Profiling the Problem of Colour Vision Deficiency and its association with Colour, Culture and Cognition- An Indian Perspective.

A thesis submitted in 2022 to the University of Hyderabad
in partial fulfilment of the award of

DOCTOR OF PHILOSOPHY

in

Health Sciences

(Optometry and Vision Science)

by

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18MOPH01

at

School of Medical Sciences

University of Hyderabad

December - 2022

DECLARATION

I **Shiva Ram Male (18MOPH01)** hereby declare that this thesis entitled ***" Profiling the Problem of Colour Vision Deficiency and its association with Colour, Culture and Cognition- An Indian Perspective."*** Submitted by me under the guidance and supervision of **Dr. BR Shamanna, Professor, School of Medical Sciences** and **Dr. Chakravarthy Bhagvati, Professor, School of Computer and Information sciences**, University of Hyderabad, is a bonafide research work.

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A) Publication related to the thesis:

1. Male, S. R., Shamanna, B. R., Bhardwaj, R., Bhagvati, C., & Theagarayan, B. (2022). Color vision devices for color vision deficiency patients: A systematic review and meta-analysis. *Health science reports*, *5*(5), e842. https://doi.org/10.1002/hsr2.842. *(Full paper)* IF: 1.95.

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OV804	Qualitative research in Health Sciences	4	Pass
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#Guru Devo Bhava!

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ABBREVIATIONS

CVD	Colour Vision Deficiency
nm	Nanometer
L-Cone	Long wavelength cone
M-Cone	Medium wavelength cone
S-Cone	Short wavelength cone
RT	Reaction time
Ms	Milli seconds
BCT	Basic colour terms
OPNL1W	OPSIN 1, Long-Wave-Sensitive.
OPNM1W	OPSIN 1, Medium-Wave-Sensitive.
NIRE	National Institute for Rehabilitation Engineering
RP	Retinitis Pigmentosa
ARMD	Age Age-related Macular degeneration
QoL	Quality of Life
PCA	Principal Component Analysis
ICVRD	Indian colour vision deficiency registry
DR	Diabetic retinopathy
PDR	Proliferative diabetic retinopathy
GRADE	Grading of Recommendations, Assessment, Development, and Evaluations
FM-100	Farnsworth–Munsell 100 Hue Color Vision test
D-15	Farnsworth Dichotomous Color Blindness Test
RFs	Receptive fields
ILM	Internal limiting membrane

OLM	Outer limiting membrane
cGMP	Cyclic GMP
CNG	Cyclic nucleotide–gated ion channel
Ca2+	Calcium ions
Na+	Sodium ions
PDE	phosphodiesterase
5GMP	5′-Guanidylic acid or guanylic acid
LGN	lateral geniculate nucleus

LIST OF TABLES

LIST OF FIGURES

Organisation of Thesis

The current thesis is organised into 8-chapters.

Chapter 1: The first chapter deals with the Background and introduction of the Colour vision and the study's Aim, objectives, including rationale.

Chapter 2: The second chapter discusses the theoretical foundations related to colour vision and quality of life in colour vision deficiency, followed by the introduction to the existence of colour terms and cross-cultural association in the Dravidian languages.

Chapter 3: The third chapter, "Colour vision devices and outcome in colour perception: A systematic review and meta-analysis", emphasise current existing colour vision devices and their outcome on colour perception and recommendation for clinical use in the CVD population.

Chapter : The fourth chapter, "Impact of Quality of Life in Colour vision deficiency in a sample of Indian population: A CVD-QoL application tool", gives insight into how the CVD population's quality of life is compromised in comparison to age control healthy population due to the colour vision deficiency and assessing it with the standardised questionnaire.

Chapter 5: The fifth chapter, A study to review the monolexemic colour terms in Dravidian languages, emphasises the hypothesis on how monolexemic colour evolved and has an association with communication and culture and provides a new hierarchy of colour terms in Telugu, Tamil, Malayalam, and Kannada languages and explains the comparison between the universality of colour terms (Berlin and Kay,1969) in English by applying the visual psychophysical experiments

Chapter 6: The sixth chapter, "Colour and emotions association in Dravidian languages", explains about between how colour and emotions are associated in cross cultures of Dravidian and how the perception of colour varies with different emotions in humans.

Chapter 7: This special chapter gives insight on recommending an Implementation of a Colourblind free environment and Quality of Life for the CVD population in Telangana and Proposed prescriptions for policy, advocacy, and registry for the CVD population.

Chapter 8: The final chapter is on Summary and Conclusion

Table of Content

Chapter-1

Introduction

Have you ever thought about what it may be like to live in a world where colours do not exist? One of the most impressive and essential components of the visual systems of both humans and animals is the capacity to see different colours. Vision scientists, ophthalmologists, philosophers, physicists, artists, linguists, and cognitive scientists have all spent years debating the existence of colour and trying to figure out how it is seen and perceived.

Others may argue that colour is all about expression, yet most people would likely agree that its beauty is evident. Some individuals may define colour as the visual effect of light reflecting and diffracting, while others contend that colour is all about expression.

In this chapter, a concise overview of the concept of colour in both nature and science, as well as how humans perceive, represent, and react to colour; how our minds choose and decide on colour; how someone with colour vision deficiency can see colour; and what difficulties they face as a result of improper colour vision or colour vision deficiency is discussed.

1.1 The concept of Colour

The word "colour" and the idea behind it may be conveyed in a variety of ways, but they all mean roughly the same meaning. **Figure 1** demonstrates how people's perceptions of colour change after listening several explanations of colour from various perspectives.

In Physics and Optics, colour derives from visible light properties. Light is composed of waves of electromagnetic energy. This particular kind of electromagnetic wave moves at the speed of light. Photons, also known as light particles, are the slightest disturbances in a system. The range of wavelengths that make up visible light ranges from (390-nm to 730-nm). Only the visible spectrum of light is capable of being experienced by humans.

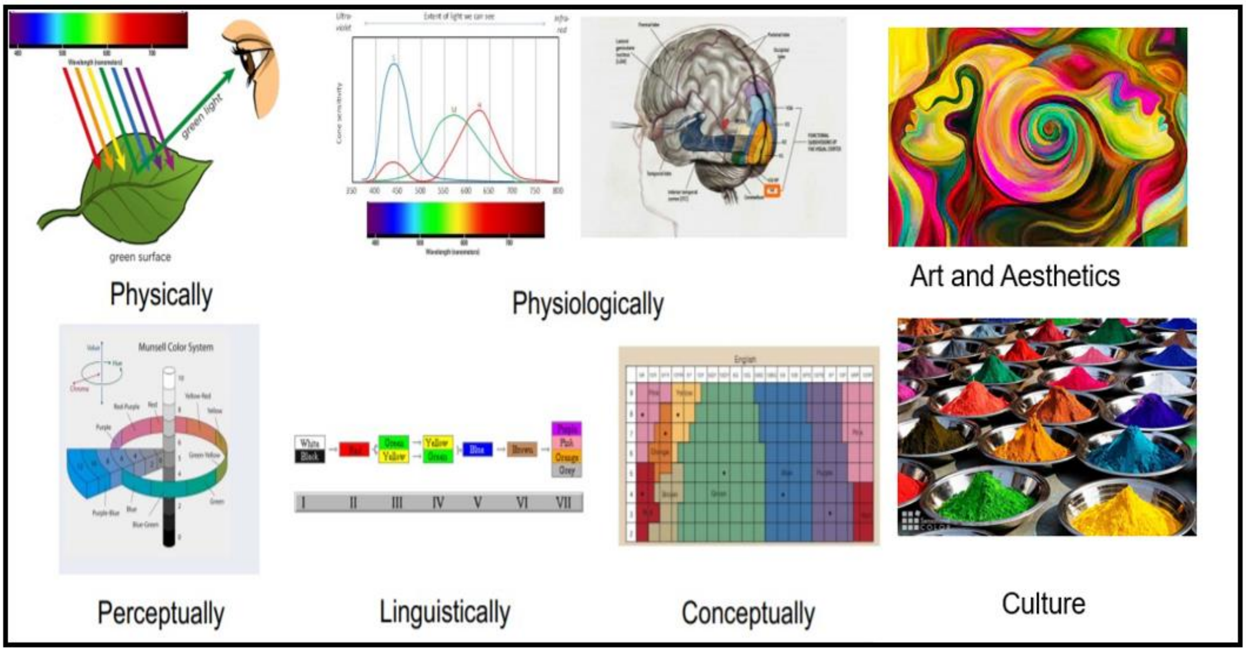


Figure 1. An illustration shows the concept of colour in different disciplines**.**

Physiologically, to process the light input, colour vision needs a particular biological system. Different animals have distinct visual systems and interpret colour differently (Marshall & Arikawa, et al., 2014). Colour vision results from a processing stream comprising opsin-containing cones in the retina, colour-opponent responses in retinal ganglion cells, colour contrast calculations in the striate of the visual cortex, and a network of temporal regions that underpins the creation of a stable colour percept. Thus, depending on the animal species, the same wavelength of visible light may elicit distinct colour perceptions and result in different behaviours.

The human eye perceives colour as a continuous spectrum consisting of red, blue, green, yellow, and everything in between. "Orange," for example, are susceptible to mathematical representation using three-dimensional models. Humans see around two million colours differently (Linhares, Pinto, & Nascimento, et al.,2018). While the exact number is unclear, research by (Masaoka, Berns, Fairchild, and Moghareh Abed, et al., 2013) indicates that each of these colours has its own individual three-dimensional representation.

Colours in these areas may be characterised and expressed mathematically in a number of ways. Their official names are colour appearance models and colour order systems. Bujack and colleagues demonstrated that employing Riemannian geometry overestimates the perception of big colour variations in recent studies (Roxana Bujack et al., 2022) which combines psychology, biology, and mathematics. This is because humans perceive a large colour difference to be smaller than the sum of little colour variations that exist between two widely separated colours. This also contradicts the previous colour theory notions proposed (E. Schrödinger et al.,1920).

In linguistics, there is more variance among colour groups than previously thought. Surprisingly, some language groups intentionally delete colour terms, contradicting long-held notions about language and colour. Because evolutionary techniques reveal how human cognitive limits and cultural variations create spoken languages, the findings of this study have far-reaching implications. Perhaps our brains have a more significant influence on society than we realise. "Brain features, or what we consider universal, are more culturally defined (Phan, M. et al., 2017). Furthermore, the continuous gradation of colour seen in nature is represented in language by a succession of distinct categories. Although there is no natural split of the rainbow, every language has colour terms that speakers use to classify and arrange the colour spectrum (McNeill, N. et al., 972).

1.2 Colour Vision

The capacity to differentiate differences in the wavelength of light independent of its intensity is called “colour vision”. The colour vision includes numerous stages of the processing of information. Cone photoreceptors, which include photopigments with varying sensitivities to various wavelengths of light, are found in every area of the retina. The output of a single cone does not allow one to distinguish the spectral characteristics of an object from those of its illuminant because each photopigment absorbs light across the entire spectrum. In addition, one cannot specify the wavelength or the light intensity using a single cone's output.

1.3 Physiology of Colour Vision

Inside the human retina, daylight vision was concentrated on the fovea, and areas within the fovea were primarily constituted of cones. The fovea was located in the central macula. On the other hand, the rods that made up most of the retina's periphery were located farther inward. Since of this, we refer to the human retina as being a duplex because it is composed of both rods and cones. Even though rods are far more sensitive than cones, cone cells give us a sensation of colour and, it is due to their tight packing and individual wiring in the fovea. Rods are significantly more sensitive than cones. The rods allow us to see anything when the light levels are low.

During the daytime vision, objects, particularly moving objects, seen out of the "corner of the eye," or sensed, in other words, by the rods in the peripheral retina, initiate a reflex that causes the eye to move until the object is brought into the confines of the fovea. This process is known as “foveation”. Moreover, light is absorbed by retinal cone photoreceptors, which convert electromagnetic energy into electrical voltages. Retinal cells convert voltages into action potentials. The lateral geniculate nucleus (LGN) sends information to the visual cortex in three different colour-opponent channels. Retina and LGN cell characteristics are major in psychophysics. This shows that colour perception involves early-stage calculations. The brain combines input from the three retinogeniculate pathways to see colours.

Recent studies (Gegenfurtner, K.R et al., 2003) reveal that colour analysis and coding can not be isolated from shape and motion. Colour vision originates from the combined activity of neurons in several brain locations. Human colour vision involves cone photoreceptors with overlapping wavelength-tuning curves in the retina. Three main pathways carry eye-to-brain colour information. 'Cardinal' systems are autonomous and efficient psychophysically, physiologically, and computationally. Several V1 neurons prefer colour. Brightness affects these neurons. However, these neurons do not prefer cardinal colours. Higher visual areas have fewer colour neurons. One-third of V2 neurons are nonlinear which is described in cortical mechanism of colour vision (Karl, RG et al.,2003). As shown in **Figure 2.**

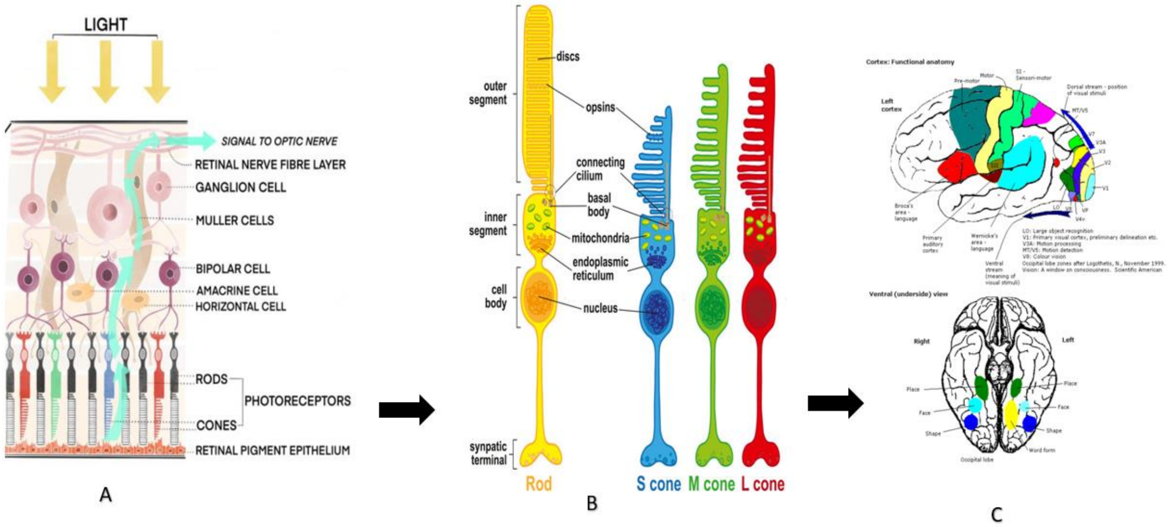


Fig-2. The illustrations show the physiological process in the retina for colour vision .

A) *The basic cellular arrangement begins with ganglionic cells. Although light reach primarily to the ganglionic cells of the retina, photoreceptors are the principal sensors and transmitters of light.* ***B)*** *Anatomical structural comparison of the rod and three different types of cone cells responsible for perceiving various forms of colour* ***C)*** *The colour vision computational process is held in the visual cortex V-8 areas.*

1.4 Biology and Evolution of Colour Vision

Animals can differentiate between different energy spectrums because of their capacity for colour vision. It has been shown that colour vision is present in many animal species to be potentially helpful in analysing and comprehending one's visual surroundings. Vertebrates cannot have colour vision without the cone opsin genes and the photopigments that they specify. During development, these essential components will exist, disappear, and resurface differently. This will occur within the confines of the constraint.

These alterations and other adaptations to the visual system have led to significant differences in the colour vision of vertebrates and the development of mammalian colour vision, including crucial biological processes and mammalian colour vision variants. These differences have been brought about by a combination of factors and are part of the evolutionary process.

Eutherian mammals maintain just two of four cone opsin gene families seen in other vertebrates. During this period, the complex system of coloured oil droplets typical of photoreceptors in many vertebrates presumably disappeared, as did much of the retinal circuitry specialised to processing colour information (Jacobs et al., 2004). Most eutherian animals now have one colour dimension. Primates evolved visual system changes that allowed for increased colour vision. Variable among monkey lineages, these modifications include a larger population of cones densely packed around a central fovea, the inclusion of the third kind of cone photopigment, and the advent of retinal circuitry compares cone signals.

Compared to other species, many of which have more extensive peripheral adaptations for obtaining colour information, mammals have poor colour vision (Goldsmith , et al.,2006) . Despite its apparent simplicity, the vast history of eutherian animals maintains colour vision.

It is sometimes apparent how appropriate it is to generalise conclusions concerning the limits of mammalian colour vision to primates. Consider that human trichromats have been found to make accurate colour distinctions based on variations in wavelength as small as (0.25 nm) (Mollon et al., 1990) and that there may be as many as (Pointer et al.,1998) 2.3 million surface colours that people can distinguish.

According to (Jacob et.al, 2009), no other species can replicate these remarkable feats, at least not yet. Moreover, primates’ large, flexible, and plastic brain allows them to use colour information in various ways generally unavailable to those species with more limited central processing capability, which may be the greatest strength of primate colour vision.

The vertical structure consisting of nine layers may be seen in the duplex structure of the retina. The structural differences between rods and cones Quantities, as well as their distribution - a design that is capable of catching the light - photoisomerisation with rhodopsin orientation *CNG Na+-Ca2+* channels - transducins - *cGMP-PDE* - dark current - light blocks dark wind - light inhibits dark current - hyperpolarisation; the conversion of *cGMP* to *5GMP* acts as a trigger CNG channel shutdown - recoverin prevents Ca2+ from being removed from the cell; - recoverin encourages GC to produce *cGMP* opsin is inactivated by rhodopsin kinase and arrestin as part of the sensory adaptation process that also helps in contrasting ciliary and rhabdomeric photoreceptors.

The photoisomerisation and retrieval of retinal cones and cone opsins - evolutionary linkages and categorisation of bipolar cells according to cytology of bipolar cells Sign-conserving rod bipolar, sign-inverting cone bipolar, and sign-inverting rod bipolar are all available. - the biological, chemical, and physical sciences - RFs (receptive fields) (receptive fields) - wiring diagrams The ILM and OLM of the Muller cells are active.

Afferent and efferent routes are the two types of inner plexiform cells. The synaptology of amacrine cells may take on many different forms, and the categorisation of ganglion cells and the possible courses of action - classification based on the anatomical and physiological aspects - the number varies depending on the location of the retina. As a result of these molecular shifts, one can see colour via a process known as phototransduction. As shown in **Figure 3**

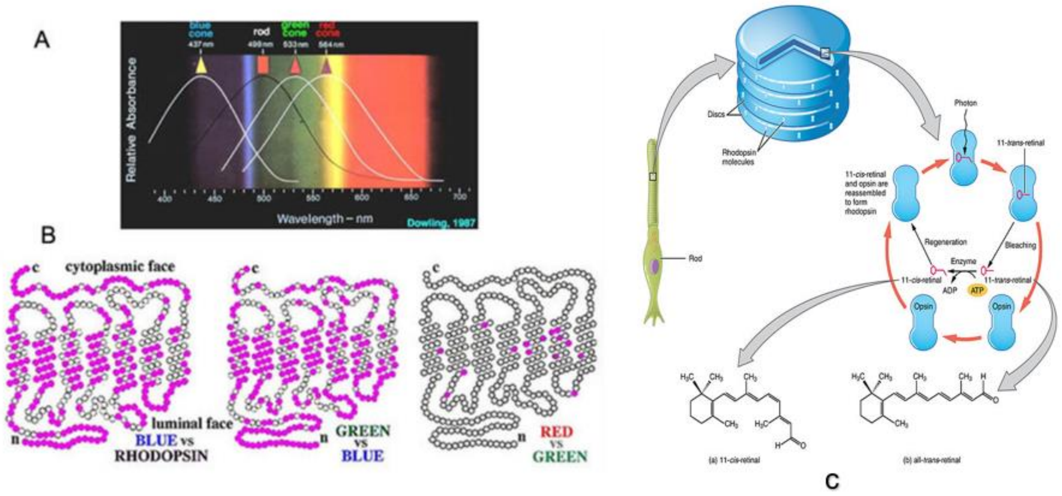


Figure-3. The illustration showing the Opsin molecules have different sequences and spectra adapted from (Kolb et.al, 1995, Photoreceptors).

A) The Spectra and pigment absorption. Primate cones and rods' maximal spectral sensitivities ***B)*** *The molecular structures of cone opsins are closely connected. Compared to rhodopsin, blue-cone opsin has a longer wavelength (left). In contrast to its counterpart, the green-cone opsin, the blue-cone opsin (centre). When compared side by side, red and green cone opsins (right) have very few distinguishing characteristics. Amino acid substitutions between comparative opsins are shown by the pink circles with their contents filled in the open circles denoting the same amino acids.* ***C)*** *Process flowchart of Visual phototransduction turns light into nerve impulses in human and animal rod and cone retinal cells. The visual cycle requires photoisomerisation of retinal-bound opsin.*

1.5 Colour Vision Theories

Aristotle is credited with developing the first theory of colour vision about the year 300 B.C., and it was based on the notions presented in his works that many other theories and ideas relating to colour vision were developed, as indicated in **Table 1**.

Author Name	**Year**	**Theory Name**
Aristotle	**330 BC**	**“Linear scale of colours”**
Summary	He proposed that the colours we see on Earth are rays from the skies sent down by God. And also found that earth, fire, wind, and water have similar hues. Aristotle's linear scale was the most significant of the previous systems. It suggested that colours might be formed by blending white and black. Aristotle put the five chromatic colours between white and black around 330 B.C., with yellow closest to white and blue closest to black. Many later authors adopted Aristotle's linear scale between white and black but rearranged the intermediate colours**.**	
Leonarda da Vinci	**15th century**	**“Alternative hierarchy of Colours”**
Summary	This hypothesis says that we see white as the "source, or the receiver" of colours and black as the absence of colour; he argued in his Treatise on Painting that both are necessary to the painter since white represents light and black represents darkness. The sequences he stated for his six colours were white, yellow for earth, green for water, blue for air, red for fire, and black for the night.	

Isac Newton	**1704**	**“Newton Colour Wheel”**
Summary	The visible spectrum was found by Isaac Newton because of his work with white light. He watched how the light seemed to split up and bend as it went through a prism. Because of Newton’s discovery, every child knows that the colours of the rainbow are red, orange, yellow, green, blue, indigo, and violet. Newton added musical notes to the colour wheel and connections to music, but the experiments also led to the idea that red, yellow, and blue are the primary colours from which all other colours are made. Even though that was not exactly right, this theory helped shape how colour wheels, like the ones we use today, were made. The importance of Newton's Colour Wheel in creating colour systems like Pantone, Munsell, and RAL cannot be overstated. These systems give designers the tools they need to use the science of colour to make palettes and designs in the modern era.	
Thomas Young	**1801**	**“The Trichromatic Theory”**
Summary	He proved that light was made of waves and quickly realised various colours had varied wavelengths. Young estimated the wavelengths of red, orange, yellow, green, blue, indigo, and violet based on Isaac Newton's hypothesis (VIBGYOR: rainbow colours). This early colour perception scientist suggested that the eye must have photoreceptor cells and that each photoreceptor can only interpret light waves of a single colour. To see all types of light, the eye needs many photoreceptors. Young stopped his experiment studies in 1814 to pursue another interest.	
Hermann von Helmholtz	**1850 - 1900**	**“Young-Helmholtz Trichromatic theory”**
Summary	After 50 years, based on studies of colour matching, this theory proposed the existence of three classes of eye colour receptors. The presence of cone-shaped receptor cells was	

	proven in the 1960s. At 445 nm, 535 nm, and 565 nm, respectively, the three types of cones have their highest absorption. Short, Medium, and Long wavelength sensitivities are abbreviated as (S, M, and L), respectively. According to the trichromatic hypothesis, colour perception results from interactions between the S, M, and L cones. White is the result of simultaneous, equal stimulation of all three. Connected to the tristimulus value system is the trichromatic colour theory.	
Maxwell	**1860**	**“Theory on Compound colour and Additive theory of colours”**
Summary	Worked and developed the theory of compound colours, and the relations of the colours of the spectrum which appeared in the Philosophical Transactions. In it, he determined which hues must be combined with others and which ones must be removed to create a new colour.	
Aemilius Müller	**1950**	**“Physiological theory of nerve energies and gradation of colour”**
	Muller introduced the physiological theory “Müller's notion of specific nerve energies,” which explains that a nerve fibre can only carry one sort of qualitative information. A nerve fibre cannot carry red and green information since they are essentially distinct. However, monotonous colour gradations may be made more appealing by permitting normal variances. To illustrate subtractive colour mixing, he filled his colour cube with yellow, (magenta) red, (cyan) blue, orange, violet, green, white, and black.	
Edwald Hering	**1892**	**“The Colour opponent process”**
Summary	According to the opponent process colour theory in the human visual system interprets information about colour by processing signals from photoreceptor cells negatively. This theory was developed to explain how the human optical system works. According to the opponent-process hypothesis, there are three opponent channels, each consisting of an opposing colour pair: red vs green, blue versus yellow, and black versus white (light).	

Erwin Schrödinger	**1920**	**“Geometrical modes of colour theory and brightness”**
	Schrödinger belonged to a school of thought that sought mathematical explanations for the properties of colour and their correlations. Because of our familiarity with colour wheels and other geometric representations in a computational models . This theory, mainly emphasize about the geometrical and space representation of colour models .	

Table-1. The tabular representation shows the different authors’ views, and theories developed related to colour vision.

1.6 Colour vision deficiency and classification

Colour vision deficiency: Insufficiencies in the capacity to see colours, sometimes referred to as colour vision deficit (CVD) or colour vision impairment, may occur if there is a problem with the cone pigments in the eye. These insufficiencies are common. A person is said to have a weakness in colour vision if they struggle to differentiate between shades of colour. The population unable to see or distinguish is considered to have colour vision deficiency. As shown in **Figure 4**

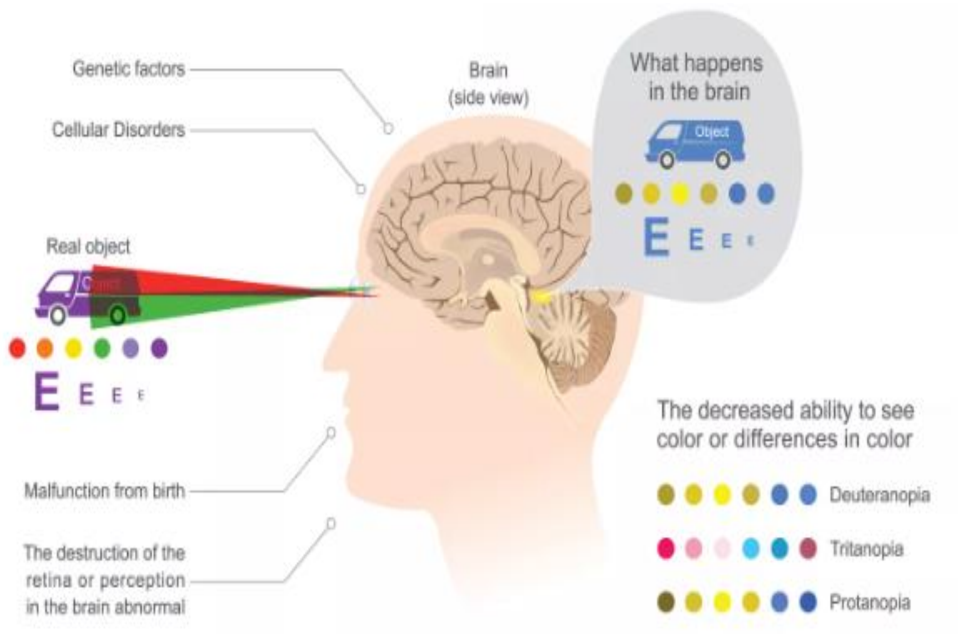


Figure-4. An illustration showing the colour vision deficiency mechanism

Classification of Colour vision deficiency

“**Trichromacy-**It describes as normal colour vision. Three cone cells (Red, Green, and Blue) function normally, and people with normal colour vision are also called Trichromats”

“**Protanopia**-In this Red cone photoreceptor, longer wavelength photopigment is absent”.

“**Protanomaly-**In this Red cone, photoreceptor is present but improper, or deficiency is observed”

“**Deuteranopia-**In this Green cone photoreceptor, middle wavelength photopigment is absent”.

“Deuteranomaly-In this Green cone photoreceptor is present but improper or deficiency is observed”.

“Tritanopia-In this Blue cone photoreceptor, short wavelength photopigment is absent”.

“Tritanomaly-In this Blue cone photoreceptor is present but improper or deficiency is observed”.

“Achromatopsia-It is a condition with cone photoreceptor malfunction or absence of cone receptors responsible for colour vision. The majority of cases are congenital in nature”.

“Blue cone Monochromacy-In this condition, colour-sensitive cones in the eye are compromised. Cone cell receptors respond to red, green, and blue. Blue cone monochromatism affects the red and green cones but not the blue cones”.

Based on the information shown above on the classification of colour vision defects, a person with faulty colour vision will have distinct perception models, which may be seen in a colour vision deficit stimulator like the one presented in **Figure 5.**

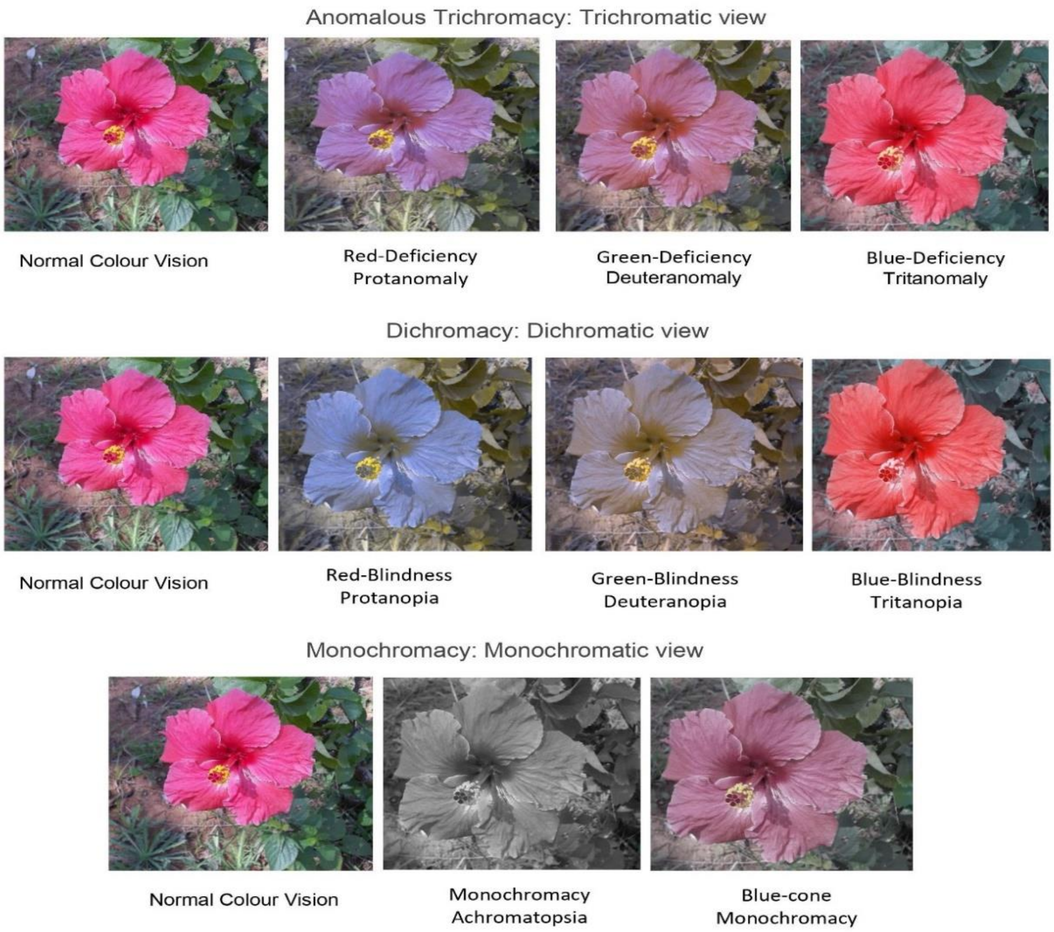


Figure-5. Illustrations modelling colour blindness using the Hibiscus flower as the object.

Colour Vision Deficiency Causes

A lack of colour vision is often the result of a genetic defect inherited from one's parents and then passed on to their offspring. Cone deficiency is the source of this condition. Cones are the cells in the retina that detect colour; some people either do not have enough or are damaged. A colour vision deficit may sometimes manifest itself in adulthood as a consequence of following an underlying health condition, such as

i. Diabetes (Diabetic retinopathy-PDR, cystoid macular oedema)
ii. Glaucoma
iii. ARMD (Age-related macular degeneration)
iv. Multiple sclerosis; a side effect of a medication, such as digoxin, ethambutol, chloroquine, hydroxychloroquine, phenytoin, and sildenafil; exposure to harmful chemicals, such as carbon disulphide and styrene; and a combination of these risk factors.
v. Neuroophthalmological conditions involving nerve injuries and Trauma
vi. Congenital and Retinal dystrophies (Retinitis pigmentosa).

1.7 Genetics of Colour Vision Deficiency

Chromosomes pass on genes that cause colour blindness and CVD. "X and Y" chromosomes determine a person's gender. Men have one X-chromosome, whereas women have two (X-chromosome). “Red-Green colour blindness” is more common in men since it's on the X-chromosome. See **Figure 6** for an illustration.

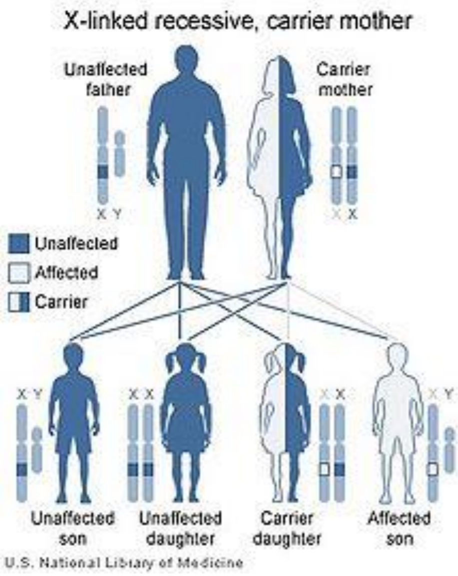


Figure-6. The inheritance characteristics of Colour vision deficiency adopted from (Poret, S et al., 2013)

Deficiency in red-green colour vision and the monochromacy of the blue cone are passed down through generations in an X-linked recessive pattern. The *“OPN1LW”* and *“OPN1MW”* genes may be found on the X-chromosome, one of the two chromosomes in a pair of sperm and egg cells. Because men only have one copy of the X chromosome, all required for the disorder to manifest itself is a single genetic mutation in each cell. Because females have two copies of the X-chromosome, a genetic change would need to occur on both copies of the chromosome for the disorder to manifest for a female to be affected by an X-linked recessive condition.

This is why X-linked recessive conditions are much more common in males. X-linked inheritance prevents fathers from passing on X-linked traits to sons. The pattern of this gene arrangement in trichromatic vision and Red and Green deficiency expressed. As shown in **Figure 7**

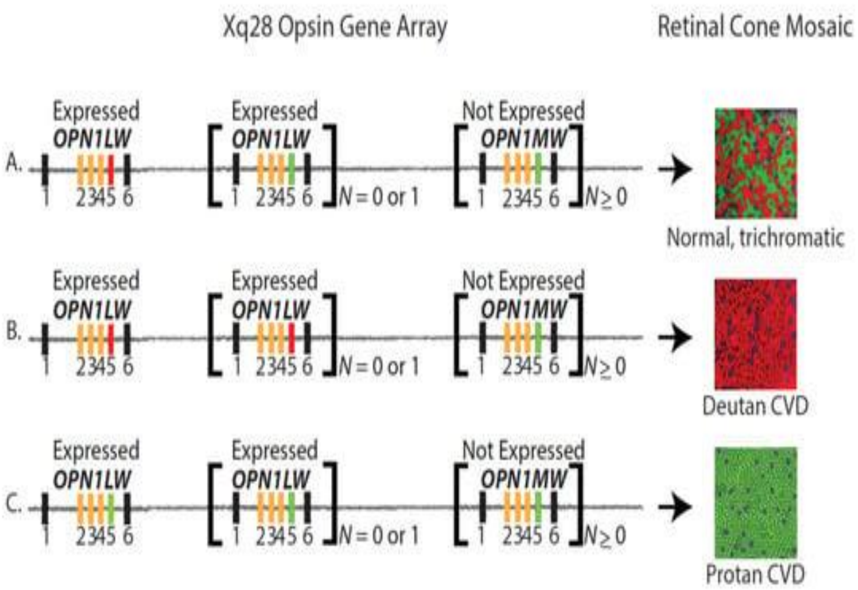


Figure 7 The opsin gene expression adapted from (Neitz, M et al., 2021).

A) An opsin gene array comprising "OPN1LW" and "OPN1MW" genes will produce L cones (red circles), M cones (green circles), and S cones (blue circles) for typical trichromatic colour vision.

B) In a retinal mosaic with L and S cones but no M cones and deutan CVD results from an opsin gene array with only 1 "OPN1LW" gene, second and third genes n = 0 or two expressed "OPN1LW" genes (second gene n = 1).

C) opsin gene array with 1 "OPN1MW" gene second and third genes n = 0 or both expressed locations second gene n = 1 would give rise to a retinal mosaic with only S cones and M cones, but no L cones, and cause protan CVD.

1.8 Prevalence of Colour Vision Deficiency

According to the (Colour-blind awareness organisation) worldwide, colour vision deficiency affects around one in 12 men (8%) and one in 200 (0.5%) women. There are roughly three million colourblind persons in the UK, which accounts for approximately 4.5% of the whole population. The majority of colourblind people are men. It is estimated that over 300 million individuals worldwide have trouble distinguishing between different colours.

There is a paucity of research on colour vision deficiencies in the scientific literature. Most of the existing studies were conducted on kids of school age, according to prevalence statistics from India. The prevalence rate among males is projected to be (3.89%) in the year (Kundu et al.,2020), while the prevalence rate among females is projected to be (0.18%). However, different studies reported an estimated prevalence of CVD among Indian states. As shown in **Table 2.**

Author	**Year**	**Sample size**	**Colour Vision Deficiency Types**				**Gender wise CVD distribution**		**Age Range**	**Study Location**
			Protan	**Deutaran**	**Others**	**Overall CVD %**	**Male**	**Female**		
Mohd Fareed et al.	2015	N=1028	3.22%	7.95%	2.27	8.35%	7.52%	0.83%	6 to 15 years	JK origin study held in Uttar Pradesh
Krishnamurthy et al.	2021	N=25,0052,	NR	NR	NR	2.76%	2.76	Nil	6 to 17 years	Tamil Nandu

Ahsana Shah et al.	2013	N=2654	NR	NR	NR	10.42%	8.73%	1.69%	6 to 15 years	Manipur
Ila Venkata Padma et al.	2021	N=1000	NR	NR	NR	7.80%	7.80%	0	NR years	Hyderabad
Subhash C Gupta et al.	2017	N=738	NR	NR	NR	2.3%	4.20%	0.59	11 to 14 years	Bhopal
Kundu et al.	2020	N=13,179	NR	NR	NR	2.98%	3.89%	0.18%	18-62 years	Delhi
Sujani et al.	2018	N=13,149	NR	NR	NR	0.89%	1.57%	0.20%	9 to 14 years	Hyderabad
Madhu gupta et al.	2009	N=1561	NR	NR	NR	2.3	3.90%	0.5	6 to 16 years	Shimla
Reddy AVP et al.	2017	N=1629	NR	NR	NR	1.90%	3.30%	0.30%	10 to 15 years	Hyderabad
Sangeeta Das et al.	2018	N=1000	0.18%	3.04%	NR	1.78%	1.33%	0.25%	9 to 16 years	Hyderabad
Himani et al.	2021	N= 1150	NR	NR	NR	3.25%	4.66%	1.72%	13 to 18 years	Uttarakhand
J S Murthy et al.	1974	N=2623	0.94%	2.11%	NR	3.20%	NR	NR	NR	Hyderabad, Telangana
Sanjeev K Mittal et al.	2022	N= 13,492	NR	NR	NR	2.20%	3%	1.4%	6 to 16 years	Rishikesh, Uttarakhand
Deepshika Agarwal et al.	2020	N= 1557	NR	NR	NR	3.3%	6.6%	0.7%	5–15 years	Raipur, Chhattisgarh
Shekhar O et al.	2019	N= 817	NR	NR	NR	0.12%	NR	NR	6–10 years	Goa
Sandhya R et al.	2017	N=225	1.8%	3.6%	NR	3%	5.4%	0.9%	15 -25 years	Tumkuru, Karnataka

Note: **NR: Not Reported. [High prevalence estimates were found in Hyderabad, Telangana]

Table 2. The estimated prevalence according to the studies reported on the prevalence of colour vision deficiency in the Indian population.

