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Development of Colour Modified Visual Acuity Charts and its Applicability in Detection and Diagnosis of Glaucoma

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ABSTRACT

Purpose: Glaucoma is the foremost cause of irreversible vision loss globally. Colour vision function is not a routinely employed vision function test in glaucoma assessment notwithstanding the assumption that colour vision is usually affected by glaucoma. This study developed four colour modified visual acuity charts (red-on-green, green-on-red, blue-on-yellow and yellow-on-blue optotype/background types) and evaluated its applicability in the detection of glaucoma.

Methodology: Masked experimental method was used in testing the visual acuities of fifty-four eyes from twenty-seven consenting respondents drawn from two groups- glaucoma and non-glaucoma respondents. They were measured individually across the four colour-modified charts and the traditional black-on-white chart which were all computer designed and projected in the same way automated visual acuity charts are projected. Their visual acuity performances on the modified colour charts were compared with their OCT results. An assumption of glaucoma was made when a difference of +/- ≥0.10 logMAR existed between the VA measured using the black-on-white chart and compared with the four colour test charts. Data were analysed; descriptive and inferential statistics were done with the level of significance set at ≤ 0.05.

Findings: When compared against their OCT results, none of the four modified colour vision test charts had sensitivity, specificity and accuracy up to 90%, with most falling below 80%. For all respondents, VA performance was best on the black-on-white and the yellow-on-blue charts, and worst on the green-on-red chart.

Unique Contribution to Theory, Practice and Policy: This study shows that although the human visual performance differs across different colour combinations; the use of these four colour modified charts as an alternative visual function assessment test for detection of glaucoma is not effective. This study has exposed the need for more studies to understand the visual responses in more colour combinations.

Keywords: *Colour Vision, Glaucoma, LogMAR Visual Acuity, OCT, Visual Acuity*

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INTRODUCTION

Glaucoma is a condition characterized by progressive loss of function of the retinal ganglion cells. It is a group of progressive optic neuropathies characterised by the degeneration of retinal ganglion cells and resulting changes in the optic nerve head (World Glaucoma Association, 2022). It is one of the foremost causes of irreversible vision loss worldwide (Uche et al., 2024). There is no known cure for glaucoma; its management is hinged on protecting residual vision and preventing further vision loss (Mamtora et al., 2022). The vision function changes associated with glaucoma include visual acuity changes, visual field changes, contrast sensitivity changes, photopic / scotopic vision changes, and colour vision changes. Visual acuity and visual field changes are the most commonly assessed visual functions in glaucoma patients. Colour vision function is not a routinely employed visual function test in glaucoma assessment despite the fact that studies have shown that colour vision is usually affected by glaucoma (Bayer et al., 2020; Li et al., 2022).

Colour vision is not a routinely assessed visual function in out-patient optometry clinic; and the reason for this could be due to the fact that most colour vision test instruments are not designed to measure progressive changes in colour vision. They are usually employed for detecting the presence or absence of known colour vision defects; and unlike in visual acuity and visual field assessments where progressive changes are measurable as they occur, traditional colour vision function testing is a yes or no assessment. Adapting colour vision assessment in a way different from the traditional colour vision test, such as integrating it into the traditional visual acuity test methods, has been unexplored over the years.

The traditional Snellen charts used for testing visual acuity is a black-on-white chart, notwithstanding the fact that real-life objects in space are not black-on-white and true visual acuity function ought to be a test of not just the ability of the eyes to discern two distinct points as distinct but the ability to discern two distinct points of light of different wavelengths (colour) in the same manner it will discern two distinct points of monochromatic light. It is assumed that the adaptation of colours into the traditional black letters on white background charts could reveal a different acuity from that of the traditionally measured acuity. This possible disparity in visual acuity measured using traditional black-on-white Snellen chart and that of the adapted coloured acuity charts could be a functional measure of the extent of affection of the glaucoma, perhaps preceding visual field and visual acuity losses. The possibility of redesigning a visual acuity chart that incorporates colour, and discovering the likelihood of disparity between visual acuity measurement whilst using it, compared to that obtained whilst using the traditional charts, as a possible early detection of vision function loss in glaucoma patients, has not been established.

METHODS

Ethics approval for this study was gotten from the Oyo State Research Ethics Review Committee, Ministry of Health, Oyo State, Nigeria (Ref. No. AD 13/479/493); and all participants for the study gave their informed consent. A total of 54 eyes were tested from twenty-seven consenting

respondents between 12 to 70 years, selected from the Police Eye hospital in Ibadan. Excluded were respondents who were blind in either of both eyes, who were previously diagnosed with any form of colour blindness, or who had any pathology, retinopathy or oculovisual conditions aside presbyopia, refractive errors and glaucoma.

The four colour modified visual acuity charts were designed from the traditional black-on-white LogMAR chart chosen because of its reliability, accuracy and result expression in decimal score. The traditional black-on-white chart; and the four developed colour-modified charts (Red-on-Green optotype/ background combination type, Green-on-Red, Blue-on-Yellow and Yellow-on-Blue types) are depicted in Figures 1, 2, 3, 4 and 5.

