of ganglionic cells have an opponent for both colour and space receptive field. To study the prevalence of colour vision deficiency in the community many studies have been carried out in past. This study provides knowledge on the prevalence and types of colour vision deficiency among school-going children attending tertiary care center in Kolkata. It will help to build up a basic database on the prevalence of colour blindness among school children in the study area. Colour vision screening should be performed for early detection of colour vision deficiency to reduce the difficulties in life. In the present study, acquired causes of colour vision deficiency were found to be nil. Thus, the possible mechanism of colour blindness was congenital in our study group.

In the present study, the prevalence of colour vision deficiency was 4 % which is similar to other studies in Thailand[13] & Britain.[14,15] But it is higher than the other studies. Niroula DR et al.[4] reported the prevalence among 964 participants as 1.9 % in Pokhara in Western Nepal. Tabansi PN [16] reported it as 2.6 % among 1300 students in Port Harcourt City in Nigeria. Yasmin A et al.[17] reported it as 1 % among 500 school children in Dhaka City in Bangladesh. The difference in results may be due to the different ethnicity and difference in the sample size in other studies.

In the present study, the prevalence of colour blindness among female students was 0.4 % which was similar to the previous researches done in Saudi Arabia 0.75 % (Oriowo and Alotaibi),[18] India 1.04 % (Mehra),[19] Punjab 1.15 % (Bansal).[20]

In our study of 500 students, protanomaly was more common (3.6 %) showing a higher prevalence among males. A similar trend had been reported in earlier studies.[21,22] A study among 941 healthy men from the Turkish army has reported the prevalence of red-green colour blindness as 7.33 +/- 0.98 % (5.10 % protanopes and 2.23 % deuteranopes).[23] This result was higher than other reported samples from Mediterranean Europe. Higher percentages of colour blindness may be due to lower education levels and more consanguineous marriages.

The most important cause of vision impairment in the current study was not a refractive error which is supported by a similar study in Nepal.[24] Colour vision deficiency was found to be 3.6 % among males and 0.4 % among female children. Although, the male : female ratio is different in different studies, many published literatures showed a higher prevalence of CVD among males compared to females. In our study this was 9 : 1. The frequency of red-green colour blindness among male was found to be higher than female in Libya (2.2 %),[21] Saudi Arabia (2.9 %),[25] Nepal (3.9 %),[26] Singapore (5.3 %),[27] Thailand (5.6 %),[28] Iran (8.1 %),[29] Jordan (8.7 %),[30] and Eastern India (8.73 %).[19] This is due to X linked recessive nature of the red green deficiency making it more predominant in males.

Colour vision test using Ishihara's chart[31] helps in the diagnosis of congenital colour vision deficiency in the mass population because it is an easier and quicker device and also reliable. Previous studies have shown the test chart has a sensitivity of 97.7 % and specificity of 98.4 %[32] Hence, Ishihara's test plates have been used in mass screening for the diagnosis of colour blindness for a long time.

The risk of transmitting the colour vision disorder to their offspring can only be reduced by identification of colour deficiency among populations. Colour vision deficiency,[33] haemophilia, Duchene muscular dystrophy are caused by mutant genes on the X chromosome. Therefore, X-linked colour blindness appears in the male at every second generation. India is acknowledged for being a rapidly developing country and a large proportion of the population belongs to the juvenile age group. As CVD does not cause complete blindness and the condition persists from the birth of the affected individuals whose experience of colour is different from that of normal individuals, it is very difficult to make them know about their deficiency. In our study, majority of the students did not undergo eye examination at all before the study. Majority of the CVD students were unaware of their colour vision status. In agreement to our study, Mulusew and Yilkal[12] reported that most of the study subjects were not aware of their colour vision status. However, this unawareness renders a CVD-affected individual highly vulnerable to rejections in some professional fields that have statutory colour vision requirements like working as a pilot, deck officers and seamen, loco pilots, traffic police, air traffic controllers, defense servant, geological service, doctors, lab technology and histopathological laboratory jobs. The previous literature[11] suggests healthcare professionals suffering from colour vision deficiency face lots of inconveniences in their professional, clinical, and laboratory skills. These difficulties include recognition of body colour changes such as cyanosis, rashes, jaundice, pallor and tissue identification while performing surgical procedures. Difficulty in recognition of blood and urine colourimetric tests-strips, and the presence of blood or bile in urine, sputum, vomit, and feces may also be encountered by them. Colour deficient healthcare professionals may also face inconvenience while studying colourful charts and slides, titration endpoints.[11] In case the physician fails to identify certain clinical symptoms due to colour deficiency, the patient's diagnosis and prognosis may be altered. In India, a considerable number of otherwise healthy and competent candidates are rejected every year in pre-employment medical check-ups in the services mentioned above due to the presence of CVD.