1.9 Management of colour vision deficiency

Diagnostics tests for assessment of CVD.

There are numerous tests available to assess colour vision, but the most common test is the "Ishihara -pseudoisochromatic colour vision test". This tests red/green colour blindness but not blue. This is the test most often used for school or medical colour vision assessment. The test contains 38 plates of irregularly coloured circles. The optometrist will be prompted to count the plates' numbers. Some plates feature information only colourblind people can see. Colour blindness is diagnosed after a certain number of errors. However, the limitation of this test is that the Blue cone or short wavelength colour deficiency is unable to detect.

According to the findings of the National Research Council of the United States (NR, Council et al., 1981), advanced diagnostic tests, such as the FM-100 Hue test, the D-15 Colour Vision Test, the Lantern Test, and the Anomaloscope, are used to diagnose colour vision deficiencies clinically. The Anomaloscope is regarded as the gold standard because of its high specificity and sensitivity rate.

Treatment

Except in cases when a patient's colour vision issues are caused by certain medications or an underlying eye ailment, there are currently no effective therapies for most colour vision disorders. The colour vision may improve when they stop taking the medicine which is causing the impairment or when they get treatment for the underlying eye illness.

The use of colour filters, coloured contact lenses, and other rehabilitation equipment may aid in increasing colour vision scores, according to the findings of systematic reviews (Male,SR et al., 2022). However, subjective colour perception does not improve or get treated clinically in this condition.

1.10 Need and Justification for this doctoral research

The prevalence of colour vision deficiency has been reported to be increasing in India (Kundu et al., 2020), particularly in research conducted in Hyderabad, Telangana state, which revealed a greater prevalence. Although CVD is rarely life-threatening, the potential consequences of CVD may influence psychological well-being, empowerment, and other aspects of everyday living. Colour vision is one of the essential visual functions necessary for most daily human activities.

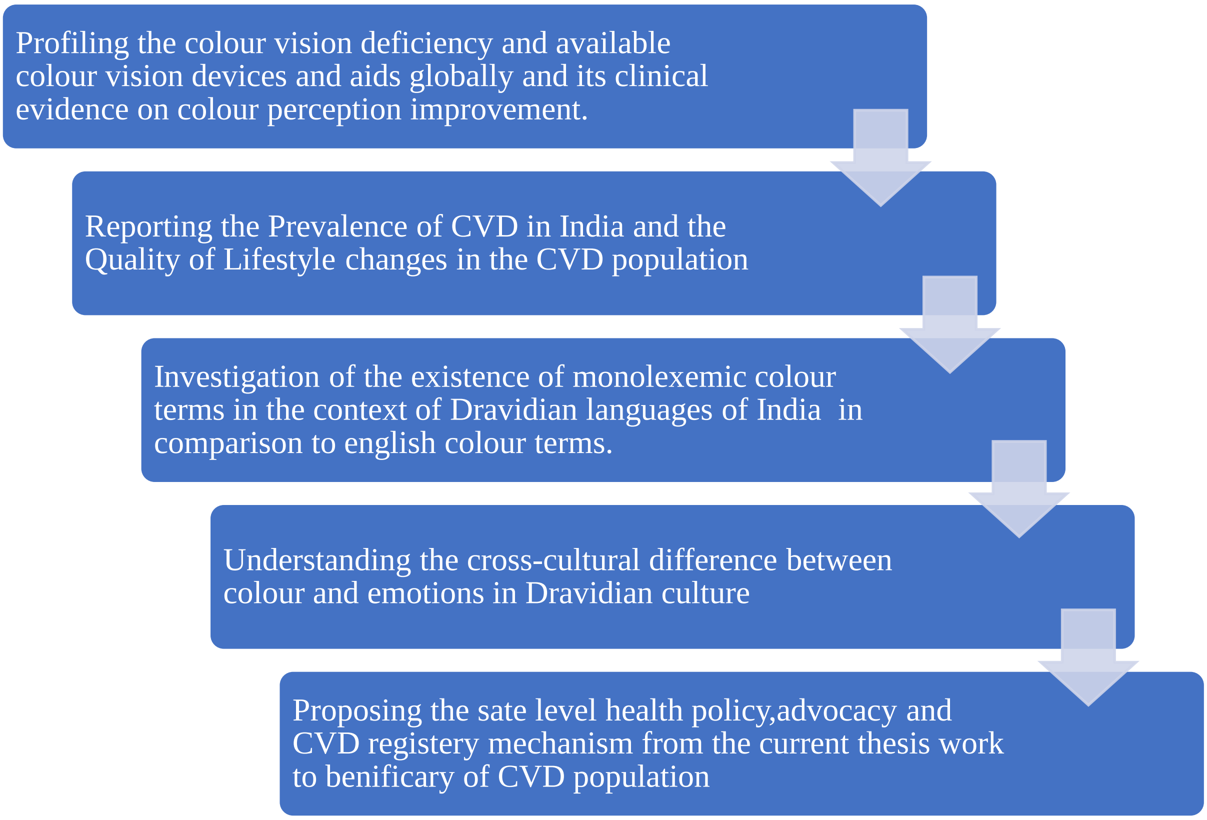
Even though there is currently no permanent treatment for CVD, in developing countries such as India, CVD is ignored and not prioritised in vision screenings. As a result, most patients are unaware of this condition. They fear being diagnosed with it because it could negatively impact their empowerment and other opportunities in the workplace.

Considering this, the present PhD work is being produced to develop a strong health policy, advocacy, CVD registry mechanism and awareness, including clinical recommendations for existing colour vision CVD devices and aids for the CVD community.

Furthermore, the current research also focused on the significance of colour in culture, the development of these cross-cultural words, and their significance in ancient Dravidian civilisation. Several scientific investigations and literary works(Kapp et al., 2004) , (Berlin and Kay, et al., 1969) have examined the correlation between colour and emotion in Western civilisations. However, little attention was paid to the cross-cultural implications of India's Dravidian languages. Dravidian culture is the most ancient of 4,500 years (Kolipakam, V et al.,2018).

It also tells us about the evolution and migration of languages but not how colour terms came to be. Because of this, interdisciplinary approaches for studying the relevance of colour vision in language and cognition need to be developed. This thesis explored the gap above in colour term naming and colour and emotion associations, as well as the monolexemic colour terms in the Dravidian languages of India.

Phased approach developed for the current research



Aim and Objectives

- ❖ To profile the problem of colour vision deficiency and its association with colour, culture, cognition, and technology from an Indian perspective.

Objectives

1. To undertake a systematic review of colour vision devices for the colour vision deficiency population
2. To study the impact on quality of life in a sample of the Indian CVD population
3. To explore the visual psychophysical approach on monolexemic colour terms in Dravidian languages.
4. To study the association of colour and emotion association in Dravidian culture.
5. To propose advocacy and policy guidelines at a state level for CVD population.

Chapter-2

Theoretical foundation and Literature review

2.0 Overview

This chapter introduces a foundation concerning different gaps identified in the proposed aims. Additionally, an overview of colour vision deficiency profiling and colour association with culture, cognition, and technology has been explained based on the literature that has been reported.

2.1 Colour terminology and properties

William E. Gladstone, Lazarus Geiger, Grant Allen, Ernst Krause, and Charles Darwin were some notable scientists who weighed in on the debate over who should get credit for creating colour nomenclature and how it should be formally recognised. Hugo Magnus, a German ophthalmologist, was the first to study the human ability to perceive different colours and to make essential suggestions about the relationship between that ability and the existing colour terms in languages worldwide (MacLaury et al., 2007) .

Magnus was one of the proponents of the theory that human colour perception had developed gradually during the evolution of the human species. Philological studies of ancient Greek texts by (William Ewart Gladstone et al.,1858) and later by (Hugo Magnus et al., 1877) focused on the terminology used to describe colours in ancient texts like the Rigveda, the Bible, and the works of classical Greek and Latin authors like Aristotle, Juvenal, Statius, and Valerius Flacchus.

Colour perception develops via four distinct phases. The only discernible hues were red and other vivid ones. They spoke only about the quantity and hues of light. As the human retina matured, red and yellow stopped blending. By the third stage, people had established a preference for shades of green other than black (dark green) and white (light green).

Magnus's recognition of colour terminology patterns echoes the Basic Colour Terms hypothesis put out by (Berlin Kay et al., 1969), who, almost a century later, identified similar patterns, relying, like Magnus, on the examination of a broad range of linguistic communities across the globe. The Magnus studies impacted the evolutionary colour-term sequences developed by berlin and kay, which in turn led to the development of universal colour names from the world colour survey experiments. However, many Dravidian languages were ignored in this experiment.

The discovery of semantic universals in colour names opposes the extreme relativism associated with the Sapir-Whorf hypothesis (Shapiro, R et al.,2005) which anticipates the division of the colour continuum in a way that is arbitrary and dependent on the language being used. In addition, they propose a specific sequence for the presentation of basic colour phrases that pertain to the categories above.

According to (Bornstein et al., 2006), Colour categorisation and naming are isomorphic in certain cultures. Human colour sensitivity appears to mirror essential colour naming and categorisation. Vision, ontogenetic, and experimental data suggest variation from uniformity and people switch from consistent colour naming to adult diversity which implies that the verbal coding produces essential category perception.

(Kapp et al., 2004) The first to note that the universal language of colour suggested by Berlin and Kay omitted terminology for colours used in the Dravidian language. When these colour words were added and compared, it was discovered that they are not universal, and that constructive criticism prompted the development of colour terminology in Dravidian languages; it was also suggested that stage-II black and white colour terms be added for clarity.

(Suntherasen, V et al., 2016) reported that Colour words exist in all languages and can express meanings subtly yet effectively. Colour names have connotations beyond their literal definitions, and the Colour terminology's connotative meanings vary by linguistic culture. Prolonged research of this sort, including additional languages, would bring more intriguing information about global languages' linguistic, cultural, and anthropological elements.

(Rinu N, et al.,2016), reported that the Malayalam colour names are consistent, suggesting colour naming is not universal. In spontaneous speech, colours' labelling phrases differ from their conventional versions. Future research may strive to study the impacts of culture on colour words (i.e., native and non-native Malayali speakers' colour naming behaviour) since ethnic backgrounds and climates affect colour classification.

Essential monolexemic colour words were not considered throughout the classification process, and the Dravidian and the primary colour terms are not supported by the universality colour terms hypothesis, as shown by a review of the relevant literature. As the Dravidian (V Kolipakam et al., 2018) languages are thought to be 45,000 years older, it is possible the western hypothesis on English colour words cannot be compared cross-culturally to explain the qualities and development of the colour terms.

2.2 Colour and cognitive association with emotions

It has been known for a very long time that there is a connection between colours and emotions. In colour therapy, for instance, different hues induce different emotional responses (Birren et al., 1978). Earlier Studies by (Boyatzis, et al., 1994) and (Hemphill, et al., 1996) demonstrate that individuals typically link specific colours to particular feelings. However, research (Egan, et al., 1974) suggests that the vividness and saturation of a colour scheme might help evoke certain emotions.

Emotions are associated with colours in various ways, and these metaphors vary across languages (e.g., red, black, or white are linked to anger) reported by (Soriano et al., 2009). In contrast to Western customs, where brides and mourners wear white and black, respectively, in China, brides and mourners wear red and white. Whether colour-emotion correlations are universal or culturally particular based on what people know and believe needs to be clarified, but these are problems that need answering before any guidance can be offered to the applied domains on the subject of the psychological influence of colours. Theoretically, understanding how colours are seen by people all across the world might provide light on how our brains are wired.

(Goethe, et al., 1840) theory on colour psychology explains that (Colour is darkness), and this phrase revolutionised the world on metaphysical and metaphorical levels, emphasising that night is always vivid, and light is only a way to "see it" with our eyes.

Correlations between colours and emotions are very widespread and persistent, meaning they manifest similarly in a broad range of contexts throughout the world. Since we are constantly bombarded by emotional clues from the language, society, and perception we are immersed in, it stands to reason that colour correlations and meanings may be determined in a controlled laboratory environment. Countless empirical research has revealed that non-specialists may quickly associate regardless of whether we are talking about emotional aspects or tangible particular objects. Psychologists (Meier et al., 2004) and vision scientists (Hulbert et al., 2010) (Ling, et al., 2007) are a few examples of the many scientific communities that have studied this phenomenon.

In humans, according to (CIE et al., 2022), "Thinking in colour" is vital in some situations. All of these actions need brain economics of cognition. The brain employs "cognitive colours" to convey and store colour information. Visual processing speeds up several cognitive processes. Formulas for analysing colour appearance and colour discrepancies may need to be revised to anticipate an observer's behaviour in demanding jobs. We must explain a cognitive colour's bounds or a "representative object" from this colour space to define it.

To further investigate the connection between colour and emotion, cognitive theories, chromotherapy, and comprehensive colour therapy were developed (Gupta R et al., 2021). Colour therapy is used in many different cultures. The workplace, manufacturing, the arts, healthcare, and hospitals may all benefit from colour therapy. Misusing colour therapy might have negative consequences. Most psychiatrists and psychologists believe that the benefits of colour therapy are just temporary. Patients' emotional and psychological well-being might benefit from colour therapy.

It was discovered through the literature review that the majority of the psychological and colour associations were quantified experimentally via the investigations, mainly using psychophysical techniques. In most cases involving cognitive and mental health, there was a deficiency in research on holistic approaches, interventional treatments, and other forms of therapeutic relevance. These methods may be employed as alternative therapies.

2.3 Colour and Culture

Colour is the foundation of artistic expression and aesthetic appeal, colours and applications have become more commonplace with the proliferation of digital media (Kumar et al., 2016) explore the relationship between colour and Indian culture. Due to the pervasive influence of colour, every marketer must pay attention to the science behind the appeal of different hues.

According to (Kashyap et al., 2013), colour preferences are affected by geographical, national, cultural, and economic factors. Colour meanings may vary depending on the culture. Preferences for colours may differ significantly from one culture to the next. Everyone has their personal colour preference. Some believe that individuals' physiological and psychological responses to colours vary.

Given that colour perception differs greatly between nations and cultures. People's colour tastes differ widely. It has been proposed that people's physiological reactions to colour have psychological consequences.

From the colour symbolism point of view (Can science explain blue skin, 2018), Worldwide, blue has religious significance. Blue symbolised divinity and the sky in ancient Egypt. Amun, the Egyptian Empire's senior deity, “King of Gods”, turned his skin blue to fly invisibly. Vishnu, Krishna, and Shiva all have blue skin in Hinduism. The Roman Catholic Church requested that artists colour the Virgin Mary with ultramarine, a new, costly pigment from Asia. It became connected with sanctity and morality. Nazar is a blue glass bead. It stems from ancient Egypt and Osiris. His followers thought Osiris' eye was protecting. Nazar’s are worn as protective talismans. Other nations believe it wards off evil and gives good luck.

India's diversity (Colour in Indian culture, 2017) means that different symbols and colours might have different meanings in other parts. All around the world, in every religion and culture, some colours have various meanings and connotations. The significance of certain hues varies from culture to culture. The vibrant hues of many spices used in cultures and faiths worldwide are their result. Both North and South India employ turmeric in their culinary traditions, as well as in their religious and wedding ceremonies. The colour yellow is associated with purity and is often used in herbal remedies throughout the subcontinent. The presence of the gods in mythology is the source of most colours’ existence.

The Dravidian culture (Shamsashtri, R , et al., 1930) explained the origin and migration of main cultural aspects, including the lifestyle, cultural rituals, and festivals, all are significantly related to colours. The arrival of Holi (festival of colours) means the start of joyful celebrations. At this event, people celebrate by throwing colourful powder into the air. People of all ages get together to dance and sing along to the rhythm of the drums. This festival is celebrated by Hindus all over the globe because of its significance in India.

On this joyous occasion, people put aside their disagreements and threw paint in each other's faces. Participants in the festival of Holi splash each other with coloured water and throw coloured powder into the air. Holi powders include “yellow, red, green, and blue to signify love and loyalty". This also implies that colour spreads the emotional aspects by creating a positive mood environment in humans.

In addition, there have not been a lot of studies done on how different colours are meant to make different emotional responses in people of Dravidian descent; most of the theories and ideas used in the studies that have been reported on have been imported from the West, while the mythological and ancient contexts for these hues have been overlooked. We can learn more about the global link between colour and culture via future documentaries and ethnographic investigations.

2.4 Colour vision devices and technology.

The prototypes (Kandler et al., 2018) based on vibrotactile sensing technology were used to experience and appreciate colour. Haptic input, a feeling processed twenty times faster than vision, might help users of these gadgets with colour comparison and identification. The *"HaptiColor"* bracelet, the most recent prototype, interpolated colours. The only colour analysis was hue; brightness and saturation were disregarded. Two areas where this technology excelled were the usage of computers online and the choice of colours while equipping in shopping and kitchen activities.

(Gomer, R et al., 2018) reported that the two manufacturers now provide red-green CVD glasses. Patients with CVD may acquire sunglasses from Vino, those with "Enchroma" can use multi-notch filtering to exclude "sharp wavelengths of light to enhance certain colours," and those with deuteranomaly or protanomaly can get single-vision or progressive-vision eyewear for use inside or out. This subjective colour perception, however, has not been shown to improve by clinical data.

(Tanuwidjaja et al., 2014) created a Google Glass augmented reality programme to help CVD patients recognise colours. The user may choose four ways to adjust the real-time stream's display: emphasising chosen colours, comparing two colours via enhanced contrasts, changing colour presentation with filters, and outlining similarly coloured regions.

According to (Lucille, A. et al., 2022), there is a wide selection of accessible mobile apps for those who are blind or have low vision. However, the selection process does not stop with CVD; it also considers vision loss and other visual impairments since their respective user bases overlap, and the discovered functionalities may be helpful. All of the chosen apps use the smartphone camera to get contextual data. While some (Chromatic Glass, Color Inspector, NowYouSee, Seeing AI) provide immediate responses, others need the user to capture an image or video before any analysis can be performed (Eye of Providence, TapTapSee).

(Microsoft support) latest Windows 10 operating system upgrade includes filters to aid colourblind users, among other special features. Most machines running Windows 10 have loaded the Fall Creators Update, which provides for colour-blindness filters; this is particularly beneficial in developing countries.

The (WHO report, 2019) estimates that 2.45 billion people worldwide could benefit from rehabilitation services. The global need for rehabilitation services will increase due to improvements in population health and shifting demographics. As people live longer, they are more likely to suffer from long-term conditions and become disabled. Over 50% of people in low- and middle-income countries do not have accessibility to rehabilitative programmes. Since CVD lacks a permanent cure, rehabilitation methods also manage it.

According to the review and gaps identified, many new powerful technologies and prototypes have been developed to correct colour vision deficiency. However, these technologies have not been tested scientifically or in clinical settings. Some of the augmented reality and virtual reality technologies might be the new ray of hope for developing colour vision aids in the future. When clinicians, computer scientists, and other rehabilitation and biomedical engineers collaborate to create innovative solutions for colour vision equipment and technologies, they will be able to solve the identified gaps in the field.

2.5 Quality of life and challenges with the CVD population

According to (Colourblind awareness org), people who are colourblind have a variety of difficulties, such as choosing and cooking food, gardening, participating in sports, operating a car, and even selecting clothes may be challenging activities and the risk of getting into problems at work if they misunderstand the instructions given to them or if they realise that they or their child have been sunburned**.**

Electrical items with red/green/orange LED displays may be annoying since all three colours might seem orange. A portable gaming system with a red-to-green indication light may be an example. Due to their colourful lights, WiFi and TV hubs/routers may be bothersome.

Congenital (Colourblind reports, India, 2019) medical students in India want to be "tested" before enrolling. This should consider "the sort of errors" people make so they know their position and constraints. This would enable pupils to take classes where colour blindness is not a problem. This is contentious in pathology and surgery, where colour vision is vital.

According to (Chakrabarti, S et al., 2018), CVD's effect is determined by its type, severity, awareness, personal circumstances, and capacity to deal with it. The social and psychological components of CVD are little researched. Early identification, awareness, and support are the only proven approaches to aid doctors with CVD. With the increased focus on equality and inclusion of persons with shortcomings, it's essential to create a balance between patient care and the right of medical professionals with CVD to work.

According to (Verriest, et al.,1980) and (Hager et al., 1963), defective colour vision while driving is dangerous. However, only 8% of drivers have impaired colour vision. Thus, the frequency of accidents attributable to it will be tiny, possibly 4 in 1000. It would be in the public interest to impose a colour vision norm, at least for commercial and public transport drivers who travel longer distances and whose accidents have more considerable societal costs. This also implies that rigorous screening and testing are required in drivers during the job recruitment process.

Recent (Hathibelagal A. R, et al., 2022) reports give new statistics on CVD's influence on the air force, army, and police employment. Identifying the nature and degree of the problem in work contexts might give alleviation for at least some persons with mild-to-moderate CVD. This new understanding of CVD and occupational setbacks might lead to modifications in the recruiting process in many professions depending on the kind, intensity, and importance of colour-related tasks in the workplace.

It was also established from the literature review that people with colour vision deficiency need a new, improved health policy or advocacy effort to help them. Better insight may be gained into the disability research field if this group is included under a category of disability by measuring the colour vision loss and providing new criteria. The requirements of the CVD population may be supported by raising awareness and developing a routine and periodic colour vision screening.

2.6 Policies for colour vision deficiency

In India, the cane foundation, which works for disability rights, presented various reports in the court for considering the CVD in inclusion for disability. But Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation Act was considered in 1995. Later in 2016 the law was abolished and replaced with the Rights of Persons with Disabilities Act (49 of 2016). According to Mr Viswanathan, the committee argues that because colour blindness is not a handicap under the 1995 Act and the 2016 Act, its nature, severity, and the disciplines they may practise must be reconsidered in future for inclusion (CANE FOUNDATION, 2018).

The Supreme Court of India (Mishra, 2017) recommended to the Indian medical council that CVD students be considered for admission into medical courses for enrolling and studying, while colourblind individuals are denied entrance into Indian institutions. These suggestions were also implemented by considering education and health policy models from the United Kingdom and the United States.

Under the Americans with Disabilities Act (Dejong, et al., 1990) , red-green colour vision deficiency is considered a disability. It receives all the benefits, and it is also recommended that all companies and organisations make reasonable accommodations for colourblind workers. ADA compels companies to offer reasonable accommodations for disabled workers who need service animal assistance.

In addition, neither Canada nor the United Kingdom recognises CVD as a disability; nonetheless, special inclusion and benefits are given according to the degree to which a person is colourblind.

Interestingly, CVD has been recognised as a disability (ADCET act 1992) in Australia. In the context of disability, the societal view of colour blindness is interesting. Some judicial precedent condones discrimination against those with colour vision deficiency in police, intelligence, and aviation. Case judgements do not appear to be based on occupation-specific research. Despite legally enforced direct discrimination against persons with CVD at work, society feels CVD is mild enough to be neglected.

The European countries also given importance in the (European Disability Strategy 2010-2020) impairments like colour-blindness are discussed. The report also addresses the importance of disabled people's rights and equal access to the workforce and the rest of society. But the regulations and new health policies still needed to be approved (Persons with Disabilities, 2012).

According to the literature above, developed countries are already evaluating colour vision deficiency as a significant impairment for considering disability and particular emphasis in the future. India, another nation with a large population, should likewise review and could update its disability laws and regulations.

2.7 Available Registry related to Retinal disorders.

Retinal abnormalities cause CVD, and registries aim to document inherited and uncommon disorders to generate novel treatments and care plans. Some of the listed registries are mentioned below.

i) MRTR= (Inherited retinal degenerative disease registry): This "My retina track registry" began in 2014 and is planned to continue until 2037, and is a twenty-year prospective patient registry primarily focusing on inherited retina disorders. (Inherited Retinal Degenerative Disease Registry - ClinicalTrials.gov, 2014)

ii) BCMR= (Blue cone monochromacy patient registry): This X-linked recessive affects one in 10,000. It is self-registry and supported by BCM families in USA; any patient suffering from blue cone monochromatism can upload their data and register in this database (Patient Registry, BCM 2022).

iii) PRO-RETINA= (Patient registry for Retinal degeneration): This national registry in Germany tracks individuals with genetic eye conditions, including retinitis pigmentosa and macular degeneration (Retina International, 2022) .

Implementing these rare eye disease registries (Sharma, M et.al 2022) needs clinically tested methods, and more than one centre may not be beneficial. Still, the registries above may provide some information since they all indicate CVD changes. A robust consolidated database of patients with retinal disorders is required in future.

Everyone from patients to physicians to researchers may benefit from this database registry. However, in India, a uniform approach for identifying uncommon eye disorders patients would be good and adding a registry towards the CVD population might be advantageous.

Chapter-3

A systematic review on colour vision devices for colour vision deficiency patients.

3. Introduction

This chapter presents an overview of the systematic approach and a meta-analysis review of the literature published between 1976 to 2022 on the effects of colour vision devices on colour perception among people with colour vision deficiencies.

While there is no cure for colour blindness, specific varieties of colour blindness can be managed. There are also visual assistance equipment and specialized software that may help persons with colour vision deficiency to understand colours and perceive contrasts or colours to make their life simpler and navigate their environment. The introduction of light filtering glasses has enabled colour vision deficiency people to discriminate between different hues of colours that would otherwise seem the same. These glasses may aid in improving the colour discrimination on Ishihara Colour Vision Test.

In recent years, commercially available products and colour vision devices claim to improve colour blindness with globally by making commercialised advertisements. How effective are colour-blindness glasses? The results vary by kind and level of colour vision loss. However, these advertised products or devices do not show any clinical studies to take into final consideration.

Although these colour-blindness devices filter light to prevent red and green wavelengths from superimposing on one another, it won’t last very long. The photoreceptors, optic nerves, and visual cortex are all unaffected by using these devices.

3.1 Earlier Studies

According (NIRE, 2002), the “*National Institute for Rehabilitation Engineering”* proposed a few models that advise comprehensive eye exams for all colour vision devices. This study outlines 20 years of therapy for colour blindness. Since the NIRE reports no longer operate in clinics, other researchers may use the data and techniques to aid persons with impaired colour perception or colour vision deficiency.

(Varikuti V et al., 2020) cohort study reported that the EnChroma filter cut error scores in the Ishihara and Farnsworth tests by a lower limit. However, the Ishihara test error scores only went down in deutan. Although using Farnsworth colour vision test, these findings only made the confusion index reduced in protan. Subjective colour perception had been improved, but due to limited sample size, the study was not compared to other colour vision deficiency models and other available colour vision devices.

(Martínez-Domingo, M. A , 2019) a comparative study reported using four colour tests (recognition, arrangement, discrimination, and colour-naming), spectral transmittance was examined for VINO 02 Amp Oxy-Iso and Enchroma glasses. Vinos' spectral transmission changed colour. Some CVD individuals, notably deutan, might pass colour recognition tests but not arrangement tests. These results show that colour-correcting glasses are ineffective.

In recent years, contact lens also developed for colour vision deficiency, but these contact lenses already existed in earlier years as X-Chrome contact lenses, which gained more popularity. However, only bespoke contact lens lab creates this non-disposable, oxygen impermeable PMMA lens. No clinical trials or clinical evidence studies on these lenses were tested for aeronautical usage and helped with pseudoisochromatic colour testing. The disadvantages of these contact lenses are that they reduce depth perception and do not enhance colour vision at night.

3.2 Objectives of the current study.

According to the gaps in the literature, no clinical studies or data demonstrate that present colour vision devices will enhance colour perception and are also indicated for clinical recommendation to eye care practitioners. As a result, the following goals were discussed in the present chapter.

i. To identify the various colour vision devices available for the population with colour vision deficiency from (1976 to 2022)

ii. To compare and determine if the above devices improve objective and subjective colour perception.

iii. To evaluate how CVD devices are utilised in clinical practice and if any interventional or clinical trials have addressed the issues.

3.3 Materials and Methods

To examine the objectives in this chapter, a qualitative research study design was conducted based on systematic review and meta-analysis methodologies, as well as PROSPERO, PRISMA, and Cochrane Collaboration criteria. During the review, all the information material (PROSPERO, 2016), (PRISMA,2018), Cochrane Handbook 6.3,2022), content and instructions were followed and implemented in the current review.

Eligibility criteria

Randomised, quasi-randomized trials, case-control studies, prototype and innovation research studies, comparison studies, pre- and post-clinical trial investigations, Case reports, narrative reviews and relevant CVD device's published research were included. Other studies that fulfilled appropriate colour vision assessment parameters were also included.

Participants

This study mainly focused on the colour-vision-deficient population and utilised the following inclusion and exclusion criteria before looking for published literature.

Inclusion and Exclusion criteria

Patients who utilise CVD devices and have colour vision deficiencies due to congenital or acquired disorders are included. Participants with colour vision loss and impairment are screened for retinal abnormalities before being shortlisted for investigations. Macular disorders, DR (diabetic retinopathy), HR (hypertensive retinopathy), ARMD (Age-related macular degeneration), cone cell retinal dystrophy and optic nerve-related issues are included.

Published data from individuals with RP (retinitis pigmentosa), acquired chemical damage, developmental delay, and mentally retarded patients were not considered for further evaluation.

Information sources

This review used PROSPERO, PRISMA, and Cochrane databases to find published information till jun-2022. PubMed, MEDLINE Ovid, Embase Ovid, BIREME LILACS, Open Grey, ISRCTN, ClinicalTrials.gov, the WHO International Clinical Trials Registry Platform (ICTRP), and the US National Institutes of Health Ongoing Trials Register provide clinical trials. The National Institute for Rehabilitation Engineering (NIRE) website offers a record of nineteenth-century devices registered and produced from 1967 to 1987 and Google-patents search portal on CVD devices.

For relevant trials, the following journal website sources that specifically publish on rehabilitation devices, such as the BJVI (British Journal of Visual Impairment) from 1983 to 06-2022, the JVIB (Journal of Visual Impairment and Blindness) from 1976 to 06-2022, Colour research and applications from 1990 to 2019, and TVST (translational vision science and technology) from 2000 to 06-2022.

Scopus, Science Citation Index, Web of Science, and the Thomson Reuters index were some search engines and information sources used to locate further trials that mentioned publications in Q1 and Q2 ranking journals according to the SCI index ranking and lists related to colour vision published literature

Search strategy

As a result, the researchers and colour vision device manufacturers asked for their support in both previously published and unpublished works. The SEARCH strategy flowchart was built using the PROSPER and PRISMA criteria. The review was not restricted in any way, either in terms of the languages it might cover or the range of years in which publications were evaluated for inclusion. However, this review only examined articles that were written in English. The SEARCH strategy Prisma Flow chart illustrates this in **Figure-8.**

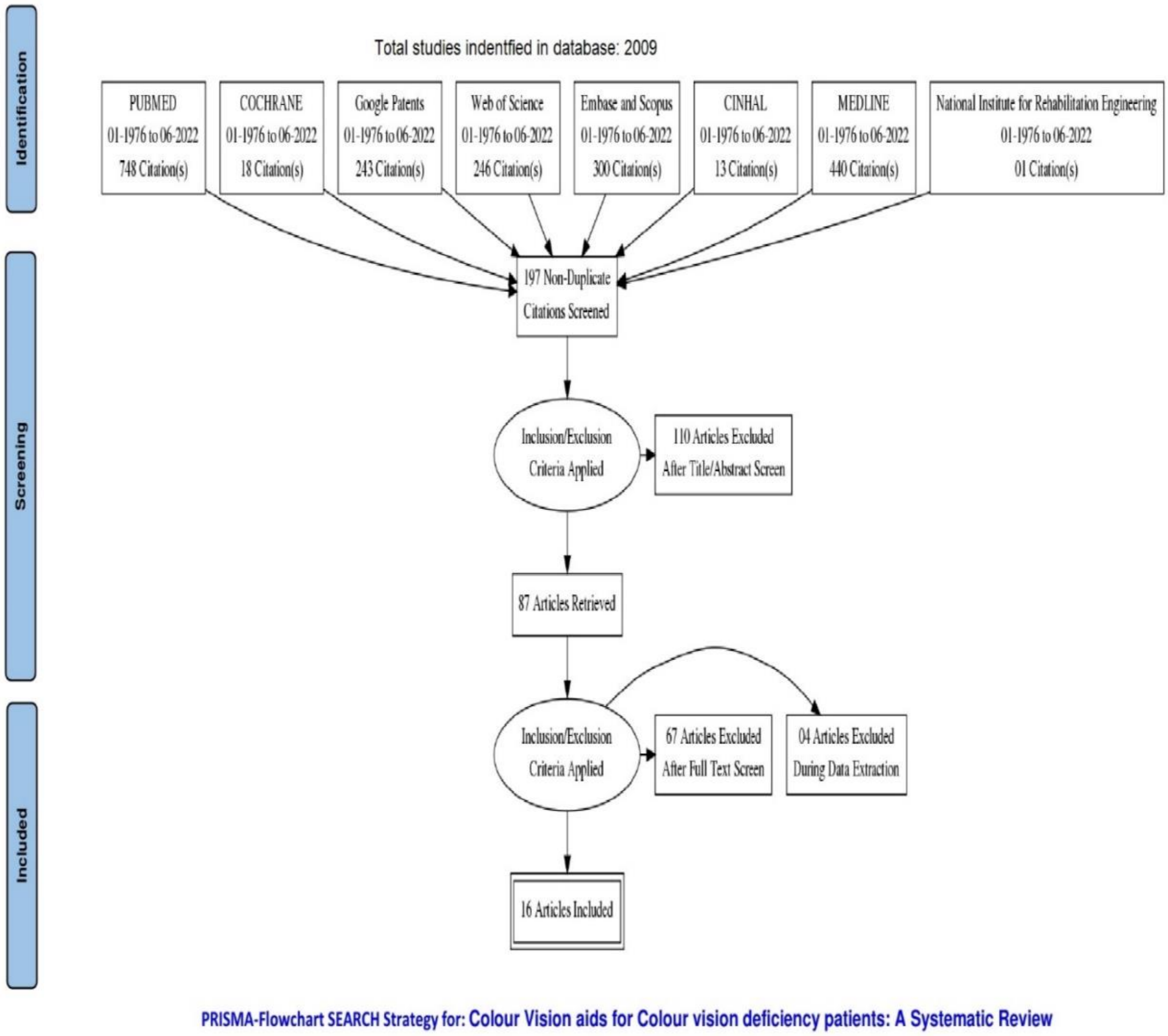


Figure-8. PRISMA-compliant flow charts describe the SEARCH method. The meta-analysis includes 16 studies.

Data Collection and Analysis

Two authors examined computer-based electronic search titles, abstracts, and full-text entries and reviewed all relevant or potentially relevant trials using the review's inclusion and exclusion criteria. Further, meeting our inclusion criteria, research goal, and methodological quality were reviewed. The writers assessed trials and studies without hiding information.

The authors agreed on whether to include a trial or study, and gathered extra information as needed. Journal Q1 and Q2 quality indices measured bias and quality. Using the (PRISMA 2020) checklist and Critical Appraisal of Published Literature, writers evaluated papers using citations for quality and analysis.

Data synthesis

The study addressed the methodology, sample size, objective and subjective improvements in colour vision scores, and the strength of the evidence found. Independently (Guyatt, G. H., 2008) checklist from the quality of evidence-based medicine was utilised to assess the retrieved data from each research for GRADE analysis.

Statistical Analysis

MedCalc (MedCalc-Version 20.1, 2019) statistical software was used to analyse the collected data. Statistical heterogeneity implied the incorporation of the following assessments. All of the papers included for the meta-analysis, the Q-test was assessed and quantified. Probability estimates I^2 and the fraction of data utilised in the analyses were determined using random effect models.

The proportions were recorded and determined whether or not there was a statistically significant difference between the studies, as well as a 95% confidence range. For the primary endpoint of objective and subjective colour vision score, a systematic approach and clinical recommendations were developed using the GRADE-Evidence-based framework (Grading of Recommendations, Assessment, Development, and Evaluations).

Eggers and Kendalis Tau tests assessed research and publication bias. A funnel plot showed significant SE and 95% CI. Nine research displayed their correlation coefficient and sample size using a linear regression model. This correlational analysis rejected seven studies owing to limited sample size, inadequate parameters, and data paucity.

Comparison

CVD patients' colour vision was compared to those without CVD, as well as to normal colour vision, best-corrected visual acuity, and healthy emmetropes.

Outcome

The primary outcome is the objective colour vision score after utilising colour vision devices; the secondary outcome is the subject's colour perception; and the third outcome is the standardised colour vision exam, which is also suitable for assessing these scores.

3.4 Results

From the electronic database search, **Figure-9,** An total of (2,009) titles and abstracts were sorted from eight data sources. However, only 87 (3.98%) were retrieved after the title and abstract. Further, 67 (3.33%) were disqualified after the full-text article screening because they did not meet the review question, did not have clinical data, had poor methodologies, or used low-quality methodologies. Finally, 20 (1%) studies were found eligible to review. Moreover, 4 reports were discarded because they lacked colour vision device data and were found not suitable to include. The meta-analysis overall includes n=16 publications.

Colour vision scores

Among all, 13 investigations found evidence of colour vision deficiencies. These studies reported the colour vision score objective and subjective parameters with the Ishihara colour vision test in 9 (56%) and 6 (46%) studies with the D-15 Colour vision test, respectively, and in 2 (15.34%) studies with the FM-100 colour vision test, followed by 1 (7%) study with RGB colour space tests. The colour vision scores from each research were compiled into a percentage distribution, and the results of the participants' subjective reactions after the use of the colour vision aid are shown in **Table-3.**

Author & Year	Country	Sample size	Colour vision aid/device	Colour vision test	CV Score	Subjective colour perception
Schiefer U,et al. (1985)	Germany	N=1	“Hydroflex central tinted contact lens by Wöhlk Company, Kiel”	Ishihara colour vision test	80%	Yes

Zeltzer HI,et al (1991)	USA	N=1	"Long wavelength pass filters"	Ishihara colour vision test	20%	No
Jk Hovis,et al. (1997)	Canada	N=10	"Contact lens for correction of colour blindness"	Ishihara and D-15 cv tests	33%	No
Helen A. Swarbrick, et al. (2001)	Australia	N=14	"ChromaGen"	Ishihara and D-15 cv tests	70%	Yes
Dain, Stephen J (2009)	Australia	N=49	"Sunglass tints"	D-15 cv tests	59%	No
O. Matthew,et al. (2011)	UAE	N=13	"Chromagen Lenses"	Ishihara colour vision test	85%	Yes
Bruce J, et al. (2014)	UK	N=33	"Coloured overlays"	Ishihara colour vision test	20%	No
Rebecca Masstey,et al.(2016)	USA	N=27	"O2 Amp and the EnChroma glasses"	D-15 and colour vision test	11%	No
Petr Veselý,et al.(2017)	Checz republic	N=39	"Red and Green Chromagen Filters"	D-15 and colour vision test	45%	Yes
Almutairi, et al.(2017)	USA	N=9	"EnChroma Cx-14 filters"	Ishihara and FM-100 colour vision tests	20%	No
L. Gómez-Robledo,et al.(2018)	Spain	N=48	"EnChroma Glasses"	FM-100 Colour vision test	10%	No
Abdel-Rahman,et al.(2018)	UK	N=0	"Bragg filters based Colour dye contact lenses"	Not reported	No	No

Ahmed E. Salih, et al. (2020)	UAE	Review	"VINO, Enchroma CVD glasses and Contact lens for CB"	Reported and compared between devices	45%	Yes
Ahmed,et al.(2021)	UAE	N=0	"Gold nanoparticle induced contact lenses"	Not reported	No	No
Jonathan sutton ,et al.(2022)	New Zealand	N=19	"Augmentation reality based computational CVD glasses"	Ishihara colour vision test and RGB colour spaces	80%	Yes
N. Roostaei, et al.(2022)	Iran	N=1	"Flexible plasmonic contact lenses for colour deficiency"	Not reported	No	No

Table-3. The objective and subjective colour vision scores of the CVD population, derived from n=16 studies that used various colour vision devices.

