Research Article

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Colour vision defect among secondary school students in Enugu, Nigeria: prevalence, pattern and impact

Abstract

Aim: To determine the prevalence, pattern and impact of colour vision defects among public secondary school students in Enugu, Nigeria with a view to guiding the affected students on appropriate career choice.

Methods: A descriptive cross-sectional study was carried out among students attending public secondary schools in Enugu-East Local Government Area, Enugu state. A total of 950 students (361 males, 589 females) were selected by multistage sampling. The students were assessed for colour vision using Ishihara 38 plate edition and Farnsworth D-15 colour caps.

An interviewer-administered structured questionnaire was used to obtain the socio-demographic data and impact of colour vision on colour-related school tasks and activities of daily living. Data was analysed using statistical package foe social sciences, version 20.

Result: The age of the students ranged from 10-20 years with mean age of 14.2 ± 1.9 years. Eleven (1.2%) students were found to have colour vision defect out of whom 9 were boys and 2 were girls, 6 (54.5%) were deutan and 5 (45.5%) were protan. No tritan defect was detected. Greater percentages of the students with colour vision defect had difficulties with colour-related school tasks and daily activities when compared to those with normal colour vision.

Conclusion: Colour vision defect may affect students' performance in colour-related school tasks and activities of daily living. Therefore, early detection of colour vision defect is important so as to guide in the choice of future career.

Keywords: colour vision defect, Secondary school students, prevalence, pattern, impact

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Abbreviations: CVD, colour vision defect; NCV, normal colour vision; LGA, local government area; CI, confidence interval

Introduction

Colour vision defect is an abnormal condition characterized by reduced ability or inability of an individual to clearly distinguish different spectrum of colours.[1,2] Humans have three types of cones – I, II, III, photosensitive to blue/yellow, green and red pigments respectively due to absorption of different wavelengths of light.[3,4] Trichromacy is normal or correct colour vision where the three cone photopigments are functioning optimally.[4] Defects in colour vision results from the absence, malfunction or alteration of one, two or all of the cone photopigments.[1] In dichromacy, there is complete absence of one type of photoreceptor cone cells while in anomalous trichromacy, all the three types of cone cells are used to perceive colours but one type of cone shows weakened colour saturation.[1,4] Anomalous trichromacy is a relatively mild form and accounts for the largest group of colour deficient persons. Severe (complete) achromatopsia is thought to be equivalent to rod monochromatism in which there is lack of functioning cone photoreceptors, poor visual acuity and aversion to light.[4] Incomplete achromatopsia is thought to be blue-cone monochromatism in which the visual acuity is normal or slightly reduced and it is rare.[4] Colour vision defect (CVD) can be classified into congenital (present at birth) or acquired (develops later in life) based on the time of occurrence.[4] Congenital CVD is usually bilateral, stable throughout life and males are mostly affected.[2] However, acquired colour vision may occur at any age due to eye diseases or lesions elsewhere in the visual pathway, mostly unilateral and are found equally in both males and females.[4] Thus, there is need for appropriate referral when such defects are suspected. Colour vision defect can also be classified based on the type of cone that is malfunctioning into deuteranomaly/deuteranopia (reduced or loss of green cone sensitivity), protanomaly/protanopia (reduced or loss of red cone sensitivity) or tritanomaly/tritanopia (reduced or loss of blue cone sensitivity).[3] There are few literatures on the effect of nutritional deficiencies such as vitamin A deficiency on colour vision. Reddy et al reported no colour vision defect in twenty-eight vitamin A deficient children aged 4-12 years.[5] Bronte-Stewart et al.[6] however found improvement in colour vision in two colour deficient patients with biliary cirrhosis and vitamin A deficiency after six weeks of vitamin A treatment.[6] Colour vision is taken for granted by many people but the importance of correct and normal colour vision should not be underestimated.[4] Colour is routinely used to code and convey information and has extensive use in the educational system.[7] Young children affected by congenital colour vision defect can have difficulties with colour-related tasks in school and may be labelled by teachers and classmates as being less intelligent.[8] Therefore, early diagnosis minimizes this, improves adaptation of the children to their dysfunction and helps in better planning of their professional future.[8]