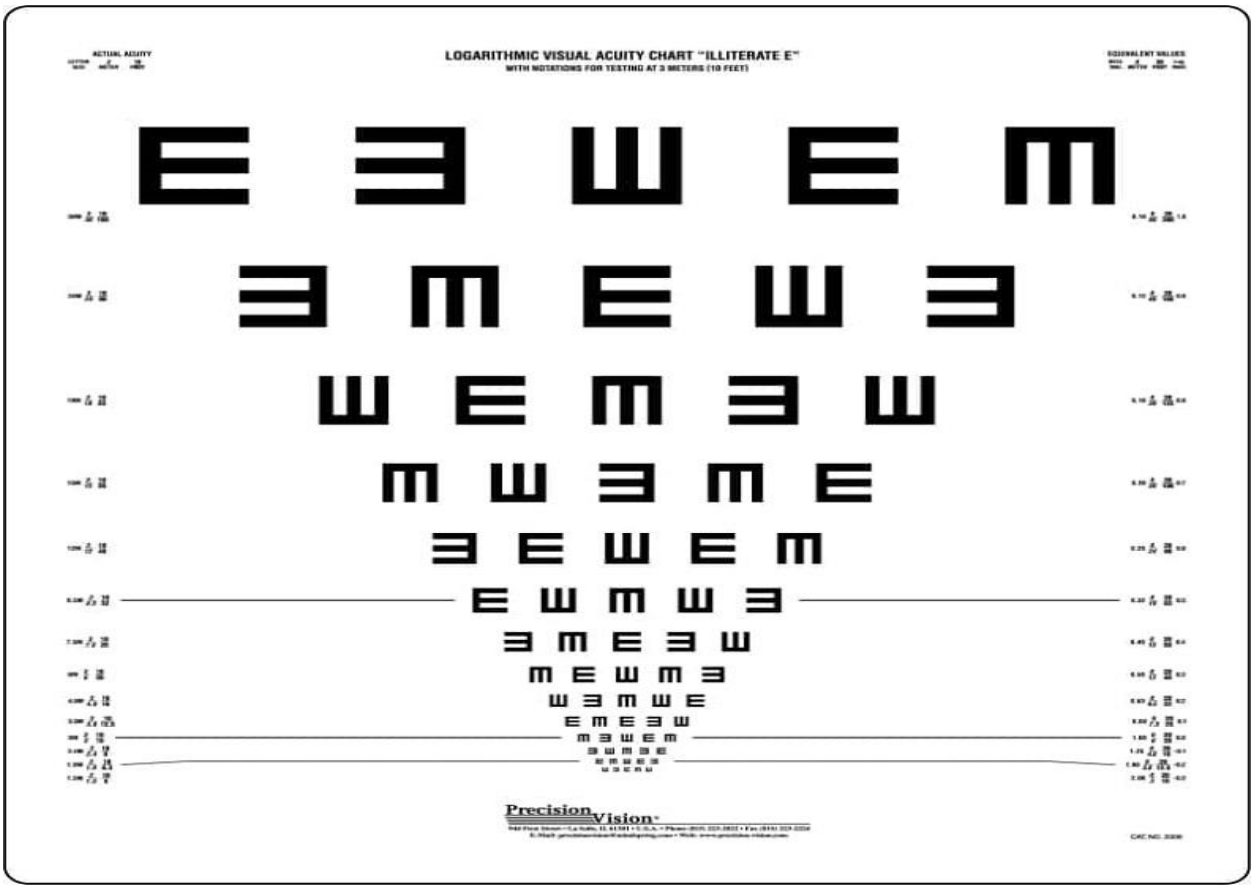

Figure 1. The traditional LogMAR acuity chart- Tumbling E optotype version. (Source: Precision vision)

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Figure 2. The Red-on-Green LogMAR visual acuity chart. (Designed by Researchers)

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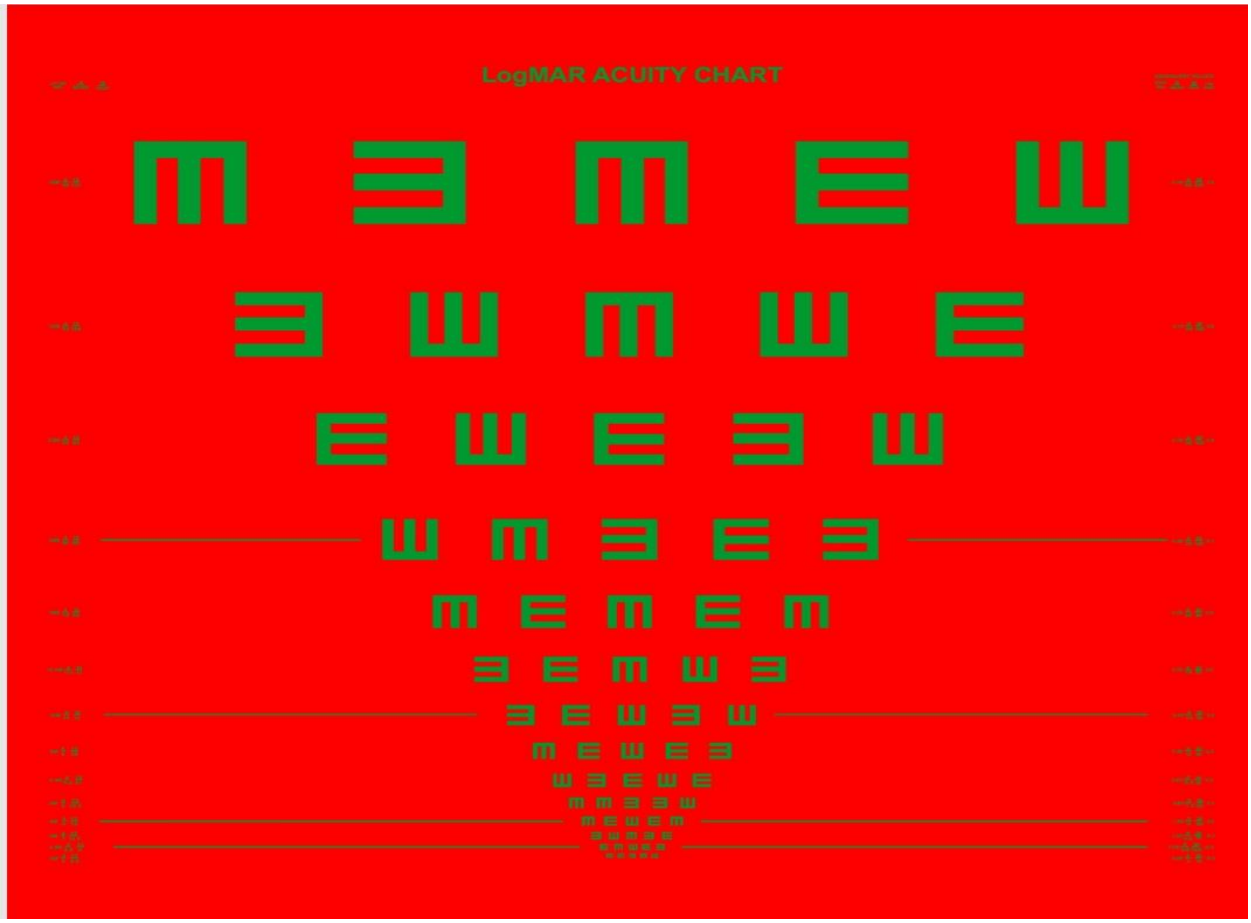