The above-mentioned 6 studies had small sample sizes. As a result, the other ten studies were used to understand the colour vision score improvement in the sample reported with the Heterogeneity tests (Q= 4.59, df=9, p=0.8681, 95% for I^2 = 0.00 to 26.67), as shown in **Figure-9**

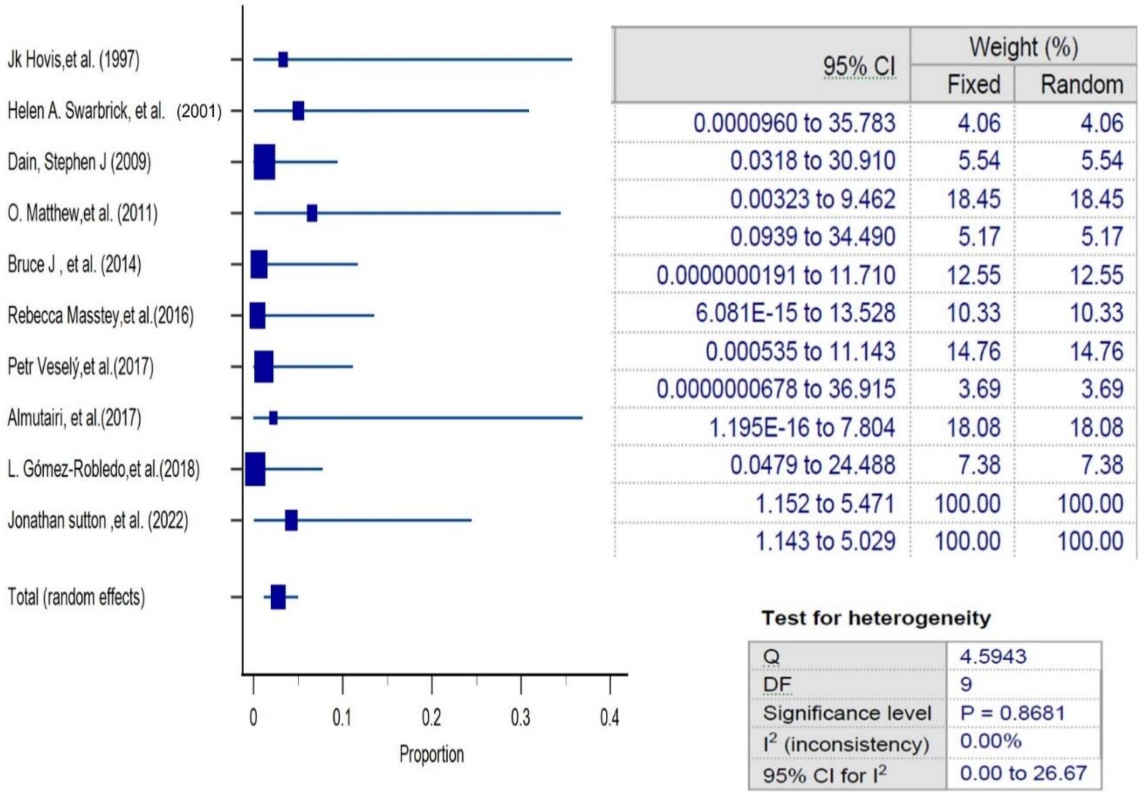


Figure-9. From 10 studies, colour vision scores indicate a forest plot with limited variety and no significant correlation. These might have occurred due to the small sample numbers reported in the research employing various colour vision devices.

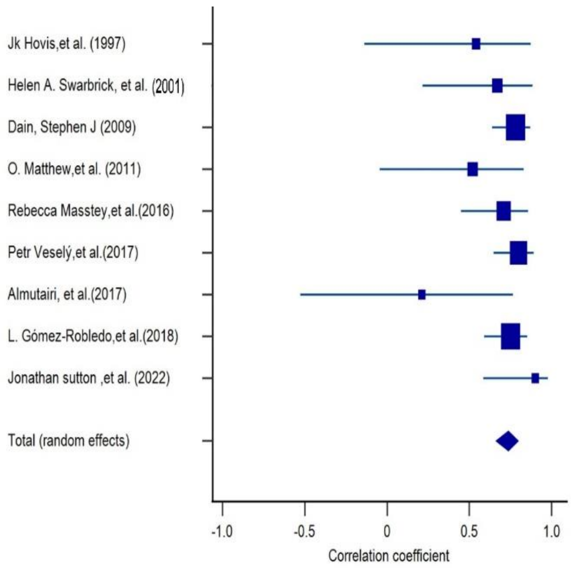
In addition, the evidence was produced by utilising GRADE-Framework analysis on the following studies shown in **Table 4**.

Author	Colour Vision Device	Year	Study design	Sample	Colour Vision score	Subjective Colour perception outcome	Certainty of the evidence. (GRADE)
Schiefer U,et al.	"Hydroflex central tinted contact lens by Wöhlk Company, Kiel"	1985	Case-report	N=1	Improved	Yes	Low certainty
Jk Hovis,et al.	"Long wavelength pass filters"	1997	Case study & comparative study	N=10	Partially improved	No	Low certainty
Zeltzer HI,et al.	"Contact lens for correction of colour blindness"	1991	Innovation, Prototype & case study	N=1	Partially improved	No	Low certainty
Helen A. Swarbrick, et al.	"ChromaGen filter"	2001	Case-control comparative	N=14	Improved	Yes	**Moderate certainty**
Dain, Stephen J, et al.	"Sunglass tints"	2009	Case-control	N=49	Partially improved	No	Low certainty
O. Matthew,et al.	"Chromagen Lenses"	2011	Comparative study design	N=13	Partially improved	No	Low certainty
Bruce J , et al.	"Coloured overlays-Society for Coloured Lens Prescribers"	2014	Randomised control trial	N=33	Partially improved	No	Low certainty
Rebecca Masstey,et al.	"O2 Amp and the EnChroma glasses"	2016	Comparative experimental pre & post-study design	N=27	Partially improved	No	Low certainty

Petr Veselý,et al.	“Red and Green Chromagen Filters”	2017	Case-control study design	N=39	Improved	Yes	**Moderate certainty**
Almutairi, et al.	“EnChroma Cx-14 filters”	2017	Comparative study design	N=9	Partially improved	No	Low certainty
L. Gómez-Robledo,et al.	“EnChroma Glasses”	2018	Pre & post study design	N=48	Improved	No	Low certainty
Abdel-Rahman, et al.	“Bragg filters based Colour dye contact lenses”	2018	Innovation & prototype design	N=0	Not reported	Not reported	Low certainty
Ahmed E. Salih, et al.	“VINO, Enchroma CVD glasses and Contact lens for CB”	2020	Comparative study design	Review	Improved	Yes	**Moderate certainty**
Ahmed,et al. [27]	“Gold nanoparticle induced Contact lenses”	2021	Prototype & innovation	N=0	Not reported	Not reported	Low certainty
N. Roostaei, et al.	“Flexible plasmonic contact lenses”	2022	Prototype & innovation	N=1	Not reported	Not reported	Low certainty
Jonathan sutton ,et al.	“Augmentation reality based computational CVD glasses”	2022	Prototype, innovation & exploratory study	N=19	Improved	Yes	**Moderate certainty**

Table-4. The GRADE analysis was used to assemble evidence from the following n=16 studies to determine the efficacy of colour vision devices for improving colour vision.

***Very-Low certainty:** “The true effect is probably markedly different from the estimated effect”
****Low-certainty**: “The true effect might be markedly different from the estimated effect”
*****Moderate-certainty**: “The authors believe that the true effect is probably close to the estimated effect”
******High-certainty**: “The authors have a lot of confidence that the true effect is similar to the estimated effect”



Study	Sample size	Correlation coefficient
Jk Hovis,et al. (1997)	10	0.540
Helen A. Swarbrick, et al. (2001)	14	0.670
Dain, Stephen J (2009)	49	0.780
O. Matthew,et al. (2011)	13	0.520
Rebecca Masstey,et al. (2016)	27	0.710
Petr Veselý,et al.(2017)	39	0.800
Almutairi, et al.(2017)	9	0.210
L. Gómez-Robledo,et al. (2018)	48	0.750
Jonathan sutton ,et al. (2022)	9	0.900
Total (fixed effects)	218	0.740
Total (random effects)	218	0.737

Test for heterogeneity

Q	8.6720
DF	8
Significance level	P = 0.3707
I^2 (inconsistency)	7.75%
95% CI for I^2	0.00 to 67.76

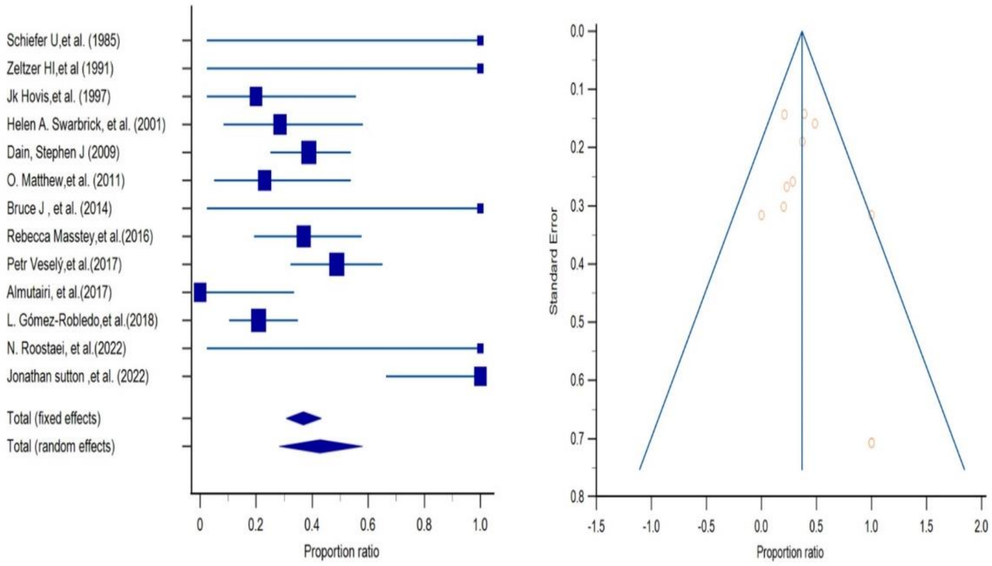
Publication bias

Egger's test	
Intercept	-1.3784
95% CI	-3.3577 to 0.6008
Significance level	P = 0.1436
Begg's test	
Kendall's Tau	-0.4226
Significance level	P = 0.1127

Figure-10. The colour vision score and the correlation coefficients from n=9 studies are shown in the form of a forest plot. The degree of heterogeneity is low. However, the significance of the association is high.

Eggers test and Begg's test, Kendall’s Tau =-0.4226, p=0.1127, after which correlation coefficients were plotted, and the distributed data was plotted in Forest plots using the Heterogeneity Q= 8.67, df=8, I2 = 7.75%, p=0.37, and as may be seen in **Figure-10.**

In 13 studies found a significant correlation between colour vision equipment and sample size, whereas 3 were removed owing ta o lack of clinical data. Measured percentage ratios from qualifying studies. The heterogeneity was assessed ($Q= 51.98$, $df=12$, $p=0.001$, $I2= 76.92$, 95 % CI for $I2 = 60.71$ to 86.4%) and showed this data using a Forest plot. SE was calculated, including publication bias with Eggers, and depicted with Funnel plots. As illustrated in **Figure 11.**



95% CI	Weight (%)	
	Fixed	Random
2.500 to 100.000	0.85	3.48
2.500 to 100.000	0.85	3.48
2.521 to 55.610	4.68	8.38
8.389 to 58.104	6.38	9.14
25.197 to 53.761	21.28	11.09
5.038 to 53.813	5.96	8.98
2.500 to 100.000	0.85	3.48
19.401 to 57.632	11.91	10.35
32.418 to 65.220	17.02	10.84
0.000 to 33.627	4.26	8.12
10.469 to 34.991	20.85	11.07
2.500 to 100.000	0.85	3.48
66.373 to 100.000	4.26	8.12
30.651 to 43.344	100.00	100.00
28.217 to 57.983	100.00	100.00

Test for heterogeneity

Q	51.9891
DF	12
Significance level	$P < 0.0001$
I^2 (inconsistency)	76.92%
95% CI for I^2	60.71 to 86.44

Publication bias

Egger's test	
Intercept	1.5538
95% CI	-1.0347 to 4.1422
Significance level	$P = 0.2133$
Begg's test	
Kendall's Tau	0.1538
Significance level	$P = 0.4641$

Figure-11. A forest plot and a funnel plot displayed colour vision devices and sample size, followed by percentage ratios and standard error for evaluating publication bias. The heterogeneity is favourable, and the proportion is distributed.

Risk of Bias Assessment

In the features of the included studies presented and summarised the Risk of Bias analysis results. Parameters such as (selection bias -allocation method), exclusion and follow-up process (outcome bias-selective reporting of outcomes), performance and detection bias with colour vision devices, and period effect -which reports whether the condition can change during subsequent phases of Testing of each colour vision aid or device, and carry-over effect reports-whether the effect on the performance of using a specific device affects the colour vision outcomes of various devices, were all considered. (McGuinness.et al., 2020) used the robvis software to create an example of a basic traffic plot to display the data on the potential for bias see **Figure 12** .

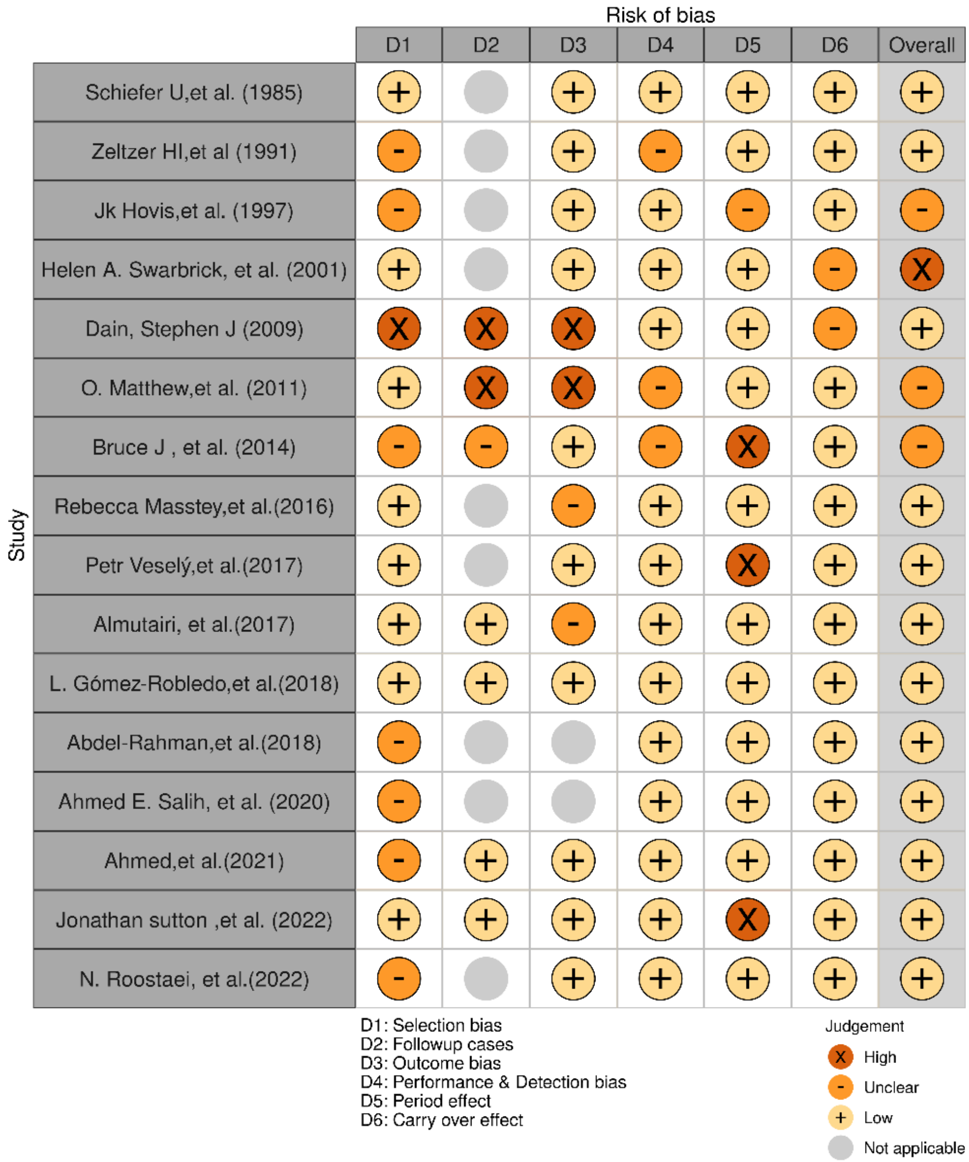


Figure-12. A simple traffic plot is shown, constructed with the use of the data on the potential for bias obtained from the robvis tool.

3.5 Discussion

This meta-analysis and systematic review highlight the rapid evolution of technology from 1967 to 2022, particularly in the field of colour vision aids, with the most advanced prototypes and models already on the market. But the NIRE research emphasised a 20-year database on practical colour-vision impairment rehabilitation methods and gadgets for CVD patients (NIRE, 2002). From 1967 to 1987, that's the time frame covered by the database. Nothing of the kind was relevant or useful here; the gadgets in issue served simply as a stopgap; and no clinical studies or evidence-based practises were implemented with their usage.

The results revealed that after wearing devices, the colour perception scores were not significantly altered, and commercially accessible device such as Enchroma Colour vision glasses were unable to provide the outcomes as advertised and promoted. The research included in this analysis revealed poor colour vision scores and minimal colour perception outcomes. In addition, neither a clinical trial nor an evidence-based research has been conducted on these devices, and it would be exceedingly difficult and costly to create a clinical guideline for their use.

These findings are further confirmed by the fact that Enchroma glasses do not enhance diagnostic test results or normalise colour vision in CVD patients (Almutairi, N. et al., 2017), (Gómez-Robledo, L.et al., 2017).

Moreover, tests for evaluating colour vision scores are essential, and for colour vision testing, it concluded that the Ishihara pseudo isochromatic test is primarily for colour discrimination and may not provide a complete diagnosis of colour vision deficiency, whereas the (D-15) and (FM-100 colour vision test) reveal the complete diagnosis and colour perception outcomes efficiently and with a high sensitivity rate. Evaluation of the RGB colour space and other colour science techniques will aid in determining the correct hue of cutting-edge technological prototypes.

These results are compatible with the idea that CVDs may pass sophisticated colour vision tests with the help of (AI-based computational stimulation) and digital colour filters, and they show that employing conventional colourimetry tools and methodology does not alter CVDs' perception of these tests. (Martínez-Domingo, M. Á. Et al., 2020).

Future directions for study, policy, and practice.

The Risk and Bias analysis also considered the described study limitations to place greater emphasis on future research and technological advancements in the development of innovative Colour Vision devices, and Results indicated that developed nations manufactured the vast majority of CVD devices. In light of this, it is imperative that India, the world's most populous nation and a region with a rapidly increasing incidence of CVD, invest in the research and development of breakthrough technological solutions for the CVD population.

It is also recommended that future researchers to consider the cone sensitivity of individual CVD patients to assess the above-mentioned possible opportunities for investigation in the subsequent years for low-cost prototypes with individualised Colour vision devices to benefit the CVD population.

Chapter-4

Impact of colour vision deficiency on quality of life in a sample of Indian population: Application of the CVD-QoL tool.

4. Introduction

This chapter focuses on the prevalence of colour vision deficiency in Hyderabad, Telangana. Additionally, the quality of life of CVD patients was measured using a standardised application of the CVD-QoL questionnaire, and the results were compared with the control group population.

The human eye can detect wavelengths between 380 to 760 nanometres, which correspond to different colours. Cone cells in the retina are accountable for the sensory and cognitive aspects of colour perception. A defect in one's colour vision would be shown by their incapacity to see certain hues is colour vision deficiency (CVD). Patients suffering from CVD have a variety of difficulties on a day-to-day basis, and they may not be aware that they have colour vision loss until a colour vision is examined as part of a work empowerment health screening or a thorough, comprehensive eye examination (Gordon N. et al.,1910).

It is essential to evaluate the impact of colour vision impairment on daily activities, emotional state, social involvement, and mobility to understand the quality of life in visual impairment or disability. Increasing these regular vision screening services can aid in preventing many ocular diseases, such as cataracts, age-related macular degeneration, glaucoma, and other eye conditions (Kovai V, et al., 2007) , (Nutheti R, et al., 2006) .

4.1 Earlier studies

According to (Kovai V, et al., 2007) and (Nutheti R, et al., 2006), it is critical to assess the impact of colour vision deficiency on daily activities, emotional state, social involvement, and mobility; doing so can aid in the prevention of many ocular diseases such as cataracts, age-related macular degeneration, and achromatopsia. Furthermore, boosting the availability of frequent vision screening services may aid in the prevention of numerous ocular diseases. Cataracts, age-related macular degeneration, and achromatopsia are examples of these disorders.

In majority qualitative studies (Krishnaiah S , et al., 2005) reported that the validated surveys address several aspects of visual functioning that are important to a person's quality of life; however, they are designed to assess the overall effect of ocular disease rather than only colour vision deficiencies, and their scope is very limited.

However, although verified surveys provide more information, the number of questions related to colour vision deficiency is limited. For example, the well-known (Mangione CM , et al., 1998) NEI-VFQ contains a single item “matching clothing” to assess individual's colour vision, which is very limited in understanding the quality of life in colour vision deficiency population.

The first ever validated questionnaire to evaluate the quality of life in the Colourblind population was done and created by (John Barry et al., 2017) in the United Kingdom. The study did show a few limitations, such as the fact that the aetiology of colour blindness was not investigated in this research and that the recruitment strategy was online, which limited the sample to people who had access to the internet and were participating in colour blindness forums or were recruited via professional groups. However, the study did reveal important findings showing that quality of life is poor in Colourblind population when compared to normal healthy individuals.

In India, according to the (Chakrabarti, S et al., 2018) study emphasized that the CVD's effect is determined by its type, severity, awareness, personal circumstances, and capacity to deal. Social and psychological components of CVD are little researched. Early identification, awareness, and support are the only proven approaches to aid doctors with CVD. With the increased focus on equality and inclusion of persons with shortcomings, it's important to create a balance between patient care and the right of medical professionals with CVD to work.

According to the findings of the previous research, quality of life is not successfully reported in developing nations or internationally. Furthermore, few studies were reported in the UK population, but the sample size and methodological approaches were not attributed to the CVD population, and in the current chapter addressed existing gaps in the literature and attempted to fill accordingly by developing a new application tool to measure the quality of life in the CVD population with a small sample in Hyderabad, India.

4.2 Objectives of the study

i. To determine the prevalence of colour vision deficiency in Hyderabad, Telangana from 1974 to 2022 using meta-analysis.

ii. To construct and validate a Telugu version of the QoL-CVD questionnaire for evaluating quality of life in a sample of the Indian population in Hyderabad

iii. To study how colour vision loss impacts CVD patients in India psychologically, economically, and in job and occupation productivity.

.

4.3 Materials and Methods

Participants

The current study N=120 was recruited that included 60 CVD patients with age (Mean=29.09) male: 52 and female: 8 who attended two eye hospitals in Hyderabad city between 2020 to 2021 and were diagnosed with colour vision deficiency with a qualified ophthalmologist and 60 normal (Mean=27.33) age-matched colour vision participants. The colour vision deficiency participants were categorised as being CVD or not and used the common terminology CVD=colour vision deficiency to all participants in the study for clarity and to avoid confusion.

Study design and setting

A descriptive and case-control questionnaire study was conducted. CVD populations were recruited from two super speciality eye hospitals after being diagnosed with colour vision deficiency.

Inclusion criteria

Participants with colour vision deficiency, both congenital and acquired, were included. To confirm CVD diagnosis colour vision score was accessed from the hospital's previous records before recruiting in the study, followed by retesting the colour vision score during the study.

Control inclusion criteria

In the current study, healthy patients with normal colour vision and general ocular health ranging in age from 19 to 30 years, both male and female genders given the opportunity.

Those recruited as controls were students and working professionals from the Hyderabad location of Telangana.

Exclusion criteria

One eyed patient, retinal surgeries, age related changes and any other ocular pathology condition that is affecting the colour vision were excluded from the study.

Procedure

This study was executed in three stages -1 Metanalysis on prevalence studies of colour vision deficiency in Telangana. 2. Developing the CVD-QoL questionnaire and followed by stage -3 collecting the QoL data from the CVD patients and age-matched control group. A detailed flow chart is illustrated. **As shown in Figure-13.**

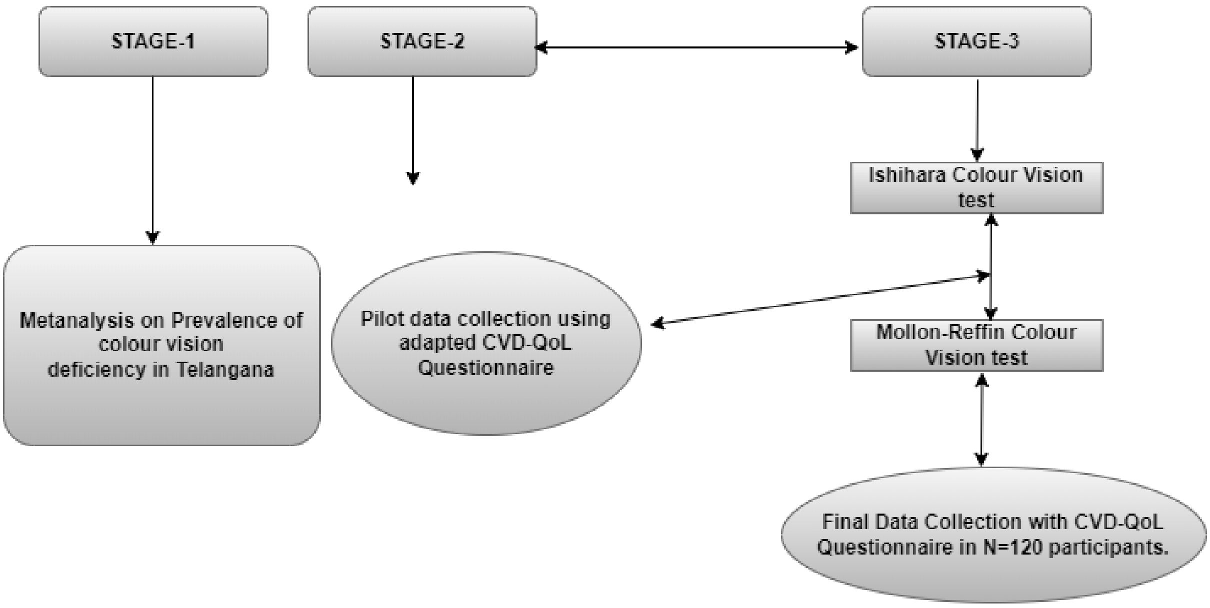


Figure-13. Flow chart illustration showing the different stages of the study.

Stage-1 Metanalysis on Prevalence of colour vision deficiency in Telangana.

Stage 1 of this research attempted to illustrate the existing literature on the prevalence of colour vision deficiencies and the prevalence rate and power of each study reviewed from the published data from 1974 to 2021. Five studies have been recorded; this is the most data that is currently accessible from any Indian research.

The power and estimates were assessed using metanalysis techniques, and the results indicated that the relative proportion of people in Hyderabad and Telangana had colour vision deficiencies.

Stage-2 Developing the CVD-QoL questionnaire.

Implemented the CB-QoL questionnaire after receiving permission from the original author who developed the questionnaire

The original CB-QoL questionnaire introduced a few modifications and questions to reflect the Indian context's daily life activities and living experiences. Before developing the CVD-QoL Indian version of the questionnaire, a focused group discussion was held in which an optometrist, an ophthalmologist, a psychologist, and a CVD patient participated to understand the various aspects of the questionnaire.

After finalising the questions, three sub-areas were highlighted (Lifestyle, Emotions, and Work). A Likert scale was used on six points as responses, and after the discussion, a total of 27 questions were generated, with few suggestions for modifications i.e., Hyderabad or Indian railways. Loss of chances because of CVD, particularly in government positions, followed by employee and employer discrimination because of CVD.

Stage-3 Collecting the responses from CVD and Normal age-matched participants with the CVD-QoL questionnaire.

Procedure

Compiled a list of all patients diagnosed with CVD at the two eye hospitals and asked for their informed consent to participate in the study. Following a review of the colour vision scores, an Ishihara colour vision evaluation and a Mollon reffin minimalist colour vision test was performed. The participants were asked to complete both the English -Telugu versions of the CVD-QoL questionnaires.

The responses received from every single participant after the questionnaire was completed, giving a total response rate of 100%. The authors asked respondents for any additional suggestions or to rank their CVD experiences on a scale of five and received all the responses on time**.**

4.4 Results

Data Collection and Analysis.

The data was collected and entered in Excel spreadsheets of Microsoft Word version -2016, and (IBM-SPSS version-22), followed by (MedCalc-version-19) used to conduct the analysis. To assess, the normality of the data, the Shapiro Wilk and Kolmogorov normality tests were used. All the data were distributed normally, and parametric statistical techniques were used to interpret the results.

Principal Component analysis (PCA-Factorial structure) of QoL-CVD questionnaire.

A Principal Component Analysis (PCA-Factorial structure) with reliability and internal consistency was measured including the Cronbach's alpha (α) was considered after the validation and standardizing of the questionnaire pilot data was collected by implementing in the N=44 sample (32=CVD and 14 Normal age-matched controls). As shown in Table-5.

Component	Questions	Chroanbach α	Interpretation
CVD-QoL (Lifestyle)	"Do you Ever feel not noticing change in colour of skin due to sunburn"	0.796	Acceptable
	"Do you feel Difficulty choosing groceries due to colour"	0.823	Good
	"Do you feel not noticing change in colour of mole on skin"	0.882	Good
	"Do you ever feel that not able to tell when food is cooked due to colour"	0.852	Good
	"Do you feel Difficulty choosing or buying clothes"	0.771	Acceptable
	"Do you feel being confused about colour of pills or other medication due to colour-coding"	0.837	Good
	"Do you feel not noticing blood in stools (faeces)"	0.891	Good
	"Do you feel difficulty knowing when fruit is ripe due to colour"	0.734	Acceptable
	"Do you feel difficulty reading maps (e.g., Hyderabad metro, Indian or any travel map)"	0.785	Acceptable
	"Do you feel not noticing a change in colour of urine"	0.794	Acceptable
	"Do you feel Problems playing sports (e.g., colours of team clothing, colours of snooker balls etc)"	0.866	Good
CVD-QoL (Emotions)	"Do you ever felt anxious because of issues caused by problems seeing colours"	0.784	Acceptable

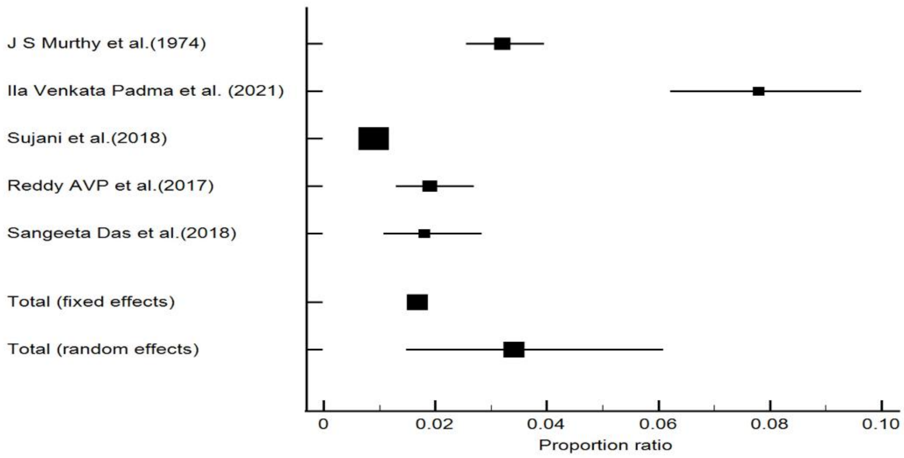
	"Do you felt depressed because of issues caused by problems seeing colours"	0.752	Acceptable
	"Do you feel unconfident because of issues caused by problems seeing colours"	0.718	Acceptable
	"Do you feel embarrassed or humiliated because of CVD issues"	0.787	Acceptable
	"Do you feel low self-esteem because of issues caused by problems seeing colours"	0.746	Acceptable
	"Do you feel anxious because you might not realise when you can't see a colour properly"	0.729	Acceptable
	"Do you feel different to other people because of issues caused by problems seeing colours"	0.771	Acceptable
	"Do you Felt that had let down self or others due to problems seeing colours"	0.754	Acceptable
	"Do you feel Avoiding conversations where colours are discussed"	0.909	Excellent
CVD-QoL (Work)	"Do you feel Being limited in choice of work or career"	0.76	Acceptable
	"Do you feel Difficulty performing work or other activities (e.g. charts, painting, drawing)"	0.793	Acceptable
	"Do you feel accomplishing less than would like at work or in career"	0.79	Acceptable
	"Do you ever felt colour vision deficiency, made you to lose government jobs in your career"	0.763	Acceptable
	"Do you ever felt colour vision deficiency is the reason for losing your opportunities"	0.702	Acceptable

	“Do you ever felt discriminated by other employees or employer in workplace due to CVD”	0.906	Excellent
	“Rate your psychological disturbance with CVD in under 1-5 grade”	0.91	Excellent

Table-5. PCA-analysis showing the standard of QoL-CVD questionnaire.

Metanalysis on prevalence studies of colour vision deficiency.

Only five of the n=16 studies on the prevalence of CVD in India fell in the Telangana state, and extracted prevalence and sample size data from these studies. Fixed effects (prevalence=1.67, 95%CI= 1.5 to 1.8) and random effects (prevalence=3.4, 95%CI= 1.48 to 6.0) were used to calculate the proportion ratio. The sustainable heterogeneity between the studies was reported as Q=282.6, DF=5, I2=98.2% p<0.001. As shown in **Figure-14.**



Test for heterogeneity	
Q	282.60
DF	5
Significance level	$p < 0.0001$
I^2 (inconsistency)	98.23%
95% CI for I^2	97.41 to 98.79

Study	Sample size	Prevalence %	95% CI	Weight (%)	
				Fixed	Random
J S Murthy et al.(1974)	2623	3.202	2.562 to 3.950	12.86	16.86
Ila Venkata Padma et al. (2021)	1000	7.800	6.214 to 9.639	4.91	16.45
Sujani et al.(2018)	13149	0.890	0.736 to 1.065	64.44	17.07
Reddy AVP et al.(2017)	1629	1.903	1.297 to 2.690	7.99	16.71
Sangeeta Das et al.(2018)	1000	1.800	1.070 to 2.830	4.91	16.45
Total (fixed effects)	20401	1.677	1.506 to 1.863	100.00	100.00
Total (random effects)	20401	3.410	1.486 to 6.084	100.00	100.00

Figure-14. Illustration of a forest plot displaying the proportional ratio of colour vision deficiency prevalence in Hyderabad, Telangana. Heterogeneity is high, with a strong correlation and significance.

Demographics of the population and sample size.

The odds ratio was estimated for CVD prevalence studies from five studies in the Hyderabad and Telangana areas to determine a sufficient sample size. (Open-epi -2013) The Kelsey and Fleiss sample size equations were used to measure the required sample size.

The factors evaluated are shown below. Two-sided confidence level (1-alpha) = 95%, Power = 80%, control to case ratio = 1, hypothetical percentage of controls with exposure = 50% and hypothetical proportion of cases with exposure = 75%, estimated odd ratio = 3. Using the given parameters, the suggested sample size was Kelsey (n=118, cases and controls), followed by Fleiss (n=116, cases and controls). Using the above recommendations, including N=120 for both cases and control groups.

Age for CVD group (Mean=29.09), Normal control group (Mean=27.33), followed by gender and occupational data represented with percentage distribution and aetiology of CVD was measured and classified CVD with Mollon refined minimalist colour vision screening as displayed in Table-6 and 7. **Table-6**

Demographic Variables			CVD Group n=60	Normal Control Group n=60	Chi-square analysis		
			Mean	**Mean**	**df**	**χ2**	**Level of significance**
Age (Years)			29.09	27.33	7	10.57	p= 0.15
Gender (%)	**Male**		52 (86%)	52 (86%)			
	Female		08 (14%)	08 (14%)			
Occupation (%)		Students	22(37%)	39 (65%)			
		Daily wage workers	21(35%)	10 (17%)			
		Farming	10 (17%)	05 (8%)			
		Electrician	03 (5%)	02 (3%)			
		Mechanic	04 (7%)	04 (2%)			

Table-6. Demographic details of the CVD and Normal Age-matched group

Factor Analysis (PCA) technique for validation of CVD-QoL questionnaire.

The questionnaire took 30 minutes to complete. The CVD-QoL is offered in both English and Telugu. The questionnaire consists of 27 questions divided into three categories: Lifestyle, Emotions, and Work. The responses were graded on a 6-point Likert scale. The PCA (Principal component analysis) was used to determine the factor structure of this questionnaire.

The Kaiser-Meyer Olkin Measure sampling adequacy = 0.811, KMO and Bartlett's test of sphericity = 498.53, df=351, and Cronbach’s values ranged from 0.70 to 0.90 (okay to outstanding). For standardising the questionnaire, a factor threshold of 0.70 was suggested. Furthermore, the ANOVA with Tukey's test for non-additivity was used to examine the reliability and additivity.

<table>
<tr><th colspan="2">Age (Mean±SD)</th><th colspan="3">Protanomaly(n=38)</th><th colspan="3">Deuteranomaly (n=19)</th><th colspan="3">Tritanomaly (n=3)</th></tr>
<tr><td colspan="2">29.09±1.10</td><th colspan="3">Protan series (%)</th><th colspan="3">Deutron series (%)</th><th colspan="3">Tritan series (%)</th></tr>
<tr><th colspan="2">Gender</th><th rowspan="2">P1</th><th rowspan="2">P2</th><th rowspan="2">P3</th><th rowspan="2">D1</th><th rowspan="2">D2</th><th rowspan="2">D3</th><th rowspan="2">T1</th><th rowspan="2">T2</th><th rowspan="2">T3</th></tr>
<tr><th>Male</th><th>Female</th></tr>
<tr><td>52 (86%)</td><td>8 (14%)</td><td>12 (20%</td><td>10 (16.6%)</td><td>8 (13.3%)</td><td>9 (15%)</td><td>5 (8.3%)</td><td>5 (8.3%)</td><td>3 (5%)</td><td colspan="2">0%</td></tr>
<tr><th colspan="2" rowspan="2">Aetiology of CVD %</th><th colspan="4">Congenital Colour Vision Deficiency</th><th colspan="5">Acquired Colour Vision Deficiency</th></tr>
<tr><td colspan="2">n=12</td><td colspan="2">20%</td><td colspan="2">n=48</td><td colspan="3">80%</td></tr>
</table>

Table-7. Aetiology of CVD and classification after evaluation with Mollon reffin Minimalist Colour vision test score in n=60 CVD

Intrinsic consistency and dependability Non-additivity between (SS=59.15.df=43, $Mean^2$ = 1.37) and within (SS=92.33, DF=26, $Mean^2$ = 3.55) was followed by p=0.04, Grand mean =2.33 and minimal Tukey's estimate of power to achieve additivity =2.02, indicating that variables interact even without replication. The Hotelling's T-Squared test was used to calculate the interclass co-relation coefficient (T^2 =95.73, F=1.54, df_1=26, df_2=18, p=0.01), which revealed significance in the interclass co-relation and consistency in the questionnaire.

