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Original Research Article

EVALUATION OF COLOR VISION DISCRIMINATION ABILITY IN DOMINANT AND NON DOMINANT EYE AMONG YOUNG ADULTS WITH NORMAL COLOR VISION

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ABSTRACT

Backgrund: The phenomenon of dominance in the domain of sensorial neurophysiology is an accepted and acknowledged framework of physiological functioning of varied precepts of sensoria. Dominance in and of vision is a function that elaborates from periphery of eye extending all along visual pathway involving both bottom-up and top-down influences. **Methods:** The present study attempts to investigate the relationship between color vision discrimination ability and eye dominance in young adults using Farnsworth Munsell 100 (FM 100) hue test. It is a cross sectional comparative type of study including 170 young adults with normal color vision. The tests used were Ishihara Pseudo-Isochromatic Plate Test (IPPT) for screening of CCVD (Congenital Color Vision Deficiency), FM100 hue test for color discrimination ability and Gundogan Test for detection of dominant eye. Color discrimination ability was assessed in terms of Total Error Scores, evaluated for two eyes used together, dominant eye and non dominant eye. P values below 0.05 were considered to be statistically significant. **Results:**The study revealed a mean Total Error Score of FM 100 Hue test for dominant eye (DE) as being 72.14±21.46 and 87.89±25.15 for the non dominant eye (NDE) indicating superior color discrimination ability in dominant eye (DE) in comparison to non dominant eye (NDE). **Conclusion:** The finding of superiority of the dominant eye with regard to color discrimination ability is hypothesised as taking place along the lines of a generalized precept wherein maximum resource economy and functional laterality of cerebral hemispheres is achieved without producing extrusive compromises in overt sensory experiences.

Keywords: Eye Dominance, Color discrimination ability,Farnsworth Munsell 100 hue test, Ishihara Pseudo-Isochromatic Plate Test,Gundogan Test.

INTRODUCTION

Vision and visual Perception are precepts that have held human inquisitiveness from time immemorial. Dominance in and of vision is a function that elaborates from periphery of eye extending all along visual pathway involving both bottom-up and top-down influences**(1)**. The eye dominance, color vision and discrimination ability are tested now a days by; Farnsworth Munsell 100 (FM 100) hue test **(2),** The Ishihara Pseudo-Isochromatic Plate Test (IPPT) **(3)** and Gundogan Test**(4).** The phenomenon of vision has been segregated into modules of colour, orientation and motion and it seems that human visual cortex evolved accordingly as a distributed modular system acting in parallel, though respective modular parallel systems reach their perceptual end-points skewed in time and are asynchronous with a seeming autonomy, upholding the premise of autonomy of visual system and modularity of consciousness of vision **(5, 6).**

The concept of ocular dominance predates from 1960s, when Hubel and Wiesel discovered the sidedskewed nature of ocular columns of visual cortex in cats **(7).** The dominant eye may be defined as that eye which performs the major function of seeing, being and with the tendency to prefer visual input, assisted by the less dominant fellow eye. Just as a person may be right handed or left handed, so he may be right eyed or left yed **(8).** Eye dominance may be determined genetically **(9).** This preference gives numerous perceptual effects such as image being clearer, bigger and more precise using their dominant Eye **(10, 11).** Imaging studies have also shown larger area activation with dominant eye stimulation **(12).** Dominant eye is functionally activated before the non-dominant eye subsequent a horizontal saccade throughout reading **(13).** Taken together these phenomena recommend that inputs from the dominant eye may be more sensitive, responsive or numerous, and may capture attention more freely, leading to an additional salient percept **(11).** It has been proposed that dominant eye seems to be leading or preferred eye with comparatively equal visual equity leading to stereopsis, binocular vision and this singularity of dominance of eye has been imported in various facet of life like shooting, photography sports such as golf **(14).**

The information coming from dominant eye is processed information more rapidly which may be attributed to more cortical neurons and efficient information processing from dominant eye **(11).** The dominant eye is important because it is the eye that the brain uses for precise positional information and hence its performance is vital in sports that require aim such as archery, darts or shooting, golf, baseball and cricket **(15, 16, 17).**