Figure 3. The Green-on-Red LogMAR visual acuity chart. (Designed by Researchers)

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Figure 4. The Blue-on-Yellow LogMAR visual acuity chart. (Designed by Researchers)

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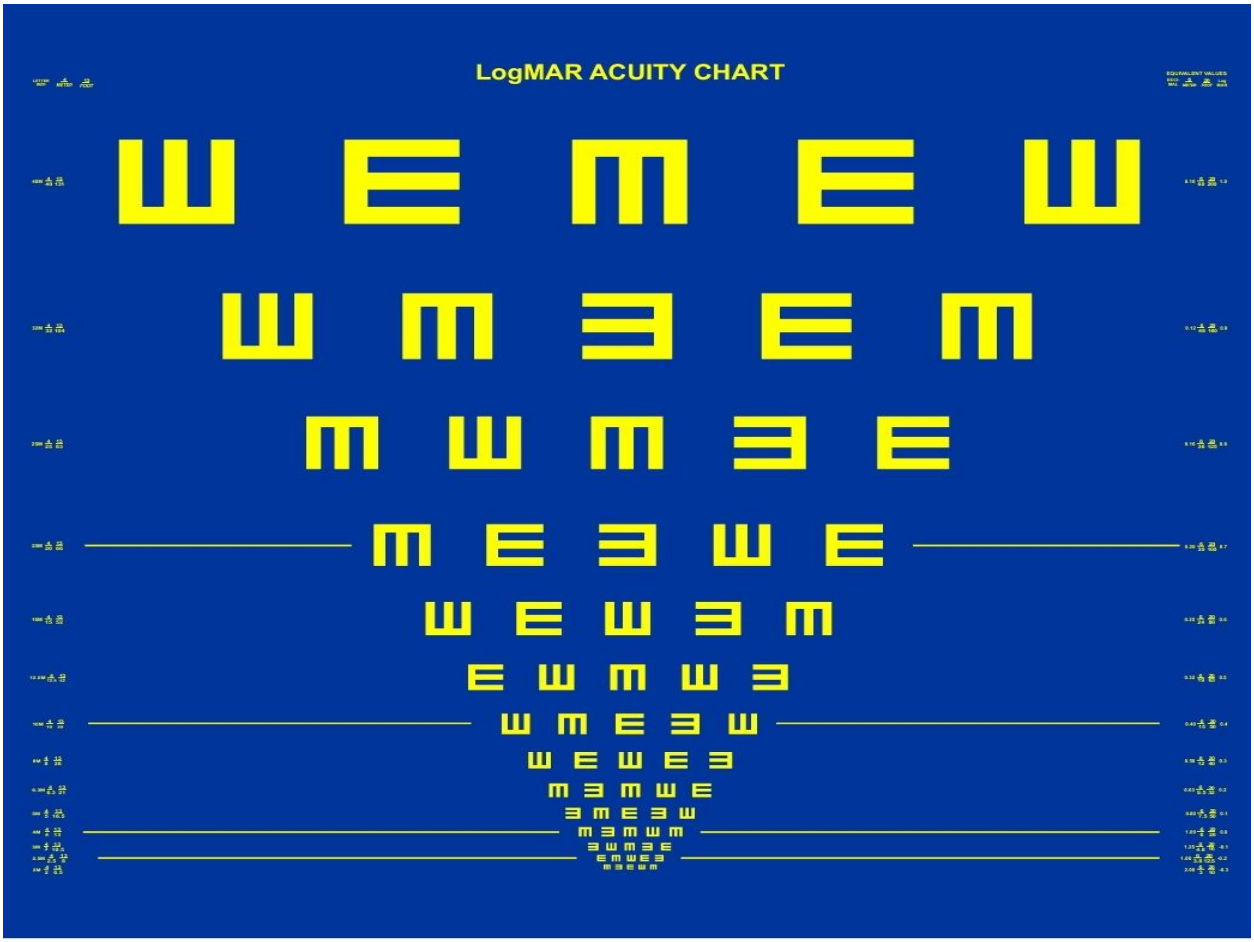

Figure 5. The Yellow-on-Blue LogMAR visual acuity chart. (Designed by Researchers)

The developed colour LogMAR charts were all designed and projected from a computer. The settings for the monitor device from where the charts were projected were: Display Resolution of 1600 x 900 pixels; 32-Bit Colour Depth; Screen Colour Enhancement of Brightness enhancement 0, Contrast 50 and Gamma 1.0; and Screen Brightness of 100%. The system ran on Intel(R) Core (TM) i7-4600M CPU @ 2.90GHz; 64-bit operating system, x64-based processor; and Windows 10 Pro operating system. An experienced software developer and graphics engineer designed the LogMAR chart on Windows Corel X8 incorporating all the features of the traditional LogMAR chart. The colour specification in the colour hue palette used were: White (R:255,G:255,B:255; C:0,M:0,Y:0,K:0; L:100,a:0,b:0; H:0,S:0,B:100; #FFFFFF); Black (R:0,G:0,B:0; C:29,M:27,Y:26,K:35; L:11,a:0,b:0; H:0,S:0,B:0; #000000); Red (R:255,G:0,B:0; C:0,M:39,Y:39,K:0; L:55,a:78,b:61; H:0,S:100,B:100; #FF0000); Green (R:0,G:250,B:0; C:65,M:0,Y:100,K:0; L:86,a:-77,b:76; H:0,S:0,B:100; #00FA00); Blue (R:0,G:0,B:255; C:89,M:78,Y:0,K:0; L:32,a:62,b:-107; H:0,S:0,B:100; #0000FF); and Yellow (R:255,G:255,B:0; C:2,M:0,Y:39,K:0; L:97,a:-16,b:90; H:60,S:100,B:100; #FFFF00).