Mean scores of CVD-QoL questionnaire.

The administered CVD-QoL questionnaire was evaluated in both groups after the mean values for the age group showed no significance (t=-1.2, p=0.67), followed by Ishihara colour vision scores between both groups showed a significance (t=4.50, p<0.001), QoL-Life style, Emotions (p<0.001), and QoL Work (p=0.001).

The lower QoL scores imply poor quality of life, while the reduced score is evident in the CVD group as compared to the normal age-matched health quality of life was seen. As indicated in **Table -8**, a bar graph depiction of the mean score is shown. **Figure-15.**

Variables	CVD group n=60		Normal age matched control group n=60			
	Mean	**SD**	**Mean**	**SD**	**t**	**p**
Age	29.09	1.10	27.33	2.50	-1.82	p= 0.67
Ishihara Colour vision score	6.50	1.36	16.92	0.22	4.50	p <0.001***
CVD- QoL Lifestyle	2.39	0.22	5.10	0.17	6.04	p <0.001***
CVD- QoL Emotions	2.29	0.18	5.03	0.19	3.06	p <0.001***
CVD- QoL Work	2.21	0.35	5.04	0.14	2.96	P=0.001**

Table-8. Mean scores showing the QoL association between CVD and normal age-matched control group

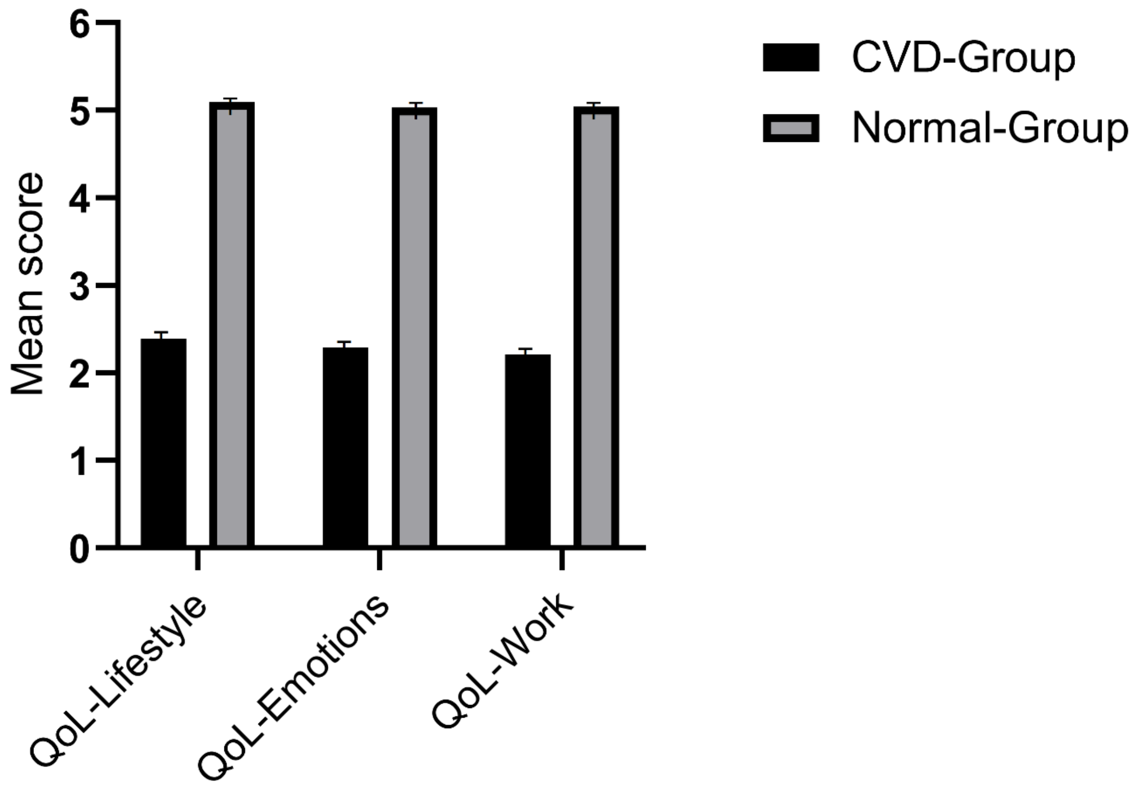


Figure-15. Bar graph showing the Mean scores of QoL in CVD and age matched control group participants with ±1 SD error bar.

Odds ratio association between CVD cases and Normal control group.

The odds ratio was measured by considering the colour vision scores as an outcome of colour vision deficiency. By applying the odds ratio calculations, found that 12 patients reported congenital colour blindness and 48 with acquired colour vision deficiency resulting in abnormal colour vision scores. However, in the control group, all the 60 participants showed normal colour vision scores. OR= 0.31, 95% CI= 0.14 to 0.65, Z=3.0, $p<0.002$.

A low CI in this analysis indicates that the OR is more precise. These odds ratios can also be used to establish a causal link between impaired colour vision to identify CVD and show influence on one's emotional, occupational, and physical well-being

4.5 Discussion

In the current research, the quality of life in the colour vision deficient population was assessed using the CVD-QoL questionnaire and the differences were compared to the normal healthy colour vision group.

Interestingly, a low QoL is reported for lifestyle followed by work and emotions, causes problems in the CVD group; nevertheless, these data showed a lower QoL score than the CB-QoL scores of the UK population (John Barry, et al., 2017).

This suggests that developing nations, such as India, should concentrate on adopting frequent vision screening programmes that prioritise CVD. The frequency is higher in younger age groups, and most of the research found that CVD is underdiagnosed because of a lack of awareness and cannot be diagnosed with routine eye care (Murty JS, et al., 1974) , (Simunovic MP, et.al 2007) .

A rigorous procedure, in addition to vision screening and colour vision assessment, should be developed in schools and educational institutions, so that if this is recognised, prognosis or management could be planned properly and will have much less impact on youth empowerment in the future. However, CVD has an impact on many parts of daily life, from infancy through adulthood. CVD has an impact on daily living, early learning and development, academic and occupational performance, and health-related activities (Chan XB, et al., 2014).

In the present research, most CVD patients were students (37%) and daily wage labourers (35%) who struggled to handle everyday life without appropriate colour vision.

Furthermore, no permanent therapy or intervention to restore colour vision is presently offered in clinics. Few commercially available products may enhance colour vision, but they could not be completely effective. To determine the main requirements and goals for the CVD population, a good, standardised questionnaire and qualitative research techniques are advised.

In the present research, only focused at work, emotions, and lifestyle quality; nevertheless, many additional variables impact CVD patients. Whereas psychological and mental health depression is also affected (Bradley N, et al., 1970).

The evaluation and use of standardised colour vision tests will rule out colour vision deficiency at an early age, which enable eye care practitioners to lead and counsel the CVD population appropriately. In developing countries, using standardised colour vision assessments during the recruitment of various jobs where colour vision is not a priority or moderate CVD might be considered. In contrast, in nations such as Australia, CVD is seen as a priority, and new health policies are designed to benefit the CVD population (Cole BL, et al., 2004).

In countries with huge populations, such as India, a new health care strategy for colour vision deficiency patients should be developed. Consequently, patients with CVD may be benefitted from low vision rehabilitation options, but not to the greater extent and health education towards CVD should begin in the high school environment.

In essence, this study adds to the existing scientific literature by conducting the first CVD-QoL study in colour vision deficiency patients from India. Although (John Barry, et al., 2017) used the similar questionnaire, their study's gaps and limitations were filled by conducting a face-to-face study and using two colour vision evaluation scores. Furthermore, the researchers assessed the relationship between CVD and odds ratios, as well as how CVD exposure can result in a lower quality of life and how this can be counterbalanced. Now it is vital to execute and propose a new model or strategy, both clinically and in terms of future potential policies or benefits, to colour vision deficiency population.

Based on prior prevalence studies published and the availability of timelines, only Hyderabad eye hospitals in Telangana state were examined. The future scope of this research could be accomplished by proposing a new classification of the severity of colour vision deficiency. Colour vision scores and how their QoL is changing might be used to include them in the Visual impairment category since colour vision is one of the functional losses that cannot be reversed.

Colour Vision deficiency awareness and teaching in workplaces, such as metro stations and other occupational areas, would be beneficial in Telangana and other parts of India. Because railways and metro rail are India's primary mode of transportation, colour-blind-friendly maps, and charts, including traffic signals and sign boards, should be introduced in workplaces and public transit facilities.

Chapter-5

A study to investigate the existence of monolexemic colour terms in Dravidian languages: A visual psychophysics approach.

5.1 Introduction

This chapter provides the basis for future study by introducing the notion of colour terms in Dravidian languages and classifying them according to factors such as their migration and evolution in India. The spread of human languages and the populaces who speak different languages are typically examined over the prism of their belonging to a language family. One of the significant language family in India is the Dravidian language with four major (Tamil, Telugu, Malayalam and Kannada) widely spoken language family that exists in the Indian subcontinent.

These Dravidian families are in the south and central Indian regions except Kurukh, Malto, and Brahui. These set of languages may be found all over the southern regions of India alongside Deccan Plateau, to the far-reaching Vindhya Mountains of the north and way down Cape Comorin.

The first known instance of it is a lithological inscription written much similar to Brahmi writing from that has been conservatively dated to around 254 BCE (Hammarström H , et al., 2016). According to the classification of (Krishnamurthy, et al., 2003) Dravidian languages are classified under four sub-groups i.e southern Group 1, South-central group, Central group, and Northern group.

The present study has considered two South-Central Dravidian-I i.e (Telugu) and South Dravidian-II (Kannada, Tamil, and Malayalam). Surprisingly about 80 dialects of the Dravidian family are spoken in the Central and Southern areas of India this may be due to contact that has emerged rapidly in this family. Few Dravidian languages are also spoken in a few other parts of (Grierson, G, et al., 1906) i.e in India's north (Kurukh and Malto), in Afghanistan and Pakistan (Brahui),of all these languages like Malayalam, Kannada, Tamil, and Telugu have literary histories that date back hundreds of years. More than two hundred million people speak the Dravidian languages as of today, which have been written for more than two thousand years which has influences of Vedic Sanskrit (Steever SB, et al., 1998) .

The bhakti movement various schools of thoughts like Saiva Siddhanta, and Virasaivism are all based on Dravidian culture prevailing in Southern Indian. Carnatic music in the southern states of India is comparatively unaffected by the influence of Mughals and others who once colonised India is due to its strong cultural roots.

In the similar context if a closely observation is made to the literary side of songs, poetry in Telugu, Tamil, Kannada and Malayalam has not been corrupted too. (Gule, G. et al.,2022) observed that various South Indian classical dance disciplines like Bharatanatyam and Kuchipudi which dates back between 200 - 500 BCE interpret that colours have a major role to play in these forms which are specific dance forms. Which can be implied that Dravidian cultural and linguistic influence of the Southeast Asia has a strong foundation to the understand the colour and its presence in these languages.

5.2 Earlier studies

In South Dravidian languages Tamil (tamiz), the most widely spoken Dravidian language (Annamalai, E. et.al. 1998) is among the oldest which can be observed in the Ashokan Brahmi script lithic inscription dates to around 254 BCE and is the first evidence of its existence. Since it is related to the more well-known Indo-Aryan language Sanskrit, it is considered a classical language of India. In contrast, Tamil has a clear link between its classical and modern forms.

A variety that is today is spoken by more than 50 million people present not alone in the state of Tamil Nadu and Union Territory Pondicherry of India but spoke in parts of other states like Kerala, Telangana, Andhra Pradesh and Karnataka, apart from India Tamil is also spoken in Sri Lanka, Malaysia, Mauritius, Singapore, Thailand and Fiji where in all these countries have more than quarter a million people who speak this language. (Prabhakara Variar, et al., 1985) .

In case of Malayalam the first known trace of the language is on the Vazappalli inscription, which dates from around the year 830 CE. Malayalam is spoken in Kerala and on the Indian Ocean Island of Lakshadweep and in parts of Tamil Nadu, and Karnataka. Caste and region-based dialects are also seen in Malayalam just like the other main Dravidian languages. Malayali's have the greatest percentage of literacy in the Indian Union, with an estimated 35 million speakers.

On the other hand Kannada speakers are around 25 million people in Karnataka its bordering states Telangana, Tamil Nadu, Maharashtra and Andhra Pradesh. The language's inscribed archives show old, modern and middle form of language historically distinct stages like Tamil and Telugu. It features at minimum of four primary topographical and caste dialects, and diglossia, though the changes in pronunciation do not appear as in Tamil.

(Sridhar, et.al 1990) provides a comprehensive explanation of the language. Given a close observation to the state of Andhra Pradesh and present Telangana states of India combines and features four regional dialects of Telugu: northern, southern, eastern, and central (Krishnamurti and Gwynn, et al., 1985).

It's also spoken in Karnataka, Orissa, Tamil Nadu, and even Kerala (Yadava's community migration to Kerala which is linked to colonial India). The formal language experienced modifications in the 19th century, as a consequence of which there are no strong variations in the modern language unlike Tamil either in spoken and written forms.

The idea in studying these major Dravidian languages is due to its rich culture and linguistics tradition which has a recorded history with a Comparative lexicon. One of the important aspects in Dravidian linguistics is the pinnacle study of (Burrow and Emeneau's , et al.,1962) compelled Dravidian Etymological Dictionary, a group of roughly 5,750 lexical groups.

The idea of understanding colours will show some strong evidences in language as the speakers of these languages has long history of Dramatics and Aesthetics (Thirumalai, M, et al., 2001) as varied tradition and cultural arts forms involve an extensive use of colours given in these Dravidian family to note a few: Kathakali in Kerala, Kalamkari of Andhra, Yakshagana of Karnataka, Theru Koothu of Tamilnadu.

Given a view on the colour terminology the seminal works of Kay and Berlin first of its kind study who collected data from 98 languages in their investigation of colour terms. In which only a minuscule Dravidian languages were taken into consideration from Indian Sub-continent. These languages include "Plains Tamil", Malayalam, Paliya and Toda, but not Telugu and Kannada which are widely spoken Dravidian languages even at that time period. There seems to be no disagreement then on the universality proposed by Kay and Berlin as data collected during this work shows an interesting insight that vocabulary of the colours from Language-to-language has variations that may or may not be common; however, there is remarkable uniformity in colour classifications.

Colour perception techniques are similar enough to explain how visible light is partitioned into several colour vocabularies. There are some differences in colour-to-word mappings, which may be due to differences in how frequently people need to refer to different hues in their communication or culture. But these considerations are obvious and the data from these four significant languages which have long tradition of colours and vocabulary, may bring new insight to this work on colours using psychophysics and corpus-based study.

The current chapter mainly investigates monolexemic colour terms in Dravidian languages (Telugu, Tamil, Malayalam, and Kannada).

5.3 Hypothesis presented

Ha = In Dravidian languages, the existence of monolexemic colour terms varies depending on communication and culture.

H_0 = In Dravidian languages, there is no existence of monolexemic colour terms, and they do not vary depending on communication and culture.

5.4 Materials and Methods

Participants

Current study recruited n=40 native speakers from four Dravidian language communities (Telugu, Tamil, Malayalam, and Kannada) in groups of ten. The age group ranges from 21 to 28 years old, and both male and female genders are represented. All participants were students pursuing higher education in different Indian universities. The experiment was naïve to all the participants. Informed consent was obtained, and the study was carried out by the Helsinki Declaration rules, with IEC approval from the University of Hyderabad.

Study design

The research design was cross-sectional, comparative, and experimental, utilising psycholinguistic and visual psychophysics methodologies as approaches.

Experimental apparatus

Equipment

The display was a Samsung 32" LCD screen from. The CRS (2019) Bits# ViSaGe, VSG2/x, and Bits++ systems were utilised for the fundamental stimulus calibration, with the PsychoPy-version 3.0 visual psych toolbox and the synchronisation feature in Windows-10 OS serving as the stimulus generator. The photometer calibration was shown on the screen, along with the calorimetric data, using the CIE-xyL coordinates of (Wyszecki, and Stiles,1967) standards. For the colour naming experiment, these calorimetric data were standardised. The screen size of the stimulus shown was 32° x 20°. To eliminate colour-matching errors, the stimulus background noise was in a dark room setting for adaption level and pattern determination. Mollen reffin colour vision kit and Ishihara colour vision test were used to check for the participants' colour vision status.

Experimental Methods

Extracting the Monolexemic colour terms from Corpus

The corpus data was used to search for the frequency of monolexemic colour terms from the four different corpora (Kilgarriff et al.,2010), which include Tamil, Telugu, Malayalam, and Kannada. The overall word size of this corpus =66,56,4862.

Semantic Fluency task

Stimulus and Procedure

Verbal fluency tasks are used to evaluate verbal aptitude, which includes lexical knowledge and the ability to recover lexical material from memory (Cohen et al., 1999; Weckerly et al., 2001; Federmeier et al., 2002, 2010). After validation, validated SVF test results are often classified using specific clustering criteria. For the purposes of knowing verbal knowledge in this study, participants were expected to name animal, fruit, and vegetables in their mother tongue i.e. Telugu, Tamil, Malayalam, Kannada, (repeated occurrences were not measured; Other than that, all other replies were deemed adequate). The clustering criteria were based on the semantic categories of the words. As mentioned previously this activity was designed to assess participants' L1 (mother tongue) fluency in 60 seconds of time.

Colour Naming task

Stimulus and Procedure

In this task, implemented the WCS survey model stimulus (Berlin and Kay et al.,1969) initially used by the (Lenneberg et.al 1956) colour stimulus array, which consisted of 320 Munsell chips of 40 equally spaced hues and 8° of brightness value at maximum saturation Chroma for each (hue and value) combination, was supplemented with nine Munsell achromatic chips (black through grey to white). The stimulus was presented **As shown in Figure-16** on the 32 inches LCD display monitor with a CRS-BITS Visage stimulus converter. The colour and chromaticity function was measured with the ColorCal-II colorimeter by CRS, and the stimulus was managed for 60 seconds to display for three trials.

The stimulus was developed by using the PsychoPy-version 3.0 psych toolbox (Peirce, J, et al., 2019). In the task, the First step was to measure semantic fluency to understand whether the participant could demonstrate and name the colour terms in his/her L1 language. And later, without the stimulus array, the participant had two responsibilities one was essentially observing the colour stimulus on the monitor. For each colour word in the focus task, the researcher was asked to name and generate each monolexemic colour term and mark it on the printed version of the Munsell chip sheet. Participants can generate as many monolexemic colour terms had considered. This experiment considered error rate and correct colour terms as measuring variables.

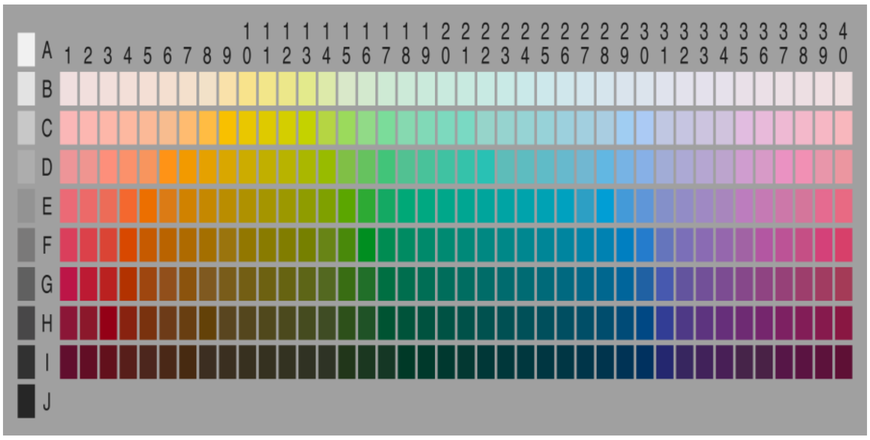


Figure-16 WCS survey stimuli Munsell chip used for the colour naming task. Adopted from (WCS , Paul K et al.,1970)

Stroop task

Stimulus and Procedure

In this Stroop task (MacLeod, C. M. et al., 2005), red, blue, black, white, green, and yellow were chosen based on their monolexemic character. Other colours and hues were omitted due to the experiment's paradigm. This test compares Stroop reaction times between primary colours of all four (Telugu, Tamil, Kannada, Malayalam) Dravidian languages and colour words. Six colours were limited to shorten the task, and the stimulus was displayed on Samsung 32 inches LCD screen at 30° from the screen's centre. 2-trial sessions gathered data. Each colour had six sessions. Between stimuli, a grey picture with a fixation point was presented as noise. The rest period between stimuli was 2 seconds to eliminate post-visual or linguistic impacts from the primary colour or colour word and to avoid confounding errors. **As shown in Figure 17.**

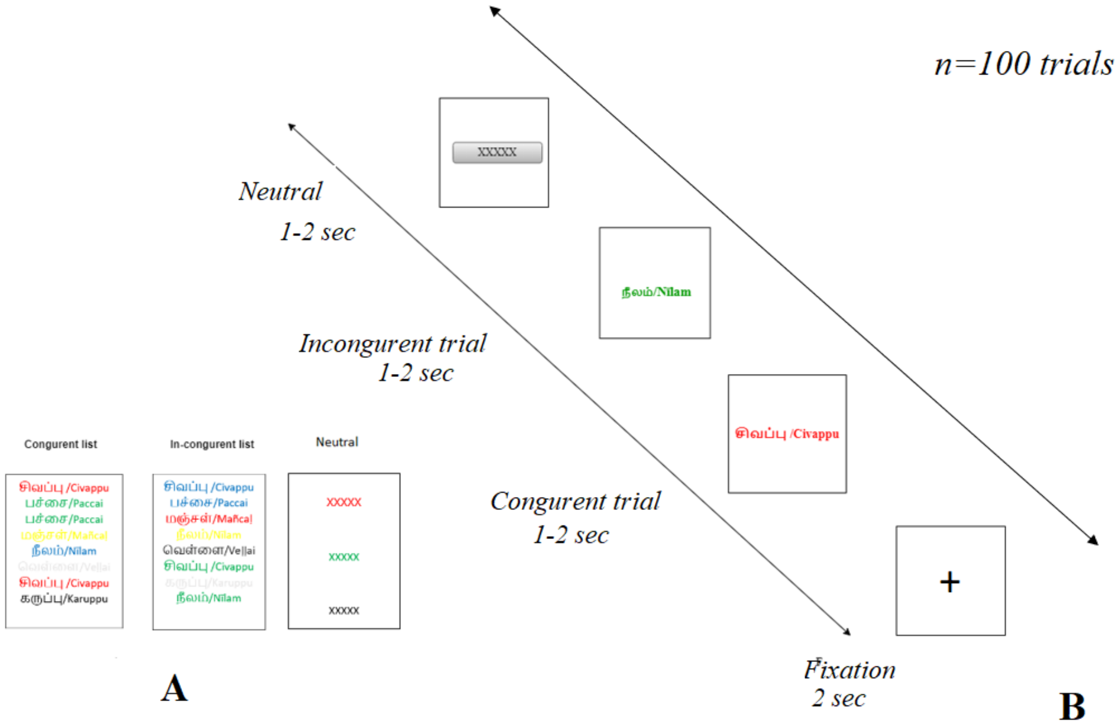


Figure 17- Representation of a Stroop task stimulus. ***A)*** *Stimulus list for congruent, incongruent, and neutral trials.* **B*)*** *The order in which the stimuli were given to the subjects. There were 100 trials.*

After a respondent responds, the researcher presses the space bar key on the keyboard to expose new stimuli. The experiment begins, syncing the two data sets as a "CSV" and "psyexp file". Correct colour terms, error rates, and response times were all considered variables.

Data Extraction and statistical analysis.

All the data from the experiments have been inspected for discrepancies, and the trial data from each of the CSV files have been removed to prevent confounders. The data that has been extracted has been saved in Microsoft Excel version 2016 and the R 3.4.1 CRAN-statistical package (R Core Team, et al., 2022). In order to measure the Bayesian models and likelihood ratio derived from the corpus extracted data, JASP and the Bayesian statistical guide (Goss-Sampson, M. et al., 2019) were utilised. Additionally, IBM-SPSS, version-19.1 was utilised for the purpose of descriptive and inferential statistics.

5.5 Results

Monolexemic colour terms of 21 terms of all four languages frequency from four corpora had been demonstrated with the likelihood ratio including the Bayesian Factors are tested for presented hypothesis on existence of monolexemic colour terms. **As shown in Table -10.** A split tree and evolutionary chart represent the monolexemic colour terms in **Figure 18** and Bayesian interface of supporting hypothesis in **Figure 19.**

Dravidian Language	**Mono lexemic Colour terms**	**Colour code**	**Frequency in Corpus**	**Likelihood ratio**	**Bayesian Factor (BF_5)**
Telugu Corpus size= 26750515 words	ఎరుపు /Erupu		2206	2.9	26.9
	నీలం/Nīlaṁ		2020	4.41	52.5
	నలుపు/Nalupu		1952	1.37	34.6
	తెలుపు/Telupu		2297	1.49	26.71
Tamil	சிவப்பு /Civappu		2431	1.71	62.1

Corpus size= 12807158 words	பச்சை/Paccai		1960	1.21	73.2
	மஞ்சள்/Mañcaḷ		2964	1.44	39.25
	நீலம்/Nīlam		1588	1.13	62.83
	வெள்ளை/Veḷḷai		2509	1.42	76.9
	கருப்பு/Karuppu		1963	2.39	42.26
Kannada Corpus size= 15950663 words	ಕೆಂಪು/Kempu		1224	1.9	21.69
	ಹಸಿರು/Hasiru		1151	1.28	18.81
	ಕಪ್ಪು/Kappu		1648	1.37	13.4
	ನೀಲಿ/Nīli		1056	1.41	15.25
	ಬಿಳಿ/Biḷi		1653	1.49	19.10
Malayalam Corpus size= 11056526	കറുപ്പ്/kaṟupp		1340	1.39	14.2
	പച്ച/pacca		2134	1.21	61.32
	നീല/nīla		1864	3.41	50.25
	മഞ്ഞ/maññа		1853	4.44	49.25
	ചുവപ്പ്/cuvapp		1420	3.71	36.21
	വെള്ള/veḷḷa		2053	1.43	17.9

Table-10. List of 21 monolexemic colour terms existence in different Dravidian language corpus sizes and estimates with Bayesian analysis.

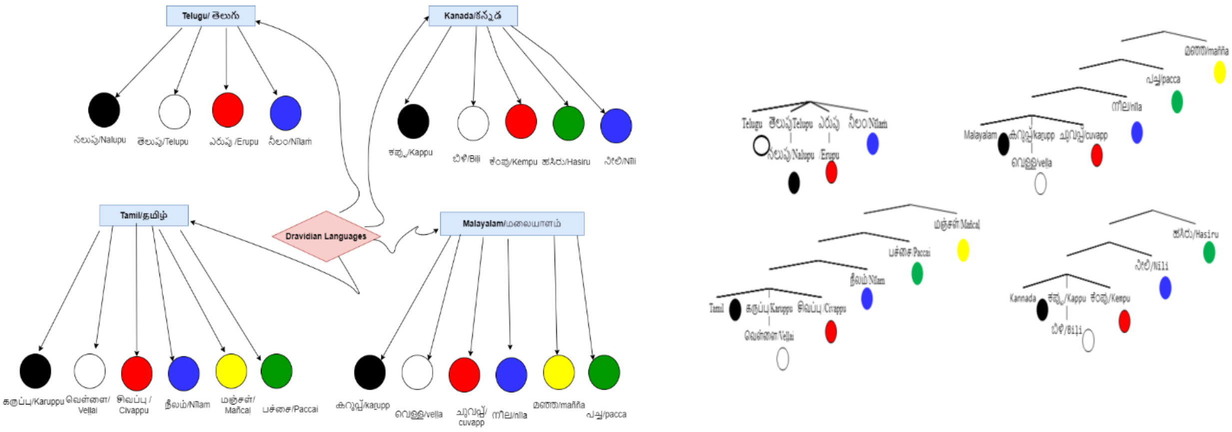


Figure-18 A split tree demonstrating the development of monolexemic colour terms in Dravidian languages.

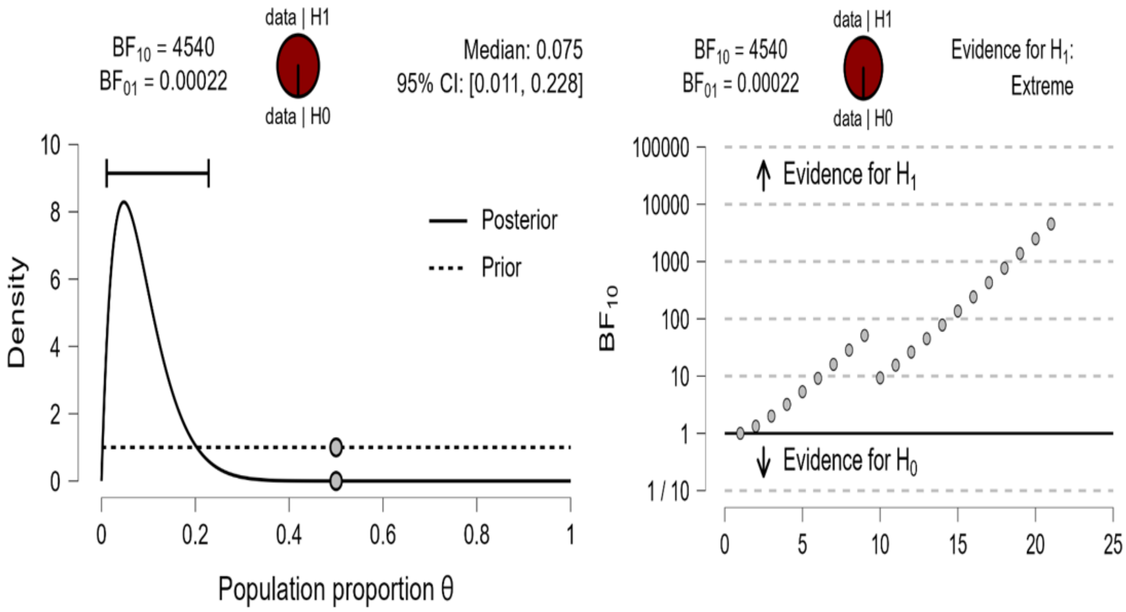


Figure-19. Bayesian statistical curves rejecting the null hypothesis for 21 monolexemic Dravidian colour terms.

Demographic profile and Semantic Fluency scores.

Tamil (M=26.54, SD=1.23,) Telugu (M=25.76, SD=0.64), Kannada (M= 24.28, SD=1.21), Malayalam (M= 26.65, SD= 0.96), age-matched analysis age-matched ANOVA revealed no significant difference (df=4,F=0.62, p=0.70). The semantic fluency scores indicated no significant difference (df=4, F=0.39, p=0.91), indicating no participant bias in the experiment. **As shown in Table 11.**

Variables	**Tamil (n=10)**		**Telugu (n=10)**		**Kannada (n=10)**		**Malayalam (n=10)**		**One Way ANOVA analysis**		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**DF**	**F**	**p**
Age	26.54	1.23	25.76	0.64	24.28	1.21	26.65	0.96	4	0.62	=0.70
Semantic fluency score	78.36	3.24	76.12	2.11	79.29	1.64	74.29	3.67	4	0.39	=0.91

**p<o.o5 is considered the level of significance*

Table-11. Demographic variables and semantic fluency task results between Dravidian language groups.

Colour naming task scores

After sifting through the retrieved data from the task, it was verified for duplication and confounding factors. The mean accurate monolexemic colour terms were found to be greater in Tamil and found significance [df=4, F=1.37,p=0.33], (M=5.30, SD=1.33, ER M=2.40, SD=0.84), followed by Telugu

(M=3.10, SD=0.73, ER M=4.30, SD=0.84) and Malayalam (M=4.30, SD=0.78, ER M=5.10, SD=0.84), Kannada (M=2.80, SD=0.78, ER M= 6.10, SD=1.66) are not significant but closer to the significance. **As shown in Table 12 and Figure 20.**

Dravidian languages	**Colour terms**		**Error rate**		**One Way ANOVA analysis**		
	Mean	**SD**	**Mean**	**SD**	**DF**	**F**	**p**
Tamil (n=10)	5.30	1.33	2.40	0.84	4	1.37	=0.33
Telugu (n=10)	3.10	0.73	4.30	1.33	4	1.57	=0.31
Malayalam(n=10)	4.30	0.94	4.20	0.94	4	0.43	=0.73
Kannada(n=10)	2.80	0.78	6.10	1.66	4	0.48	=0.79

**p<o.o5 is considered the level of significance*

Table-12. Colour naming task results between Dravidian language groups.

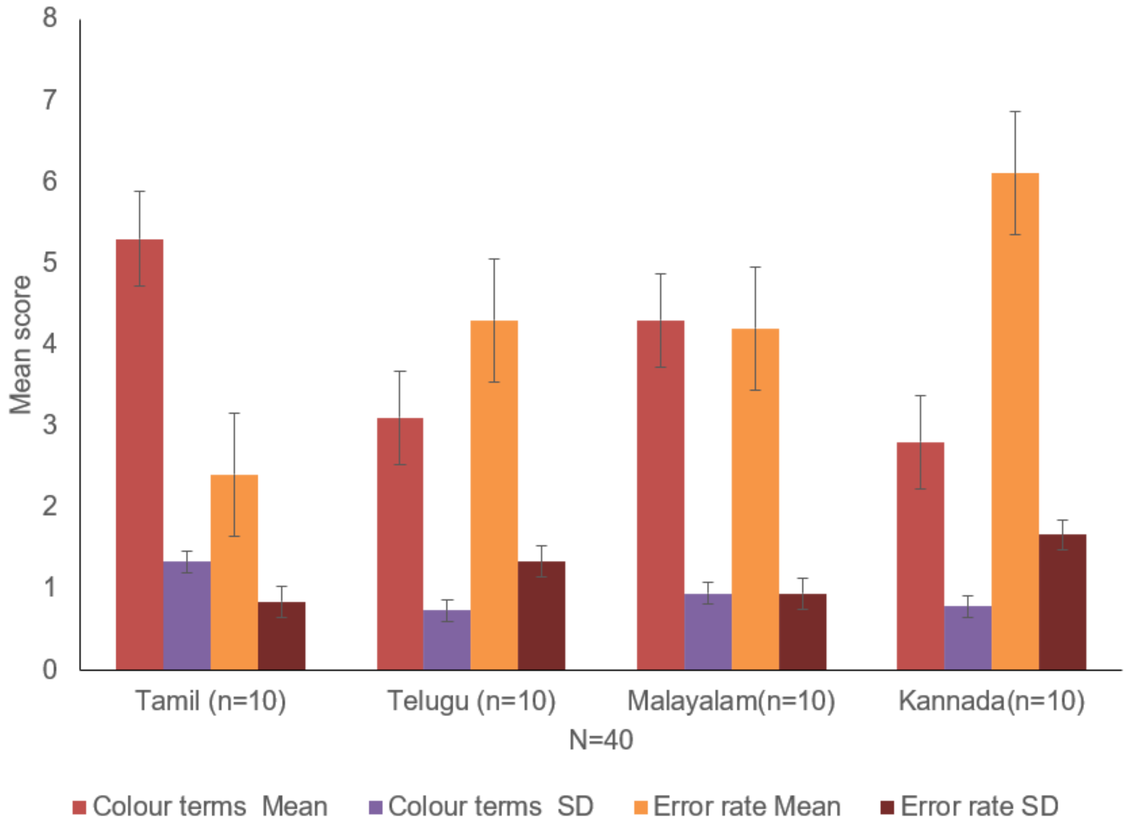


Figure-20. A bar graph representation showing the Mean scores and SD for colour terms and error rate.

Stroop task RTs scores.

Stroop data All trial data was deleted from the csv files before the final analysis. Data ranged from 700 to 1500 sec. Neutral, congruent, and incongruent trials Tamil (df=8,F=4.7, p=0.01) has a significant difference from Telugu (df=8,F=1.70, p=0.42). Malayalam (df=8,F=1.05, p=0.64) and Kannada (f=8, F=0.71, p=0.69) showed no significance. **As shown in Table 13 and Figure-21.**

Dravidian languages	Congruent RT (sec)		Incongruent RT (sec)		Neutral RT (sec)		One Way ANOVA analysis		
	Mean	SD	Mean	SD	Mean	SD	DF	F	p
Tamil (n=10)	775.64	117.04	910.36	11.04	896.72	13.64	8	4.7	=0.01
Telugu (n=10)	936.74	90.61	1106.09	104.09	1064.11	28.96	8	1.70	=0.42
Malayalam (n=10)	1386.09	32.28	1384.82	54.40	1390.36	56.90	8	1.05	=0.64
Kannada (n=10)	1461.82	75.35	1367.18	41.51	1392.55	59.78	8	0.71	=0.69

**p<o.o5 is considered the level of significance [RT= Reaction time, Low RT= High attention, High RT= Low attention]*

Table-13. Stroop task results between Dravidian language groups.

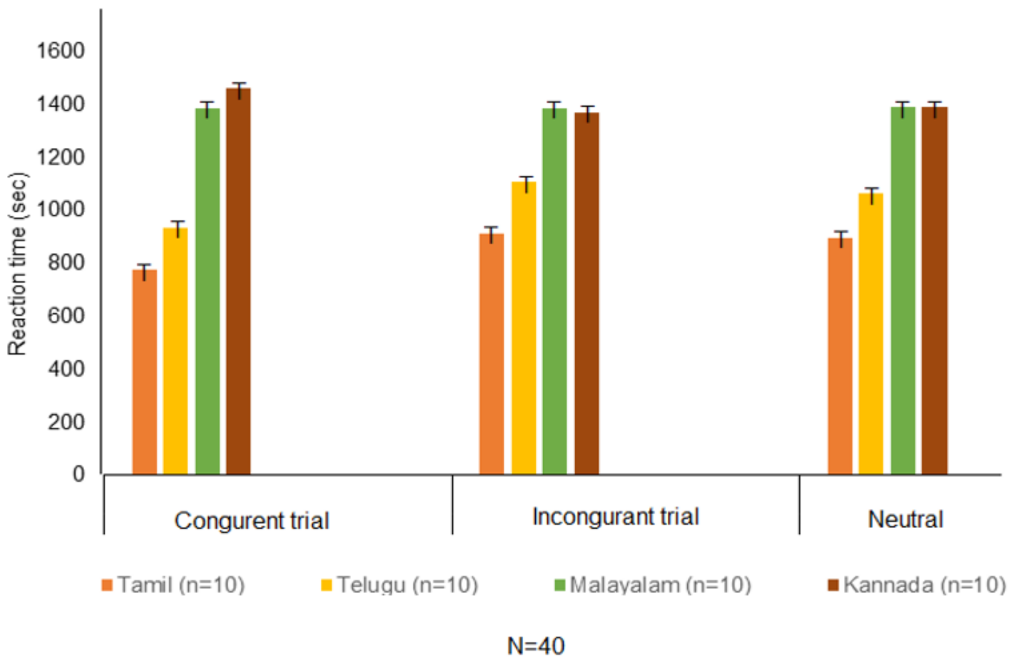


Figure- 21 A bar graph representation showing the Mean scores of Reaction times in the Stroop task error bar represents ±1SD.

5.6 Discussion

The current experiments investigated monolexemic collocations from four Dravidian corpora. The monolexemic colour existence theory is deep-rooted as per the observation from the data received and analysed. Previous studies of (Kay & Berlin ,1969) who's work did not include major Dravidian languages and later work of (Kapp, 2004) was specific to Tribal languages did not think of these exitance of the specific colours and linguistic angle attached to it. This paper brings in a new light where in these 4 major families show great account of linguistic and psychophysical attributes to colour perception and colour terminology.

Monolexemic colour concepts were accessed and exist in the corporal analysis and visuopsychophysical approaches to comprehend the Dravidian languages and culture. Colour and emotion differ by culture, including Dravidian (shiva et al., 2021).

