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Colour Vision Performance Test

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Abstract
Colour vision is important in everyday life and colour vision deficiency generally lowers the quality of life. The objective of the study was to investigate colour vision performance through tests and measurements. The visual acuity tests were obtained using the Snellen letters while the Colour vision measurements were achieved through designed colour targets. A total number of 8 participants were tested. The results of the measurements further confirmed that having good visual acuity is necessary but not sufficient for good colour vision performance.
Keywords: Colour Vision, Visual Acuity, Snellen Letters, Ishihara, Dvorine Colour Test, Performance

1. Introduction

The importance of colour vision cannot be overemphasized and it is hypothesized that colour vision in the visual system evolved as a means of overcoming the extremely unfavourable lighting conditions in the natural environment of early vertebrates (Maximov 2000). Colours are the basic information carriers of any natural scene (Khan et al 1994). Daily life depends on colour to an enormous extent in education, packaging, medicine, sport, horticulture, transport, and many industrial activities (Fletcher and Voke 1985). Minor frustrations for the colour abnormal individual include weather forecast (because of the colour coding on the legends), light emitting diodes, traffic lights, purchasing clothing, bank tellers (normally in triplicate, each for a specified box) e.t.c. According to Lennie (1984), colour vision has attracted scientific attention for at least 275 years, though it was not until the nineteenth century that we began to understand it properly. Since then, Scientists have provided very precise descriptions of the phenomena of colour vision and provided much new information on the mechanisms of colour vision. The loss of information due to inadequate colour decoding prevents or slows down comprehension, increases reaction time and generally lowers the quality of life. 8% of men and 0.5% of women have colour deficiency or colour blindness in the civilized world. It is more prevalent among the whites than other racial groups (Kilborn and Beh 1934; Shuey 1936) and colour vision tests are necessary for different professions(Squire et al, 2005). In order for colour to be seen, electromagnetic energy has to reach the eye. An object is seen when light is reflected from it. If it looks green in daylight, then this must imply that it is only reflecting the green part of the light back to our eyes. The remainder of the spectrum is absorbed.

With regard to cost-effectiveness, labour planning always opts for the minimum amount of workers needed Colour vision deficiency is a condition in which certain colours cannot be distinguished, and is mostly due to an inherited condition. Red-Green colour deficiency (blindness) is by far the most common form, about 99%, and causes problems in distinguishing reds and greens. Another colour deficiency, Blue-Green also exits, but is rare and there are no commonly available tests for it. Abnormal colour vision interests a wide range of people, including the millions who realize that their appreciation of colour is 'defective', their families and many more who are responsible for the dangers and other consequences of their condition, including industrial and professional implications. The objective of this study was to perform tests and measurements to investigate the colour vision performance.

2. Theoretical Background

The optics of the eye bear a general resemblance to a camera system, but the way in which the retina image is processed into a mental image and stored for later use in the memory is almost infinitely complicated. The human eye's key features include: a highly-corrected optical design, repeatable geometry of materials, control by the brain, processing of retina information, interfacing with the brain from six different levels of sensor cells in the retina, colour vision, compression of data going to the brain, and the highly specific make up and orientation which enable each eye to function and memory of scenes to take place (Deckert 2008). The visual acuity of the eye is an important measure of its ability to function well.