An indication of laterality of ocular dominance may guide clinical decisions in considering some refractive and surgical interventions and management for its role in predicting patient satisfaction with mono-vision correction as in cataract surgery, refractive surgery, laser eye surgery and contact lens wear **(18, 19).** Patients with full thickness macular holes affecting the dominant eye suffer more visual disability and had to undergo surgery more often than patients with illness in their non-dominant eye **(20).** Eye dominance is described as “the eye controlling binocular function” and represents the tendency to prefer visual input from one eye to the other **(21).** Dominance may determine the deviating eye in strabismus **(22)** and is thought to be important in development and control of reading **(23)** and may have a plausible role to play in the aetiology of dyslexia **(24).** An association between eye dominance and binocular rivalry has also been demonstrated **(25).**

The Gundogan Test **(4)** is used to determine the eye dominance of an individual. The subjects are tested by means of the near-far alignment test. The subject is asked to keep two reference points in the horizontal eye-level plane **(26).**

Eye dominance has been appreciated in various facets and modules of vision but its association with the subgroup/module of color vision is still not clear, hence the present study was designed to evaluate and explore neurophysiological relevance and significance of dominant eye upholding the premise of visual autonomy and modularity of conscious perception of vision and to assess the ability of dominant eye to discriminate color as compared to that of non-dominant eye in young adults with similar educational background.

MATERIAL AND METHODS

The present study was carried out in the Department of Physiology in collaboration with the Department of Ophthalmology, SMS Medical College, Jaipur, India after obtaining approval from Institutional Ethics Committee and Research Review Board. Total 170 young adults in the age group of 18-25 years of both sex who were ready to volunteer and willing to take part in the study were included after screening them for normal visual acuity and normal ocular motility. Subjects with a history of ocular surgery, presence of ocular diseases such as strabismus, nystagmus, retinal pathology and/or any other co-morbid states like diabetes mellitus, hypertension etc. and subjects who were unable to communicate were excluded. Also the subjects were screened with IPPT for the presence of CCVD and if found, were excluded from the study. Each participant underwent a complete ophthalmological examination including tests for best corrected visual acuity, fundoscopy, perimetry, and slit-lamp bi-microscopy. The color vision was tested by using IPPT and normal color vision subjects were further tested by FM100 hue test for color discrimination ability. The DE assessment was carried out to all participants by using Gundogan method.

Ishihara Pseudoisochromatic Plate Test (IPPT) (3)

Presence of Congenital Color Vision Deficiency (CCVD) was investigated using the IPPT, which is in the form of a booklet. Each participant was screened with 38 Ishihara plates under day light during same time of the day with best corrected visual acuity. The plates were held at 75 cm distance from the subject. It was ensured that the time consumed for each plate should not exceed more than three seconds.

The Gundogan Test (4)

All the subjects were tested in the same laboratory conditions wherein two equal size black round shape reference points were used. The first point as a near point (NP) was on the middle of the fixed transparent thin glass board 0.4 m away from the eyes which had two centimeter schedules placed on both sides. The second reference point was a mobile far point (FP) 3.0 m away from the eyes on the wall. The subjects were asked to place their jaws and foreheads on the jaw support and headrest, and an elastic band was gently secured in order to avoid head movements. Then the subjects were asked to focus both eyes on the FP as the FP moved till it came at the same line with the reference NP. When the two points were overlapping in the same line, the subject was then directed to close one eye without moving his or her head and eyes. The subject was then asked whether points were shifting or not. If the reference NP shifted from the FP in the horizontal plane when one eye was closed, subject was asked to read the shifting distance between two points from the transparent board where centimeter schedule was placed on the two sides of the reference NP. The same procedure was repeated for the other eye. The eye representing minimum shifting distance between two points was accepted to be dominant. Some subjects who have very slight mismatches of shifting distance for both eyes were considered as both eye dominant and these few subjects were excluded from the study.