However, phylogenetic, and archaeological investigations have indicated that Dravidian languages are 4500 years older than previously claimed (Kolipakam, V et al., 2018). This also shows that Tamil is the oldest Dravidian language, followed by Telugu.

In a recent study (Krishna, P. et al., 2021) shows that the word see in terms of visual perception is higher in the frequency in Telugu language, which can infer those terms in these languages belonging to this family attached to visual aesthetics and history. According to our results, participants performed better in colour naming tasks in Telugu and Tamil than Kannada and Malayalam. 21 monolexemic colour terms were measured with Bayesian factors that revealed testing the strong evidence.

Similarly, evidence was reported in (Loreto, V et al., 2012) that the hierarchy of colour names by using WCS data and few psychophysics methods revealed that the colour spectrum based on naming on colour terms is varied in the context the of colour hierarchy on universality. So as to say that Universality cannot be easily validated for all the culture and languages. The factors of cultural evolution and its influence on language may also play a role in diversifying these different colour names and hierarchy. Our results reports that cross-cultural and linguistic linkage varies in monolexemic colours.

When compared (Berlin and Kay, et al., 1969) implication hierarchy of colour words with the monolexemic colour terms of Dravidian languages and recognized that compound colours are not monolexemic. Colours like Brown, Purple, Pink, Orange, and Grey are in Tamil, Telugu, Malayalam, and Kannada are not monolexemic in its nature. This comparison shows that Dravidian languages have just 3 to 6 monolexemic colour terms identified in our work, while English has 11 colours (Berlin and Kay, et al., 1969).

Colour naming scores in Telugu and Tamil participants were higher and better than in Malayalam and Kannada participants. This may be due to these two languages' long evolutionary and literary foundations. The error rate, however, differed across these groups, and post hoc -analysis of within-group differences was also observed.

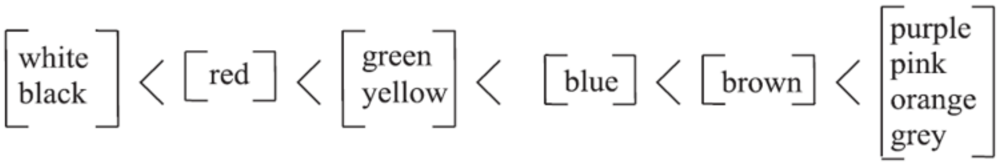
These empirical findings imply that Tamil and Telugu speakers are quick to name the current monolexemic colour names. However, the error rate in Telugu was sizable due to the use of compound colour terms rather than monolexemic in nature. Similarly, (Hannah, J et al., 2016) studies in anthropological and computational models on Australian languages were searched to identify the evolution and discovered that phylogenetic approaches only provide historical aspects and that the interlinkage between physiologists, colour scientists, and linguists are possible source to help in understand the evolution in depth, nevertheless, in the current study, is a similar approach with empirical methods.

Form the analysis of the data it is observed that in the Stroop task experiments, Tamil and Telugu participants identified colour words quicker than Malayalam and Kannada. Four groups had comparable L1 scores. Choosing Monolexemic colour words was different. According to selective attention theory, identifying word colours requires more effort than reading text (Treisman, A., et al., 1964).

That is to say Humans can read faster than name colours. Similarly, Stroop theory also brings in a view that language and cultural factors may affect participants' attention. In the current experiment, results found that cross-cultural variation and linguistic presentation of monolexemic colour terms might have influence on how the attention in generating and responded for the monolexemic colour terms. However, (Ravi et al.,2009) experimental models suggest that the role of colour affects cognitive performance. Similarly, present findings support of the current experiment suggests that the cross-cultural and monolexemic nature of colour terms also affects cognitive performance mainly attention.

The present experiment findings also reject the universality hypothesis (Berlin and Kay et al., 1969). Moreover, supports the (Roberson, et al ., 2000) relativistic theory. There are only about three to six monolexemic colour terms in Dravidian languages, and this research provides proof for this claim, according to the observed of reaction times in the naming of a colour term in Tamil and Telugu takes statistically less time than naming in Kannada and Malayalam.

Furthermore, this research shows that reaction times are faster in incongruent trials across all groups. All these findings support the concept of the existence of monolexemic colour terms in Dravidian languages, which contradicts the Universality theory, and more qualitative investigations will be conducted in the future to supplement the current data. Given the Implicational Hierarchy, **As shown in Figure-22** (Berlin and Kay et al., 1969) cannot claim a superior model due to various sociolinguistic factors.



Berlin and Kay's (1969) implicational hierarchy.

Figure-22 An implicational hierarchy of (Berlin and Kay, et.al 1969) on the universality of colour terms.

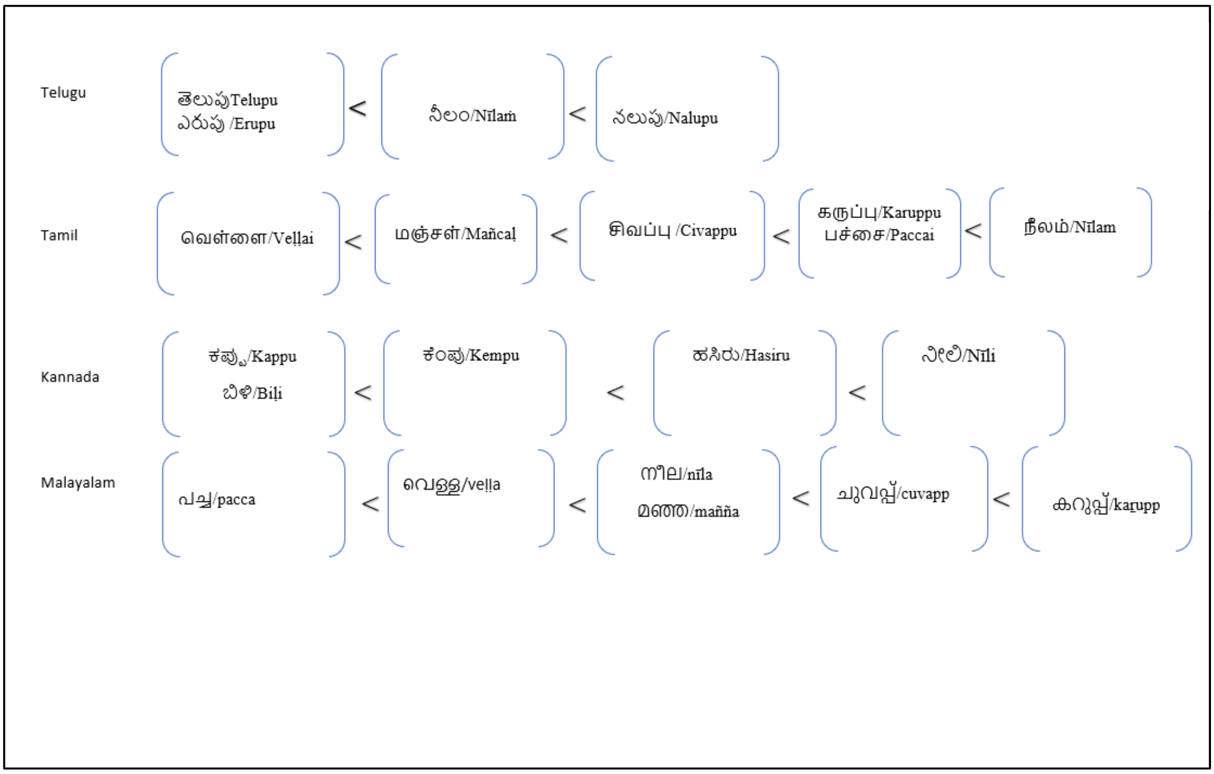


Figure-23. A proposed stages of monolexemic colour terms in Dravidian languages.

The Dravidian monolexemic colour hierarchy from current study **As shown in Figure-23.** It is observed that the colours like Blue and Black, have few common and shared phonological and morphological features between Tamil, Telugu, Malayalam, and Kannada, this can be due to the borrowing or contact with each other.

It can be hypothesised that these words may have come from Tamil due to its vast untouched evolutionary tradition exits as per the available data. Basing on which Tamil language might have had these words that are now shared with its other family members.

Yet this can also be purely Individual disposition, that is to say a words, concepts or sentences are created, modified and transformed by individual humans as per their needs as suggests in the theory of Ka:rmik Linguistics (Chilukuri, B, et al., 2016).

Furthermore, this theory suggests it can Individual-Collective-Contextual-Conjunction-and-Standardisation of Lingual Action (ICCCS(L)A) according to this cutting-edge theory. As per corpus and data collected from these four language speakers it is observed that monolexemic colours are perceived quickly and their seems to higher usage of this vocabulary in these languages.

In summarizing the number of monolexemic colour terms in Dravidian languages ranges from 3 to 6, and these colour terms do not adhere to the universality of colour theory. Surprisingly, as per our observations made from the work of (Berlin and Kay 1969; Wysecki, G. et al., 1967; Roberson, D. et al., 2000; Kapp, D.B. 2004; Loreto, V. et al., 2012.), white and black seems to dominative in nature in all the languages of the world. By these findings, it is believed that the existence of these colours in all the languages of the world is because of the two most important natural phenomena in the atmosphere of the earth i.e. Day and Night. Day with the Sun – the light emitting from the sun which is bright to eye, in-turn it can be emergence of colour White and the Night which is dark on a no moon day can be seen as an emergence of Black.

This phenomenon is the sole event of having at least Black and White colours and colour terminology throughout the languages of the world. Apart from, this pioneering empirical understanding of colour terms in four Dravidian languages, there is a need for future phylogenetic and ethnographic research models in various languages of the world that will provide greater insight into the evolution of these colour names and their cross-cultural relationships in various languages.

Chapter-6

A study of colour and emotion associations in Dravidian culture.

6.1 Introduction

This chapter provides a foundational understanding of how emotions are linked to colours in Dravidian culture and how this relationship varies across different cultures; previous research has shown that colour has a curative quality, and that colour plays a vital role in the emotions and moods of humans. Colour is all around us and has a significant influence on the way that is perceived the world around us.

It has the ability to bring thrill and sensation into our everyday lives, which is a genuine possibility. Our dispositions are affected by colours, and the emotions brought on by a specific shade or colour combination are referred to as "colour emotions" (Martin, A, et al., 1995).

Not only does colour appeal aesthetically, but it also serves a purpose in the natural world with its myriad of vibrant hues and subtle gradations. When colouring is used appropriately, it helps accurately identify emotional feelings and the strong expression of those feelings; it amplifies pleasure, warms love, inflames rage, and deepens mourning (Dravida, S, et al., 2013).

Colour influences both behaviour and society. In Western culture, brides traditionally wear white, whereas mourners favour black. Many people believe that different colours have different connotations.

These colour correlations have been more well-known because of popular psychological studies and books. These ancient paintings lend credence to commonly held beliefs on colour, such as the concept that an individual's colour preferences reflect their personality and that one's surroundings affect their mood. These ideas presume culturally and contextually significant relationships between different colours and feelings (Pulver muller, F. et al.,2005). Similarly, in India, the colour is widely represented in various perspectives with different emotions.

6.2 Earlier studies

(Adams and Osgood et al.,1973) found remarkable universality in colour phrase evaluations on semantic differential measures in 23 ethnic groups. Black was ranked most consistently across ethnic groups, whereas rated least. They identified human retinal physiological changes, similar human experiences, and shared cultural ideas, either from ancient ordinary beginnings or from more recent cultural influences, as plausible causes of universality.

Twenty years later, (Valdez and Mehrabian, et al.,1994) examined colour-affective relationships in a controlled laboratory. To explore the link between colour and affective dimensions, they thought it was essential to analyse colour-effect correlations with tangible colours (colour patches) rather than colour terminology. Colour patches systematically correlated with emotional characteristics and found that the darker colours were less pleasant than brighter, and less saturated colours were more exciting and compelling.

The following are brief summaries of the many empirical studies that have been conducted to determine the relationship between colour words or Effective and useful dimensions and self-reported associations between colour patches and emotions (Eysenck, et al., 1941; Jonauskaite et al., 2016; Palmer & Schloss et al., 2010; A. E. Skelton & Franklin, et al., 2019). The hue orange conjures up feelings of energy and vitality.

Since yellow is linked to feelings that are predominantly upbeat, proactive, and passive. Positive connotations are linked to the colours green and blue and settling the nerves The colours pink and turquoise evoke cheerful thoughts and feelings, respectively. The colour purple is connected, albeit not always conclusively, with sound, relaxing, and submissive feelings Brown identity is seen negatively.

The colour grey has negative, soothing, and irresponsible feelings. White and other light colours are pure, peaceful, and submissive. emotions. Last but not least, the colour black and other dark hues are often connected with unpleasant, stimulating, and powerful connotations emotions.

Greater colour saturation (also called chroma) is typically linked with more visually striking and less subtle hues, whereas less saturated hues (desaturated colours) are associated with negative, dismal feelings connected with not just bad, but also powerful feelings.

(Xie, A. et al., 2018) highlights the fact that Indian cosmologists believed that the three Guna were the building blocks from which the cosmos began. Because colours are divided into these three categories (Tamas, Rajas, and Sattva), Indian culture assigns a variety of connotations to each hue. The relationship between the Gunas and the colours, with black, stands in for Tamas. A gloomy view, together with death, decay, denial, and death.

The Rajas guna (quality) particularly favour the colour red. Red is representative of anger, vehemence, vigour, energy, and activity. White is the colour that is linked with the renowned sattva, and white is a colour that is symbolic of enlightenment, perfection, and tranquillity. These are all qualities that properly define this esteemed sattva. The combination of black with the triadic opposites of the other colours suggests that it is not fortunate. The southern region of India places a strong emphasis on the symbolic significance of these colours.

However, Indians celebrate Holi with colour. Indian culture appreciates colour. Colour symbolism impacts Indian customs, food, clothes, and interior decor. Colour meanings in Indian culture are religious, yet they nevertheless influence people's decisions.

In reviewing the current literature and earlier investigations, reported that empirical studies mainly focused on colour preferences but not on colour and emotions. However, colour and emotion are also subjective.

6.3 Objective

To understand colour and emotional associations between the four most frequently known Dravidian culture languages (Tamil, Telugu, Malayalam, and Kannada) .

6.4 Materials and Methods

Participants

In the current study, n=60 native (Telugu, Tamil, Malayalam, and Kannada) speakers were recruited with male = 46 and female =14 student volunteers. Each group fifteen participants were included for the experiment. All the participants were naïve to research. With regard to the declaration of Helsinki norms and IEC approval, verbal and written consent was gained. The research used a random sampling approach. For data gathering, a cross-sectional interview approach was adopted.

Study design and setting

The data were obtained at the Visual psychophysics research laboratory at the University of Hyderabad's School of Medical Sciences utilising cross-sectional-observational and survey methodologies, with a colour and emotions association, standardised questionnaire.

Development of Colour and Emotions Questionnaire

The authors developed a questionnaire by applying the basic eight emotions in four different Dravidian languages (Tamil, Telugu, Malayalam, and Kannada). The variables of eight emotions, **as shown in Table 14**. such as love, sadness, fear, hatred, desire, happiness, jealousy, and anger, were considered. Participants were asked to choose colours from the listed, i.e., violet, blue, green, yellow, orange, red, white, black, or to specify any other colour they associated most related to a specific emotion.

To consider standardisation Item-analysis for the questionnaire's selected eight parameters, including pilot data, was statistically evaluated.

Telugu	Tamil	Kannada	Malayalam
ఆశా (Desire)	ஆசை(Acai)	Desire (ಆಸೆ)	Desire(മമാഹം)
దుఃఖము (Sadness)	சோகம் (cokam)	Sadness(ದುಃಖ)	Sadness(സങ്കടം)
భయం (Fear)	பயம் (payam)	Fear (ಭಯ)	Fear (സങ്കടം)
ద్వేషం (Hatred)	வெறுப்பு (veruppu)	Hatred (ದ್ವೀಷ)	Hatred (പക)
ప్రేమ (Love)	அன்பு (Anpu)	Love (ಪ್ರೀತ್)	Love (സ്മനഹം)
సంతోషం (Happiness)	மகிழ்ச்சி (Makilcci)	Happiness (ಸಂತೀಷ)	Happiness (സമതാഷം
ఈర్ష్య(Jealousy)	பொறாமை (Poramai)	Jealousy (ಅಸೂಯೆ)	Jealousy (അസൂയ)
కోపం (Anger)	கோபம் (kopam)	Anger (ಕೀಪ)	Anger (മകാപം)

Table 14. A list of emotions from four Dravidian languages to see the association with different colours.

Experimental procedure

All participants from the four separate groups (Tamil, Telugu, Malayalam, and Kannada) were instructed to sit comfortably. Before taking part in the experiment, the participants' colour vision was tested using the Ishihara colour vision test and the mollon reffin colour vision test to see whether they had a colour vision defect.

The participants were given a questionnaire on emotions and colour associations. They were asked to select the colour that was best associated with each of their eight emotions based on their previous experiences. In addition, the participants were allowed to associate with two colours that they preferred the most. If a particular colour was not included on the list, they were given the option to include any other colour that was specifically associated with their state of emotions.

Data collection and Analysis

All the collected data were stored in Microsoft Excel version 2016 and the R 3.4.1 CRAN-statistical package (R Core Team, et al., 2022) To measure the Bayesian models and likelihood ratio, and binomial tests, JASP and the Bayesian statistical guide (Goss-Sampson, M. et al., 2019) were utilised. Additionally, IBM-SPSS, version-19.1, was used for item analysis and standardising the questionnaire.

6.5 Results

Item analysis for developed questionnaire on colour and emotions

The developed colour and emotion association 8-question scale was evaluated using item analysis item co-relation score (Telugu=0.72, Tamil=0.98, Kannada=0.75, and Malayalam=0.86). Then the scale's internal consistency was evaluated using Cronbach's alpha (Telugu=0.81, Tamil=0.74, Kannada=0.75, and Malayalam=0.8), indicating a range of acceptable to good consistency. 95% confidence interval (CI) lower upper= 0.27, Upper= 0.83 for the correlation between a single measure and the mean of all measures is 0.14 (0.27 - 0.58). This indicates that the questionnaire is of sufficient quality for data collection to proceed. **As shown in Table 15.**

Questionnaire Language	**Questions numbers in total**	**Item correlation**		**Cronbach alpha**	**Interclass correlation**		**95%CI**	
Telugu		0.72		0.81	Single measure's	Average Measure's	Upper	Lower
Tamil		0.98		0.74	0.14	0.58	0.27	0.83
Kannada	08	0.75		0.89				
Malayalam		0.86		0.80				

Table-15. Item analysis illustrating how the questionnaire was standardised for the accuracy of results.

Colour and emotions association

The binomial test and Bayesian inference for measuring the individual colour and emotion, followed by the group-wise comparison, and found that red, black, green, and yellow were more significantly associated with desire, sadness, love, hatred, and joy; it is also found that the cross-cultural association between the four groups are varied, as can be seen in **Table-16**.

The Bayesian independent samples t-test (BF_{10}=32.12, df=15, t=14.09, p<0.001) showed the significance as shown in **Table-17 and Figure-24** showing the density curve and Sequential plot showing the evidence between colour and emotions association and **Figure-25** shows a bar graph illustration between these groups.

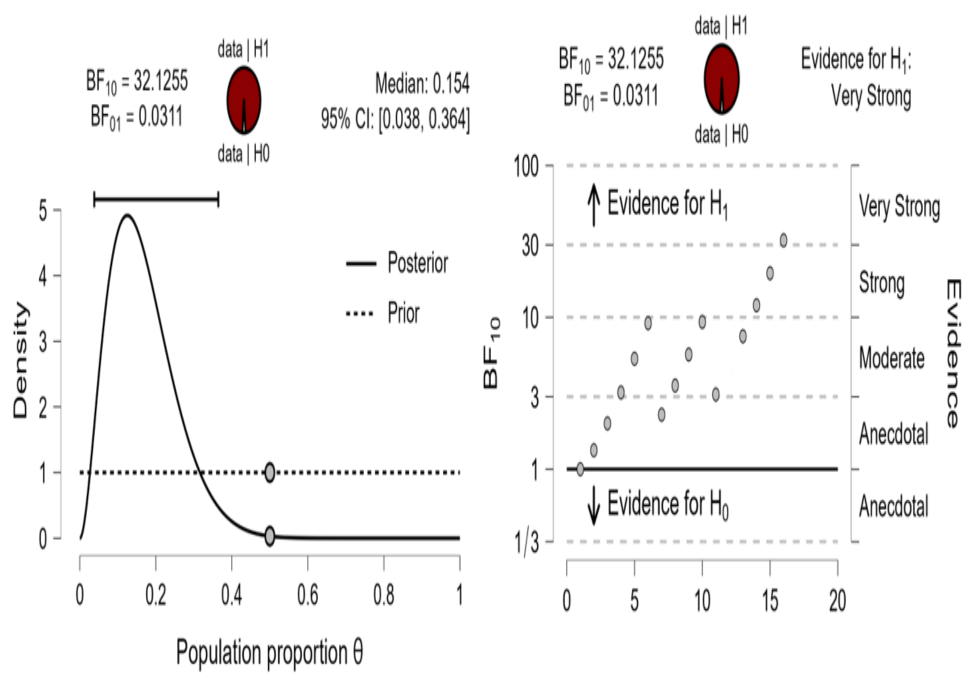


Figure-24 shows the density curve and the Sequential plot showing the evidence between colour and emotional association

Emotions	Telugu N=15		p-value	Tamil N=15		p-value	Kannada N=15		p-value	Malayalam N=15		p-value
Desire	Red	10	<0.01	Red	6	0.02	Orange	6	0.02	Pink	8	0.91
	Yellow	5		Green	9		Yellow	9		Green	7	
Sadness	Blue	4		Orange	7	0.91	Red	6		Red	10	<0.01
	Black	11		Black	8		Black	9		Black	5	
Fear	Black	3		Black	11	<0.01	Black	5	<0.01	Black	6	0.02
	Red	12		Red	4		Red	10		Orange	9	
Hatred	Green	6		Green	6	0.02	Violet	6	0.02	Red	10	<0.01
	Red	11		Yellow	9		Orange	9		Black	5	
Love	Red	6	0.02	Pink	8	0.91	Pink	6		Pink	7	0.91
	Orange	9		Red	7		Blue	9		Green	8	
Happiness	Green	8	0.91	Green	3	<0.01	Green	5	<0.01	Blue	4	<0.01
	Blue	7		Blue	12		Pink	10		Pink	11	
Jealousy	Black	5	<0.01	Black	4		Black	6	0.02	Black	8	0.91
	Red	10		Violet	11		Red	9		Red	7	
Anger	Red	11		Red	5		Orange	7	0.91	Red	10	<0.01
	Black	4		Black	10		Black	8		Black	5	

**p<0.05 is considered as the level of significance.*

Table-16. A binomial test showing the association between various colours and emotions in Dravidian culture n=60.

Participants (N=60)	95% Credible Interval		Bayes Factor BF_{10}	df	t	Level of significance
	Lower Bound	Upper Bound				
Telugu	.034	.331	32.12	15	14.09	p<0.001
Tamil	.043	.382				
Kannada	.061	.396				
Malayalam	.034	.331				

Table-17. Bayesian analysis with t-test showing the comparison between the four groups

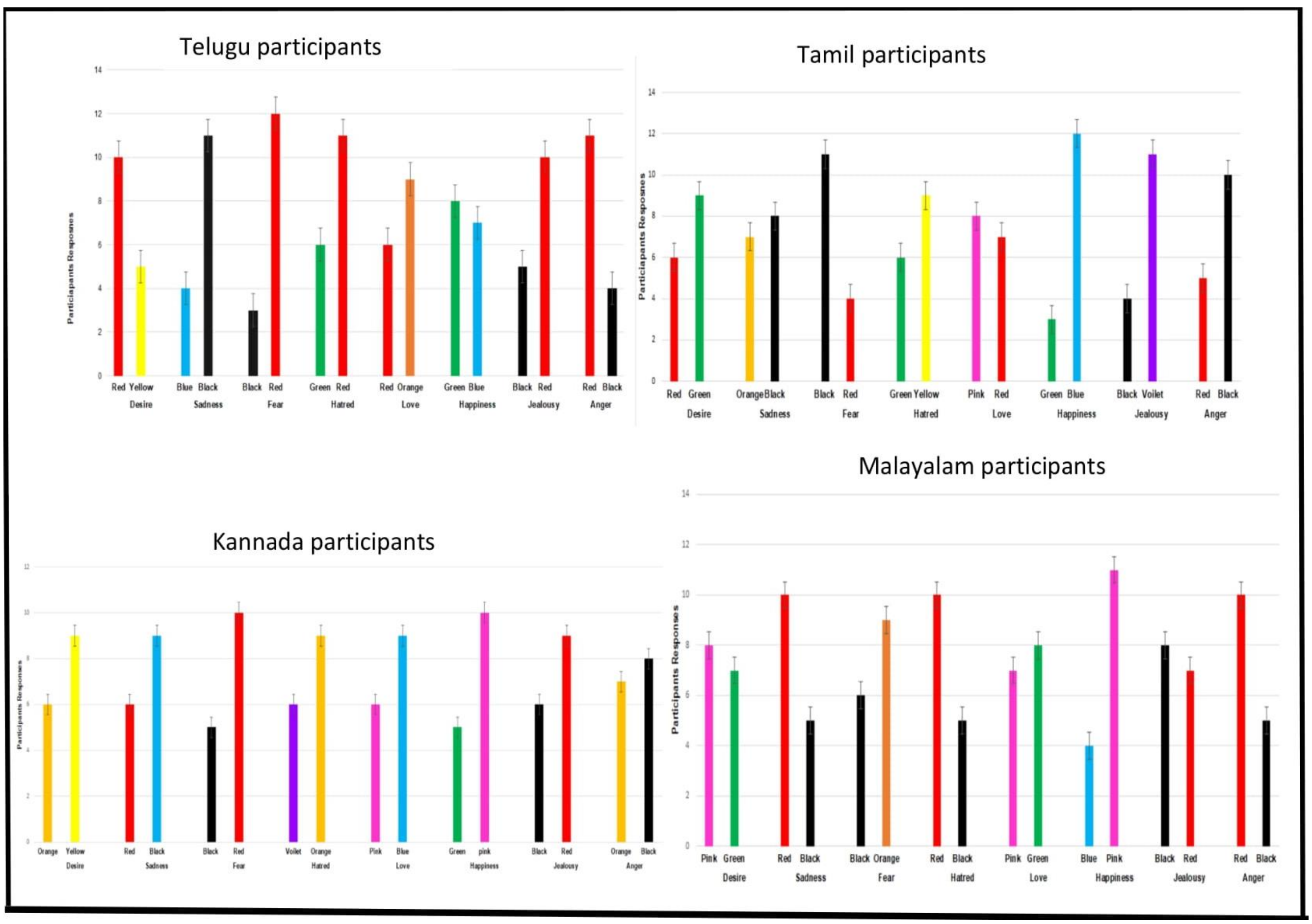


Figure-25. A comparison between colour and emotion association in Dravidian culture n=60.

6.5 Discussion

In Dravidian culture, emotions are most often connected with the use of warm colours. However, these results were indirectly confirmed by the theory presented in (Carlos, et.al 2018) that the colour of the face has a significant influence on emotions. There is a restriction placed on the colour terminology used in Dravidian culture due to the theory proposed by (Berlin and Kay et al. 1991) on the universality of colour names.

This research used a useful questionnaire to gather the colour-term-linked emotions from the participants. This produces fascinating data, such as the fact that colour and emotions are connected and vary cross-culturally in the Dravidian population.

The distribution of the colours red, blue, and black as expressions of joy, anger, and terror among the four groups was quite close. These results are consistent with those of other investigations (Jonauskaite et al., 2016), and the sample size may be a contributing cause to the apparent disparity.

Nevertheless, this is the foundational research that has assessed the connection between colour and emotions for the very first time. **Figure-26**, as shown, has analysed, evaluated, and examined the data on the universality of colour and emotion provided by (Jonauskait Domicel, et al., 2021).

The current research provides new results that can be compared to the data. These findings can also be depicted on a worldwide map showing how differences in colour and emotion manifested with other cultures and from the perspective of the Dravidian culture (Shiva, R et al., 2021).

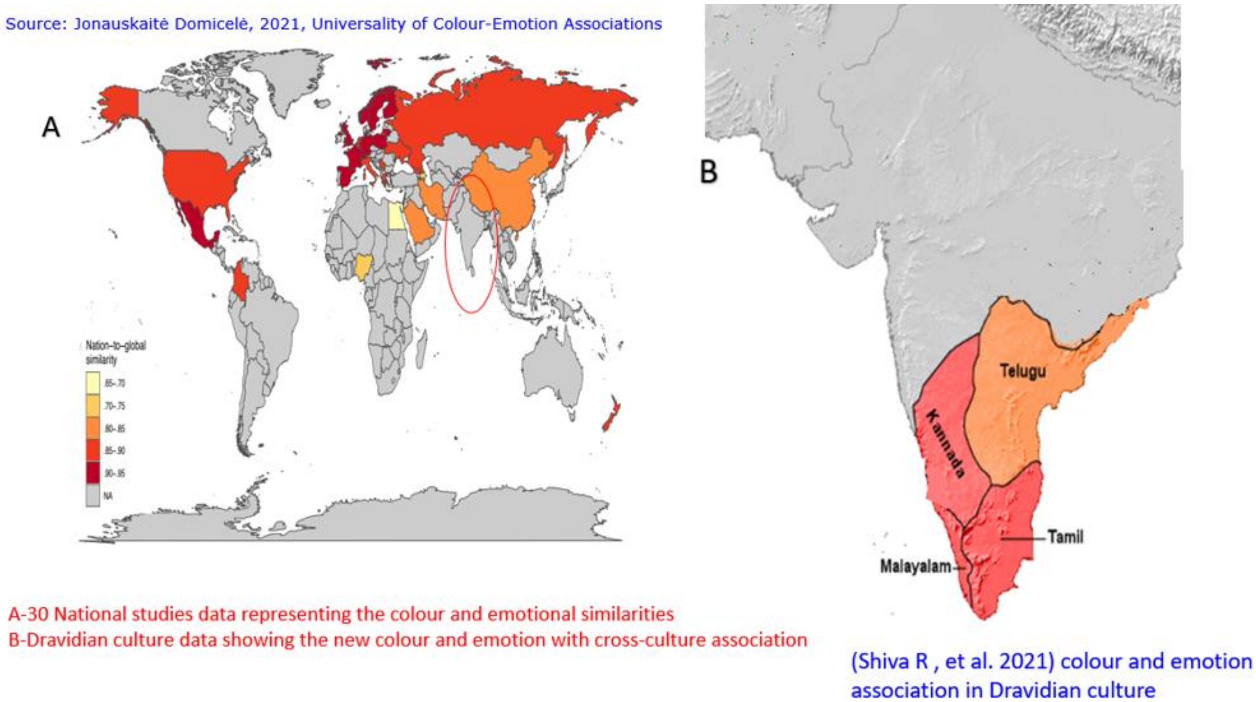


Figure-26. An illustration between Dravidian colour and emotion association from Indian data and global data.

In addition, doing ethnographic research in these communities might provide more insights into the relationship between colour and emotion in the long run and provide us with some preliminary knowledge of how colours are seen. This research adds to the growing body of evidence supporting chromotherapy as an interventional study modality in treating medical and clinical conditions based on colour's ability to reflect emotional states.

There are just a few studies supporting the use of colour and chromotherapy for healing, however these methods are widely used in the West. According to a report conducted by (Samina, T. et al.,2005), many aspects of human exploration are lost, ignored, or discarded. Colour therapy is one of those components of medical treatment that gets overlooked too frequently.

Allopathic medicine, acupuncture, Unani, homoeopathy, and biochemical medicine all aim to cure illness and restore health. To learn more about the disorders that can be cured with colours. Further, the findings also advise including colour therapy as part of a holistic approach to ophthalmology and eye care.

However, cognitive therapy and vision therapy are already in clinical use. Introducing the already established colour therapy as a holistic approach under new education policy and curriculum in India may provide us with a better understanding.

In the future, these interventions and therapies may be helpful to treat or manage the disorder without the use of drugs by delivering the treatment.

Chapter-7

A special chapter -Proposed prescriptions for policy, advocacy, and registry for the CVD population.

7.0 Introduction

In this chapter, various outcomes from the research carried out on colour vision deficiency is proposed and how this research can be beneficial to the population affected by colour vision deficiency. Additionally, policy ideas, advocacy efforts, and registries geared toward the CVD population is explained.

7.1 Proposed policy and Advocacy for the CVD population in Telangana.

Preamble

The importance of colour in modern life is undeniable. It is difficult to conceptualise life without colour. One such condition that leads to a diminished standard of living and increased difficulty sustaining one's livelihood is colour blindness. Recent findings from this PhD thesis have examined the relationship between colour vision deficiency and life quality in Telangana. The study's main findings showed an increase in the percentage of children and teenagers losing social inclusivity and empowerment opportunities at college and university, but this trend is manageable with the right set of new strategies and objectives.

Summary and Key findings.

i) From 1972 to 2020, a prevalence of (3.4%) CVD was recorded in Hyderabad; most of this data comes from school-aged children and age groups ranging from 10 to 18 years.

ii) Compared to normal healthy colour vision, the quality of life, emotions, and work was impaired twice as much in the CVD group.

iii) A low (odd ratio= 0.31) is observed, implying that 2 to 3 patients out of 10 examined will have CVD.

iv) The male gender is disproportionately affected; the most prevalent kind of CVD is a red-green deficiency that interferes with everyday life and activities.

Suggested Points as possible Recommendations and implementation strategies.

1. **Travel and transportation:** To consider placing the colourblind free charts and railways maps in public transportation and work areas like Hyderabad Metro and local stations, workplaces, traffic charts and Government offices. Considering mandatory colour vision screening of Drivers-RTC, and other public transport facilities to avoid major accidents and supportive rehabilitation.

2. **Education:** To consider providing colour-blind free resources for children in schools along with appropriate visual aid technologies.

3. **General:** To consider providing the awareness and mandatory screening of colour vision for further counselling and career planning for CVD population .
4. **Industry:** To consider developing new innovative methods for colour vision aids manufacturing with T-Hub an ecosystem for innovation.
5. **Social Security:** To consider including the severe colour vision deficiency population and issuing the CVD impairment or visual disability certificate.
6. **Livelihoods**: Allowing assistive technologies or advanced colour vision evaluation for youth during the recruitment process of constabulary and other forces.

Benefits.

1. Telangana government will be the first state to take the initiative to include a colour-blind free work environment at its workplaces, i.e., Traffic, Public transport, Schools, and other places.

2. As per National Education policy, Visual aids and play school environments, and practical-based learning with practical approaches have evolved. A colour-blind free education material can be implemented as Telangana state has rich information and software technology. This could help contribute to the Technology for special population.

3. International colour-blind day is implemented every year on September -6th globally. Similarly, implementing International Colour-Blind awareness day among regional Eye hospitals and Government schools could create advocacy avenues and more awareness on colour vision deficiency.

4. Special training and teaching methods for the Faculty and Teachers in school education and higher education should be considered. An inclusive way of considering the colourblind free teaching environment should be created.

5. Kantivelugu is the most successful programme which also got credentials for the Guinness book. Implementing and documenting the colour vision deficiency also would give a brief insight on occupation and age groups .

7.2 ICVDRA – A registry for Colour vision deficiency

ICVDR (Indian colour vision deficiency registry) is an initiative proposed to understand and document colour vision deficiency; according to the literature, prevalence studies in India showed an increase, and age groups and other parameters were not well documented. Furthermore, the majority of the time, colour vision deficiency goes undiagnosed due to a lack of awareness, low esteem for declaring CVD in society and community, and a fear of losing opportunities for empowerment.

Vision

To provide and maintain a registry as a repository of all CVD populations and to understand the impact and prevalence of colour vision deficiency and types of colour vision deficiency in India.

Objectives

1. To register all CVD population in the country

2. To determine the eye conditions that cause colour vision deficiency in India.

3. To quantify and develop a severity of colour vision impairment classification per the Indian occupations.

4. To report and conduct a massive multicentre data registry study for colour vision deficiency in India's available eye hospitals.

About ICVRD Logo

This is a simple illustration of three primary cone pigment Red, Green and Blue and White and Black represents Dark and Light. Any deficiency in these cone pigments may lead to improper colour vision deficiency, who can miss the beautiful rainbow with their eyes.

Figure-27. An illustration and logo of ICVDR.

Chapter-8

Summary and Conclusion

The primary goal of this thesis was to offer a thorough account of profiling the problem of colour vision deficiency and its relationship with colour, culture, cognition, and Technology from an Indian perspective.

The researcher introduced the basic colour concept and how it is perceived in interdisciplinary nature by implementing different mixed methods, both experimental and qualitative approaches.

In the first objective, Systematic review, and meta-analysis methods to investigate the existing colour vision devices and aids commercially available in the market and their benefit in improving colour perception in the CVD population was presented.

This review included randomised, experimental, comparative studies, narrative reviews, prototype and innovation studies, and translational studies, followed by case-control and clinical trials with nonsurgical interventions. The objective and subjective performance of colour vision devices were studied. Secondary results included colour vision equipment use and accessibility.

The GRADE framework was utilised to provide a systematic strategy for consideration and clinical practice recommendations for CVD devices for colour-deficient people. Using consistent inclusion and exclusion criteria, we included meta-analyses from 16 vision, optical, and contact lens-based research. EnChroma Glasses, Chromagen filters, and EnChroma Cx-14 do not enhance subjective colour perception, a review indicates. Therefore, suggesting colour vision equipment to CVD patients may be counterproductive.

In the second objective, the researcher conducted a case-control study to understand the Impact of colour vision deficiency on the quality of life in a sample of the Indian population by applying the standardised QoL-CVD questionnaire tool. From these findings, it was reported that this research found that CVD impairs Indians' quality of life. Lifestyle, Emotions, and Work scores were lower than the UK study.

Since CVD is under-reported and may impact impoverished nations more, colour vision deficit might be considered a visual impairment. Advocacy and raising public awareness might potentially aid the CVD population.

In objectives five and six, the research implemented with an interdisciplinary understanding on how colour terms evolved and how colour is associated with culture, language, and cognition by applying both the visual psychophysical experiments and cognitive task and corpus linguistic methods, and from the findings, it was found that the existence of monolexemic colour terms in Dravidian languages is limited to 3 to 6.

These colours were developed from nature because of day and night, the 2 most important natural phenomena on earth. A day with the Sun is white, but a no-moon night is black. All languages use black-and-white terminology and colours for this reason. Future phylogenetic and ethnographic research models in many languages of the globe will give further insight into the development of colour names and their cross-cultural links.

The research highlights that emotions are most typically connected with sparkling and warm colours, and we discuss the function of language in displaying variances in the correlations between colours and emotions among a Dravidian culture from South India. These findings were supported and can be pooled in the Universality of colour and emotions.

In conclusion, the relevance of CVD has been recognised, and new advocacy and policy have been made for consideration; in developing countries like India, documentation and screening of CVD populations are not well standardised, which has implications for the colour vision-deficient community. In light of this, it has been suggested that future research include a registry for those with colour vision impairments.

The "Monolexemic colour terms hypothesis in Dravidian languages" is credited with introducing the concept of colour terms. This hypothesis will be a foundational starting point for future researchers seeking to understand the role that language and colour association play in relation to a culture's significance.

We also proposed to implement colour therapy in health sciences as an interventional therapy to understand more about cognitive and vision therapies and how they relate to mental health and human well-being based on the current research findings. In the same way, colour has the ability to heal by altering a person's mood or emotions.

The research may be expanded to learn more about colour vision and its significance by using cutting-edge methodologies and tools from various disciplines to address previously unresolved topics.