2.1 Visual Acuity

Standard visual acuity is defined as the ability to see an object so small that the angle subtended at the eye is only one minute of arc or one sixtieth of a degree. Visual acuity is also defined as the reciprocal of the visual angle expressed in minutes of arc. Acuity is said to be normal if details in an object can be resolved with a visual angle of one minute of arc (Beynon 1985). Many factors affect visual acuity, which could be psychological, retinal location, target orientation, pupil size, state of mind, photoreceptor size, refractive error, eye movement, shape, distance, illumination conditions, age, hue, and background (Glezer et al 1974; Levi 1980; Longhurst 1973; Ike and Jwanbot 2002 and Kelton et al 1978). Visual acuity measurements are generally carried out using the Snellen letters which are the most widely used clinically. This is a primary test normally done to ascertain whether the person has normal or abnormal visual response. The black targets (Snellen letters) are normally presented at a standard reading distance of 6 meters. At each acuity level, different Snellen letters are presented for the subject or participant to identify the letter. Someone with 6/6 vision (visual acuity) is just able to decipher a letter that subtends a visual angle of *5 minutes of arc* (written *5'*) at the eye. (5' of arc is 5/60 of a degree, because there are 60' of arc in 1 degree.) What this means is that if you draw a line from the top of a 6/6 letter to the eye and another line from the bottom of the letter to the eye, the size of the angle at the intersection of these two lines at the eye is 5' of arc. (Also, the individual parts of the letter subtend a visual angle of 1' of arc at the eye.) It does not matter how far away something is from the eye; if it subtends an angle of 5' of arc at the eye, then a person with 6/6visual acuity will just be able to determine what it is. Now, someone with 6/6 visual acuity does not have "perfect" vision, since it is quite possible to see better than 6/6. The less the denominator in the visual acuity ratio, the better the acuity; and the greater the denominator, the worse the acuity. Therefore, 6/5 acuity is better than 6/6 acuity, and 6/9 acuity is worse than 6/6 acuity. Although 6/6 is "normal" visual acuity for most people, it is possible (and, in fact, very common) to be able to see better than that.

2.2 Colour Vision Theory

Colour processing begins at a very early level in the visual system (within the retina) through initial color opponent mechanisms. Opponent mechanisms refer to the opposing colour effect of red-green, blue-yellow, and light-dark in the X and Y cells of the retina. Visual information is then sent back via the optic nerve to the optic chiasm: a point where the two optic nerves meet and information from the temporal (contralateral) visual field crosses to the other side of the brain. After the optic chiasm the visual fiber tracts are referred to as the optic tracts, which enter the thalamus to synapse at the lateral geniculate nucleus (LGN). There are three categories of colour vision theory or model; three-components theory, opponent-colour theory and stage theory.

2.2.1 Three Components Theory:

This theory was briefly stated in 1807 by Thomas Young and was elaborated by Helmholtz about 50 years later. It is also known as the trichromatic theory of colour vision. It assumes the existence of three independent response mechanisms in the normal eye: one predominantly sensitive to long-wave light and yielding the response red; a second predominantly sensitive to middle-wave light and yielding the response green; and a third sensitive to short-wave light and yielding the response violet (Judd, 1966). The theory assumes that yellow is produced by the sum of red and green responses and that white is produced by the sum of equal amounts of red, green and violet responses. The theory fails to explain the way some colour stimuli appear to an observer. Colour vision is possible with two receptor types. However, not all colors can be seen.

2.2.2 Opponent-Colours Theory:

This theory was proposed and explained in detail by E. Hering in 1878. It is based on an analysis of sensations of colour rather than of the stimuli required to evoke them. It assumes that there are six independent unitary colours (red, yellow, green, blue, white and black), no one of which partakes of any other; that is for example, yellow is a basic colour in its own right, not a product of combining red and green. The Hering theory assumes that light is absorbed in the receptors by photopigments, that this absoption starts activity in the rest of the visual system and that this activity is directly responsible for the colours we see. This activity is not found in six separate systems, but in three opposing pairs of processes: black-white, yellow-blue and red-green. Black and white blend to produce gray but equal amounts of yellow and blue and of red and green cancel to zero (Judd 1966 and Goldstein 1989). The theory fails to explain certain types of "colour blindness" or deficiencies.