Farnsworth Munsell 100 Hue Test (2)

The test was done under best corrected visual acuity with using with a Farnsworth Munsell 100 Hue Test Kit (X RITE MUNSELL COLOR). It consists of four trays (panels) containing a total of 85 removable color reference caps (incremental hue variations) spanning the visible spectrum. The caps 85-21 (red/yellow) are arranged in first panel and the caps 22-42 (yellow/blue-green), the caps 43-63 (blue/green-purple), and the caps 64-84 (purple-red) are arranged in this order in the remaining 3 panels. A Total Error Score (TES) of 0-100 is considered normal for healthy individuals but related reciprocally to the test performance. In this study, the test was performed from a reading distance of approximately 40 cm. Color vision aptitude is detected by the ability of the test subject to place the color caps in order of hue. The usual time given was about 2.5 minutes for each row. The aim of the test was to arrange the shown color tiles in the correct order and any misplacement could point to some sort of color vision deficiency. The test was performed three times with two days gap in between the tests for two eyes, right eye and left eye during the same time of the day in order to ensure near similar illumination and lighting conditions.

The data so obtained in the form of TES was entered and tabulated in Microsoft Excel Office 2010. Qualitative data was expressed in rates and proportions and quantitative data was expressed in terms of mean & standard deviation and median. Categorical variables were statistically evaluated by Fisher's Exact test. Statistical analysis was performed with the SPSS, version 21 for Windows statistical software package (SPSS inc. Chicago, IL, USA). Probability was considered to be significant if p values were registered as less than 0.05 ($p<0.05$).

RESULTS

A total of 170 subjects participated in the study with a mean age of 18.62±0.91 years out of which 101 (59.42%) were males and 69 (40.58%) were females. When tested for eye dominance (irrespective of gender difference), 118 subjects (69.41%) showed right eye dominance and 52 subjects (30.59%) showed left eye dominance.

Table 1: Comparison between Mean and Standard Deviation of Total Error Score of Right Eye with Dominant Right Eye and Dominant Left Eye among young adults

	TEST EYE = RE	
	Mean	**SD**
Dominant Right Eye	73.28	22.29
Dominant Left Eye	85.06	24.42
P value	0.002	

Table 2: Comparison between Mean and Standard Deviation of Total Error Score of Left Eye with Dominant Right Eye and Dominant Left Eye among young adults

TEST EYE = LE		
	Mean	**SD**
Dominant Right Eye	89.01	25.51
Dominant Left Eye	69.37	19.59
P value	p<0.001	

Table 3: Comparison between Mean and Standard Deviation of Total Error Score of Two Eyes with Dominant Right Eye and Dominant Left Eye among young adults

TEST EYE = TE		
	Mean	**SD**
Dominant Right Eye	65.09	17.69
Dominant Left Eye	63.25	19.13
P value	0.546	

Table 4: Comparison of Mean Total Error Score of FM100Hue test between DE (RE+LE) and NDE (RE+LE) among young adults including males and females

	Mean	**SD**
Dominant RE+LE)	72.14	21.46
Non Dominant RE+LE)	87.89	25.15
P value	P<0.001	

Table 1 exhibits the mean and standard deviation of Total Error Scores FM100 hue test when right eye was tested and a comparison was made with regard to laterality of eye dominance as right/left. mean and standard deviation of Total Error Scores when right eye served as both test eye and dominant eye was 73.28±22.29 and 85.06±24.42 (right eye test eye) was not dominant. Similarly, Table 2 exhibits the mean and standard deviation of Total Error Score FM100 hue test when left eye served as test eye and compared in terms of dominance of right eye/left eye. mean and standard deviation of Total Error Scores when left eye happened to be the dominant eye was 69.37±19.59 in comparison to a score of 89.01±25.51 when right eye was dominant.

When a comparison was made between the TES of right dominant eye and left dominant eye for the test wherein two eyes were used during FM100 hue test (Table 3), the difference between the test performance of either of the dominant eye (left/right) was not statistically significant as exhibited by a TES of 65.09±17.69 when right was dominant and 63.25±19.13 when left eye was dominant.

When an overall comparison was made between the Total Error Score of FM100 hue test (Table 4) obtained with dominant eye and non dominant eye irrespective of their laterality and procedural specificity of the test eye (RE/LE/TE) , the difference so observed as 72.14±21.46 and 87.89±25.15 for dominant and non dominant eye respectively.

