Original Article

Beyond the Hues: Forensic Analysis and Restoration of Color Vision

To Assess Transference Of Color Blindness

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ABSTRACT

Objective: Main purpose of this study to assess transference of color blindness in genetic pedigree and to discuss as to how to cope with the challenge with color vision deficiency friendly techniques.
Study Design: Cross Sectional Study
Place and Duration of Study: This study was conducted at the King Edward Medical University students from 1st year to final year from July 01, 2024 to 31st December 2024.
Methods: It was a cross-sectional observational study where Ishihara chart handouts were distributed among Medical University students. Any potential deficit whether complete or partial was duly noted as to identification of embedded numbers within colored dots with exclusion criteria were acquired color blindness, active ocular diseases, systemic diseases.
Results: According to these statistics male had predominance over females in being color blind. 2.2 % male had reported to be completely color blind, whereas 3 male candidates had color weakness. Only 1 female had red-green deficiency and 1 reported to be weakness in appreciating the colors overall.
Conclusion: Color blindness is predominantly expressive in males with consanguinity as a dominant inherent trait.
Key Words: Color Weakness, Color Blindness, Consanguinity

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INTRODUCTION

Colors are associated with apparent light continuum i.e. the spectrum of color is an electromagnetic range of pattern detectable by the human eye. Human perception of color is behavioral interaction between light and object as to what wavelengths are absorbed and which are reflected back to human eye and eventually interpreted by the brain, denoting the observed colors. Hence all the visible wavelengths are appreciated as light. Black color is either absorption of all the colors or absence of light altogether.[1]

The color spectral range falls between 380 nanometer of violet hue to 750 nanometer of red color, identifying a range of red, orange, yellow, green, blue, indigo and violet.[2]

This range of reflected wavelengths enter the human eye through cornea and pupil, focused by the lens is finally directed to light sensitive region of retina having photoreceptor cells comprising of rods and cones.[3] Rods, about 120 million in each human eye, are responsible for vision in dim light conditions and peripheral vision appreciative of gray scale only.[4] Cones are the anatomical structure in human eye responsible for color appreciation with acute visual acuity. These cones are about 6 million in each eye concentrated mostly within the macula especially in the fovea centralis. These cone cells are further sub-classified as per wavelength perception ranging from, short wavelength cones sensitive to blue light to medium wavelength cones acknowledging the green light to finally red light appreciating long wavelength cones. The light stimulates all the three cone cell receptors simultaneously producing the spectral array of colors as per stimulus provoked response.[5]

Any defect anatomical or pathological can lead to color inefficiency with the individual suffering from color perception deficit. This defect in color awareness ranges from absolute color insensitivity to a mixed deficiencies of color recognition. Monochromacy is absolute lack of color realization which could be a rare inherent disorder or result of a mutation, in which the cone cells of all wavelengths, are non-existent or totally non-functional. Further categorization of color inadequacy includes protanomaly/ protanopia i.e. reduced sensitivity to red light to absence of red color reception respectively. Deuteranomaly/ Deuteranopia is partial deficiency or absolute lack of green color

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recognition respectively. Finally, Tritanomaly/ Tritanopia is reduced sensitivity to blue/yellow light, to blue appearing as green and yellow as gray or violet respectively.[6]

This color perception anomaly can also be acquired later in life due to either pathology like glaucoma, macular degeneration, cataract, diabetic retinopathy, injures to either brain or eyes and eventually aging can also lead to faulty color perception.[7]

Although color vision defectiveness can cause occupational rejection during the screening process of disciplines like police, army, railways, electronics, communication and medical personnel.[8] However, this research is specifically addressed towards the issue of color vision deficit in forensic medicine doctors and forensic scientists. What implications can be faced by such field experts and what remedial strategies can be applied to overcome such a handicap. Establishing the consequences of this visual deficit in the field of forensic medicine ranges from observational anomalies in medicolegal examination of the injuries like bruises, abrasions and lacerations including their appearance and age assessment to evaluation of post mortem staining, injuries along with microscopic slide examination and toxicological analytical experiments requiring chemical reagents which produce certain color reactions for final observatory remarks.[9] Besides this misinterpretation of trace evidence like fibers, paint chips and several biological versus non-biological material comparisons and difficulties in appreciating the latent fingerprints by forensic scientists can pose serious challenges. Furthermore, errors in blood spatter pattern analysis can be misinterpret any subtle details affecting the consequential opinion.[10]

Pursuing further in the intricacies of the research it is mandatory to also mention the mitigating strategies. Instead of isolating and secluding an individual from a certain specialty that he or she may not opt their desired choice of profession it should be more appropriate to introduce the remedial steps to overcome the obstacles and hurdles for maximum proficiency and output. Screening at an early age can be extremely beneficial in educating and training for not only awareness but also regarding adoption of early compensatory plan of action.[11] These remedial maneuvers include using alternative cues like texture and shapes or color independent coding procedures like using labels or patterns for color matching. Besides these certain assistive technologies can be adapted like specialized glasses or artificial intelligence enhanced software. Finally, in forensic field where this color challenge is a continuous process a standardized protocol might be applied including standardized color charts, controlled lightning conditions or numeric color perception systems for more objective approach towards color appreciation.[12]

Hence the main objective of this research study is to introduce an early screening plan and to create a user friendly atmosphere with all the helping gadgets and steps to alleviate and facilitate the color challenged individuals to be the best version of themselves to be a productive element of society instead of being a burden and handicap personnel.[13]

METHODS

Cross-sectional observational study was done; Ishihara handouts were distributed among Medical University students. Potential deficits whether complete or partial were noted as to identification of embedded numbers within colored dots. Convenience sampling technique was used and a diverse sample was extracted of medical college students from first year to final year. Inclusion criteria was young healthy individuals with no apparent vision defects. Exclusion criteria were acquired color blindness, active ocular diseases, systemic diseases. The sample size was determined based on power analysis to ensure statistical significance. Participants were screened for color blindness using standardized color vision tests, such as the Ishihara test. The study adhered to ethical guidelines and regulations, ensuring the protection of participant rights and confidentiality. Informed consent was obtained from all participants, and their privacy was maintained throughout the research process. Collected data was analyzed using IBM SPSS Statistics version 26.0. Variables of the data included same caste, distant blood relation, first paternal uncle's offspring, first paternal aunt's offspring, first maternal uncle's offspring, second cousin, no blood relation.