2.2.3 Stage –theory:

This is also called the zone theory of colour vision. According to Fletcher and Voke (1985). The rival theories of trichromatism and colour opponency competed until the stage theory was introduced principally by Muller, which incorporated the two views. The stage theory separates colour vision processing into a series of three stages or zones namely: photopigment stage, cone-response stage and optic-nerve stage. Signals resulting from the reception of light by the photoreceptors are modified at each successive zone often associated with a physiological level. The photopigment stage follows the three components theory based on the Young primaries. The cone-response stage follows an opponent-colours form and the optic-nerve stage is the opponent-colours formulation of Hering with red opposing green and blue opposing yellow. The two-stage theory is based on the retinal photopigment stage and the cone-response stage. There has been a considerable uncertainty as to precisely at what stage of the visual process the signals from the receptors can be said to be organized in opponent colours, whether this is in the retina, the optic nerve, or the occipital lobe of the cortex (Judd 1966).

3. Materials And Method

The investigations were carried out in two parts: Visual Acuity Measurements (Songden and Ike 2004; Beynon 1985) and Colour arrangement Test. All sessions were done under normal natural lighting room condition, which was good for near and distance acuity measurements. All subjects on glasses were tested without their glasses on to avoid any effect of such on the measurements. Since the focus of the work is on the colour performance, details of the visual acuity measurements are described in an earlier paper (Songden and Ike 2010).

3.1 Visual Acuity Measurements

Visual acuity measurements of the participants were carried out using the Snellen letters. The black targets were designed on the computer following established method (Songden and Ike 2004; Beynon 1985) and presented using power point on the computer screen. The standard reading distance of 6 meters was used. This was carried out in a spacious room in the Physics Laboratory of the University of Jos. At each acuity level, the different Snellen letters were presented one at a time.

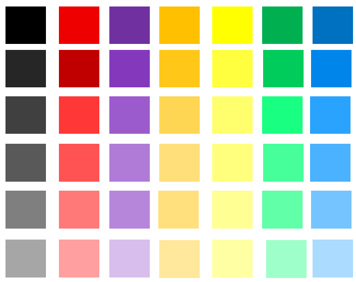
3.2 Colour Arrangement Test

Another test given to the participants was that of arranging different colour targets into colour groups according to their saturation. The targets were squares of dimensions 1.27 cm each and a total of 42 of them randomly scattered. They were designed using microsoft power point and each participant was told to group same or similar colour targets and then arrange them according to their saturation in decreasing order. They were not told the number of colour groups.

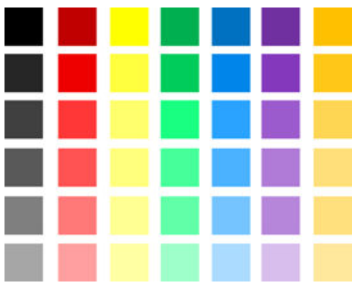
4. Results

Figure 1 and Table 1 show the results of the arrangements of the 8 participants. Figure 1(a) was the target designed and presented on power point for the arrangement according to the colour groups and saturation. Figure 1(b) was arranged by participant A, who missed two targets (interchanged the first two) in the red group. Figure 1(c) was arranged by participant B who got everything correctly and this was the case for C, D and H. Figure 1(d) was arranged by participant E who missed two targets (interchanged the first two) in the blue group. Figure 1(e) was arranged by participant F who missed thirty seven targets and figure 1(f) was by participant G who missed thirty three targets.

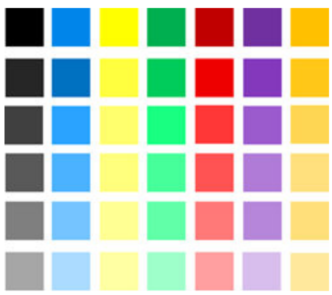
(a)



(b)



(b)



(d)