DISCUSSION

In healthy subjects the color vision discrimination performance is affected by race, age, sex and level of education. Age range has been proposed as the most important factor influencing color vision **(27, 28)**.This circumstance is attributed to the age-related decline in Lutein and Zeaxanthin pigments in macula **(29, 30).** Age-related changes in the crystalline lens, as well as myosis have also been demonstrated as negatively affecting the color vision in elderly **(26, 31).** Roy et al **(32)** carried out the Farnsworth-Munsell (FM100) hue test in north American subjects reporting optical factor of lenticular senescence as the chief contributor towards age-related color discrimination ability change. A model based on age-related changes in lenticular transmission density demonstrated high compatibility with the experimental data of observers with phakic eyes, indicating optical factors as one of the important cause for the age-related changes in the tasks of color vision **(33)**

To compensate for these physiological changes leading to differences in the Error Score of the FM100 hue test young adults with the age range of 18-25 years were included in our study. Karaca et al **(34)** reported that FM 100 hue test Error Scores decreased when education levels of the subjects increased but the inclusion of subjects with similar educational levels in the present study ensured freedom from the probable confounding effects of level of education.

IPPT and FM100 hue test were applied to subjects with visual acuity of 6/6 with refractive correction in our study. FM100 hue test is dependent on environmental factors for generating accurate and consistent results of color vision. It has been suggested that the distance between the light source and the eye in addition to the distance between the light source and the test, and the direction of the light were also significant **(4).** It was predicted that the light source affects the brightness of the colors and can lead to changes in the color quality of the pieces of hues due to the long-lasting effect of the temperature, therefore in order to adjust for the effects of illumination of the testing environment; it was planned to take advantage meet in natural daylight which as per the literature **(26)** should be preferred one in comparison to artificial lighting. The requirements specified in the literature were implemented in the present study and each test was applied in daylight at the same time in same condition **(26).**

Some studies **(30, 34, 36)** reported significant difference in the Total Error Scores between RE and LE, but the results were possibly confounded due to the effect of ‘learning’ that might have taken place in successive application of the test with different eyes in the same sitting. The present study took cognizance of this problem and planned to test the respective eyes (TE, RE, LE) of each subject one at a time after a gap of two days in between, during which the potentially confounding effect of ‘memorization and learning’ were duly taken care of.

The results of the present study demonstrated a correlation between the superiority in total error scores of any particular eye in comparison to the other eye when that particular side also happened to be the dominant side as evident from the statistically significant difference ($p<0.05$) between the total error scores between right dominant eye and left dominant eye when the test eye was right (Table.1) and between left dominant eye and right dominant eye when in fact the test eye was left (Table. 2).

When a comparison was made between the Total Error Scores of right dominant eye and left dominant eye when two eyes (Table. 3) were used during performance of FM100 hue test, no statistically significant difference was found in the Total Error Scores indicating the coveted operation of the dominant eye during the test and hence resulting in a relatively superior total error scores with both dominant and non dominant eye.

When a direct comparison of mean Total Error Scores of FM100 hue test was made between dominant eye irrespective of (right/left) and non dominant eye irrespective of (right/left) (Table. 4) in all the subjects taken together irrespective of gender, a Mean ± SD score of 72.14 ± 21.46 was obtained for the dominant eye while a score of 87.89 ± 25.15 was obtained for non dominant eye indicating a clear advantage in the prowess of the dominant eye in discriminating subtle differences in the hues of different color reference caps in the panels of FM100 hue test. The results obtained in the present study are in accordance to a previous study **(36)** wherein similarly superior Total Error Scores were deciphered in dominant eye.

CONCLUSION

The present study demonstrates that the singularity of eye dominance is evident even amongst the multifarious sensory percepts like color vision and possibly points towards a generalized notion in sensory perception wherein functional laterality in the cerebral hemispheres while achieving a phenomenal resource economy is accommodated and cleverly concealed at peripheral (end organ) as well as at perceptual levels.

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