Good colour vision is very important in many occupations and everyday tasks. On daily bases, colour vision ability is used to discern and evaluate objects, signs and situations that concern work, safety, pleasure and observation.[4] Colour vision defect can seriously affect daily activities.[9–11] Affected individuals who drive and even pedestrians may find it difficult to recognize the traffic light colour codes leading to confusion and accidents. Occupations relying on colour are on the increase because tasks are becoming more complex due to emerging technologies.[4] Some professionals requiring good colour vision includes photographers, air traffic controllers, aircraft pilots, art teachers, street lighting technicians, bus drivers, clinical laboratory technicians/scientists, colour printing press operators, clothing sellers, painters, nurses, dentists, electricians, fire fighters, graphic artists, pharmacists, police officers and weather analysts.[4] Thus, early detection of colour vision defect, which is not treatable, will guide the career choice of affected students to avoid frustrations, job dissatisfaction or disappointments in future.[1] It is extremely important to examine children for colour vision defect at the earliest age possible. The optimal age for colour vision screening or testing should be from four to six years upwards.[8,11] In counselling for defects when found, it should be explained that congenital CVD is due to gender-linked X- chromosome mainly affecting males.[4] If a male's single X-chromosome is colour defective, he will be colour vision deficient. For a female to have CVD, she must have inherited two colour defective X-chromosomes from both of her parents who are colour vision defective or from a colour vision defective father and a mother who is a carrier. Such conditions are rare, thus females are less susceptible. Individuals mildly affected may use colour filters to increase contrast. Those with medium to severe defects should avoid activities where colour confusion may jeopardize others.[4] Studies have been done on the prevalence of colour vision defects among school children in the South-West, South-South and Northern Nigeria[12–15] There is paucity of data regarding the prevalence, pattern and impact of colour vision defect among school children in South-East Nigeria. This study is therefore aimed at providing a database on the prevalence, pattern and impact of colour vision defect among secondary school children in Enugu, South-East Nigeria.

Methodology

This study was a descriptive cross-sectional study among public secondary school students in Enugu-East Local Government Area (L.G.A) of Enugu state between September and December 2017. In the course of the study, the tenets of the Helsinki declaration and the National code of Health research was adhered to. Approval for the study was obtained from the Enugu State Post Primary School Management Board. From the statistics obtained from Enugu State Post Primary School Management Board, there were ten registered public secondary schools in Enugu-East L.G.A. The student's population ranged from 287 to 3524 students per school with a total student population of about 13,881. A total of 950 students were selected by multi-staged sampling technique. In stage one, the sample size was proportionately allotted to the 10 public secondary schools in Enugu-East L.G.A depending on the population of each school. In stage two, the sample size for each school was proportionately allotted to its 6 levels depending on the population of each level. The range of number of students per level is between 28 and 760. In each level of the 10 schools, there were different classes which ranged between 1 to 9 arms. Number of students in each class ranged between 28–85 students. In stage three, the sample size for each level in the 10 schools was proportionately allotted to the different classes depending on the population of each class. In stage four, the students were selected from each class using simple random sampling by balloting. The list of students in each class as recorded in the register was used as the sampling frame. The details of the study were explained to the school principals, parents/guardian (in writing) and the students. Informed verbal consent was obtained from the schools' principals and written informed consent was obtained from the parents/guardian of each selected student. Verbal consent was obtained from each student before enrolment into the study. Students with presenting visual acuity 6/60 or worse in either eye were excluded from the study. If a student was selected but was absent from school on the day of the study or did not meet the inclusion criteria or did not consent, he or she was replaced by another student from the same class. A structured interviewer-administered questionnaire divided into 3 sections was used for the data collection. Section A consisted of the demographic data. Section B which was adapted from Steward and Cole questionnaire was for documenting the difficulties the students had in performing colour-related school activities and difficulties with daily activities. Section C was used to document the colour vision test results. Both eyes of each student were tested. The students were tested for colour vision using Ishihara 38 plate and Farnsworth D-15 plate.

Colour vision assessment

Ishihara test

This was done uniocularly with Ishihara 38 plate chart 2011 edition in a room illuminated by daylight. The chart was held at 75cm from the student and tilted perpendicular to the line of vision. The students were asked to read out the numbers seen on the test plates and the answers were noted down. The time allowed to read the number in a given plate was 5 seconds before moving to the next. One student was examined at a time to ensure some privacy and also prevent the other students not being tested from memorizing the letters on the test plates. Those who were able to read all the letters in plates 1-21 correctly or failed to read four or fewer letters in plates 1-21 were regarded as having passed the Ishihara test and thus have normal colour vision. Those who failed to read more than four letters in plates 1-21 were regarded as having failed the Ishihara test. Failure of Ishihara test in only one eye was suggestive of an acquired cause since congenital colour vision defect is rarely unilateral.