The procedure for use of the designed colour-modified LogMAR acuity charts was the same as the procedure used in the regular black-on-white LogMAR acuity chart. The participant was comfortably seated 4m from the screen, was asked to close one eye with his palm and with the other opened eye was asked to indicate the directions of the E from the top rows downwards until he or she was no longer able to correctly identify the right direction. The designs of the charts were such that each chat has their letters arranged differently, to prevent possible memorization by the respondents.

All respondents were tested without grouping them. After all the experimental tests had been carried out before the OCT result was then used in classifying them into Glaucoma and Non-Glaucoma groups. This was important to avoid bias in the test process. The research assistants were divided into three groups and each group was blinded from each other- not having knowledge of the respondent's result from the other tests carried out by the other research assistant. The respondents were not serially attended to by all the assistants, but were randomly assigned to the various assistants for the respective assessments carried out by them. The first research assistant after obtaining informed consent, collected the biodata of the respondent, and assigned the respondent a code number. The biodata collected included age, sex and telephone number. The second assistant measured the respondent's visual acuity across the black-and-white the four developed colour charts and also performed refraction. He was not privy to the findings of either the first or third assistant. The third assistant then performed the fundoscopy using indirect ophthalmoscopy to estimate the C/D ratio and rule out any retinopathy, measured the intra-ocular pressure using Goldman's applanation tonometer, and then performed the OCT to classify the participant into Glaucoma or Normal / Non-Glaucoma group. The data collected from the participants were coded and analysed by the researchers using the IBM/Statistical Package of the Social Sciences (IBM/SPSS) version 25.0. All inferential results were analysed with α set at 0.05.

At the end of the collection of the visual acuities and the OCT, the glaucoma diagnosis results from the OCT (those with obvious nerve fiber layer compromise) were compared with the glaucoma diagnosis result obtained from all the modified colour vision charts. The hypothetic threshold for glaucoma diagnosis was any difference of more than 1-line Snellen acuity or 0.10logMAR between the visual acuity when measured on the black-on-white chart and when measured with the colour modified chart. The following were then calculated for the four different developed colour charts:

True-Positive (TP): When there is a visual acuity difference of more than 0.10LogMAR between the black-on-white chart and the particular colour chart; and there was also nerve fiber layer defect from the OCT result.

True-Negatives (TN): When there was no visual acuity difference or difference of less than 0.10LogMAR between the black-on-white chart and the particular colour chart; and there was also no nerve fiber layer defect from the OCT result.

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False Positives (FP): When there is a visual acuity difference of more than 0.10LogMAR between the black-on-white chart and the particular colour chart; but there was no nerve fiber layer defect from the OCT result.

False Negatives (FN): When there was no visual acuity difference or difference of less than 0.10LogMAR between the black-on-white chart and the particular colour chart; but there was nerve fiber layer defect from the OCT result.

The experiment was carried out individually for each eye (right and left eye separately). The result was analysed for each colour modified chart (red-on-green; green-on-red; yellow-on-blue; and blue-on-yellow chart). The Sensitivity, Specificity, Accuracy, Positive Predictive Value (PPV), and Negative Predictive Values (NPV) were calculated for each colour modified chart using the following formulae (Al-Ashwal et al., 2023; Trevethan, 2017):

Sensitivity=TP / (TP+FN); Specificity=TN / (TN+FP); Accuracy=(TP+TN) / (TP+TN+FP+FN); PPV=TP / (TP+FP); NPV=TN / (TN+FN).

RESULTS

Respondents' Socio-demographic Characteristics

A total of 54 eyes from 27 respondents were tested with a mean age of 45.26 years (SD=18.04); and nearly equal representation of sex as shown in Table 1.

Table 1: Respondents' Sociodemographic Characteristics (N=54)

Demography	Freq.	%
Sex		
Male	26	48.1
Female	28	51.9
Age (years)		
12-39	11	8.7
40-65	62	49.2
65 and above	53	42.1

Respondents' Oculovisual Assessment

The Ophthalmoscopy findings of the 54 eyes tested revealed that majority of the respondents had C/D ratios between 0.4 and 0.6. Hyperopia was their most common type of refractive error. Most (77.8%) of them had normal IOP ranging from 11-20mmHg; and OCT showed that only 40.7% of the respondents had Glaucoma. (Table 2)

Table 2: Respondents' Oculovisual Assessment (N=54)

Oculovisual assessment	Freq.	%
C/D ratio (Ophthalmoscopy)		
0.0 – 0.3	12	22.2
0.4 – 0.6	26	48.2
0.7 – 1.0	16	29.6
Refractive Error		
Emmetropia	9	16.7
Hyperopia	26	48.1
Myopia	9	16.7
Astigmatism	10	18.5
Tonometry		
11-20 (mmHg)	42	77.8
21 and above (mmHg)	12	22.2
OCT diagnosis		
Glaucoma	22	40.7
No Glaucoma	32	59.3
Total	**54**	**100**

Comparison of the VA of glaucoma respondents when measured using black-on-white charts and the four modified charts

Measuring the VA of the respondents using the modified colour charts was possible and posed no challenge to the respondents. Table 3 shows the t-test result analysing the differences between the VA when measured with the black-on-white charts (VA-B/W) and the four test charts (red-on-green (VA-R/G); green-on-red (VA-G/R); blue-on-yellow (VA-B/Y); and yellow-on-blue (VA-Y/B)). The paired t-test results revealed that at 95% CI, for the glaucoma respondents, only two of the modified charts- the red-on-green ($t = -6.288$, $p=0.000$) and the green-on-red ($t = -5.932$, $p=0.000$) had significant differences in VA when compared with the black-on-white chart. There was no statistically significant difference for the blue-on-yellow ($t = -1.658$, $p=0.112$) and the yellow-on-blue ($t = 0.087$, $p=0.931$) charts when compared with the black-on-white chart.