Strengths and Limitations of the current Thesis

Objectives	Strengths
I	• First Systematic review and Meta-analysis on CVD devices reported to Optometry and Vision Sciences (Colour vision) • Optometrists could consider, while clinically recommending CVD devices to the CVD population as per the level of evidence • Developing countries (India) should consider making a new policy for Health science researchers in Rehabilitation aids
II	• First CVD-QoL study ever conducted in a sample of Telangana, India Population • A translated CVD-QoL questionnaire is registered under copyright (under process) for implementation as an application tool in Clinical setup • A new policy has been proposed for consideration by the Government of Telangana on CVD
III	• Interdisciplinary collaboration and investigation to link colour, culture language and cognition by applying cognitive linguistics methods and visual psychophysical tools. • A new classification and theory on monolexemic colour terms have been proposed. Which is equivalent to the western English colour terms theory of Berlin and Kay. • The evolution of Dravidian colour terms has been understood and represented. This can lead to a basic foundation in the future to understand and see the link between CVD Genetics in culture and geographical locations.
IV	• Colour has a property of healing, and cognitively, it plays a significant role in emotions and perceptions • This study will lay a foundation to implement colour therapy as, a holistic approach clinically to healing various diseases. • Syntonic and Chromotherapy are widely practised overseas (Australia, UK and USA). • A Mixed Methods approach has been implemented to study various Hypotheses.

Limitations

1. COVID-19 lockdown challenges that lead to avoiding the field work for conducting the ethnographic approach on colour terms and emotions

2. Limited sample size due to covid-19 guidelines and protocols for a case-control study.

3. Timeline and funding resources are limited.

4. An exploratory type of study with limited scope for associations and also developing and implementing interventions as it is one of its kind.

References

- E. Schrödinger, Theorie der Pigmente von größter Leuchtkraft. Ann. Phy. (4), 62, 603–622 (1920). (translation: Theory of pigments of greatest lightness. Available at http://www.iscc.org/resources/translations.php)

- Phan, M. (2017, March 23). *The Evolution of Color Linguistics: A Phylogenetic Approach to Color Terms – Yale Scientific Magazine*. The Evolution of Color Linguistics: A Phylogenetic Approach to Color Terms – Yale Scientific Magazine. Retrieved November 17, 2022, from https://www.yalescientific.org/2017/03/the-evolution-of-color-linguistics-a-phylogenetic-approach-to-color-terms/

- McNeill, N. (1972). Colour and colour terminology. *Journal of Linguistics, 8*(1), 21-33. doi:10.1017/S002222670000311X.

- Gegenfurtner, K. R., & Kiper, D. C. (2003). Color vision. *Annual review of neuroscience*, *26*, 181–206. https://doi.org/10.1146/annurev.neuro.26.041002.131116

- Gegenfurtner, K. R. (2003). Cortical mechanisms of colour vision. *Nature Reviews Neuroscience*, *4*(7), 563-572.

- Jacobs, G. H. (2009). Evolution of colour vision in mammals. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1531), 2957-2967.

- Kolb, H., Fernandez, E., & Nelson, R. (1995). Webvision: the organization of the retina and visual system [Internet].

- Mollon, J. D. (1999). Color vision: Opsins and options. *Proceedings of the National Academy of Sciences of the United States of America*, *96*(9), 4743-4745. https://doi.org/10.1073/pnas.96.9.4743

- Pérez, V. V., Saiz, D. D. F., & Verdú, F. M. (2010). Colour vision: theories and principles. In *Colour Measurement* (pp. 3-e2). Woodhead Publishing.

- Neitz, M., & Neitz, J. (2021). Intermixing the OPN1LW and OPN1MW Genes Disrupts the Exonic Splicing Code Causing an Array of Vision Disorders. *Genes*, *12*(8), 1180.

- Poret, S., Dony, R., & Gregori, S. (2013, January 1). *Image processing for colour blindness correction | Semantic Scholar*. Image Processing for Colour Blindness Correction | Semantic Scholar. Retrieved November 23, 2022, from https://www.semanticscholar.org/paper/Image-processing-for-colour-blindness-correction-Poret-Dony/68cf9659e389971b1093fdc824fc02a23c98448e/figure/5

- Council (US) Committee on Vision, N. R. (1981, January 1). *CLASSIFICATION OF COLOR VISION DEFECTS - Procedures for Testing Color Vision - NCBI Bookshelf*. CLASSIFICATION OF COLOR VISION DEFECTS - Procedures for Testing Color Vision - NCBI Bookshelf. Retrieved November 23, 2022, from https://www.ncbi.nlm.nih.gov/books/NBK217820/?report=reader

- Suntharesan, V. (2016). Colour Terms in Languages. *Language in India*, *16*(2).

- Von Goethe, J. W. (1840). *Goethe's theory of colours*. J. Murray.

- *Cognitive colour | CIE*. (n.d.). Cognitive Colour | CIE. Retrieved November 23, 2022, from https://cie.co.at/publications/cognitive-colour#:~:text=Cognitive%20colour%20is%20very%20important,i.e.%20as%20%22cognitive%20colours%22.

- Gupta, R. (2021). Color therapy in mental health and well being. *International journal of all research education and scientific methods (IJARESM), ISSN*, 2455-6211.

- Kumar, R. (2016). A note on colour psychology of Indian and Chinese culture and possible impact on advertising. In *International Conference on India, China and The New World Order, Bhubaneswar, Odisha. Consultado em https://www. researchgate. net/publication/312172043*.

- *Colour Symbolism – Emotional Values of Colour - IJAR - Indian Journal of Applied Research*. (n.d.). Colour Symbolism – Emotional Values of Colour - IJAR - Indian Journal of Applied Research. Retrieved November 23, 2022, from https://www.worldwidejournals.com/indian-journal-of-applied-research-(IJAR)/fileview/January_2013_1357045974_cf1fd_25.pdf

- *Can science explain blue skin of Lord Krishna?* (2016, August 25). Can Science Explain Blue Skin of Lord Krishna? Retrieved November 23, 2022, from https://www.downtoearth.org.in/news/health/did-lord-krishna-really-have-blue-skin--55392

- Colors in Indian Culture. (2017, December 23). Retrieved from https://study.com/academy/lesson/colors-in-indian-culture.html.

- Shamsashtri, R., & Shamshastri, R. (1930). DRAVIDIAN CULTURE. *Annals of the Bhandarkar Oriental Research Institute*, *11*(4), 336–360. http://www.jstor.org/stable/41688192

- Kandler, A. (2018). Interactive Technology for People with Colour Vision Deficiency–Translating Colours into Haptic Feedback.

- Tanuwidjaja, E., Huynh, D., Koa, K., Nguyen, C., Shao, C., Torbett, P., ... & Weibel, N. (2014, September). Chroma: a wearable augmented-reality solution for color blindness. In *Proceedings of the 2014 ACM international joint conference on pervasive and ubiquitous computing* (pp. 799-810).

- Lucille, A. et al 2022, *What Are the Best Mobile or Web Apps for Blind People? | American Council of the Blind*. (n.d.). What Are the Best Mobile or Web Apps for Blind People? | American Council of the Blind. Retrieved November 24, 2022, from https://www.acb.org/what-are-best-mobile-or-web-apps-blind-people

- *Use color filters in Windows - Microsoft Support*. (n.d.). Use Color Filters in Windows - Microsoft Support. Retrieved November 24, 2022, from https://support.microsoft.com/en-us/windows/use-color-filters-in-windows-43893e44-b8b3-2e27-1a29-b0c15ef0e5ce

- *Study on Colour Blind Medical Students Shows Need for Screening, Counselling*. (n.d.). The Wire. Retrieved November 24, 2022, from https://thewire.in/education/colour-blind-medical-students-seeks-screening-counselling
- Hathibelagal A. R. (2022). Implications of inherited color vision deficiency on occupations: A neglected entity!. *Indian journal of ophthalmology*, *70*(1), 256–260. https://doi.org/10.4103/ijo.IJO_1100_21

- NIRE. (2002). *Vision Devices for People with Impaired Colour Perception*. National Institute for Rehabilitation Engineering (NIRE) Copyright © 2002 by The N.I.R.E.

- Varikuti, V. N., Zhang, C., Clair, B., & Reynolds, A. L. (2020). Effect of EnChroma glasses on color vision screening using Ishihara and Farnsworth D-15 color vision tests. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, *24*(3), 157-e1.

- Martínez-Domingo, M. A., Gómez-Robledo, L., Valero, E. M., Huertas, R., Hernández-Andrés, J., Ezpeleta, S., & Hita, E. (2019). Assessment of VINO filters for correcting red-green Color Vision Deficiency. *Optics express*, *27*(13), 17954-17967.

- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Systematic reviews*, *10*(1), 1-11.

- Higgins, J. P., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (Eds.). (2019). *Cochrane handbook for systematic reviews of interventions*. John Wiley & Sons.

- *PRISMA Diagram Generator*. (2020). PRISMA Diagram Generator; prisma.thetacollaborative.ca. http://prisma.thetacollaborative.ca/

- *https://www.elsevier.com/__data/promis_misc/ISSM_PRISMA_Checklist.pdf*. (2020). PRISMA 2020 Checklist. https://www.elsevier.com/__data/promis_misc/ISSM_PRISMA_Checklist.pdf

- Guyatt, G. H., Oxman, A. D., Kunz, R., Vist, G. E., Falck-Ytter, Y., & Schünemann, H. J. (2008). What is "quality of evidence" and why is it important to clinicians?. *Bmj*, *336*(7651), 995-998.

- Schoonjans, F. (2020). MedCalc statistical software. *Accessed June*, *28*.

- Schiefer, U., Kurtenbach, A., Braun, E., Kraus, W., & Zrenner, E. (1995). Centrally tinted contact lenses. A useful visual aid for patients with achromatopsia. *German journal of ophthalmology*, *4*(1), 52–56.

- Hovis J. K. (1997). Long wavelength pass filters designed for the management of color vision deficiencies. *Optometry and vision science : official publication of the American Academy of Optometry*, *74*(4), 222–230. https://doi.org/10.1097/00006324-199704000-00024

- I. Zeltzer, H. (1991, March 12). Contact lens for correction of color blindness.

- Swarbrick, H. A., Nguyen, P., Nguyen, T., & Pham, P. (2001). The ChromaGen contact lens system: colour vision test results and subjective responses. *Ophthalmic and Physiological Optics*, *21*(3), 182-196.

- Dain, S. J., Wood, J. M., & Atchison, D. A. (2009). Sunglasses, traffic signals, and color vision deficiencies. *Optometry and vision science : official publication of the American Academy of Optometry*, *86*(4), e296–e305. https://doi.org/10.1097/OPX.0b013e318199d1da

- Oriowo, O. M., & Alotaibi, A. Z. (2011). Chromagen lenses and abnormal colour perception. *African Vision and Eye Health*, *70*(2), 69-74.

- Evans, B. J., & Allen, P. M. (2014). Coloured filters may reduce symptoms of dyslexia in those with visual stress. *BMJ*, *349*.

- Mastey, R., Patterson, E. J., Summerfelt, P., Luther, J., Neitz, J., Neitz, M., & Carroll, J. (2016). Effect of "color-correcting glasses" on chromatic discrimination in subjects with congenital color vision deficiency. *Investigative Ophthalmology & Visual Science*, *57*(12), 192-192.

- Veselý, P., Patočková, L., Hanák, L., & Beneš, P. (2017). Colour vision in group of subjects with and without chromagen filter. *Ceska a Slovenska Oftalmologie: Casopis Ceske Oftalmologicke Spolecnosti a Slovenske Oftalmologicke Spolecnosti*, *73*(3), 118-122.

- Almutairi, N., Kundart, J., Muthuramalingam, N., Hayes, J., Citek, K., & Aljohani, S. (2017). Assessment of Enchroma Filter for Correcting Color Vision Deficiency. *Pacific University (Oregon)*.

- Gómez-Robledo, L., Valero, E. M., Huertas, R., Martínez-Domingo, M. A., & Hernández-Andrés, J. (2018). Do EnChroma glasses improve color vision for colorblind subjects?. *Optics express*, *26*(22), 28693-28703.

- Badawy, A. R., Hassan, M. U., Elsherif, M., Ahmed, Z., Yetisen, A. K., & Butt, H. (2018). Contact Lenses for Color Blindness. *Advanced healthcare materials*, *7*(12), e1800152. https://doi.org/10.1002/adhm.201800152

- Elsherif, M., Salih, A. E., Yetisen, A. K., & Butt, H. (2021). Contact lenses for color vision deficiency. *Advanced Materials Technologies*, *6*(1), 2000797.

- Salih, A. E., Elsherif, M., Alam, F., Yetisen, A. K., & Butt, H. (2021). Gold Nanocomposite Contact Lenses for Color Blindness Management. *ACS nano*, *15*(3), 4870–4880. https://doi.org/10.1021/acsnano.0c09657

- Roostaei, N., & Hamidi, S. M. (2022). Two-dimensional biocompatible plasmonic contact lenses for color blindness correction. *Scientific reports*, *12*(1), 2037. https://doi.org/10.1038/s41598-022-06089-8

- Sutton, J., Langlotz, T., & Plopski, A. (2022). Seeing Colours: Addressing Colour Vision Deficiency with Vision Augmentations using Computational Glasses. *ACM Transactions on Computer-Human Interaction*, *29*(3), 1-53.

- McGuinness, LA, Higgins, JPT. Risk-of-bias VISualization (robvis): An R package and Shiny web app for visualizing risk-of-bias assessments. Res Syn Meth. 2020; 1- 7. https://doi.org/10.1002/jrsm.1411.

- NIRE. (2002). *Vision Aids for People with Impaired Color Perception*. National Institute for Rehabilitation Engineering (NIRE) Copyright © 2002 by The N.I.R.E.

- Martínez-Domingo, M. Á., Valero, E. M., Gómez-Robledo, L., Huertas, R., & Hernández-Andrés, J. (2020). Spectral filter selection for increasing chromatic diversity in CVD subjects. *Sensors*, *20*(7), 2023.

- French, A., Rose, K., Cornell, E., & Thompson, K. (2008). The evolution of colour vision testing. *Australian orthoptic journal*, *40*(2), 7-15.

- Alenazi, A. (2018). The Role of Tinted Lenses in the Perception of Color Deficiency.

- Gómez-Robledoa, L., Hernández-Andrésa, J., Huertasa, R., Martínez-Domingoa, M. A., & Valeroa, E. M. Effect of Colorlite filters on colorblind observers.

- Gordon N. Colour blindness. Public health. 1998 Mar 1;112(2):81-4.Allen, F. (1910). Colour-Blindness. *Nature*, *83*(2107), 69-70.

- Ward , Kathryn Albany. *About Colour Blindness - Colour Blind Awareness*. Colour Blind Awareness; (2010, January 1). Available at : https://www.colourblindawareness.org/colour-blindness/ , cited on [8/5/2022].

- Kundu BK, Chakma B. Prevalence of colour vision defect in the indian population-results from a pre-employment screening centre of a tertiary care hospital. J Contemp Med Res. 2020;7:I19-23.

- Murty JS, Vijayalaxmi C. Frequency of colour-blindness in Hyderabad school children. Annals of Human Biology. 1974 Jan 1;1(2):225-8.

- Fareed M, Anwar MA, Afzal M. Prevalence and gene frequency of color vision impairments among children of six populations from North Indian region. Genes & Diseases. 2015 Jun 1;2(2):211-8.

- Krishnamurthy SS, Rangavittal S, Chandrasekar A, Narayanan A. Prevalence of color vision deficiency among school-going boys in South India. Indian Journal of Ophthalmology. 2021 Aug;69(8).

- Ahsana SH, Hussain R, Fareed M, Afzal M. Prevalence of red-green color vision defects among Muslim males and females of Manipur, India. Iranian journal of public health. 2013;42(1):16.

- Padma, I. V. ., & Panda, S. A Study on Prevalence of Colour Vision Defects and Correlation with Sex, Visual Acuity and Blood Groups of the Study Group. *International Journal of Physiology*, . 2021. *9*(1), 18–22. https://doi.org/10.37506/ijop.v9i1.2606

- Gupta SC, Saxena SP, Gupta S, Saxena R, Sharma S. The prevalence of colour blindness in middle school student of southern Bhopal. prevalence. 2017 May;3(5).

- Gupta M, Gupta BP, Chauhan A, Bhardwaj A. Ocular morbidity prevalence among school children in Shimla, Himachal, North India. Indian J Ophthalmol. 2009 Mar-Apr;57(2):133-8. doi: 10.4103/0301-4738.45503. PMID: 19237787; PMCID: PMC2684438.

- Alla Venkata Pitchi Reddy, G. Ravi Babu, K. Vara Prasad. Prevalence of colour blindness in school children in Guntur City, Andhra Pradesh. International Journal of Contemporary Medical Research 2017;4(11):2266-2268

- Das, S., Kondam, R., & Spandana, N. Prevalence and Awareness of Colour Vision Deficiency in School Children.

- Jailkhani H, Tityal GS, Mehrotra N. To Study the Prevalence of Colour Blindness among Adolescent (9th–12th Std.) Schoolchildren in Haldwani. Int J Sci Stud 2021;8(10):108-114.

- Mittal SK, Mittal S, Saraswat NK, Kishore S, Agrawal A, Singh A, Samanta R, Bahurupi YA. et, al. Burden of ocular morbidities and color blindness among school-attending children in a foothill town of Uttarakhand State. Indian Journal of Ophthalmology. 2022 Jan;70(1):249.

- Agrawal D, Sahu A, Agrawal D. Prevalence of ocular morbidities among school children in Raipur district, India. Indian journal of ophthalmology. 2020 Feb;68(2):340.

- Akarkar SO, Naik PG, Cacodcar JA. Prevalence and distribution of ocular morbidities among primary school children in Goa. Journal of Clinical Ophthalmology and Research. 2019 May 1;7(2):61.

- R, S., & H, R. J. S. Colour vision abnormalities among medical students. *Indian Journal of Clinical and Experimental Ophthalmology*, 2017, *July-September,2017;3(3): 315-318* . https://doi.org/10.18231/2395-1451.2017.0078
- Kovai V, Krishnaiah S, Shamanna BR, Thomas R, Rao GN. Barriers to accessing eye care services among visually impaired populations in rural Andhra Pradesh, South India. Indian journal of ophthalmology. 2007 Sep;55(5):365.
- Nutheti R, Shamanna BR, Nirmalan PK, Keeffe JE, Krishnaiah S, Rao GN, Thomas R. et,al . Impact of impaired vision and eye disease on quality of life in Andhra Pradesh. Investigative ophthalmology & visual science. 2006 Nov 1;47(11):4742-8.
- Krishnaiah S, Das T, Nirmalan PK, Nutheti R, Shamanna BR, Rao GN, Thomas R. et, al. Risk factors for age-related macular degeneration: findings from the Andhra Pradesh eye disease study in South India. Investigative ophthalmology & visual science. 2005 Dec 1;46(12):4442-9.
- Mangione CM, Lee PP, Pitts J, Gutierrez P, Berry S, Hays RD, et, al. NEI-VFQ Field Test Investigators. Psychometric properties of the National Eye Institute visual function questionnaire (NEI-VFQ). Archives of Ophthalmology. 1998 Nov 1;116(11):1496-504.
- Barry JA, Mollan S, Burdon MA, Jenkins M, Denniston AK. Development and validation of a questionnaire assessing the quality of life impact of Colour Blindness (CBQoL). BMC ophthalmology. 2017 Dec;17(1):1-7.

- Barry John, Questionnaire help on quality of Life impact on Colour Blindness (CBQoL), personal e-mail communication, March 18, 2020.

- Statistics IS. IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Google Search. 2013.

- "MedCalc Statistical Software version 19.2.6 (MedCalc Software bv, Ostend, Belgium; https://www.medcalc.org; 2020)".

- Epi O. Sample size calculation, 2020.

- Simunovic MP. Colour vision deficiency. Eye. 2010 May;24(5):747-55.

- Chan XB, Goh SM, Tan NC. Subjects with colour vision deficiency in the community: what do primary care physicians need to know?. Asia Pacific Family Medicine. 2014 Dec;13(1):1-0.

- Bradley N. Colour blindness: Notes on its developmental and clinical significance. International Journal of Psycho-Analysis. 1970;51:59-70.

- Cole BL. The handicap of abnormal colour vision. Clinical and Experimental Optometry. 2004 Jul 1;87(4-5):258-75.

- Hammarström H, Forkel R, Haspelmath M, Bank S. 2016Glottolog 2.7. Jena, Germany: Max Planck Institute for the Science of Human History.

- Steever SB. 1998, Introduction to the Dravidian languages. In The Dravidian languages (ed. Steever SB), pp. 1–39. London.

- Krishnamurti B. 2003, The Dravidian languages. Cambridge, UK: Cambridge University Press.
- Grierson, G. (1906) Linguistic Survey of India, vol. 4, The Munda and Dravidian Languages, Calcutta.

- Kr̥ṣṇamūrti, B., & Gwynn, J. P. L. (1985). A grammar of modern Telugu. Oxford University Press.

- Annamalai, E. and Steever, S. B. 1998. Modern Tamil. In Steever (ed.), 100–28

- Burrow, T. and Emeneau, M. B. 1961. A Dravidian Etymological Dictionary [DED]. Oxford: Clarendon Press

- Sridhar, S. N. 1990. Kannada. London and New York: Routledge

- Prabhakara Variar, K. M. (ed.). 1985. History of Malayalam Language. Madras: University of Madras.

- Wysecki, G., & Stiles, W. S. (1967). Color science. John Willey, New York.

- Kilgarriff, A., Reddy, S., Pomikálek, J., & Avinesh, P. V. S. (2010, May). A corpus factory for many languages. In LREC.

- Male Shiva Ram, B.R. Shamanna, Rishi Bhardwaj, Chakravarthy Bhagvati, Baskar Theagarayan; Color and Emotion Associations in Dravidian Culture.. Journal of Vision 2021;21(9):2406. doi: https://doi.org/10.1167/jov.21.9.2406.

- Peirce, J. W., Gray, J. R., Simpson, S., MacAskill, M. R., Höchenberger, R., Sogo, H., Kastman, E., Lindeløv, J. (2019). PsychoPy2: experiments in behavior made easy. Behavior Research Methods. 10.3758/s13428-018-01193-y

- Berlin, & Kay. (1969). WCS Data Archives. WCS Data Archives. https://www1.icsi.berkeley.edu/wcs/data.html cited on [10-Sept-2022] .

- Lenneberg, E.H., Roberts, J.M. The Language of Experience: A study in Methodology. Memoir 13 of International Journal of American Linguistics. (1956).

- MacLeod, C. M. (2005). The Stroop Task in Cognitive Research.

- R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

- Goss-Sampson, M. (2019). Statistical analysis in JASP: A guide for students.

- Kolipakam, V., Jordan, F. M., Dunn, M., Greenhill, S. J., Bouckaert, R., Gray, R. D., & Verkerk, A. (2018). A Bayesian phylogenetic study of the Dravidian language family. Royal Society open science, 5(3), 171504.

- Loreto, V., Mukherjee, A., & Tria, F. (2012). On the origin of the hierarchy of color names. Proceedings of the National Academy of Sciences, 109(18), 6819-6824.

- Haynie, H. J., & Bowern, C. (2016). Phylogenetic approach to the evolution of color term systems. Proceedings of the National Academy of Sciences, 113(48), 13666-13671.

- Mehta, R., & Zhu, R. (2009). Blue or red? Exploring the effect of color on cognitive task performances. Science, 323(5918), 1226-1229.

- Roberson, D., Davies, I., & Davidoff, J. (2000). Color categories are not universal: replications and new evidence from a stone-age culture. Journal of Experimental Psychology: General, 129(3), 369.

- Gule, G. G., & Sarkar, S. K. (2022). Reframing of Ethics and Aesthetic Values of Rasasidhanta in the Contemporary Indian Art. ECS Transactions, 107(1), 7841.

- Thirumalai, M. (2001). An introduction to natya shastra-gesture in aesthetic arts. Language in India, 1(6), 27-33.

- Krishna, P.P., Arulmozi, S. & Mishra, R.K. "Do You See and Hear More? A Study on Telugu Perception Verbs". J Psycholinguist Res 51, 473–484 (2022).

- Kapp, D.B. Basic Colour Terms in South Dravidian Tribal Languages. Indo-Iran J 47, 193–201 (2004).

- Treisman, A., 1964. Selective attention in man. British Medical Bulletin, 20, 12-16.

- Chilukuri, B. (2016). A KA: RMIK LINGUISTIC APPROACH. *Scientific Newsletter Modern linguistic and methodical-and-didactic research*, (1), 34-42.

- Martin, A., Haxby, J. V., Lalonde, F. M., Wiggs, C. L., & Ungerleider, L. G. (1995).

- Discrete cortical regions associated with knowledge of color and knowledge of action. Science, 270(5233), 102-105.

- Dravida, S., Saxe, R., & Bedny, M. (2013). People can understand descriptions of motion without activating visual motion brain regions. Frontiers in psychology, 4, 537.

- Pulvermüller, F. (2005). Brain mechanisms linking language and action. Nature Reviews Neuroscience, 6(7), 576.

- Röder, B., Rösler, F., & Spence, C. (2004). Early vision impairs tactile perception in the blind. Current Biology, 14(2), 121-124.

- Heller, M. A. (2013). The psychology of touch. Psychology Press.

- Bedny, M., Caramazza, A., Grossman, E., Pascual-Leone, A., & Saxe, R. (2008). Concepts are more than percepts: the case of action verbs. Journal of Neuroscience, 28(44), 11347-11353.

- Grant, A. C., Thiagarajah, M. C., & Sathian, K. (2000). Tactile perception in blind Braille readers: a psychophysical study of acuity and hyperacuity using gratings and dot patterns. Perception & psychophysics, 62(2), 301-312.

- *Color Meanings in India: Find Out What Colors Symbolize in Indian Culture - Color Meanings*. (2020, November 6). Color Meanings. Retrieved October 3, 2022, from https://www.color-meanings.com/color-meanings-indian-culture/

- Xie, A. (2018, March 26). *The Colorful Indian Culture. Color plays a significant role in. . . | by Angel Xie | Medium*. Medium. Retrieved October 3, 2022, from https://angelxie.medium.com/the-colorful-indian-culture-7b4eeafcf66f

- Azeemi, S. T. Y., & Raza, M. (2005). A critical analysis of chromotherapy and its scientific evolution. *Evidence-based complementary and alternative medicine*, *2*(4), 481-488.

Appendix-A

List of Publications fom current thesis

Received: 27 July 2022 | Revised: 5 September 2022 | Accepted: 5 September 2022

DOI: 10.1002/hsr2.842

ORIGINAL RESEARCH

Health Science Reports Open Access WILEY

Color vision devices for color vision deficiency patients: A systematic review and meta-analysis

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Abstract

Background and Aims: There is insufficient evidence to support that using electronic or optical color vision devices improve color perception with current advanced technology. The purpose of this study is to compare and analyze the different color vision devices available for patients with color vision deficiency (CVD) and evaluate whether these devices improved their color perception.

Methods: This review included randomized, experimental, comparative studies, as well as narrative reviews, prototype and innovation studies, and translational studies, followed by case-control and clinical trials with nonsurgical interventions studies, that is, electronic color vision devices, optical devices, and contact lens-based studies, with standardized inclusion and exclusion criteria.

Results: The primary outcome studied was the performance of color vision devices, both objective and subjective. Secondary outcomes included the ease of use and accessibility of color vision devices and technology. The grading of recommendation, assessment, development, and evaluation framework was used to develop a systematic approach for consideration and clinical practice recommendation for CVD devices for color-deficient populations. We incorporated meta-analysis reports from a total of $n = 16$ studies that met the criteria which consisted of case-control studies, prototype and innovation studies, comparative studies, pre- and post-clinical trial studies, case studies, and narrative reviews. Proportion and standard errors, as well as correlations, were calculated from the meta-analysis for various available color vision devices.

Conclusion: This review concludes that commercially available color vision devices, such as EnChroma Glasses, Chromagen filters, and EnChroma Cx-14 do not provide clinically significant evidence that subjective color perception has improved. As a result, recommending these color vision devices to the CVD population may not prove high beneficial/be counterproductive. However, only a few color shades can be perceived differently. This systematic review and analysis will aid future research and development in color vision devices.

NIHR | National Institute for Health Research

PROSPERO
International prospective register of systematic reviews

Colour vision aids for colour vision deficiency patients and outcome in colour perception

Male Shiva Ram, Rishi Bhardwaj, Chakravarthy Bhagvati, Shamanna BR, Baskar Theagarayan

This version was published on 28 April 2020 and is not the current version.

Citation

MALE SHIVA RAM, RISHI BHARDWAJ, CHAKRAVARTHY BHAGVATI. Colour Vision aids for Colour vision deficiency patients and outcome in colour perception.. PROSPERO 2020 CRD42020155169 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020155169

Review question

To compare different colour vision aids available for CVD (colour vision deficiency) patients and whether the previously available and current devices available with advanced technology really solving the problem for colour perception

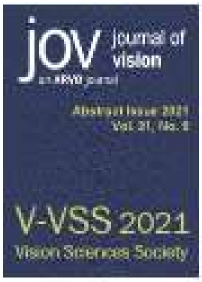
Searches

We want to search in , PROSPERO, PRISMA and Cochrane Central Register of Controlled Trials (CENTRAL) (which contains the Cochrane Eyes and Vision Trials Register) databases available till (2019). PubMed, MEDLINE Ovid; Embase Ovid; BIREME LILACS, OpenGrey, the ISRCTN registry; ClinicalTrials.gov and the World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP), US National Institutes of Health Ongoing Trials Register Clinical trials. National Institute for Rehabilitation Engineering (NIRE) database from 1967 to 1987 , it has a registery of devices registered and manufactured in 19th centuary.

We also would like to hand search the British Journal of Visual Impairment from 1983 to 2019 , Journal of Visual Impairment and Blindness from 1976 to 2019, Colour research and applications from 1990 to 2019, TVST(translational vision science and technology) from 2000 to 2019, Journal of Ophthalmic and Physiological Optics from 2000 to 2019 for relevant trials, and any other High impact journals that providing the information releated on outcome of colour perception in Human subjects.

We also want to search the reference lists of relevant articles to find additional trials. We used the Scopus, Science Citation Index, Web of science, and Thomson ruters index to find articles that cited relevant articles in Q1 and Q2 ranking journals based on SCI index ranking and lists.

We also want to approach and contact investigators and manufacturers of Colour vision aids for helping in other published and unpublished reports.



September 2021
Volume 21, Issue 9
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OPEN ACCESS
Vision Sciences Society Annual Meeting Abstract | September 2021

Color and Emotion Associations in Dravidian Culture.

Male Shiva Ram; B.R. Shamanna; Rishi Bhardwaj; Chakravarthy Bhagvati; Baskar Theagarayan

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Journal of Vision September 2021, Vol.21, 2406. doi:https://doi.org/10.1167/jov.21.9.2406

SHARE TOOLS

Abstract

Color is present all around us and its presence affects our perception. It can add excitement and emotion to our everyday life . Past psychological models reported emotional responses with color, but the Language is a factor which is linked to the culture and expressed verbally. In the current study, we investigated the cross-cultural associations between color and emotion among Dravidian's (Telugu, Tamil, Kannada, and Malayalam) language participants. A random sample of 60 participants in the age group of 19 to 40 years who are native to Dravidian culture were included. A standardized questionnaire of color and emotions was used in all four languages, by executing the face to face interview of participants. Observational and survey methods were used to collect the data. The variables of eight emotions such as love, sadness, fear, hatred, desire, happiness, jealousy and anger were considered and participants were asked to choose any colors from the listed i.e., violet, blue, green, yellow, orange, red, white, black or to specify any other color that they associate most related to a specific emotion. We used binomial test's and likelihood ratios to understand the specificity of color and emotion associated. Confidence interval of proportions was compared to see the similar color and emotion association's significance. We emphasize that the emotions are most commonly associated with warm and shiny colors and the role of language display differences in color and emotion associations among a Dravidian culture of South India.

PERCEPTION

43rd European Conference on Visual Perception (ECVP) 2021 Online

Perception
2021, Vol. 50(1S) 1–244

DOI: 10.1177/03010066211059887
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Colour vision aids for Colour vision deficiency patients: A Systematic Review

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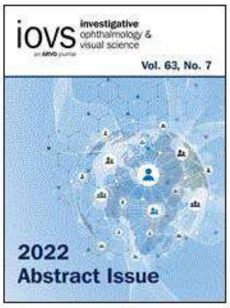
Colour vision deficiency is the inability to distinguish certain shades of colour and there is no cure for inherited colour deficiency. The current review aimed to compare different colour vision aids available for colour vision deficiency (CVD) and whether these devices improve their colour perception. However, there is insufficient evidence supporting the use of electronic or optical colour vision aids that improve colour perception with the current advanced technology although devices such as Enchroma CVD device, Cytochromic oxide filters are commercially available. We used search strategies in, PROSPERO, PRISMA and Cochrane Central Register of Controlled Trials (CENTRAL) (which contains the Cochrane Eyes and Vision Trials Register) databases available till (2020) followed by PUBMED, MEDLINE Ovid; Embase Ovid; BIREME LILACS, Open Grey, the ISRCTN registry; ClinicalTrials.gov and the World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP), US National Institutes of Health Ongoing Trials Register Clinical trials. National Institute for Rehabilitation Engineering (NIRE) database from 1967 to 1987, has a registry of all the colour vision devices manufactured. From the (N=26) reviewed studies and analysis, we found that only a few studies reported clinical trials with colour vision aids and found colour vision scores improved. There is poor and low level of clinical evidence to claim that commercially available colour vision aids improve the colour perception. The analysis informs further exploration and studies in this area related to the title of the presentation. [Acknowledgements: PROSPERO Systematic review database, University of York for registering the Systematic review title: Colour Vision aids for Colour vision deficiency patients and outcome in colour perception. CRD42020155169 (PROSPERO-2020) https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020155169.]



June 2022
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ARVO Annual Meeting Abstract | June 2022

Impact of color vision deficiency on quality of life in a sample of Indian population.

shiva ram Male; Rishi Bhardwaj; Shamanna B R; Bhagvati Chakravarthy; Rashmin Gandhi; Baskar Theagarayan

+ Author Affiliations & Notes

Investigative Ophthalmology & Visual Science June 2022, Vol.63, 2243 – F0451. doi:

SHARE TOOLS

Abstract

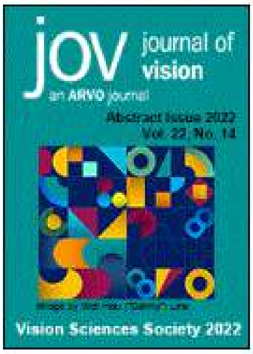
Purpose : According to the Colorblind awareness organization, color vision deficiency (CVD) affects 1 in 12 men (8.3%) and 1 in 200 women (0.5%) globally. In India (Kundu et al., 2020), the overall prevalence of CVD is 3.89% in males, followed by 0.18% in females. However, most cases are undiagnosed and only detected in screening programmes or during work empowerment. Besides this, CVD patients experience multiple difficulties in day-to-day life. The current study aimed to investigate the quality of life in a sample of CVD patients in India and how color vision impairment affects them psychologically, economically, and work-productivity wise.

Methods : This descriptive and cross-sectional questionnaire study was conducted on N=44 diagnosed CVD patients (male=36 and female=8) who visited two eye hospitals in the Hyderabad region between 2020 to 2021. The comparison group included a age matched control group of normal color vision (normal CV) participants (N=12). In the current study, we validated and used a Telugu version of a questionnaire (CVD-QOL) which was developed and validated by Barry et al. in 2017 for CVD patients. In this study, Color vision was assessed by Ishihara color vision test. The questionnaire consists of twenty-three questions on Likert scale with variables (Lifestyle, Emotions and Work). Six-point Likert scale was used, with lower scores indicating worse quality of life (1=severe problem to 6=no problem).

Results : Data analysis included 66 participants (CVD= 44 and normal CV= 12). Shapiro Wilk normality test resulted in normal data distribution. The mean age of participants did not show ($p=0.064$) a significant difference between the groups. There was a significant difference between CVD and normal CV participants for Color vision score ($p<0.001$). There was also a significant difference between the groups for the CVD-QoL variables, Lifestyle ($p<0.001$), Emotions ($p<0.001$) and Work ($p=0.027$) The results are shown in Table-1. The group differences among gender revealed that men tend to be more psychologically weaker in facing CVD than women.

Conclusions : This study results revealed that color vision deficiency has a significant impact on the quality of life in this sample of Indian population. The mean scores on the questionnaire for Lifestyle, Emotions and Work was much lower than the UK sample (Barry et al. 2017) indicating that there was a higher impact of CVD on these domains in this population.

This abstract was presented at the 2022 ARVO Annual Meeting, held in Denver, CO, May 1-4, 2022, and virtually.



December 2022
Volume 22, Issue 14
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OPEN ACCESS
Vision Sciences Society Annual Meeting Abstract | December 2022

The Existence and Mapping of Colour Terms in Dravidian Languages.

Male Shiva Ram; BR Shamanna; Chakravarthy Bhagvati; S Arulmozi; P Phani Krishna

+ Author Affiliations

Journal of Vision December 2022, Vol.22, 3840. doi:https://doi.org/10.1167/jov.22.14.3840

SHARE TOOLS

Abstract

Typological patterns of basic colour terms exhibit eleven colour prototypes in the English language and other languages (Berlin & Kay, 1969). Berlin and Kay's pioneering work on the universality of basic colour terms did not include major Dravidian languages. (Kapp 2004) attempted to study the basic colour terms in South Dravidian tribal languages. In the current work, we have attempted to review the monolexmic colour hypothesis and the existence of these proposed colour terms in Dravidian colloquially spoken languages and to map them from a vision sciences perspective. Visual psychophysical tools were used in the experiment by recruiting n=20 participants of four L1 mother tongue language in the experiment. The Colour naming task, colour mapping task and stoop task was measured in the experiment. It is found that the monolexmic colour terms hypothesis proposed for the English language varies in major Dravidian languages and the majority of colour terms are restricted to seven to eight colours. Interestingly few colour terms were found in some similarity among the Dravidian languages.

Color and Emotion Associations in Dravidian Culture.

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प्रतिष्ठित संस्थान
INSTITUTION OF EMINENCE
राष्ट्रीय अपेक्षाएँ, वैश्विक मानक
National Needs, Global Standards

University of HUDDERSFIELD
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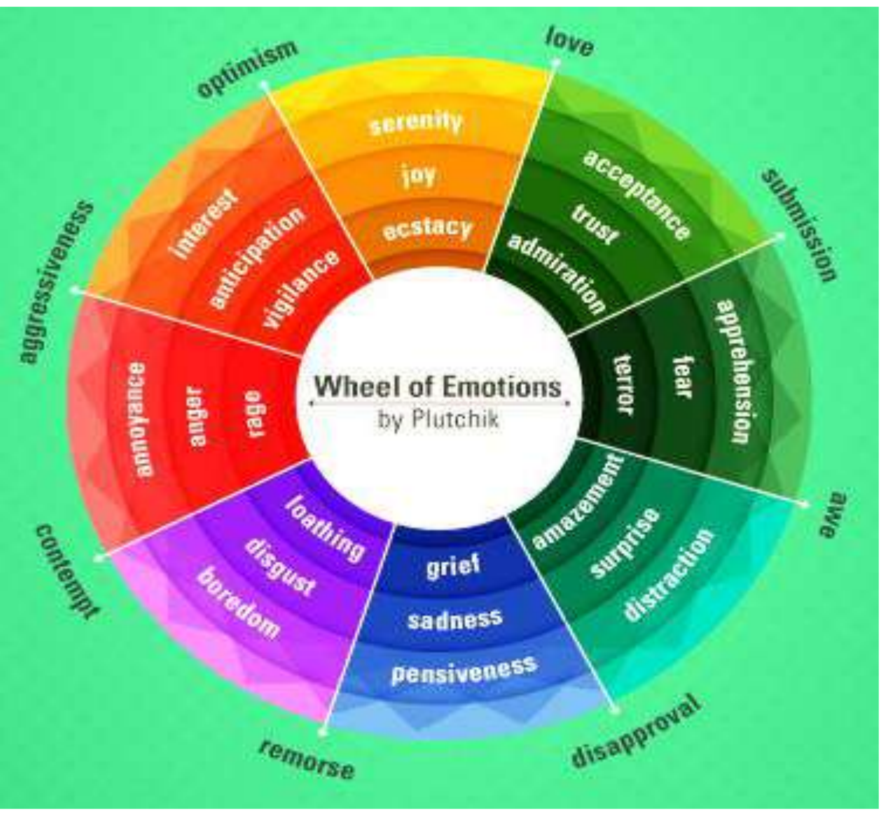
Introduction

- Color presence affects our perception. It can add excitement and emotion to our everyday life (Birren, F 2016) .
- Psychological models reported emotional responses with color, but the language is a factor lacking with color and culture association among Dravidian population.