Farnsworth panel D-15 test

This was done uniocularly at a working distance of 50cm from the student in a room illuminated by daylight. It was done on a black background to prevent the surroundings from affecting the colour perception of the students.

The plastic set containing the colour caps was opened. The colour caps were kept on the black background with the numbered surface in contact with the black background and the coloured surface facing up. The examiner selected the reference cap which has R written on the underside and placed it on the black background to one end. Each student was instructed to then select the colour cap which most closely matches the reference cap and place it facing up next to the reference cap. The student continued to select the next closest colour cap and placed each in sequence on the black background. Each student was given about two minutes to complete the colour cap arrangement and was free to alter the sequence before completion. When the student completed the test, the examiner turned the colour caps (maintaining the sequence of arrangement) with the coloured surface facing down and the undersurface with written number now facing up.

The number on the underside of the colour cap was recorded in the sequence of arrangement by the student and plotted on a copy of the score sheet template by drawing a linking line from the starting point (the reference cap) to the end. If the line remained along the outside of the circle, the student had normal colour vision. If there

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were one or two cross-over lines across the centre (few coloured discs out of order), the student was classified as mildly colour deficient. The student was classified as moderately colour deficient if there were more than two but less than ten cross-over lines across the centre of the chart. The student was classified as strongly colour deficient if there were ten or more cross-over lines across the centre of the chart. The type of defect was determined by comparing the cross-over lines to see if they were parallel to protan, deutan or tritan confusion axes. Cross-over lines occurring frequently in a certain direction revealed the type of colour defect.

Data analysis

Data obtained was entered into a computer, edited, cleaned and then analysed using the Statistical Package for Social Science (SPSS) version 20. The demographics, prevalence, pattern and impact of colour vision as well as other categorical variables were summarized using proportions and percentages while quantitative variables were summarized using mean and standard deviation for normally distributed data. Relationship between qualitative variables such as colour vision defect and performance in school and daily activities were determined using chi-square. The relationship between sex and colour vision diagnosis as well as sex and type of colour vision defect were determined using Fisher's exact. The level of significance was set at a p-value <0.05.

Results

A total of 950 students were examined from the 10 schools, out of whom 361 (38.0%) were males and 589 (62.0%) were females with male to female ratio of 1:1.6. The age of the students ranged from 10-20 years with mean age of 14.2±1.9 year. Out of the 950 students examined with both Ishihara colour plates and D-15 colour caps, 11 students were found to have colour vision defect (CVD) giving a prevalence of 1.2% (95% CI = 0.51–1.89) while 939 (98.8%) students had normal colour vision. Out of the 11 students that were found to have CVD, 6 (54.5%) students had deutan defect while 5 (45.5%) students had protan defect. These defects were bilateral and no unilateral defect was found. None of the students had tritan defect. Out of the 11 students who had colour vision defect, 9 (2.5% of all males, n=361) were males and 2 (0.3% of all females, n= 589) were females. This was statistically significant on cross tabulation (Fisher's exact test = 9.06, $p < 0.01$; Table 1A). However, on cross tabulation of sex with type of colour vision defect present, it was not statistically significant (Fisher's exact test = 2.67, $p > 0.05$; Table 1B).

Table 1(A) Relationship between Sex and colour vision diagnosis among the study participants

Sex	Diagnosis		Total	Fisher's Exact	Odd Ratio	P-value
	Normal colour vision	Colour vision deficient				
Male	352 (97.5)	9(2.5)	361 (100.0)	9.06	0.133 (95% CI= 0.029-0.620)	0.004
Female	587 (99.7)	2 (0.3)	589 (100.0)			

CI, confidence interval

Table 1(B) Relationship between Sex and Type of Color vision defect present

Sex	Colour defect present		Total	Fisher's Exact	Odds Ratio	P-value
	Protan	Deutan				
Male	5 (55.6)	4 (44.4)	9 (100.0)	2.667	0.333 (95% CI = 0.132-0.840)	0.182
Female	0 (0.0)	2 (100.0)	2 (100.0)			

On cross tabulation of students with colour vision defect and those with normal colour vision, a statistically significant greater percentage of students with colour vision defect had difficulties with colour-related school activities than the students with normal colour vision (Table 2). Greater percentage of students with colour vision defect had difficulty with daily activities and it was statistically significant when compared with students who had normal colour vision (Table 3).