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Table 3. Paired Samples T-Test result comparing VA of black-on-white chart with four other colour modified charts for the Glaucoma respondents. (N=22 for all pairs)

		Paired Differences							
		Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	VA Black-on-White chart - VA Red-on-Green chart	-0.13636	0.10173	0.02169	-0.18147	-0.09126	-6.288	21	0.000
Pair 2	VA Black-on-White chart - VA Green-on-Red chart	-0.15364	0.12148	0.02590	-0.20750	-0.09977	-5.932	21	0.000
Pair 3	VA Black-on-White chart - VA Blue-on-Yellow chart	-0.04091	0.11571	0.02467	-0.09221	0.01040	-1.658	21	0.112
Pair 4	VA Black-on-White chart - VA Yellow-on-Blue chart	0.00182	0.09757	0.02080	-0.04144	0.04508	0.087	21	0.931

Comparison of the VA of non-glaucoma (normal) respondents when measured using black-on-white charts and the four modified charts

The paired t-test results for the non-glaucoma (normal) respondents revealed that at 95% CI, only two of the modified charts- the red-on-green ($t = -7.855$, $p=0.000$) and the green-on-red ($t = -6.889$, $p=0.000$) had significant differences in VA when compared with the black-on-white chart. There was no statistically significant difference for the blue-on-yellow ($t = 0.088$, $p=0.930$) and the yellow-on-blue ($t = 1.445$, $p=0.158$) charts when compared with the black-on-white chart. (Table 4)

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Table 4. Paired Samples T-Test result comparing VA of black-on-white chart with four other colour modified charts for the non-glaucoma (normal) respondents. (N=32 for all pairs)

		Paired Differences							
		Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	VA Black-on-White chart - VA Red-on-Green chart	-0.09938	0.07157	0.01265	-0.12518	-0.07357	-7.855	31	0.000
Pair 2	VA Black-on-White chart (LogMAR) - VA Green-on-Red chart (LogMAR)	-0.12313	0.10110	0.01787	-0.15958	-0.08667	-6.889	31	0.000
Pair 3	VA Black-on-White chart (LogMAR) - VA Blue-on-Yellow chart (LogMAR)	0.00125	0.08015	0.01417	-0.02765	0.03015	0.088	31	0.930
Pair 4	VA Black-on-White chart (LogMAR) - VA Yellow-on-Blue chart (LogMAR)	0.01687	0.06606	0.01168	-0.00694	0.04069	1.445	31	0.158

Evaluating the accuracy, sensitivity and specificity of modified colour VA charts using the difference in VA between the traditional black-on-white chart and the colour modified charts as a possible means for detection of glaucoma.

For this study, an assumption of glaucoma was made when the difference between the VA measured using the black-on-white chart and the colour test chart was of ≥0.10 logMAR. The assumption was then compared against the OCT diagnosis of glaucoma. The cross-tab analysis of each colour test chart diagnosis compared against the OCT diagnosis is shown in Tables 5a-d. The Sensitivity, Specificity, Accuracy, PPV and NPV for each chart was calculated.

Red-on-Green chart diagnosis against OCT diagnosis

From Table 5a; True Positive (TP): 18; True Negative (TN): 17; False Positive (FP): 15; False Negative (FN): 4.

Using the formulae: Sensitivity=TP / (TP+FN); Specificity=TN / (TN+FP); Accuracy=(TP+TN) / (TP+TN+FP+FN); PPV=TP / (TP+FP); NPV=TN / (TN+FN):

Sensitivity = 18 / (18+4) = 0.818; Specificity = 17 / (17+15) = 0.531; Accuracy = (18+17) / (18+17+15+4) = 0.648; PPV = 18 / (18+15) = 0.546; NPV = 17 / (17+4) = 0.810

Table 5a. Cross-tabulation of glaucoma diagnosis by Red-on-Green chart against OCT diagnosis

		Glaucoma Diagnosis by Red-on-Green chart		
		Glaucoma	**No Glaucoma**	**Total**
OCT Diagnosis	Glaucoma	18	4	22
	No Glaucoma	15	17	32
Total		33	21	54

Green-on-Red chart diagnosis against OCT diagnosis

From Table 5b, the following was extrapolated:

TP: 17; TN: 12; FP: 20; FN: 5.

Sensitivity = 17 / (17+5) = 0.531; Specificity = 12 / (12+20) = 0.375; Accuracy = (17+12) / (17+12+20+5) = 0.537; PPV = 17 / (17+20) = 0.459; NPV = 12 / (12+5) = 0.706

Table 5b. Cross-tabulation of glaucoma diagnosis by Green-on-Red chart against OCT diagnosis

		Glaucoma Diagnosis by Green-on-Red chart		
		Glaucoma	**No Glaucoma**	**Total**
OCT Diagnosis	Glaucoma	17	5	22
	No Glaucoma	20	12	32
Total		37	17	54

Blue-on-Yellow chart diagnosis against OCT diagnosis

From Table 5c, the following was extrapolated:

TP: 13; TN: 22; FP: 10; FN: 9.