- **Purpose:** In the current study we investigated to understand how color and emotion is associated in Dravidian culture (Tamil,Telugu,Malayalam and Kannada).



- ✓ The Concept of emotions and its framework have expressed with color coding.
- ✓ Eight major Emotions : Anger, Love, Joy, Trust, Fear, Surprise, Sadness and Disgust.
- ✓ These emotions intensify as they move from the outside towards the centre of the wheel.

Fig-1. Plutchik's Wheel of Emotions

Methods

- A random sample of N=60 participants in the age group of 19 to 40 years who are native to Dravidian culture were included. A standardized questionnaire of color and emotions was used in all four languages, by executing the face to face interview of participants. Observational and survey methods were used to collect the data.

- The variables of eight emotions such as love, sadness, fear, hatred, desire, happiness, jealousy and anger were considered and participants were asked to choose any colors from the listed i.e.; violet, blue, green, yellow, orange, red, white, black or to specify any other color that they associate most related to a specific emotion

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Results

We used binomial test's and likelihood ratios to understand the specificity of color and emotion associated. Confidence interval of proportions was compared to see the similar color andemotion association's significance. **As shown in Table-1. and Figure-2.**

Telugu Participants		N=15	p-value	Tamil Participants		N=15	p-value	Kannada Participants		N=15	p-value	Malyalam Participants		N=15	p-value
Desire	Red	10	<0.01***	Desire	Red	6	0.02*	Desire	Orange	6	0.02*	Desire	Pink	8	0.91
	Yellow	5			Green	9			Yellow	9			Green	7	
Sadness	Blue	4		Sadness	Orange	7	0.91	Sadness	Red	6		Sadness	Red	10	<0.01***
	Black	11			Black	8			Black	9			Black	5	
Fear	Black	3		Fear	Black	11	<0.01***	Fear	Black	5	<0.01***	Fear	Black	6	0.02*
	Red	12			Red	4			Red	10			Orange	9	
Hatred	Green	6		Hatred	Green	6	0.02	Hatred	Voilet	6	0.02*	Hatred	Red	10	<0.01***
	Red	11			Yellow	9			Orange	9			Black	5	
Love	Red	6	0.02*	Love	Pink	8	0.91	Love	Pink	6		Love	Pink	7	0.91
	Orange	9			Red	7			Blue	9			Green	8	
Happiness	Green	8	0.91	Happiness	Green	3	<0.01***	Happiness	Green	5	<0.01***	Happiness	Blue	4	<0.01***
	Blue	7			Blue	12			pink	10			Pink	11	
Jealousy	Black	5	<0.01***	Jealousy	Black	4		Jealousy	Black	6	0.02*	Jealousy	Black	8	0.91
	Red	10			Voilet	11			Red	9			Red	7	
Anger	Red	11		Anger	Red	5		Anger	Orange	7	0.91	Anger	Red	10	<0.01***
	Black	4			Black	10			Black	8			Black	5	

**p<o.o5 level considered as level of significance*

Table-1. Binomial test showing the significance association in color and emotions of participants

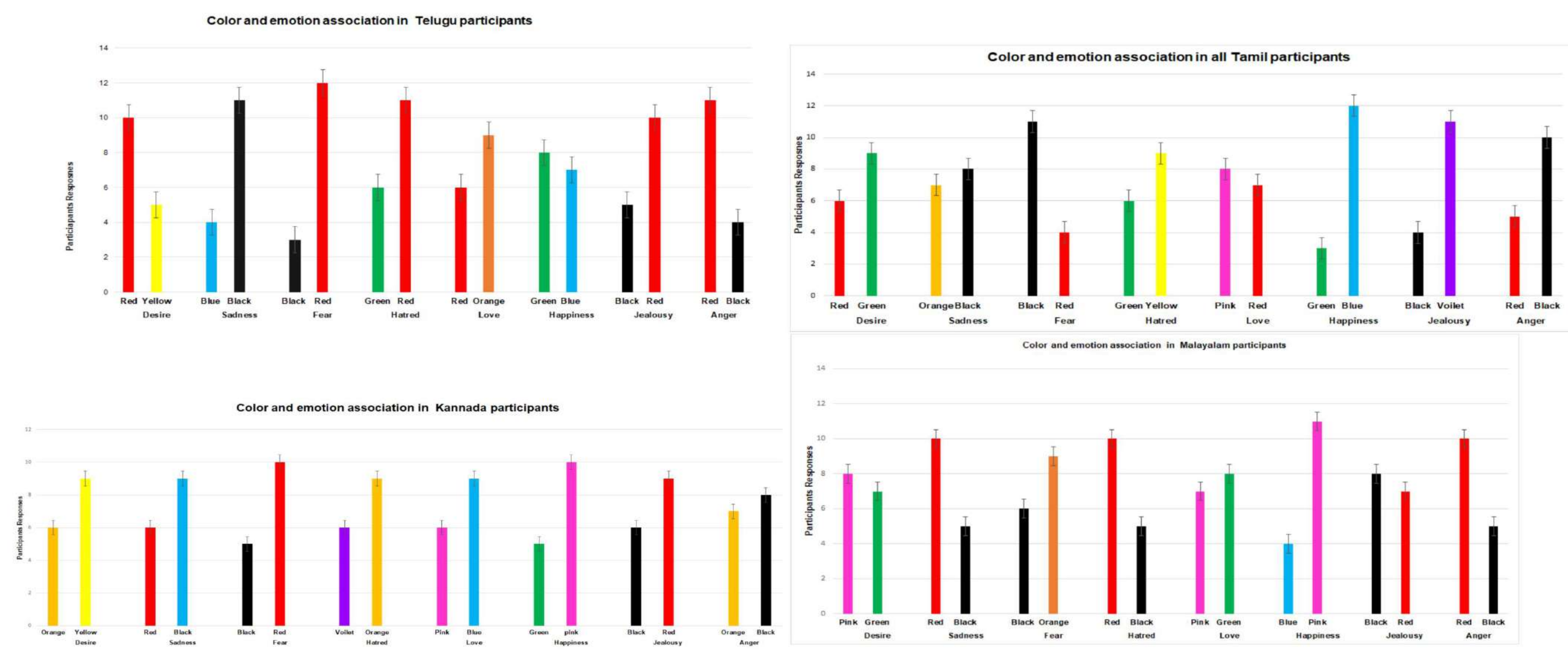

Fig-2. Bar Graph representing the specificity of the color among the Dravidian culture and Emotions.

Discussion

- We found that the warm colors are more associated with emotions in Dravidian culture . However these findings were indirectly supported by the(Carlos, 2018) that facial color play major role in emotions.

- The concept of (Berlin and Kay , 1991) on Universality of color terms , have a limitation on Dravidian culture color terminology. In the current study we tried to link the language and color emotion associations in relation to the Dravidians culture.

Conclusion

- We emphasize that the emotions are most commonly associated with warm and shiny colors and the role of language display differences in color and emotion associations among a Dravidian culture of South India.

- In the future we would like to compare the findings with English speaking participants' to understand the difference in color perception and cross cultural evolution in a larger sample.

References

1. Birren, F. (2016). *Color psychology and color therapy; a factual study of the influence of color on human life*. Pickle Partners Publishing.
2. Cuykendall, S. B., & Hoffman, D. D. (2008). From color to emotion: Ideas and explorations. *Irvine, CA: University of Irvine, California*.
3. Benitez-Quiroz, C. F., Srinivasan, R., & Martinez, A. M. (2018). Facial color is an efficient mechanism to visually transmit emotion. *Proceedings of the National Academy of Sciences*, *115*(14), 3581-3586.
4. Berlin, B., & Kay, P. (1991). *Basic color terms: Their universality and evolution*. Univ of California Press.

Acknowledgement

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Impact of Colour vision Deficiency on Quality of Life in Indian Population

Male Shiva Ram[1], B.R.Shamanna[1], Rishi Bhardwaj[1], Chakravarthy Bhagvati[2], Rashmin Gandhi[3], Baskar Theagarayan[4]

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[3] Centre for Sight Eye Hospital, Hyderabad, India, [4] Department of Optometry and Vision Sciences, University of Huddersfield, UK.

Abstract ID # 3708264

Background

- According to the Colorblind awareness organization, color vision deficiency (CVD) affects 1 in 12 men (8.3%) and 1 in 200 women (0.5%) globally.
- In India (Kundu et al., 2020), the overall prevalence of CVD is 3.89% in males, followed by 0.18% in females.

Purpose

- To investigate the quality of life in a sample of CVD patients in India and how color vision impairment affects them psychologically, economically, and work-productivity wise.

Methods

Descriptive and cross-sectional questionnaire study was conducted on N=44 patients diagnosed with CVD (male=36 and female=8) who visited two eye hospitals in the Hyderabad region between 2020 to 2021.

- Comparison group included age matched control group of normal color vision (normal CV) participants (N=12).
- In the current study, we validated and used a Telugu version of a questionnaire (CVD-QOL) which was developed and validated by (Barry et al,2017)
- CVD-QOL questionnaire consists of twenty-three questions on Likert scale with variables (Lifestyle, Emotions and Work). Six-point Likert scale was used, with lower scores indicating worse quality of life (1=severe problem to 6=no problem).

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Results

- Data analysis included 66 participants (CVD= 44 and normal CV= 12).
- Shapiro Wilk normality test resulted in normal data distribution. The mean age of participants did not show (p=0.064) a significant difference between the groups.
- There was a significant difference between CVD and normal CV participants for Color vision score (p<0.001).
- There was a significant difference between the groups for the CVD-QoL variables, Lifestyle (p<0.001), Emotions (p<0.001) and Work (p=0.027)
- The results are shown in Table-1. The group differences among gender revealed that men tend to be more psychologically weaker in facing CVD than women.

Variables	CVD Group n=44		Normal Age matched Control Group n=12			
	Mean	SD	Mean	SD	t	p
Age	29.09	5.10	27.33	2.50	-1.67	p= 0.64
Ishihara Color vision score	3.50	0.28	16.92	0.28	3.80	p <0.001***
CVD- QoL Lifestyle	2.40	0.20	5.92	0.63	5.01	p <0.001***
CVD- QoL Emotions	2.29	0.28	4.86	0.13	2.06	p <0.001***
CVD- QoL Work	2.24	0.38	4.90	0.12	0.96	P=0.027**

Note: p<o.o5 is considered as level of significance, [CVD= Color vision deficiency], [QoL=Quality of Life]

Table-1. The group differences among CVD and Normal participants in relation to QoL.

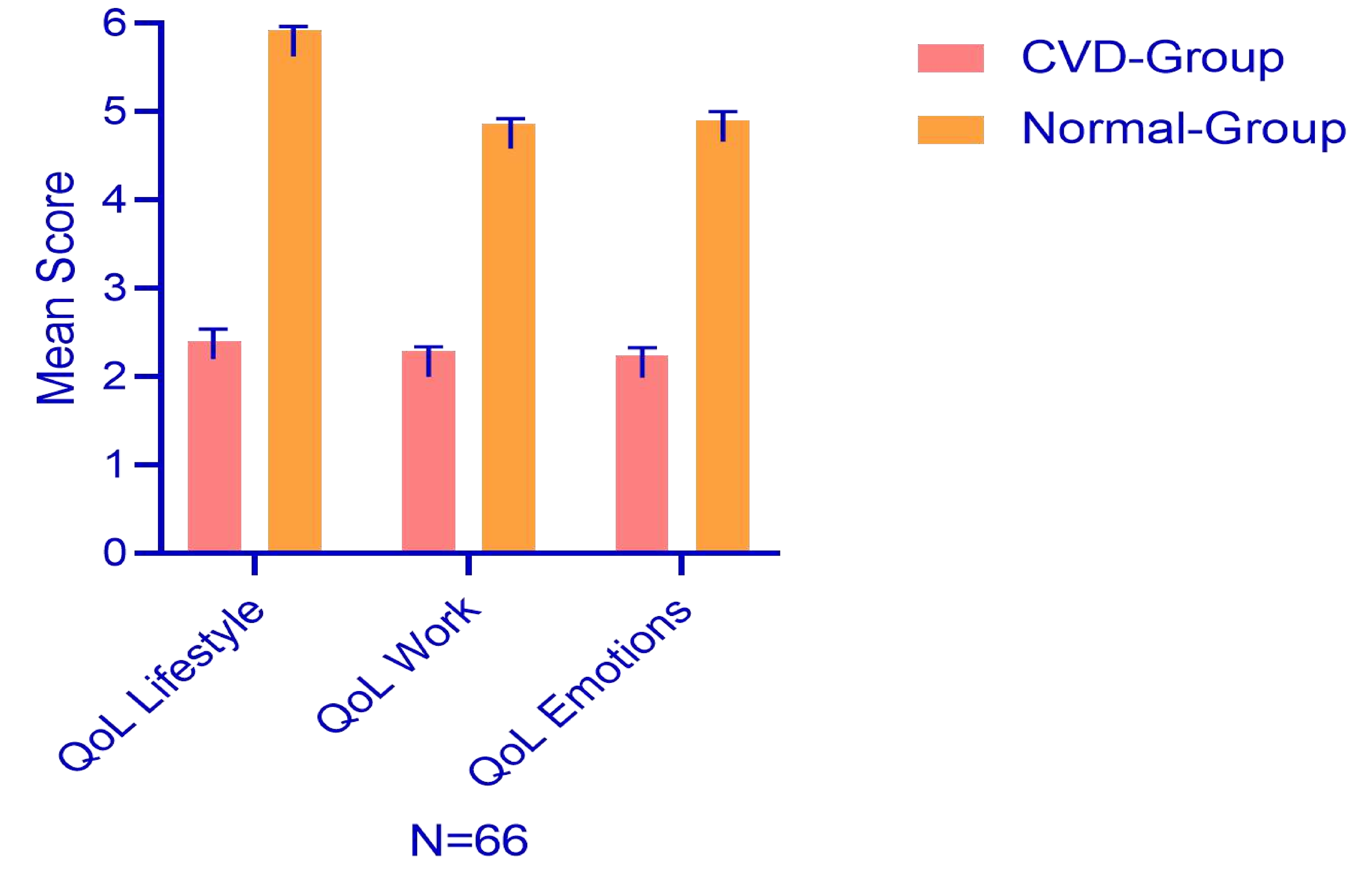

Figure.1- Bar graph illustrating Mean score of QoL CVD questionnaire among CVD group and Normal age matched participants

Conclusion

- This study results revealed that color vision deficiency has a significant impact on the quality of life in this sample of Indian population.
- The mean scores on the questionnaire for Lifestyle, Emotions and Work was much lower than the UK sample (Barry et al. 2017) indicating that there was a higher impact of CVD on these domains in this population.

References

- Barry, J. A., Mollan, S., Burdon, M. A., Jenkins, M., & Denniston, A. K. (2017). Development and validation of a questionnaire assessing the quality of life impact of Colour Blindness (CBQoL). *BMC ophthalmology*, *17*(1), 1-7.
- Kundu, B. K., & Chakma, B. (2020). Prevalence of Colour Vision Defect in the Indian Population-Results from a Pre-Employment Screening Centre of a Tertiary Care Hospital. *Journal of Contemporary Medical Research*, *7*(9), I19-I23.

Acknowledgements

- Dr. Santhosh G Hanovar and Dr. Raja Lingam for providing permission to collect data.
- 2022 ARVO Foundation Developing Country Eye Researcher Travel Fellowship.
- Dr.John A Barry. University College London ,UK for providing CB-QoL English version questionnaire

Colour Vision aids for Colour vision deficiency patients: A Systematic Review.

Male Shiva Ram[1] Rishi Bhardwaj [1] Shamanna BR[1] Chakravarthy Bhagvati [2] Baskar Theagarayan[3]

[1]School of Medical Sciences, University of Hyderabad, India
[2]School of Computer and Information Sciences, University of Hyderabad, India
[3] Department of Optometry and Vision sciences, University of Huddersfield, Huddersfield, UK

Introduction

Colour vision deficiency is the inability to distinguish certain shades of colour and there is no permanent cure for colour deficiency.

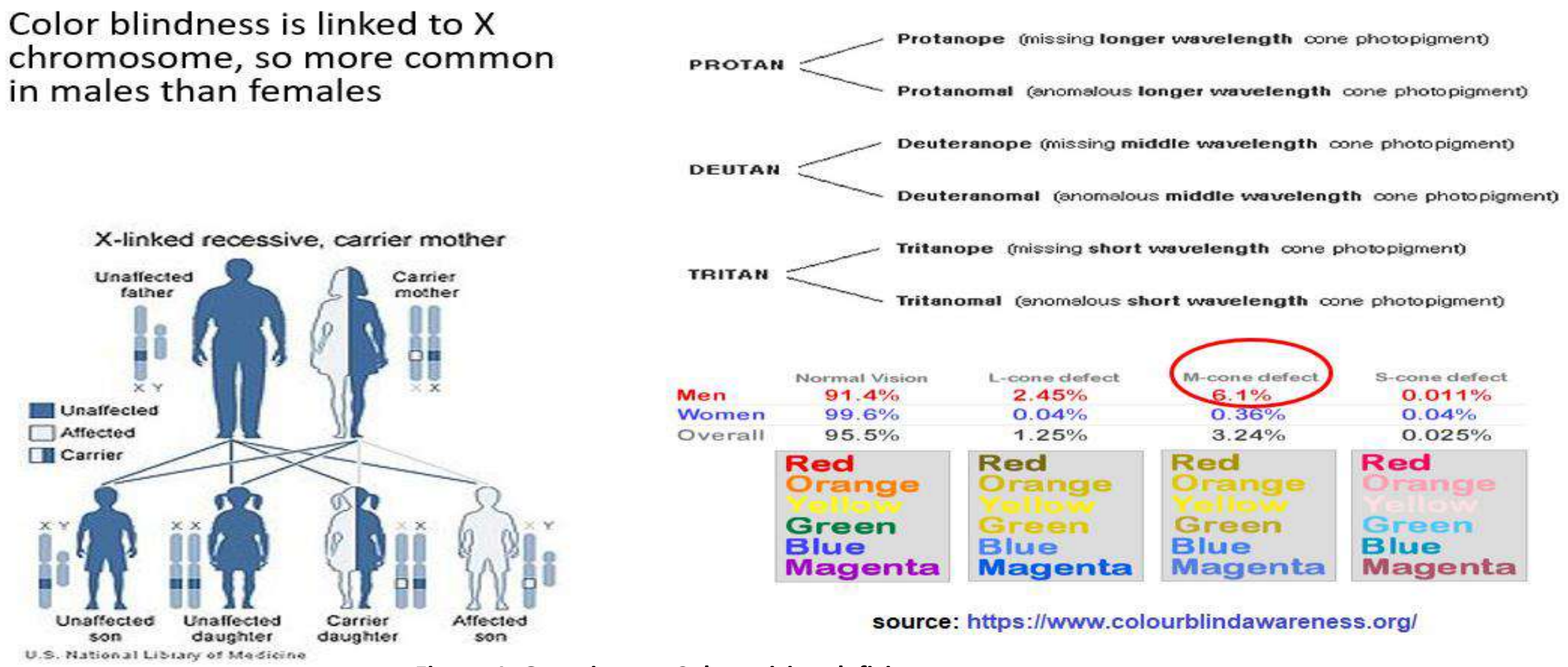

Figure-1. Overview on Colour vision deficiency

Aim

The current review aimed to compare different colour vision aids available for colour vision deficiency (CVD) and whether these devices improve their colour perception

Methods

We used search strategies in, PROSPERO, PRISMA and Cochrane Central Register of Controlled Trials (CENTRAL) (which contains the Cochrane Eyes and Vision Trials Register) databases available till 2020 followed by PUBMED, MEDLINE Ovid; Embase Ovid; BIREME LILACS, Open Grey, the ISRCTN registry; ClinicalTrials.gov and the World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP), US National Institutes of Health Ongoing Trials Register Clinical trials.
National Institute for Rehabilitation Engineering (NIRE) database from 1967 to 1987, has a registry of all the colour vision devices manufactured.

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Results

Author	Colour Vision Device	Year	Study design	Sample	Colour Vision score	Subjective Colour perception outcome	Certainty of the evidence (GRADE)
U Schiefer, et al.	Hydroflex Wöhlk Company, Kiel	1985	Case study	N=1	Improved	Yes	Moderate-certainty
Jk Hovis, et al.	Long wavelength pass filters	1997	Case and comparitive	N=10	Partially improved	No	Low-certainty:
Zeltzer HI, et al.	Contact lens for correction of color blindness	1991	Innovation and Prototype	N=1	Partially improved	No	Low-certainty:
Helen A. Swarbrick, et al.	ChromaGen	2002	Case control comparative	N=14	Improved	Yes	Moderate-certainty
Dain, Stephen J, et al.	Sunglass tints	2009	Case control	N=49	Partially improved	No	Low-certainty:
O. Matthew, et al.	Chromagen Lenses	2011	Comparative	N=13	Partially improved	No	Low-certainty:
Bruce J , et al.	Coloured overlays	2014	Case study	N=1	Partially improved	No	Low-certainty:
Rebecca Masstey, et al.	O2 Amp and the EnChroma glasses	2016	Comparative experimental Pre and Post study design	N=27	Partially improved	No	Low-certainty:
Petr Veselý, et al.	Red and Green Chromagen Filters	2017	Case control	N=39	Partially improved	Yes	Moderate-certainty
Almutairi, et al.	EnChroma Cx-14 filters	2017	Comparative	N=9	Partially improved	No	Low-certainty:
L. Gómez-Robledo, et al.	EnChroma Glasses	2018	Pre and post study design	N=48	Improved	No	Low-certainty:
Abdel-Rahman, et al.	Colour dye contact lenses	2018	Innovation and prototype design	N=0	Not reported	Not reported	Low-certainty:
Ahmed, et al.	Gold nanoparticle induced Contact lenses	2021	Prototype and innovation	No clinical validation	Not reported	Not reported	Low-certainty:

1.High-certainty: we are very confident that the true effect lies close to that of the estimate of the effect.
2.Moderate-certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is substantially different.
3.Low-certainty: we have low confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is subs tantially different.
4.Very low-certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect

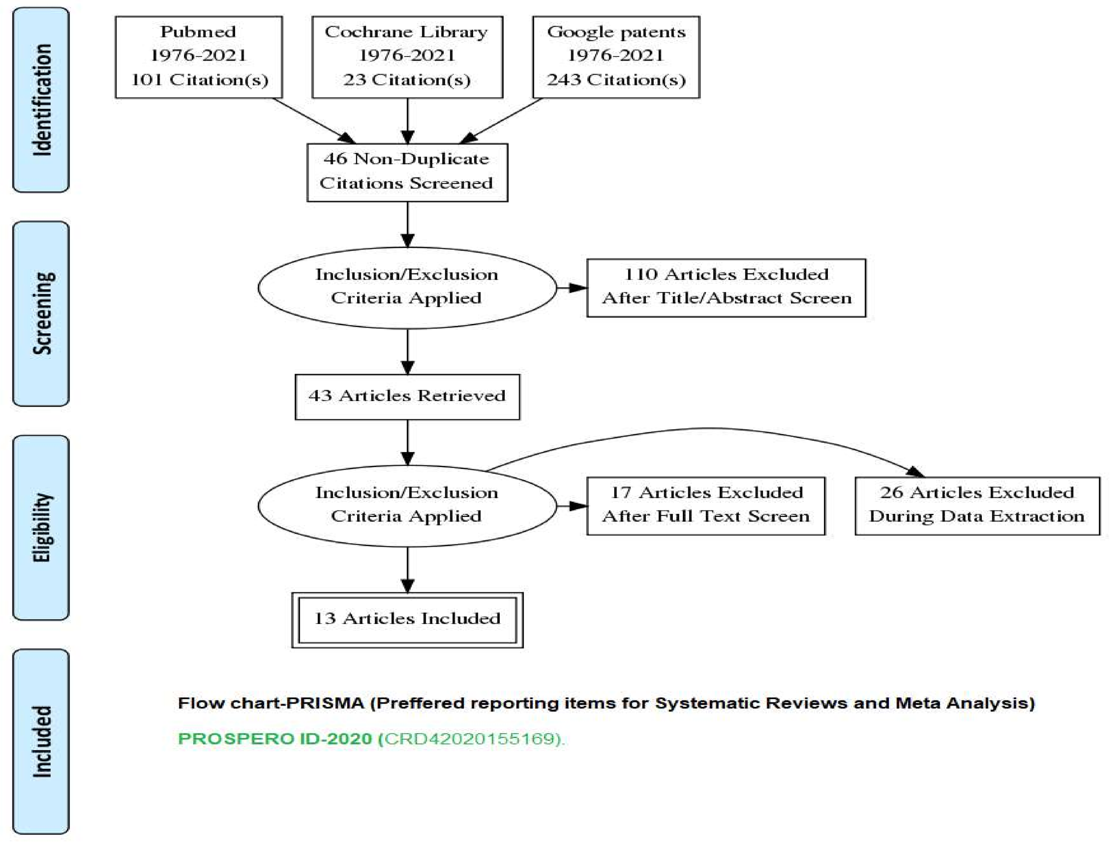

Figure-2. Search strategy with PRISMA flow diagram

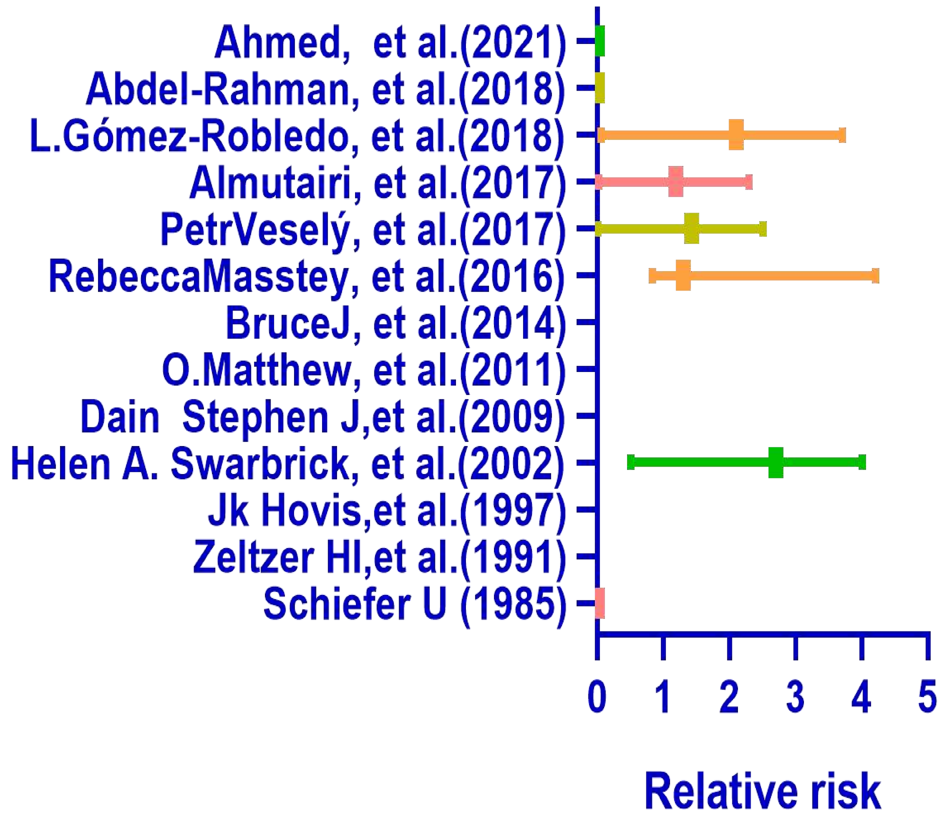

Figure-3. Forest plot showing the outcome of colour perception of various studies (n=13)

Discussion

However, there is insufficient evidence supporting the use of electronic or optical colour vision aids that improve colour perception with the current advanced technology although devices such as Enchroma CVD device, Cytochromic oxide filters are commercially available.

The meta-analysis showed low certainty of evidence on colour perception improvement, with current colour vision aids that are available in the market.

Conclusion

We found that only a few studies reported clinical trials with colour vision aids and found colour vision scores improved.
There is poor and low level of clinical evidence to claim that commercially available colour vision aids improve the colour perception. The Meta-Analysis informs further exploration and studies in this area related to the title of the presentation

References

1. Veselý, M. P., & Beneš, M. P. Color Vision Changes in Group of Subjects with Chromagen Filter.
2. Mastey, R., Patterson, E. J., Summerfelt, P., Luther, J., Neitz, J., Neitz, M., & Carroll, J. (2016). Effect of "color-correcting glasses" on chromatic discrimination in subjects with congenital color vision deficiency. *Investigative Ophthalmology & Visual Science*, *57*(12), 192-192.
3. Gómez-Robledo, L., Valero, E. M., Huertas, R., Martínez-Domingo, M. A., & Hernández-Andrés, J. (2018). Do EnChroma glasses improve color vision for colorblind subjects?. *Optics express*, *26*(22), 28693-28703.
4. Salih, A. E., Elsherif, M., Alam, F., Yetisen, A. K., & Butt, H. (2021). Gold Nanocomposite Contact Lenses for Color Blindness Management. *ACS nano*, *15*(3), 4870-4880.

Acknowledgements

PROSPERO Systematic review database, University of York for registering the Systematic review title: Colour Vision aids for Colour vision deficiency patients and outcome in colour perception. CRD42020155169 (PROSPERO-2020)
https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020155169

The Existence and Mapping of Colour Terms in Dravidian Languages.

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[1]School of Medical Sciences, University of Hyderabad, India
[2]School of Computer and Information Sciences, University of Hyderabad, India
[3] CALTS , School of Humanities University of Hyderabad, India
[4] Department of Linguistics, University of Delhi, India.

(Abstract ID: 3840)

Introduction

- Typological patterns of basic colour terms exhibit eleven colour prototypes in the English language and other languages (Berlin & Kay, 1969).
- Berlin and Kay's pioneering work on the universality of basic colour terms did not include major Dravidian languages.
- (Kapp 2004) attempted to study the basic colour terms in South Dravidian tribal languages

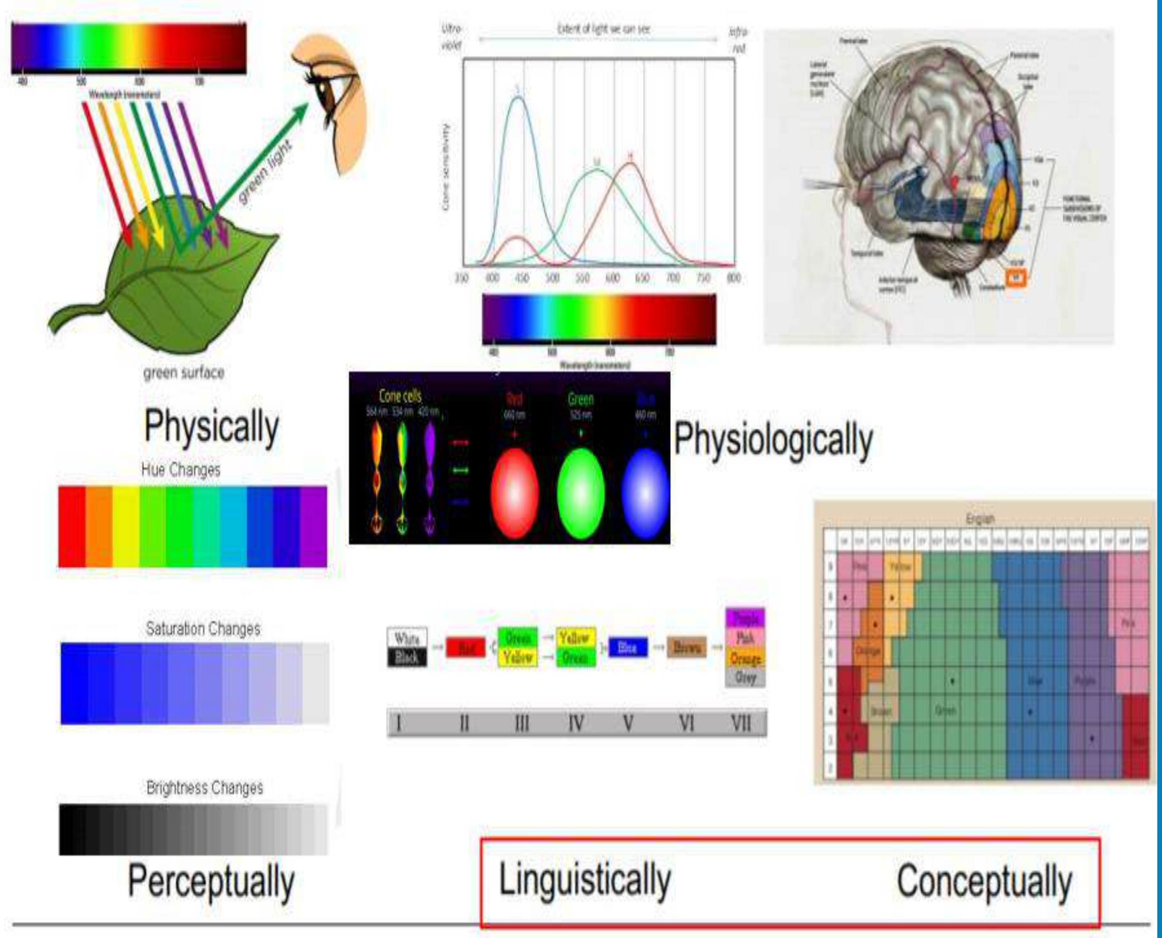

Fig-1. The concept of colour and its illustration

Aim

- In the current work, we have attempted to review the monolexemic colour hypothesis and the existence of these proposed colour terms in Dravidian colloquially spoken languages and to map them from a vision sciences perspective.

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Methods

Visual psychophysical tools were used in the experiment by recruiting n=20 participants of four L1 mother tongue language (Telugu,Tamil,Malayalam and Kannada) in the experiment.

Colour naming task

↓

colour mapping task

↓

Stroop-task

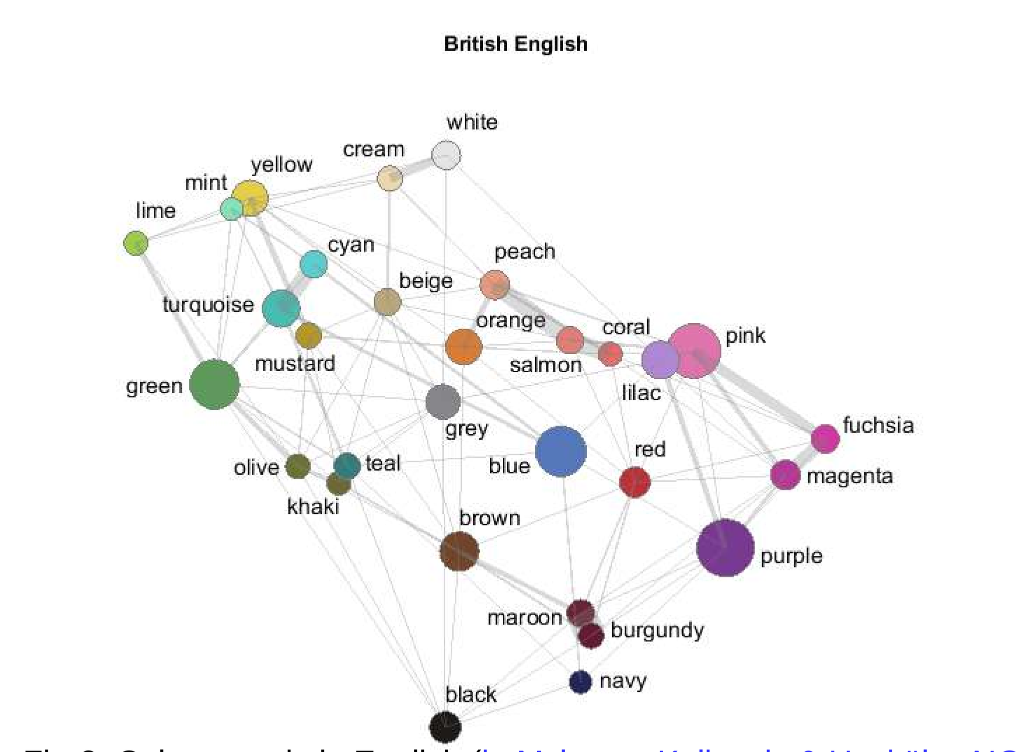

Fig-2. Colour words in English (in Mylonas, Koliousis & Uusküla, AIC 2021). Model

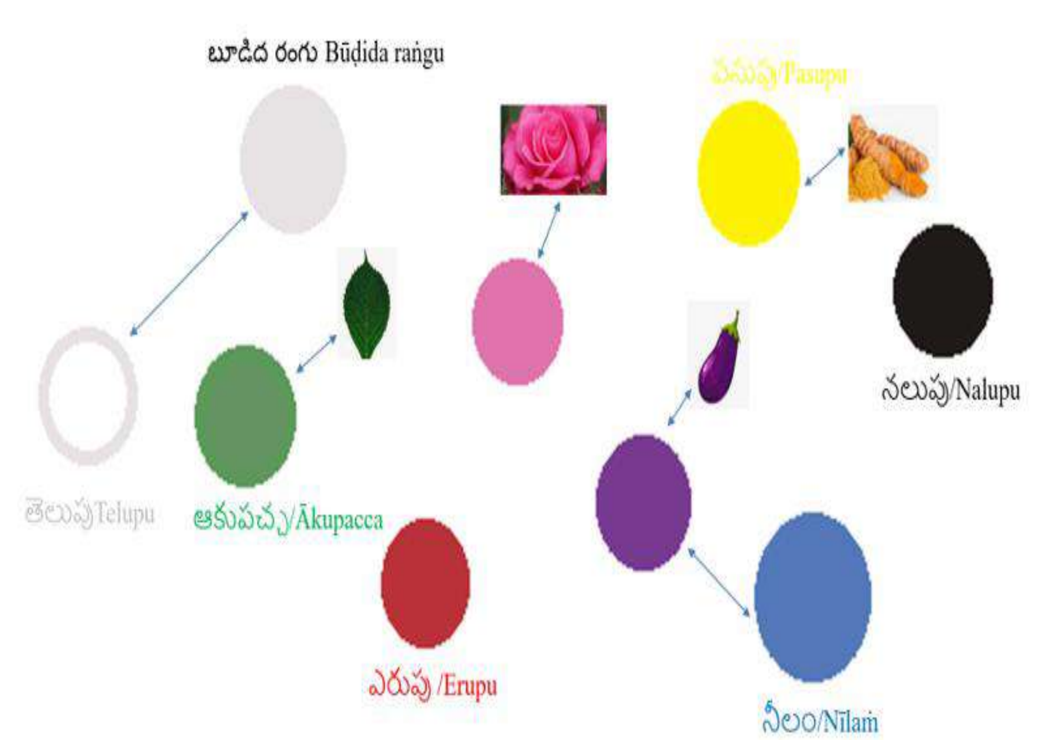

Fig-2. Colour Mapping model in Dravidian Language and existence on Monolexemic colours

Results

Groups	Colour Naming task (correct terms) Mean	Colour Naming task (errors) Mean	Stroop task (congruent trial) Mean	Error rate Mean	Reaction time(ms) Mean
Telugu (n=5)	3.69	6.3	4.5	6.7	6789
Tamil (n=5)	4.21	5.7	6.4	3.6	4537
Kannada (n=5)	3.45	6.21	4.21	5.8	7635
Malayalam (n=5)	2.23	7.45	3.5	7.8	8645

Table-1. Experiments showing the Mean differences between four Dravidian languages

ANOVA

Colour Naming task (correct terms)	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.333	3	4.778	4	P<0.001
Within Groups	.000	0	.		
Total	14.333	3			

Table-2. Colour naming task showing Mean differences between and within the groups.