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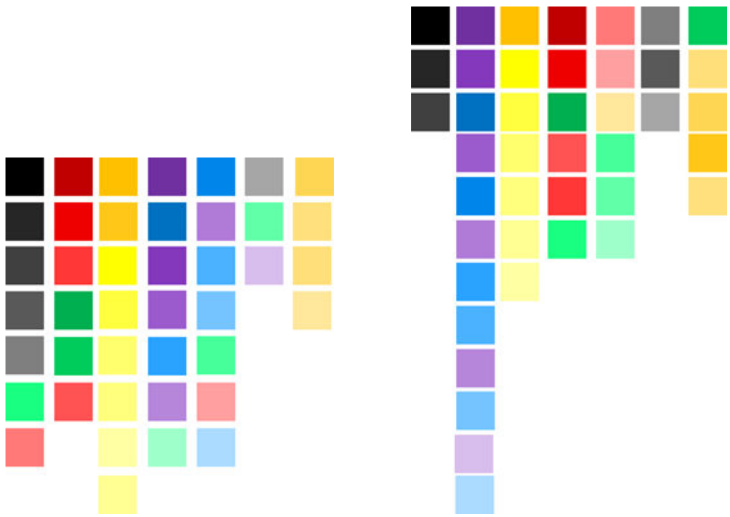

(e) (f)

Figure 1: Colour Arrangements by the Participants. Where (a) was the target presented for arrangement,(b) was arranged by A, (c) by B,C,D &H, (d) by E, (e) by F and (f) by G.

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Table 1: Results of Colour Arrangement.

	A	B	C	D	E	F	G	H
Age(yrs)	35	22	42	40	43	25	41	38
VA	6/5	6/5	6/6	6/6	6/6	6/6	6/5	6/6
Missed	2	0	0	0	2	37	33	0
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	5	4
5	5	5	5	5	5	5	4	5
6	6	6	6	6	6	21	6	6
7	8	7	7	7	7	11	7	7
8	7	8	8	8	8	6	8	8
9	9	9	9	9	9	23	19	9
10	10	10	10	10	10	36	10	10
11	11	11	11	11	11	7	9	11
12	12	12	12	12	12	8	21	12
13	13	13	13	13	13	9	37	13
14	14	14	14	14	14	19	13	14
15	15	15	15	15	15	20	14	15
16	16	16	16	16	16	10	15	16
17	17	17	17	17	17	39	16	17
18	18	18	18	18	18	41	17	18
19	19	19	19	19	19	40	18	19
20	20	20	20	20	20	42	11	20
21	21	21	21	21	21	37	12	21
22	22	22	22	22	22	38	42	22
23	23	23	23	23	23	13	22	23
24	24	24	24	24	24	14	23	24
25	25	25	25	25	26	15	24	25
26	26	26	26	26	25	16	20	26
27	27	27	27	27	27	18	40	27
28	28	28	28	28	28	17	39	28
29	29	29	29	29	29	26	38	29
30	30	30	30	30	30	34	41	30
31	31	31	31	31	31	28	31	31
32	32	32	32	32	32	29	32	32
33	33	33	33	33	33	22	25	33
34	34	34	34	34	34	12	33	34
35	35	35	35	35	35	30	26	35
36	36	36	36	36	36	31	34	36
37	37	38	37	37	37	25	27	37
38	38	37	38	38	38	32	28	38
39	39	39	39	39	39	33	35	39
40	40	40	40	40	40	27	29	40
41	41	41	41	41	41	35	36	41
42	42	42	42	42	42	24	30	42

5. Discussion And Conclusion

The results obtained indicated all the participants having good visual acuity. Four of the participants (B,C,D & H) arranged all the targets correctly. Participant A missed 2 only, which are the first two targets of the red group. This is not a serious problem and therefore negligible. The case of participant E is similar to that of A, missing only 2, in the blue group. Again this is negligible and not an indication of a colour deficiency. However, this is not the case with the participants F and G whose arrangements were clear indication of colour vision deficiencies.

This is a confirmation that having a good visual acuity is necessary but not sufficient for good colour vision. The participant F mixed up red and green and was able to group all the yellow targets though not all in the order of saturation. Participant G was also able to arrange all the yellow targets in one group and in the right order of saturation but grouped all the blue and purple targets together. The colour deficiencies of the two participants are closely related though that of F is worse. These results also confirmed those obtained in an earlier study (Songden and Ike 2010) using the Ishihara (1995) and Dvorine (1963) test plates and that colour targets arrangements could be used in colour vision determination.

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