Sensitivity = 13 / (13+9) = 0.591; Specificity = 22 / (22+10) = 0.688; Accuracy = (13+22) / (13+22+10+9) = 0.648; PPV = 13 / (13+10) = 0.565; NPV = 22 / (22+9) = 0.710.

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Table 5c. Cross-tabulation of glaucoma diagnosis by Blue-on-Yellow chart against OCT diagnosis

		Glaucoma Diagnosis by Blue-on-Yellow chart		
		Glaucoma	**No Glaucoma**	**Total**
OCT Diagnosis	Glaucoma	13	9	22
	No Glaucoma	10	22	32
Total		23	31	54

Yellow-on-Blue chart diagnosis against OCT diagnosis

From Table 5d, the following was extrapolated:

TP: 6; TN: 26; FP: 6; FN: 16.

Sensitivity = 6 / (6+16) = 0.273; Specificity = 26 / (26+6) = 0.813; Accuracy = (6+26) / (6+26+6+16) = 0.593; PPV = 6 / (6+6) = 0.500; NPV = 26 / (26+16) = 0.619.

Table 5d. Cross-tabulation of glaucoma diagnosis by Yellow-on-Blue chart against OCT diagnosis

		Glaucoma Diagnosis by Yellow-on-Blue chart		
		Glaucoma	**No Glaucoma**	**Total**
OCT Diagnosis	Glaucoma	6	16	22
	No Glaucoma	6	26	32
Total		12	42	54

Table 5e summarised the Sensitivity, Specificity, Accuracy, PPV and NPV for the four colour test charts. From the summary, most of the charts scored low in sensitivity. The highest sensitivity score was from the Red-on-Green chart, which with a sensitivity of 81.8% can be regarded as poor, especially considering the fact that glaucoma has no cure, can lead to blindness and thus, all diagnostic tests should be as close to 100% as possible. The Yellow-on-Blue chart had the worst sensitivity score.

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Table 5e. Summary of the Sensitivity, Specificity, Accuracy, PPV and NPV for the four test charts.

	Red-on-Green chart	*Green-on-Red chart*	*Blue-on-Yellow chart*	*Yellow-on-Blue chart*
Sensitivity	81.8%	53.1%	59.1%	27.3%
Specificity	53.1%	37.5%	68.8%	81.3%
Accuracy	64.8%	53.7%	64.8%	59.3%
PPV	54.6%	45.9%	56.5%	50.0%
NPV	81.0%	70.6%	71.0%	61.9%

Grading the VA performances across all charts, for both normal and the glaucoma respondents.

It is evident from this study that there are differences in VA of respondents when measured with Black-on-White chart and compared with the four test charts; and the observed differences exists for both the glaucoma and non-glaucoma respondents (Tables 3 and 4). The ranking of all the five charts based on respondents' VA performance is shown in Figures 6a – d.

Glaucoma respondents

Figures 6a and b respectively shows the best and worst VA performances for the charts for the glaucoma respondents.

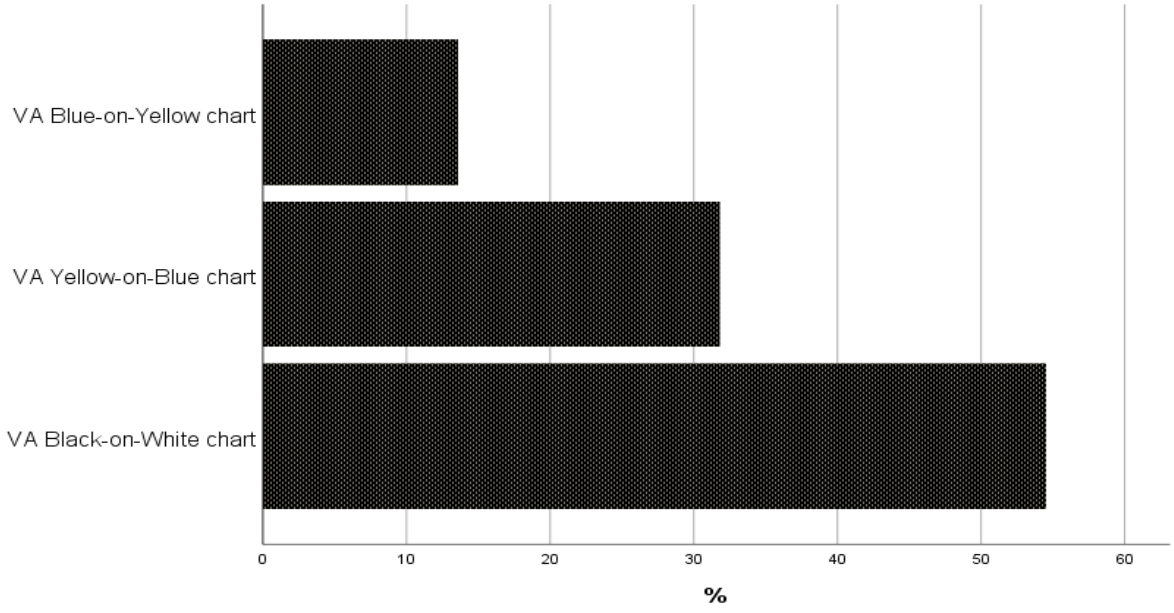

Figure 6a. Bar chart showing the charts with the best VA performance for Glaucoma respondents.

For the Glaucoma respondents, VA performance was best on the Black-on-White test chart (54.5% of the glaucoma respondents reported best VA in this chart type), whilst the Yellow-on-Blue had the second-best VA performance (31.8%).