RESULTS

According to these statistics male had predominance over females in being color blind. 2.2 % male had reported to be completely color blind, whereas 3 male candidates had color weakness. Only 1 female had red-green deficiency and 1 reported to be weakness in appreciating the colors overall.

Table No.1: Gender and Color Blindness

		Color weakness	Color blindness	Normal color vision	Red-green deficiency	Total
Gender	Female	1	0	308	1	310
	Male	3	5	214	0	222
Total		4	5	522	1	532

Table No.2: Consanguinity

	Color weakness	Normal Color vision	Red-green deficiency	Total Color Blindness	Total
Same caste	0	184	0	0	184
Distant blood relation	0	42	0	1	43
First paternal uncle's offspring	1	35	0	1	37
first paternal aunt's offspring	0	35	0	1	36
First maternal aunt's offspring	1	16	0	1	18
First maternal uncle's offspring	1	29	0	1	31
Second cousin	1	35	1	0	37
No blood relation	0	146	0	0	146
Total	4	522	1	5	532

DISCUSSION

Color blindness and its implications in Forensic Medicine is a mainstream point to be validated for educational purposes. Color vision, a fundamental aspect of human perception, plays a crucial role in various fields, including forensic medicine as well as forensic science.[14] Forensic expertise is reliant upon visual analysis techniques to examine evidence, such as injuries color changes such as analysis of bruise age, bloodstain patterns, fingerprints, and trace evidence. However, color blindness, a condition that affects color perception, can potentially compromise accuracy and reliability of forensic investigations.[15]

Here we need to elucidate the types of color blindness, beginning by defining what color deficiency is, color cecity is a hereditary condition that results from absence or malfunction of specific cone cells in the retina responsible for color vision. Different types of color sightlessness exist, ranging from mild deficiencies to complete color blindness. The most common forms are, Red-Green color blindness, this is most common type, affecting primarily ability to discern between red and green hues. Next in line defect is Blue-Yellow color blindness which is less common and affects ability to differentiate between blue and yellow hues. But the main inherent defect is total color blindness, a rare condition where individuals perceive the world in gray spectre.[16]

A main cardinal etiology for color deficiency or absolute color blindness is consanguinity or marriage between close relatives, which increases risk of genetically acquiring recessive genetic disorders.[17] This is due to immediate relatives being more prone to share same harmful recessive genes, increasing the chance that their offspring will inherit two copies of the defective genes, leading to developmental disorder. Color blindness is an X-linked recessive trait i.e. gene responsible for it is located on the X chromosome. Males genetic makeup has only one X chromosome, so if they inherit a copy of color blindness gene from their female parent, they will develop this condition. Females express two X chromosomes, so they need to inherit both recessive genes, one from each parent, to develop color blindness.[18] Consanguinity increases risk of color amaurosis in both genders, however effect is more pronounced in males. This is because males only need to inherit one gene to be affected, while females need to inherit both copies. Studies have shown that prevalence of color anopsia is higher in populations with a high rate of consanguinity, such as the Pukhtoon population in Pakistan.[19]

Considering the impact on Forensic Medicine and forensic science it is significant to tackle color blindness which can have significant implications for forensic experts in various disciplines. The very first scenario to be considered is the bloodstain pattern analysis. Difficulty in Pattern Recognition occurs in color-blind individuals who struggle to differentiate between bloodstain patterns, such as impact spatter, cast-off patterns, and arterial spurts, which can vary in color depending on factors like oxygenation levels and the age of the stain.[9] Moreover, color changes over time especially in case of bruises that undergo color changes as they heal. Color-blind individuals may have difficulty interpreting these changes, which can be crucial for estimating the time of the incident.[20] Fingerprint examination via visualization techniques is an integral part of forensic trace evidence. Many fingerprint visualization techniques rely on chemical reagents that produce colored reactions. Color-blind candidates have difficulty interpreting these colored reactions, leading to potential errors in fingerprint identification.[21]

Color obscurity is a challenge both in field of forensic medicine and sciences for which mitigating strategies need to be ensured for improvisation.[22] Alternative Visual Cues may be applied that rely on texture, shape, or other non-color cues to differentiate between evidence.[23] Secondly color-blind-friendly color palettes may be utilized which are distinguishable for color vision deficient personnel. Finally, specialized imaging techniques are available which utilize contrast enhancing techniques and highlight specific features, like infrared or ultraviolet photography among other advancements in technology.[24]

CONCLUSION

Hue changes in color perception can be challenging task for the color compromised individuals especially for forensic personnel who have to routinely come across various color related scenarios like injury inspection, trace evidence collection etc.[25]

Hence instead of segregating individuals for not opting either forensic medicine or forensic sciences as a career, strategic reforms should be introduced and adapted for recognition of blood spatter analysis, dactylography, injury examination.

Finally, consanguinity is an inherent etiological factor consequential in color perplexity, which is a totally preventable causality i.e. avoid consanguineous marriages, undergo genetic counseling before having children and to get tested for color blindness before conceiving.[26]

Author's Contribution:

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Agreement to accountable for all aspects of work:	All the above authors

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