Dravidian Languages	Mono lexemic Colour Terms	Compound colour terms
Telugu	ఎరుపు /Erupu	ఆకుపచ్చ/Ākupacca
	నీలం/Nīlaṁ	పసుపు/Pasupu
	నలుపు/Nalupu	
	తెలుపుTelupu	
Tamil	சிவப்பு /Civappu	
	பச்சை/Paccai	
	மஞ்சள்/Mañcaḷ	
	நீலம்/Nīlam	
	வெள்ளை/Veḷḷai	
	கருப்பு/Karuppu	
Kannada	ಕೆಂಪು/Kempu	
	ಹಸಿರು/Hasiru	ಹಳದಿ/Haḷadi
	ಕಪ್ಪು/Kappu	
	ಬಿಳಿ/Biḷi	
Malayalam	കറുപ്പ്/kaṟupp	
	പച്ച/pacca	
	നീല/nīla	
	മഞ്ഞ/mañña	
	ചുവപ്പ്/cuvapp	

Table-2. Existence of Monolexmic Colour terms in four Dravidian Languages

Discussion

- A new Quantification and colour mapping model required to understand How the Colour evolved and perceived in Dravidian languages.
- Colour is an important communication language in Both Animal and Human daily life activities.
- Colour Misnomers can be avoided .
- Previous cross-language and culture and emotion (Ram MS et al 2021) investigations also have revealed that colour categorical perception is a linguistic rather than a perceptual phenomenon. Roberson et al. (2005)

Conclusion

- It is found that the monolexmic colour terms hypothesis proposed for the English language varies in major Dravidian languages and the majority of colour terms are restricted to seven to eight colours.
- Interestingly few colour terms were found in some similarity among the Dravidian languages.

References

- Kapp, D. B. (2004). Basic colour terms in South Dravidian tribal languages. *Indo-Iranian Journal*, *47*(3/4), 193-201.
- Ram, M. S., Shamanna, B. R., Bhardwaj, R., Bhagvati, C., & Theagarayan, B. (2021). Color and Emotion Associations in Dravidian Culture. *Journal of Vision*, *21*(9), 2406-2406.
- Davies, I., Corbett, G., Roberson, D., & Vandervyver, M. (2005). Free-sorting of colors across cultures: Are there universal grounds for grouping?. *Journal of cognition and culture*, *5*(3-4), 349-386.
- Berlin, B., & Kay, P. (1969). Basic color terms. Berkeley. *Cal. University of California Press*.

Acknowledgements

- CALTS-CORPUS, University of Hyderabad.
- Vision science society
- Institute of Eminence- University of Hyderabad

Gmail

Shiva Ram Reddy <shivaram.ram180@gmail.com>

Thank you, We received your Message.

1 message

REPUBLIC INDIA <noreply@republicindia.in> Fri, Sep 16, 2022 at 4:05 AM
Reply-To: noreply@republicindia.in
To: SHIVARAM.RAM180@gmail.com

Dear Shiva Ram Reddy Male

We Received Your Message / Suggestion as you have submitted :

Send to : Hon'ble Chief Minister , Telangana

Subject: A research report submitted to the Honourable Chief Minister of State of Telangana for the considera

Your Suggestion: According to our new research study conducted on (CVD) Colour vision deficiency and Quality of Life in Hyderabad, a meta-analysis statistical result that the prevalence of colour vision deficiencies has been on the rise. More cases of CVD are seen in adolescents and school-aged youngsters. Low levels of awareness and a shortage of colour vision screening facilities and programmes are the primary contributors to the rise in CVD. When we examined the data that had been published between the years 1974 and 2021, we were surprised to find that five studies had been documented; this is the most data that is now available from any Indian research studies. The power and estimates were evaluated using metanalysis methods, and the findings suggested that it is a need of the hour in Hyderabad and Telangana for those suffering from colour vision deficiencies.

Suggested Points as Recommendations and implementation strategies.

1. Travel and transportation: To Consider placing the Colourblind free charts and railways maps in Hyderabad Metro and local stations, Workplaces, traffic charts and Govt offices.
2. Education: To Consider providing colour-blind free resources for children in schools when applied with Visual aid technologies.
3. General: To Consider providing the awareness and mandatory screening of colour vision for further counselling and career planning.
4. Industry: To consider developing new innovative methods for colour vision aids manufacturing with T-Hub an ecosystem for innovation.
5. Social Security: To Consider including the severe colour vision deficiency population and issuing the visual disability certificate.
6. Education: To consider providing the education cell for Visual impaired students: A chance or choice to be considered for including the CVD population.
7. Livelihoods: Allowing assistive technologies or advanced colour vision evaluation for youth during the recruitment process of Police forces.
8. Travel and transportation: Considering mandatory colour vision screening of Drivers-RTC, and other public transport facilities to avoid major accidents and supportive rehabilitation.

What Positive change your Suggestion will bring: 1. Telangana govt will be the first state to take the initiative to include a colour-blind free work environment at its workplaces, i.e., Traffic, Public transport, Schools, and other places.

2. As per National Education policy. Visual aids and play school environments, and practical-based learning with practical approaches have evolved. A colour-blind free education material can be implemented as Telangana state has rich information and software technology. This could help contribute to the Technology for Special population.

3. International colour-blind day is implemented every year on September -6th Globally. Similarly, implementing International Colour-Blind awareness day among regional Eye hospitals and Government schools could create more awareness on Colour vision deficiency.

4. Special training and teaching methods for the Faculty and Teachers in school education and higher education should be considered. An inclusive way of considering the colourblind free teaching environment should be created.

5. Kantivelugu is the most successful programme which also got credentials for the Guinness book. Implementing

and documenting the colour vision deficiency also would give a brief insight on occupation and age groups

How to Implement: A detailed Research report has been emailed to cmo@telangana.gov.in .

Your Personal detail as you have submitted :

Your Name: Shiva Ram Reddy Male

Date of Birth: 21 November 1993

Education: P.hD

Profession: Student

Mobile no.: 9059513019

Email ID: SHIVARAM.RAM180@GMAIL.COM

Address: Street Address: School of Medical Sciences
Street Address Line 2: University of Hyderabad
City: Hyderabad
State / Province: Telangana
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Appendix-B
List of Conference presentation from current Thesis

V-VSS 2021 Certificate of Participation

May 27, 2021

This certifies that **Male Shiva Ram** participated in the 2021 Vision Sciences Society Annual meeting, which was held virtually, May 21-26, 2021.

Presentation: Poster D50 **Color and Emotion Associations in Dravidian Culture.** in Poster session **Color, Light and Material** on Sunday, May 23, 2021.

Certified by

Shauney Wilson

Shauney Wilson
VSS Executive Director

Vision Sciences Society
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vss@visionsciences.org
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VSS Account #1818

43RD ECVP 2021 GOES ONLINE

CERTIFICATE

To whom it may concern,

We hereby state that Shiva Ram Male presented the work entitled "Colour vision aids for Colour vision deficiency patients: a systematic review" as a poster during the 43rd European Conference on Visual Perception (www.ecvp2021.org) that was held virtually from August 22nd to August 27th, 2021.

Sincerely yours,

Prof. Dr. Tiziano Agostini (University of Trieste)
Prof. Dr. Marco Bertamini (University of Padova)
Prof. Dr. Claus-Christian Carbon (University of Bamberg)
Dr. Cristina de la Malla (University of Barcelona)
Dr. Dražen Domijan (University of Rijeka)
Prof. Dr. Mark Greenlee (University of Regensburg)
Prof. Dr. Michael Herzog (École Polytechnique Fédérale de Lausanne)
Prof. Dr. Brian Rogers (Oxford University)
Dr. Katherine Storrs (Gießen University)
Prof. Dr. Ian Thornton (University of Malta)
Prof. Dr. Sunčica Zdravković (University of Novi Sad)

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ARVO2022

Certificate of Presentation and Participation

The Association for Research in Vision and Ophthalmology
certifies that

SHIVA RAM MALE
M.Optom, PhD.Research Scholar, School of Medical Sciences, UoH.

presented research titled:

Impact of color vision deficiency on quality of life in a sample of Indian population.

ARVO 2022 Annual Meeting
In Person: May 1– 4 | Virtual: May 11 – 12

ARVO.
5515 Security Lane, Suite 500
Rockville, Maryland 20852
ARVO.org

Iris M. Rush, CAE
ARVO Executive Director

V-VSS 2022 Certificate of Participation

June 5, 2022

This certifies that **Male Shiva Ram** participated in the Virtual 2022 Vision Sciences Society Annual meeting (V-VSS 2022), held virtually on June 1-2, 2022.

Presentation: Poster **The Existence and Mapping of Colour Terms in Dravidian Languages.** in Poster session **Poster Session 6** on Thursday, June 2, 2022.

Certified by

Shauney Wilson
VSS Executive Director

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VSS Account #1818

48th All India Conference of Dravidian Linguists

Organised by

Department of Linguistics, Bharathiar University
Dravidian Linguistics Association of India
International School of Dravidian Linguistics
&
Central Institute of Indian Languages, Mysuru

Certificate

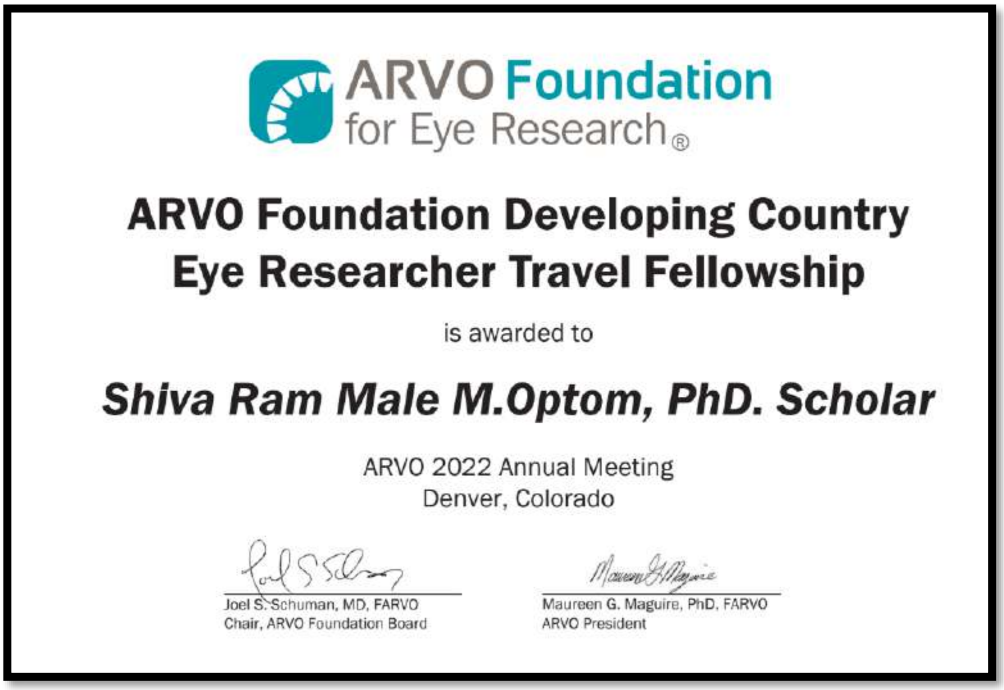
This is to certify that ~~Mr.~~/Ms./Dr. Shiva Ram

Participated / Presented / Chaired a paper entitled Colour terms existence and mapping of Dravidian Languages in the

48th ALL INDIA CONFERENCE OF DRAVIDIAN LINGUISTS held at the Department of Linguistics, Bharathiar University, Coimbatore on 25th and 26th February 2022.

Dr. V.M. Subramanian Local Secretary 48th AICDL Asst. Prof. and Head i/c Bharathiar University, Coimbatore	**Prof. Umarani Pappuswamy** Professor - Cum - Deputy Director Central Institute of Indian Languages Mysuru	**Prof. Naduvattom Gopalakrishnan** Director, ISDL Thiruvananthapuram Kerala	**Prof. P. Kaliraj** Vice - Chancellor Bharathiar University Coimbatore

Appendix-C
Achievements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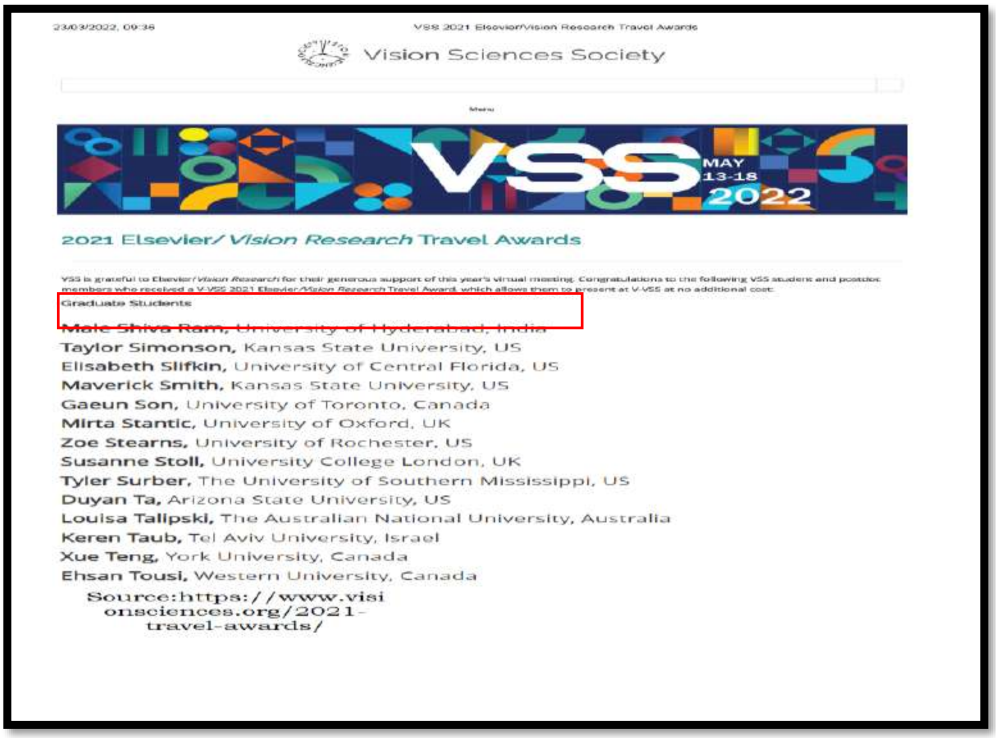
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VSS MAY 13-18 2022

2021 Elsevier/ *Vision Research* Travel Awards

VSS is grateful to Elsevier/*Vision Research* for their generous support of this year's virtual meeting. Congratulations to the following VSS student and postdoc members who received a V-VSS 2021 Elsevier/*Vision Research* Travel Award, which allows them to present at V-VSS at no additional cost:

Graduate Students

Male Shiva Ram, University of Hyderabad, India
Taylor Simonson, Kansas State University, US
Elisabeth Slifkin, University of Central Florida, US
Maverick Smith, Kansas State University, US
Gaeun Son, University of Toronto, Canada
Mirta Stantic, University of Oxford, UK
Zoe Stearns, University of Rochester, US
Susanne Stoll, University College London, UK
Tyler Surber, The University of Southern Mississippi, US
Duyan Ta, Arizona State University, US
Louisa Talipski, The Australian National University, Australia
Keren Taub, Tel Aviv University, Israel
Xue Teng, York University, Canada
Ehsan Tousi, Western University, Canada

Source:https://www.visionsciences.org/2021-travel-awards/

This is to certify that

Shiva Ram Male

M.Optom, Ph.D Research Scholar. School of Medical Sciences University of Hyderabad

Attended the Adaptive Optics European Summer School

13th – 17th June 2022

Laura Young **Karen Hampson**

Laura K Young K. Hampson

ADAPTIVE OPTICS
European Summer School

ICVS Summer School 2020

INTERNATIONAL COLOUR VISION SOCIETY

Certificate of Attendance

is hereby granted to

Shiva Ram Male

for attending the ICVS Virtual Summer School 2020 (3–6 August 2020)

David Brainard	Neil Parry	Hannah Smithson	Manuel Spitschan
University of Pennsylvania	University of Manchester	University of Oxford	University of Oxford

neuromatch
academy

We are honored to present this

Certificate of Completion

to

Male Shiva Ram

On the 31st day of July 2020

for completion of the interactive track
at the inaugural Neuromatch Academy

tutorials

Neuromatch Board of Directors

Megan Peters, PhD	Brad Wyble, PhD
Gunnar Blohm, PhD	G. Sean Escola, MD, PhD
Konrad Körding, PhD	Paul Schrater, PhD

Appendix-D

IEC-Approval letter and Consent and permission letters

UNIVERSITY OF HYDERABAD

INSTITUTIONAL ETHICS COMMITTEE DECISION LETTER

IEC No. Application No:	UH/IEC/2019/215	**Date of review**	29-08-2022
Project Title:	Profiling the Problem Of Colour Vision Deficiency And Its Association With Colour, Culture And Cognition - An Indian Perspective		
Principal Investigator/ Co-PI:	PI: M. Shiva Ram CI: Prof. B. R. Shamanna and Prof. Bhagavati		
Participating Institutes if any	----	Approval from Participating Institute	----
Documents received and reviewed	Protocol & ICF		
In case of renewal submission of update	----		
Decision of the IEC:	Approved for amendment Duration: One year from date of approval		
Any other Comments Requirements for conditional Approval	----		
Members Present	Dr. A.S. Sreedhar, Sri. A. Madhava Rao, Dr. Stalin Chowdary Bala, Dr. M. Srinivas, Dr.P. Uday Kumar, Dr. M. Varalakshmi and Dr. Deepa Srinivas		

Please note:

a. Any amendments in the protocol must be informed to the Ethics committee and fresh approval taken.
b. Any serious adverse event must be reported to the Ethics Committee within 48 hours in writing (mentioning the protocol No. or the study ID)
c. Any advertisement placed in the newspapers, magazines must be submitted for approval.
d. If the conduct of the study is to be continued beyond the approved period, an application for the same must be forwarded to the Ethics Committee.
e. It is hereby confirmed that neither you nor any of the members of the study team participated in the decision making/voting procedures and declared conflict of interest.

A S Sreedhar
29/8/22

29/8/2022

Chairman

(Dr. A S Sreedhar)

Convenor

(Dr. M. Varalakshmi)

School of Medical Sciences
University of Hyderabad

CONSENT FORM FOR PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about all my questions have been answered to my satisfaction. I understand that I am free to Request further information at any stage and I know that:

- ✓ My participation in the project is entirely voluntarily.
- ✓ I am free to withdraw from the project at any time without any disadvantage.
- ✓ The results of the project may be published with my initials and name indicating which data came from me.
- ✓ I agree to take part in this project by reading and understanding above consent and also by filling this questionnaire I agree to participate in research.
- ✓ No monetary reward is awarded on participating in this study.

(Signature of Participant) (Signature of Investigator)

(Date)...................................... (Date) ....

UNIVERSITY OF HYDERABAD.

Dr. Rishi Bhardwaj
B.S. (opto), Ph.D (Vision Science)
Assistant Professor
School of Medical Sciences

SDEH Date: 17/01/2020
Inward No. 141
MRD

To,
The Superintendent
Sarojini Devi Eye Hospital
Hyderabad

Dear Sir,

Sub: (i)Permission to collect data on squint patients using virtual reality synoptophore
(ii) Permission to collect data on congenital colour impaired patients

Sir, my research group from University of Hyderabad (UOH) and Prof Kavita's research group from International Institute of Information Technology Hyderabad (IIIT –Hyderabad) have developed a virtual reality synoptophore. We have done testing on normal subjects and there is good correlation between virtual reality synoptophore and synoptophore. Now we want to test using strabismic patients. In regards to the same we have approached Dr. Raman. It would be very kind of you to provide us accesses to 1000 strabismic patients from Dr. Raman's OPD. The institute will be acknowledge in the publications coming out of the study. My PhD student is working on quality of life of colour impaired patients. It is going to be a questionnaire based study. For this we need accesses to the congenital colour impaired patients visiting Sarojini Devi Eye Hospital.

Looking forward to your support

Thanking you

Yours truly

Dr. Rishi Bhardwaj

Dr. RISHI BHARDWAJ
Assistant Professor
School of Medical Sciences
University of Hyderabad
HYDERABAD

Dr. Rishi Bhardwaj
Contact no: +91-8331629461

Prof. C.R. Rao Road, Old Science Complex, Gachibowli, Hyderabad - 500 046. A.P.
Tel. (O) : +91-40-23135474, Fax (O) : +91-04-23013279
e-mail : rbmd@uohyd.ernet.in

UNIVERSITY OF HYDERABAD.

Dr. Rishi Bhardwaj
B.S. (opto), Ph.D (Vision Science)
Assistant Professor
School of Medical Sciences

Date: 17-01-2020

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The Superintendent
Sarojini Devi Eye Hospital
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Thanking you

Yours truly

Dr. Rishi Bhardwaj

Dr. RISHI BHARDWAJ
Assistant Professor
School of Medical Sciences
University of Hyderabad
HYDERABAD

SAROJINI DEVI EYE HOSPITAL HYDERABAD

Prof. C.R. Rao Road, Old Science Complex, Gachibowli, Hyderabad - 500 046. A.P.

CVD-QoL Study Questionnaire
CVD-QoL అధ్యయన ప్రశ్నాపత్రం

CV Score__________ Diagnosis: Proton __ Deutran__ MRF Score________

Name________________ Age___________ Contact number___________ Occupation____________

1. Do you Ever feel not noticing change in colour of skin due to sunburn?
   1. వడదెబ్బ కారణంగా చర్మం రంగులో మార్పు కనిపించడం లేదని మీరు ఎప్పుడైనా భావిస్తున్నారా?

   1 2 3 4 5 6

2. Do you feel Difficulty choosing groceries due to colour?

   2. రంగు కారణంగా కిరాణా వస్తువులను ఎంచుకోవడంలో మీకు ఇబ్బంది అనిపిస్తుందా?

   1 2 3 4 5 6

3. Do you feel not noticing change in colour of mole on skin?

   3. చర్మంపై పుట్టుమచ్చ రంగులో మార్పు కనిపించడం లేదని మీరు భావిస్తున్నారా?

   1 2 3 4 5 6

4. Do you ever feel that not able to tell when food is cooked due to colour?

   4. రంగు కారణంగా ఆహారాన్ని ఎప్పుడు వండుతారో చెప్పలేమని మీకు ఎప్పుడైనా అనిపిస్తుందా

   1 2 3 4 5 6

5. Do you feel Difficulty choosing or buying clothes?

   5. బట్టలు ఎంచుకోవడం లేదా కొనడం మీకు కష్టంగా అనిపిస్తుందా?

   1 2 3 4 5 6

6. Do you feel being confused about colour of pills or other medication due to colour-coding?

   6. రంగు-కోడింగ్ కారణంగా మీరు మాత్రల రంగు లేదా ఇతర మందుల గురించి గందరగోళంగా భావిస్తున్నారా?

   1 2 3 4 5 6

7. Do you feel not noticing blood in stools (faeces) ?

మలం (మలం) లో రక్తాన్ని గమనించడం లేదని మీకు అనిపిస్తుందా.

   1 2 3 4 5 6

8. Do you feel difficulty knowing when fruit is ripe due to colour?

   రంగు కారణంగా పండు ఎప్పుడు పండుతుందో తెలుసుకోవడంలో మీకు ఇబ్బంది అనిపిస్తుందా?

   1 2 3 4 5 6

9. Do you feel difficulty reading maps (e.g. Hyderabad metro, Indian or any travel map) ?

   . మ్యాప్‌లను చదవడానికి మీకు ఇబ్బంది అనిపిస్తుందా (ఉదా. హైదరాబాద్ మెట్రో, ఇండియన్ లేదా ఏదైనా ట్రావెల్ మ్యాప్).

   1 2 3 4 5 6

10. Do you feel not noticing a change in colour of urine?

   మీరు మూత్రం రంగులో మార్పును గమనించడం లేదని భావిస్తున్నారా?

   1 2 3 4 5 6

11. Do you feel Problems playing sports (e.g. colours of team clothing, colours of snooker balls etc)?

   . మీకు క్రీడలు ఆడటం సమస్యగా అనిపిస్తుందా (ఉదా. జట్టు దుస్తులు, స్నూకర్ బంతుల రంగులు మొదలైనవి).

   1 2 3 4 5 6

12. Do you ever felt anxious because of issues caused by problems seeing colours?

   రంగులను చూడటం వలన సమస్యల వలన మీరు ఎప్పుడైనా ఆందోళనకు గురయ్యారా?

   1 2 3 4 5 6

13. Do you felt depressed because of issues caused by problems seeing colours?

రంగులను చూడటం వలన సమస్యల వలన మీరు నిరాశకు గురయ్యారా?

1 2 3 4 5 6

14. Do you feel unconfident because of issues caused by problems seeing colours?

   రంగులను చూడటం వలన సమస్యల వలన మీకు విశ్వాసం లేదని భావిస్తున్నారా.

   1 2 3 4 5 6

15. Do you feel embarrassed or humiliated because of CB issues ?

CB సమస్యల కారణంగా మీరు ఇబ్బందిగా లేదా అవమానంగా భావిస్తున్నారా.

1 2 3 4 5 6

16. Do you feel low self esteem because of issues caused by problems seeing colours ?

రంగులను చూడటం వలన సమస్యల వలన మీకు తక్కువ ఆత్మగౌరవం అనిపిస్తుందా

1 2 3 4 5 6

17. Do you feel anxious because you might not realise when you can't see a colour properly ?
మీరు ఒక రంగును సరిగ్గా చూడలేనప్పుడు మీరు గ్రహించకపోవచ్చు కాబట్టి మీరు ఆందోళన చెందుతున్నారా?

1 2 3 4 5 6

18. Do you feel different to other people because of issues caused by problems seeing colours ?
రంగులను చూడటం వలన సమస్యల వలన మీరు ఇతర వ్యక్తులకు భిన్నంగా భావిస్తున్నారా.

1 2 3 4 5 6

19. Do you Felt that had let down self or others due to problems seeing colours ?
రంగులను చూడడంలో సమస్యల కారణంగా మిమ్మల్ని లేదా ఇతరులను నిరాశపరిచినట్లు మీకు అనిపిస్తుందా.

1 2 3 4 5 6

20. Do you feel Avoiding conversations where colours are discussed ?

రంగులు చర్చించబడే సంభాషణలను నివారించడాన్ని మీరు భావిస్తున్నారా.

1 2 3 4 5 6

21. Do you feel Being limited in choice of work or career ?

మీరు ఉద్యోగం లేదా కెరీర్ ఎంపికలో పరిమితంగా ఉన్నట్లు భావిస్తున్నారా.

1 2 3 4 5 6

22. Do you feel Difficulty performing work or other activities (e.g. charts,painting,drawing) ?
    పని లేదా ఇతర కార్యకలాపాలు (ఉదా. చార్ట్‌లు, పెయింటింగ్, డ్రాయింగ్) చేయడంలో మీకు ఇబ్బంది అనిపిస్తుందా.

    1 2 3 4 5 6

23. Do you feel accomplishing less than would like at work or in career?
    మీరు ఉద్యోగంలో లేదా కెరీర్‌లో కోరుకున్న దానికంటే తక్కువ సాధించినట్లు భావిస్తున్నారా

    1 2 3 4 5 6

24. Do you ever felt colour vision deficiency ,made you to lose government jobs in your career?.
    మీకు ఎప్పుడైనా రంగు దృష్టి లోపం అనిపించిందా, మీ కెరీర్‌లో ప్రభుత్వ ఉద్యోగాలు కోల్పోయేలా చేసింది.

    1 2 3 4 5 6

25. Do you ever felt colour vision deficiency is the reason for losing your opportunities?
    మీ అవకాశాలను కోల్పోవడానికి రంగు దృష్టి లోపం కారణమని మీరు ఎప్పుడైనా భావించారా

    1 2 3 4 5 6

26. Do you ever felt discriminated by other employees or employer in work place due to CVD.?

CVD కారణంగా పని ప్రదేశంలో ఇతర ఉద్యోగులు లేదా యజమాని ద్వారా మీరు ఎప్పుడైనా వివక్షకు గురయ్యారా?

1 2 3 4 5 6

27. Rate your psychological disturbance with CVD in under 1-5 grade?

1-5 గ్రేడ్ లోపు CVD తో మీ మానసిక భంగం రేట్ చేయండి

1 2 3 4 5 6

Note: Interpretation

Responses were on a 6-point Likert scale from1 = Strongly agree to 6 = No problem, with an option for
'Not applicable'.

- Strongly Agree = 1 (బలంగా నమ్ముతున్నాను)
- Agree=2 (నమ్ముతున్నాను)
- Undecided=3 (నిర్ణయించబడలేదు)
- Disagree=4 (అంగీకరించలేదు)
- Strongly Disagree=5 (తీవ్రంగా విభేదిస్తున్నారు)
- No Problem or NA=6 (ఏమి ఇబ్బంది లేదు)

✓ Lower the score: Poor quality of Lifestyle and Higher the score better quality of Life

✓ తక్కువ స్కోర్: పేలవమైన జీవనశైలి ఎక్కువ స్కోర్ మెరుగైన జీవన నాణ్యత

School of Medical Sciences
University of Hyderabad

INFORMATION SHEET FOR PARTICIPANTS

Thank you for showing an interest in this project .Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the aim of the Project?

We are studying to look at the Colour and Emotion associations in Dravidian culture, Southern part of India

What Type of Participant is being sought?

All individuals Both Men and women of age < 18 yrs. To > 45yrs with Normal colour vision can participate in this study. This includes People who wear glasses as long as they had their vision checked by an Optometrist ,Ophthalmologist or Eye care professional within the last one year .Feel free to direct any Queries as to your suitability to the Research investigator.

What will Participants be asked to do?

Should you agree to take part in this Project, You will be asked to fill a colour and emotions association questionnaire.

Can participants change their Minds and withdraw from the Project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind or discomfort that you feel.

What Use will be Made of the Data collected?

The data collected will be securely stored on computers accessible only to Project Supervisor and student conducting optometry and vision sciences Research at University of Hyderabad. The Data will be stored for at least of five years. Results of this Project may be published in Academic Journals .It is customary in optometry and vision sciences research to print the initials of Observers next to their

results, to allow those data to be compared with data obtained from the same person in other studies.

You are most Welcome to Request a copy of the results of the Project should you wish.

What if Participants have any Questions?

If you have any questions about our project, either now or in future, please feel free to contact either any one or both of us or

Principal Investigator

MALE SHIVA RAM

I.M.SC (Optometry& Vision Sciences)
PhD Scholar (Optometry & Vision sciences)
School of Medical Sciences
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Co-Investigator-1

Dr.Rishi BHARDWAJ

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Email: rbmd@uohyd.ernet.in

School of Medical Sciences
University of Hyderabad

CONSENT FORM FOR PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about all my questions have been answered to my satisfaction. I understand that I am free to Request further information at any stage and I know that:

- ✓ My participation in the project is entirely voluntarily.
- ✓ I am free to withdraw from the project at any time without any disadvantage.
- ✓ The results of the project may be published with my initials and name indicating which data came from me.
- ✓ I agree to take part in this project by reading and understanding above consent and also by filling this questionnaire I agree to participate in research.
- ✓ No monetary reward is awarded on participating in this study.

(Signature of Participant) (Signature of Investigator)

(Date).................................... (Date) ……………………

School of Medical Sciences
University of Hyderabad

1. Which age group do you belong to?

- ○ <18
- ○ 18-25
- ○ 25-35
- ○ 35-45
- ○ >45

2. Please select your gender

- ○ Male
- ○ Female

Other

3. Which country were you born in?

- ○ India
- ○ USA
- ○ UK
- ● Europe
- ○ Africa
- ○ Other (please specify)__________________

4. If you weren't born in other than india, at what age did you move here?

- ○ <5
- ○ 6-12
- ○ 13-19
- ○ 20-29
- ○ >30
- ○ I don't live in India

5. What is your preferred language (language you speak at home)?

- ○ English
- ○ Telugu
- ○ Tamil
- ○ Kannada
- ○ Malyalam
- ● Hindi

Other (please specify)____________

6. Are you color deficient.

- ○ Yes
- ○ No

School of Medical Sciences
University of Hyderabad

Telugu

<u>దిగువ భావోద్వేగాలకు మీరు ఏ రంగును ఇష్టపడతారు</u>

1.ఆషా (Desire)

వంగ పండు రంగు	నీలము	ఆకుపచ్చ	పసుప్పచ్చ	నారింజ
ఎరుపు	తెలుపు	నలుపు	మిగతావి:	

2.దుఃఖము (Sadness)

వంగ పండు రంగు	నీలము	ఆకుపచ్చ	పసుప్పచ్చ	నారింజ
ఎరుపు	తెలుపు	నలుపు	మిగతావి:	

3.భయం (Fear)

వంగ పండు రంగు	నీలము	ఆకుపచ్చ	పసుప్పచ్చ	నారింజ
ఎరుపు	తెలుపు	నలుపు	మిగతావి:	

4.ద్వేషం (Hatred)

వంగ పండు రంగు	నీలము	ఆకుపచ్చ	పసుప్పచ్చ	నారింజ
ఎరుపు	తెలుపు	నలుపు	మిగతావి:	

5.ప్రేమ (Love)

వంగ పండు రంగు	నీలము	ఆకుపచ్చ	పసుప్పచ్చ	నారింజ
ఎరుపు	తెలుపు	నలుపు	మిగతావి:	

6.సంతోషం (Happiness)

వంగ పండు రంగు	నీలము	ఆకుపచ్చ	పసుప్పచ్చ	నారింజ
ఎరుపు	తెలుపు	నలుపు	మిగతావి:	

7.ఈర్ష్య (Jealousy)

వంగ పండు రంగు	నీలము	ఆకుపచ్చ	పసుప్పచ్చ	నారింజ
ఎరుపు	తెలుపు	నలుపు	మిగతావి:	

8.కోపం (Anger)

వంగ పండు రంగు	నీలము	ఆకుపచ్చ	పసుప్పచ్చ	నారింజ
ఎరుపు	తెలుపు	నలుపు	మిగతావి:	

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University of Hyderabad

Tamil

<u>ஒவ்வொரு உணர்ச்சியுடனும் எந்த வண்ணத்தை நீங்கள் இணைக்கிறீர்கள்?</u>

1.**ஆசை** (Acai)

ஊதா	ப்ளூ	பசுமை	மஞ்சள்	ஆரஞ்சு
சிவப்பு	வெள்ளை	பிளாக்	மற்ற:	

2.**சோகம்** (cokam)

ஊதா	ப்ளூ	பசுமை	மஞ்சள்	ஆரஞ்சு
சிவப்பு	வெள்ளை	பிளாக்	மற்ற:	

3.**பயம் (payam)**

ஊதா	ப்ளூ	பசுமை	மஞ்சள்	ஆரஞ்சு
சிவப்பு	வெள்ளை	பிளாக்	மற்ற:	

4.**வெறுப்பு (veruppu)**

ஊதா	ப்ளூ	பசுமை	மஞ்சள்	ஆரஞ்சு
சிவப்பு	வெள்ளை	பிளாக்	மற்ற:	

5.**அன்பு** (Anpu)

ஊதா	ப்ளூ	பசுமை	மஞ்சள்	ஆரஞ்சு
சிவப்பு	வெள்ளை	பிளாக்	மற்ற:	

6.**மகிழ்ச்சி** (Makilcci)

ஊதா	ப்ளூ	பசுமை	மஞ்சள்	ஆரஞ்சு
சிவப்பு	வெள்ளை	பிளாக்	மற்ற:	

7.**பொறாமை** (Poramai)

ஊதா	ப்ளூ	பசுமை	மஞ்சள்	ஆரஞ்சு
சிவப்பு	வெள்ளை	பிளாக்	மற்ற:	

8.**கோபம்** (kopam)

ஊதா	ப்ளூ	பசுமை	மஞ்சள்	ஆரஞ்சு
சிவப்பு	வெள்ளை	பிளாக்	மற்ற:	

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University of Hyderabad

Kannada

ಕೆಳಗಿನ ಭಾವನೆಗಳಿಂದ ನೀವು ಯಾವ ಬಣ್ಣವನ್ನು ಬಯಸುತ್ತೀರಿ

1. **Desire (ಆಸೆ)**

ನೇರಳೆ	ನೀಲಿ	ಹಸಿರು	ಹಳದಿ
ಕೆಂಪು	ಕಪ್ಪು	ಬಿಳಿ	ಇತರರು:

2. **Sadness (ದುಃಖ)**

ನೇರಳೆ	ನೀಲಿ	ಹಸಿರು	ಹಳದಿ
ಕೆಂಪು	ಕಪ್ಪು	ಬಿಳಿ	ಇತರರು:

3. **Fear (ಭಯ)**

ನೇರಳೆ	ನೀಲಿ	ಹಸಿರು	ಹಳದಿ
ಕೆಂಪು	ಕಪ್ಪು	ಬಿಳಿ	ಇತರರು:

4. **Hatred (ದ್ವೇಷ)**

ನೇರಳೆ	ನೀಲಿ	ಹಸಿರು	ಹಳದಿ
ಕೆಂಪು	ಕಪ್ಪು	ಬಿಳಿ	ಇತರರು:

5. **Love (ಪ್ರೀತಿ)**

ನೇರಳೆ	ನೀಲಿ	ಹಸಿರು	ಹಳದಿ

ಕೆಂಪು	ಕಪ್ಪು	ಬಿಳಿ	ಇತರರು:

6. **Happiness (ಸಂತೋಷ)**

ನೇರಳೆ	ನೀಲಿ	ಹಸಿರು	ಹಳದಿ
ಕೆಂಪು	ಕಪ್ಪು	ಬಿಳಿ	ಇತರರು:

7. **Jealousy (ಅಸೂಯೆ)**

ನೇರಳೆ	ನೀಲಿ	ಹಸಿರು	ಹಳದಿ
ಕೆಂಪು	ಕಪ್ಪು	ಬಿಳಿ	ಇತರರು:

8. **Anger (ಕೋಪ)**

ನೇರಳೆ	ನೀಲಿ	ಹಸಿರು	ಹಳದಿ
ಕೆಂಪು	ಕಪ್ಪು	ಬಿಳಿ	ಇತರರು:

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University of Hyderabad

Malyalyam

താഴെയുള്ള എമിഷന് ഏത് നിറമാണ് നിങ്ങൾ ഇഷ്ടപ്പെടുന്നത്

1. **Desire (മോഹം)**

വയലറ്റ്	നീല	നീല	മഞ്ഞ
ചുവപ്പ്	വെള്ള	കറുപ്പ്	മറ്റുള്ളവർ:

2. **Sadness (സങ്കടം)**

വയലറ്റ്	നീല	നീല	മഞ്ഞ
ചുവപ്പ്	വെള്ള	കറുപ്പ്	മറ്റുള്ളവർ:

3. **Fear (സങ്കടം)**

വയലറ്റ്	നീല	നീല	മഞ്ഞ
ചുവപ്പ്	വെള്ള	കറുപ്പ്	മറ്റുള്ളവർ:

4. **Hatred (പക)**

വയലറ്റ്	നീല	നീല	മഞ്ഞ
ചുവപ്പ്	വെള്ള	കറുപ്പ്	മറ്റുള്ളവർ:

5. **Love (സ്നേഹം)**

വയലറ്റ്	നീല	നീല	മഞ്ഞ
ചുവപ്പ്	വെള്ള	കറുപ്പ്	മറ്റുള്ളവർ:

6. **Happiness (സന്തോഷം)**

വയലറ്റ്	നീല	നീല	മഞ്ഞ
ചുവപ്പ്	വെള്ള	കറുപ്പ്	മറ്റുള്ളവർ:

7. Jealousy (അസൂയ)

വയലറ്റ്	നീല	നീല	മഞ്ഞ
ചുവപ്പ്	വെള്ള	കറുപ്പ്	മറ്റുള്ളവർ:

8. Anger (കോപം)

വയലറ്റ്	നീല	നീല	മഞ്ഞ
ചുവപ്പ്	വെള്ള	കറുപ്പ്	മറ്റുള്ളവർ:

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