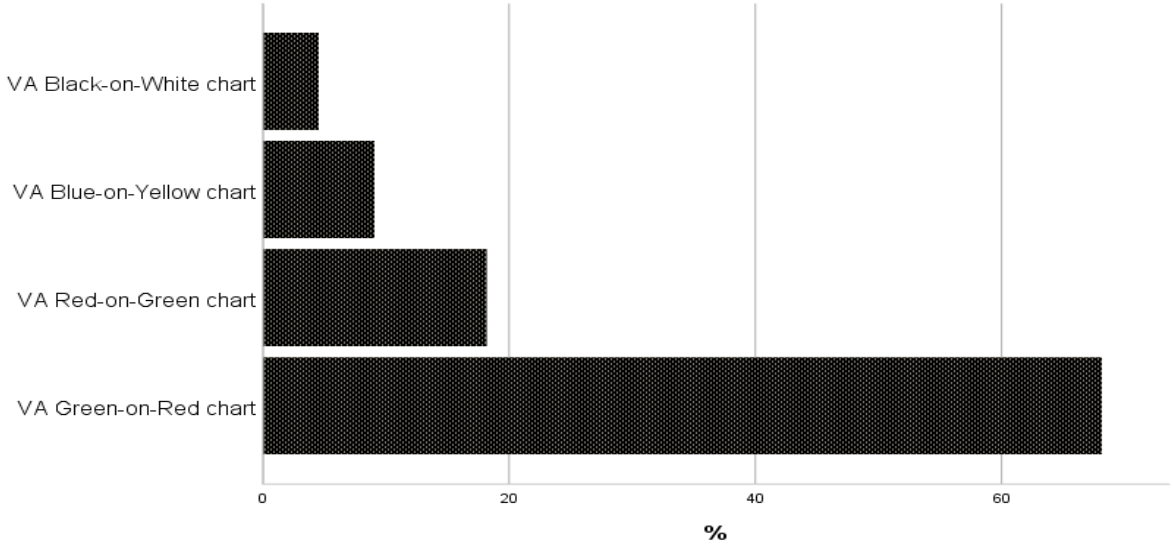

Figure 6b. Bar chart showing the charts with the worst VA performance for Glaucoma respondents.

The worst VA performance for the Glaucoma respondents was recorded on the Green-on-Red chart (68.2%), followed by the Red-on-Green chart (18.2%).

Non-Glaucoma (Normal) respondents

Figures 6c and 6d respectively shows the best and worst VA performances for the test charts for the non-glaucoma (normal) respondents.

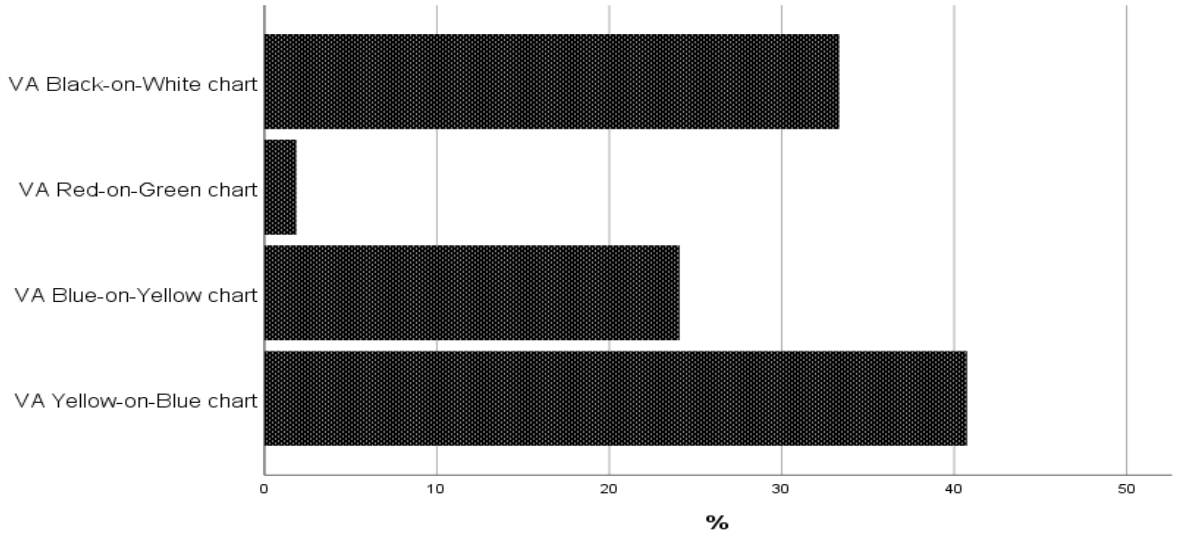

Figure 6c. Bar chart showing the charts with the best VA performance for Non-Glaucoma (Normal) respondents.

For the Non-Glaucoma (Normal) respondents, the Yellow-on-Blue test chart recorded the best VA performance (40.7% of the glaucoma respondents), whilst the Black-on-White had the second-best VA performance (in 33.3%).