So, it is very crucial to identify and guide a CVD-affected person at an early stage. The basic level of awareness among students and their family members must be increased as an affected individual's career can be rescued only when he / she is informed about his / her deficiency at an early stage of life. Organizations like "Colour Vision Awareness" often arrange awareness programs in British schools. In Japan, the Education Ministry also issues guidance on how to make the classroom accessible to students with CVD and even ensured suitable textbooks for colour-blind students in the year 2003. Initiatives to increase "Colour Vision Awareness" if taken by school authorities in India, will benefit a large section of our youth in selecting the right career pathway. Therefore, it is vital to introduce colour vision screening tests in the school curriculum to raise

awareness and help the teachers and parents to adjust their teaching techniques to provide a better learning environment as there is no cure. Only adaptive strategies and behaviours can help the colour vision deficient people to deal with potential difficulties they face in their professional and personal life.[12] Those with colour blindness may need to limit their career options which require good colour perception.

CONCLUSIONS

Colour blindness is chiefly a congenital disease that is carried by the X chromosome. The present study shows that the prevalence of colour blindness was quite low and more prevalent among males (3.6 %). Screening for colour vision deficiency in students at the time of selection is very important. This may help in early detection and counseling more effectively. As a recommendation, community-based screening of children for colour vision should be done at regular intervals at all schools.

Limitations

Anomaloscope and Farnsworth-Munsell 100 hue test should be used for detailed quantitative and qualitative analysis of colour perception. We couldn't use anomaloscope and Farnsworth-Munsell 100 hue test in this study due to lengthy procedures and difficulty in use in the younger age group. Population based sample survey would have better than the school-based survey which was also a limitation of this study. Despite the above limitations, our study provides valuable information about the magnitude of colour vision deficiency among school children in the city of Kolkata.

Data sharing statement provided by the authors is available with the full text of this article at jebmh.com.
Financial or other competing interests: None.
Disclosure forms provided by the authors are available with the full text of this article at jebmh.com.