Table 2 Reported impact of Colour vision on performance in school activities of the study participants

Variables	Option category	Colour vision diagnosis frequency (%)		Fisher's exact	Degree of freedom	P-value
		NCV	CVD			
Difficulty identifying colour and picture charts in mathematics	All the time	13 (1.4)	2 (18.2)	16.823	3	0.001
	Frequently	25 (2.7)	0 (0.0)			
	Occasionally	140 (14.9)	5 (45.5)			
	Never	761 (81.0)	4 (36.3)			
	Total	939 (100.0)	11 (100.0)			

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Table continue

Variables	Option category	Colour vision diagnosis frequency (%)		Fisher's exact	Degree of freedom	P-value
		NCV	CVD			
Difficulty working with computer	All the time	11 (1.2)	1 (9.1)			
	Frequently	30 (3.2)	1 (9.1)			
	Occasionally	144 (15.3)	3 (27.3)	8.375	3	0.03
	Never	754 (80.3)	6 (54.5)			
	Total	939 (100.0)	11 (100.0)			
Difficulty with fine art	All the time	7 (0.7)	1 (9.1)			
	Frequently	18 (1.9)	2 (18.2)			
	Occasionally	99 (10.5)	0 (0.0)	13.309	3	0.005
	Never	815 (86.9)	8 (72.7)			
	Total	939 (100.0)	11 (100.0)			
Difficulty identifying different houses or teams based on their jersey colour during inter-house sports	All the time	8 (0.9)	2 (18.2)			
	Frequently	11 (1.2)	0 (0.0)			
	Occasionally	89 (9.5)	4 (36.4)	19.438	3	0.001
	Never	831 (88.4)	5 (45.4)			
	Total	939 (100.0)	11 (100.0)			

NCV, normal colour vision, CVD, colour vision deficient

Table 3 Reported impact of Colour vision on daily activities of the study participants

Variables	Option category	Frequency (%)		Fisher's exact value	Degree of freedom	P-value
		NCV	CVD			
Difficulty selecting colour of clothes	All the time	6(0.6)	1(9.1)	9.299	3	0.07
	Frequently	1 (0.1)	0(0.0)			
	Occasionally	55(5.9)	1(9.1)			
	Never	877(93.4)	9(81.8)			
Total		939 (100.0)	11 (100.0)			
Difficulty identifying flower based on colour	All the time	5(0.5)	1(9.1)	11.165	3	0.017
	Frequently	8 (0.9)	0(0.0)			
	Occasionally	87(9.3)	3(27.3)			
	Never	839(89.3)	7(63.6)			
Total		939 (100.0)	11 (100.0)			
Difficulty judging ripeness of fruits and vegetables	All the time	6(0.6)	1(9.1)	10.432	3	0.024
	Frequently	6(0.6)	0(0.0)			
	Occasionally	50(5.3)	2(18.2)			
	Never	877(93.5)	8(72.7)			
Total		939 (100.0)	11 (100.0)			

Table continue

Variables	Option category	Frequency (%)		Fisher's exact value	Degree of freedom	P-value
		NCV	CVD			
Difficulty watching sports because of colour of colour of team jersey	All the time	12(1.3)	2(18.2)	19.379	3	0.001
	Frequently	18(1.9)	2(18.2)			
	Occasionally	103(11.0)	2(18.2)			
	Never	806(85.8)	5(45.4)			
Total		939 (100.0)	11 (100.0)			
Difficulty to identify friends based on the colour of their clothes	All the time	4(0.4)	1(9.1)	8.09	3	0.128
	Frequently	4(0.4)	0(0.0)			
	Occasionally	62(6.6)	0(0.0)			
	Never	869 (92.6)	10 (90.9)			
Total		939 (100.0)	11 (100.0)			
Difficulty describing and identifying cars based on colour	All the time	5(0.5)	1(9.1)	9.533	3	0.041
	Frequently	3(0.3)	0(0.0)			
	Occasionally	87(9.3)	2(18.2)			
	Never	844(89.9)	8(72.7)			
Total		939 (100.0)	11 (100.0)			
Difficulty recognising traffic signal lights	All the time	6(0.6)	1(9.1)	17.763	3	0.001
	Frequently	3(0.3)	1(9.1)			
	Occasionally	46(4.9)	2(18.2)			
	Never	884(94.2)	7(63.6)			
Total		939 (100.0)	11 (100.0)			