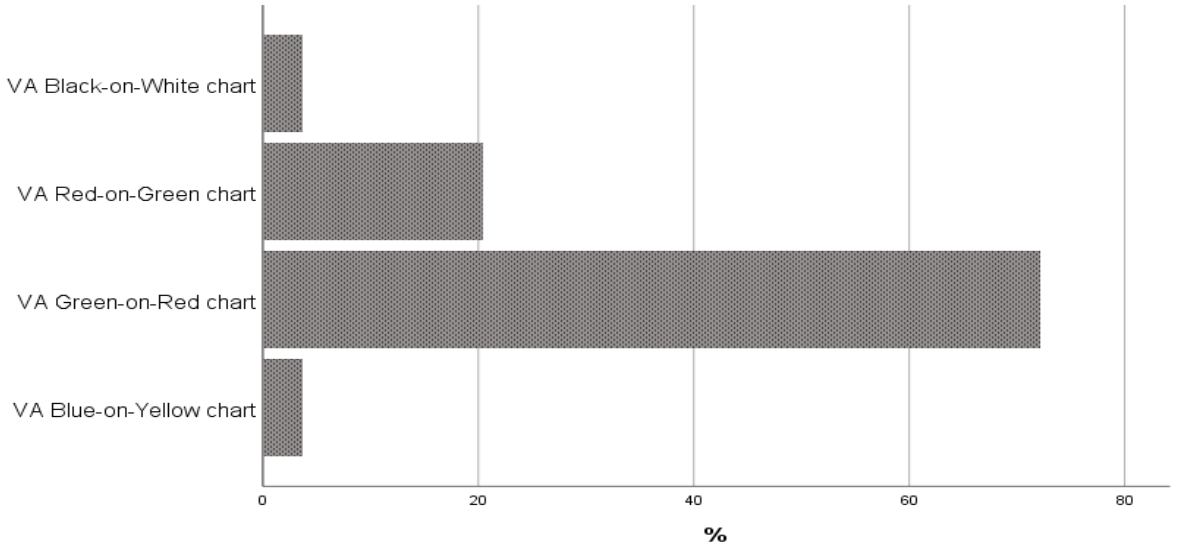

Figure 6d. Bar chart showing the charts with the worst VA performance for Non-Glaucoma (Normal) respondents.

For the Non-Glaucoma (Normal) respondents, the Green-on-Red chart recorded the worst VA performance (72.2% of the glaucoma respondents), whilst the Red-on-Green had the second-worst VA performance (20.4%).

DISCUSSION

Studies over the years have pointed to the fact that colour vision is usually affected in people with glaucoma (Bayer et al., 2020) and using the commonly available colour vision tests, they have highlighted changes in colour vision function of glaucoma patients. It was therefore expected that these modified colour vision test charts used in this study will show a difference in VA when compared with the traditional black-on-white chart, if truly glaucoma affects colour vision. Our study was able to show that indeed there is a statistically significant difference in the VA responses of glaucoma respondents for the red-on-green and green-on-red charts when compared with the black-on-white chart, which is similar to the red-green anomaly in glaucoma patients observed from the study by Niwa et al. (2014). However, the result from this study cannot be concluded to imply a red or green colour vision anomaly for the glaucoma respondents because the same statistically significant difference was equally observed in the VA responses of the normal respondents for the red-on-green and green-on-red charts when compared with the black-on-white chart. Therefore, this study using the modified colour charts can only be emphatic in highlighting the fact that all respondents (both normal and glaucoma respondents) do not have the same level of visual acuity function with varying colour scenario; the red-on-green and green-on-red pattern having the worse visual acuity functions. This difference in visual acuity across different colour scenarios has been similarly highlighted in the study by Chen and Muhamad (2022), where they showed that colour can influence the visual resolution outcome of the human eyes.

In evaluating the applicability of the modified colour VA charts as an effective means of screening for glaucoma, the assumption was that glaucoma results in a +/- ≥0.10 logMAR.difference between the VA measured using the black-on-white chart and that measured when using the colour test chart. After comparing the diagnosis of glaucoma based on this assumption against the OCT result, it was observed that none of the four modified colour vision test chats had Sensitivity, Specificity and Accuracy of up to 90%, with the most falling below 80% (Table 4.5e). This therefore meant that the use of these colour modified charts as an alternative visual function assessment method for early detection of glaucoma was not effective. Although no literature was found utilising this study's modified charts to assess glaucoma patients, a very old study by Pacheco-Cutillas et al (Pacheco-Cutillas et al., 1999) foretold that the challenges of using colour vision tests in screening for glaucoma include low specificity and sensitivity. They attributed it to the fact that in the actual sense, colour vision assessments only tested colour vision function of the fovea, whereas glaucoma typically affects peripheral retinal functions before getting to the fovea.

The findings from this study also revealed that for both the glaucoma and normal respondents, the visual acuity performance varied across different colour charts. For the glaucoma respondents, VA

performance was best on the black-on-white test chart followed by the yellow-on-blue chart. Their worst VA performance was recorded on the green-on-red chart followed by the red-on-green chart. Similarly, for the normal respondents, the yellow-on-blue test chart recorded the best VA performance followed by the black-on-white chart. The green-on-red test chart recorded their worst VA performance followed by the red-on-green chart. This implies that the level of resolution of the human eyes for objects on different colour backgrounds is not the same. Some colours result in better acuity than others. This is somewhat related to the findings from the study by Arslan et al. (2020), where they observed that for different colour-resolution tasks placed a distance away, the visual resolution across different colours were not the same. They however attributed these differences to be caused by refractive error. From this study, it can be therefore assumed that the human visual system (in both normal and glaucoma affected vision) is able to resolve details more easily when it is viewed from a yellow-blue or black-white object-background space than when it is viewed from a red-green object-background space.

CONCLUSION AND RECOMMENDATION

In conclusion, although colour vision function is not a routinely employed vision function test in glaucoma assessment despite the fact that some studies in the past have claimed that colour vision is usually affected by glaucoma, this study which aimed to adapt the traditional black-on-white Snellen's visual acuity (VA) chart by incorporating four different colour optotype-background combinations, showed that whilst there were differences in the VA of glaucoma respondents when measured using the traditional Snellen's black-on-white chart and compared with the colour adapted charts, these differences were equally displayed by the normal (non-glaucoma) respondents. All respondents (both normal and glaucoma respondents) do not have the same level of visual acuity across varying colour scenario; the yellow-on-blue and black-on-white charts elicited the better visual acuities, whilst the red-on-green and green-on-red combination had the worse visual acuities. When used as a glaucoma screening test, the modified colour charts results when compared with OCT diagnosis showed unimpressive sensitivity, specificity and accuracy; implying that the use of these colour modified charts as an alternative visual function assessment for the detection of glaucoma was not effective.

It is therefore recommended that the use of various modified colour charts in routine assessment of visual function should be explored in optometry clinics; not be used as a diagnosis or screening for glaucoma, but as an objective assessment of the visual function of patients across various possible colour scenario. And, because colour vision function has potentials for deeper understanding of the visual system, it is recommended that more studies in this field be encouraged.

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