REFERENCES

[1] Fareed M, Anwar MA, Afzal M. Prevalence and gene frequency of colour vision impairment among children of six populations from North Indian region. Genes Dis 2015;2(2):211-218.
[2] Starr C, Evers C, Starr L. Biology: concepts and applications. 6th edn. Belmonte, CA: Thompson, Brooks/ Cole 2006.
[3] Simunovic MP. Colour vision deficiency. Eye 2010;24(5):747-755.
[4] Niroula DR, Saha CG. The incidence of colour blindness among some children of Pokhara, western Nepal. Nepal Med College 2010;12(1):48-50.
[5] Dohvoma VA, Mvogo SRE, Kagmeni G, et al. Colour vision deficiency among biomedical students: a cross-sectional study. Clin Ophthalmol 2018;12:1121-1124.
[6] Ahasana SH, Hussain R, Fareed M, et al. Prevalence of Red-Green colour vision defect among Muslim males and females of Manipur, India. Iranian J Public Health 2013;42(1):16-24.
[7] Swanson WH, Cohen JM. Colour vision. Ophthalmol Clin North Am 2003;16(2):179-203.
[8] Cruz EM, Cerdana HG, Cabrera AM, et al. Prevalence of colour vision deficiency among male high school students. Philipp J Ophthalmol 2010;35(1):20-24.
[9] Dalton J. Extraordinary Facts Relating to the Vision of Colours with observation. Memories of the Literacy and Physiological Society of Manchester 1798;5:28-45.
[10] Young T. II. Bakerian Lecture: on the theory of light and colours. Lond: The Royal Society 1802;92:12-48.
[11] Balasundaram R, Reddy SC. Prevalence of colour vision deficiency among medical students and health personnel. Malaysian Family Physicians 2006;1(2-3):52-53.
[12] Mulusew A, Yilikal A. Prevalence of congenital colour vision defects among school children in five schools of Abeshge District, Central Ethiopia. JOECSA 2013;17:10-14.
[13] Napaporn T, Manassakorn A, Worapong A, et al. Vision screening in school children two years results. J Med Assoc Thai 2004;87(6):679-684.
[14] Cole BL. Assessment of inherited colour vision defect in clinical practice. Clin Exp Optom 2007;90(3):157-175.
[15] Cumberland P, Rahi JS, Peckham CS. Impact of congenital colour vision defects on occupation. Arch Dis Child 2005;90(9):906-908.
[16] Tabansi PN, Anochie IC, Nkanginieme KEO, et al. Screening for congenital colour vision deficiency in primary children in Port Harcourt City: teachers knowledge and performance. Nigerian J Med 2008;17(4):428-432.
[17] Yasmin A, Janan N, Akhter R. Assessment of colour blindness and erythrocyte G6PD enzyme status among the school children of Dhaka City. J Bangladesh Soc Physio 2009;4(2):64-70.
[18] Oriowo OM, Alotaibi AZ. Colour vision screening among Saudi Arabian children. S Afr Optom 2008;67(2):56-61.
[19] Mehra KS. Incidence of colour blindness in Indians. Brit J Ophthalmol 1963;47(8):485-487.
[20] Bansal IJ. The frequency of colour blindness among the Punjabis of India. J Genet Hum 1967;16(1):1-5.
[21] Rahman SA, Singh PN, Nanda PK. Comparison of the incidence of colour blindness between sections of Libyan and Indian population. Indian J Physiol Pharmacol 1998;42(2):271-275.
[22] Shah A, Hussian R, Fareed M, et al. Prevalence of Red-Green colour vision defects among Muslim males and females of Manipur, India. Iran J Public Health 2013;42(1):16-24.
[23] Citirik M, Acaroglu G, Batman C, et al. Congenital colour blindness in young Turkish men. Ophthalmic Epidemiol 2005;12(2):133-137.
[24] Nepal BP, Koirala S, Adhikary S, et al. Ocular morbidity in school children in Kathmandu. Br J Ophthalmol 2003;87(5):531-534.

[25] Osuobeni EP. Prevalence of congenital Red-Green colour vision defects in Arab boys from Riyadh, Saudi Arabia. Ophthalmic Epidemiol 1996;3(3):167-170.
[26] Shrestha RK, Joshi MR, Shakya S, et al. Colour vision defects in school-going children. J Nepal Med Assoc 2010;50(180):264-266.
[27] Chia A, Gazzard G, Tong L, et al. Red-Green colour blindness in Singaporean children. Clin Experiment Ophthalmol 2008;36(5):464-467.
[28] Adam A, Puenpatom M, Davivongs V, et al. Anomaloscopic diagnosis of red-green blindness amongst Thais and Chinese. Hum Hered 1969;19(5):509-513.
[29] Modarres M, Mirsamadi M, Peyman GA. Prevalence of congenital colour deficiencies in secondary school students in Tehran. Int Ophthalmol 1996-1997;20(4):221-222.
[30] Al-Aqtum MT, Al-Qawasmeh MH. Prevalence of colour blindness in young Jordanians. Ophthalmologica 2001;215(1):39-42.
[31] Ishihara S. Ishihara Instructions Japan Academy. https://www.goodlite.com/cw3/Assets/documents/730019%20Ishihara%20Instructions-web.pdf. Accessed 26 Oct 2018.
[32] Birch J. Identification of red-green colour deficiency: sensitivity of the Ishihara and American Optical Company (Hard, Rand and Rittler) pseudo-isochromatic plates to identify slight anomalous trichromatism. Ophthalmic Physiol Opt 2010;30(5):667-671.
[33] McClements M, Davies WIL, Michaelides M, et al. X linked cone dystrophy and colour vision deficiency arising from a miss sense mutation in a hybrid L/M cone opsin gene. Vision Res 2013;80:41-50.