Discussion

The importance of good colour vision cannot be over-emphasized. It is required in colour-related school tasks, daily activities and some occupations. However, it is often overlooked in visual function assessment. The prevalence of colour vision defect found in this study was 1.2% (95% CI = 0.51–1.89). There is no national figure for the prevalence of colour vision defect in Nigeria as it was not captured in the Nigerian National Blindness and Visual impairment Survey. The prevalence varies in the different geopolitical zones of the country. This low prevalence of colour vision defect found in this study is comparable to the prevalence reported in previous studies from other geopolitical zones in Nigeria (1.2-2.6%).[10,14–16] Studies from Egypt, Tehran and India also reported low prevalence – 0.9%, 2.2% and 2.02% respectively.[17–19] However, two studies in Ethiopia found slightly higher but similar prevalencies of colour vision defects (4.2% each).[7,20] A study in Gabon which is in West Africa as Nigeria found a very high prevalence of colour vision defect (15.5%).[21] Their reason for this high prevalence was due to some false positive readings which may be due to poor comprehension and reading of Ishihara chart by some students. Deutan defect (54.5%) was the commonest colour vision defect found in this survey. This finding is similar to that of the previous studies in North Iraq[2], India[19], Ethiopia[20] and Tehran.[22] However, this differs from the findings of a study in Ibadan, South-West Nigeria where protan defect (35%) was found to be the commonest colour vision defect followed by deutan defect (32%) and tritan defect (3.0%).[12] The disparity could be due to the ethnic differences between the western and eastern parts of the country.

Although more females participated in this study than males, more males (2.5%) were found to have colour vision defect than females (0.3%) and it was statistically significant (p<0.01). It could be because colour vision defect has an x-linked recessive inheritance pattern with more males being affected than females. This agrees with results of previous studies in North Iraq[2], India[19], Ethiopia[20] and Tehran.[22] Some other studies did not elaborate on the pattern of colour vision defect.[1] Although the prevalence of colour vision defect is generally low but it can negatively impact on the school performance of the few affected students. In this study, greater percentage of students with colour vision defect had difficulty with school performance in terms of colour-related tasks and it was statistically significant when compared with the students who had normal colour vision. This was similar to what was observed in Ibadan.[10] It was found that 63.7% of students with colour vision defect and 19.0% of students with normal colour vision had varying difficulties identifying colours and picture charts in mathematics in this study. This difference was statistically significant (p=0.001). These students with color vision defect may perform poorly in mathematics than those with normal colour vision as was seen in a study in Italy.[23] However, a study done in Britain in contrast found that children with colour vision defect scored higher in mathematics and reading than those with normal colour vision and this was statistically significant suggesting that colour defective children may do well as their peers educationally.24 A higher proportion of participants with colour vision defect had difficulty with fine art. This is similar to the finding in Brazil where colour defectives had problems with coloring during artistic education classes.[25]

In this study, 36.4% of students with colour vision defect and 5.8% of those with normal colour vision had varying degrees of difficulty identifying traffic light signals. The difference between the two groups was statistically significant (p=0.001). Previous studies in Brazil and Italy had similar findings.25,26 However, a study among motorcyclists in Enugu, South-East Nigeria found that road traffic accident was significantly associated with colour vision defect whereas studies in Italy and Ilorin, North-Central Nigeria found that the frequency of road accidents was similar for both colour defective subjects and normal colour vision subjects with no significant association.26–28 The present study found that 18.2% of students with colour vision defect had varying degrees of difficulty in selecting colour of clothes compared to 6.6% of normal colour vision students with the difference not being statistically significant; $p > 0.05$. This was again similar to the study in Italy where 23.8% of subjects with colour vision defect had difficulty choosing clothing and outfits compared to 1.0% of subjects with normal colour vision.26 Statistically significant greater proportion of colour defective students had difficulty watching sports because of colour of team jersey, difficulty identifying flowers based on colour, difficulty judging ripeness of fruits and vegetables and difficulty describing and identifying cars based on colour when compared to normal colour vision students. This shows that people with colour vision defect may really find it difficult to perform day to day activities that involve colour appreciation.

Conclusion

Secondary school students in Enugu-East L.G.A of Enugu state had low prevalence of colour vision defect and majority of the affected students had difficulty with colour-related school and daily activities. Therefore, early detection of colour vision defect and knowledge about one's colour vision status may be helpful in the choice of future career.

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Conflicts of interest

None.

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