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A comparative study of an Ishihara colour vision online test to the traditional Ishihara handbook at Bindura University of Science Education.

By

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A dissertation that was submitted to fulfil a portion of the criteria for the Bachelor of Science Honors in Optometry (HbScOpt).

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Declaration

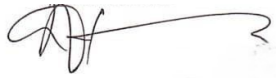
I Aisha Msusa , declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the University of Zimbabwe

Aisha Msusa



APPROVAL FORM

We hereby certify that we have read this thesis prepared under our direction by Aisha Msusa, titled, "A comparative study of an Ishihara colour vision online test to the traditional Ishihara handbook at Bindura University of Science Education," and recommend that it be accepted as fulfilling the dissertation requirements for the degree of BSc Honours in Optometry HBsc Opt OPTC 405



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Dedication

This dissertation is dedicated to my parents, Mr and Mrs Msusa, my loudest cheerleaders. You mean the world to me and it is your support that got me this far. This one is for you.

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Abstract

Introduction: The Ishihara test is a widely used method for detecting red-green colour vision deficiencies. However, online versions of the Ishihara test, which have been limitedly researched for validity and reliability are increasingly being used for screening purposes. This study compared the effectiveness of the traditional Ishihara handbook with an Online Ishihara version in detecting colour vision deficiencies.

Aim: This study was a comparative analysis of the traditional Ishihara handbook and an online Ishihara version at Bindura University of Education. The research assessed the validity, reliability, consistency and accuracy between these two methods of colour vision testing.

Setting: This study was conducted at Bindura University of Science Education Optometry Clinic in Bindura, Zimbabwe 2026.

Methodology: One hundred and eighty participants (n= 180), between the ages of eighteen and twenty-five years at Bindura University between April to June 2026 were recruited to the study. Data was collected on the number of correctly identified plates.

Results: The findings were expected to be the same for both the Ishihara traditional handbook and the online Ishihara.

Conclusion: The results suggested that the online Ishihara colour vision test performs similarly to the traditional Ishihara handbook in detecting red-green colour vision deficiencies among BUSE students. Therefore, the online version may serve as a reliable screening tool where access to the traditional handbook is limited.

DEFINITION OF CONCEPTS

Colour vision- The ability to distinguish and identify lights and objects on the bases of their spectral properties (Wandell 1995).

Colour vision deficiency- It is the diminished capacity to perceive colors or variations in color vision. It is a genetic disorder or abnormality in one of the retina's three classes of cone cells that mediate color perception. (Nathans 1999)

Anomaloscope- An optical tool used to measure color vision by contrasting a variable-intensity yellow light with a set of constant-intensity red and green lights. (Pokorny, Smith 1999)

Achromatopsia- A group of congenital disorders in which colours cannot be perceived and VA is reduced particularly in brightly illuminated environments. (Kohl et-al., 2004)

Chromatic- Colour with hue such as blue, yellow, red or green. (Wandell 1995)

Sensitivity- Refers to tests to designate an individual with disease as positive. Because there are fewer false negative findings from a highly sensitive test, fewer disease cases are overlooked.

Specificity A highly sensitive test has a low false-positive rate for identifying a healthy person as negative. There are few false positive outcomes when a test is extremely specialised.

LIST OF ABBREVIATIONS

CVD - Colour Vision Deficiency

VA – Visual Acuity

PIP – Pseudoisochromatic Plate

HRR – Hardy Randy Rittler

BUSE- Bindura University of Science Education

CHAPTER 1: INTRODUCTION

Color vision, a remarkable aspect of human perception, allows individuals to distinguish between different wavelengths of light, translating into the rich tapestry of colors we experience daily. This ability is not merely aesthetic; it plays a crucial role in various aspects of life, from identifying ripe fruit and recognizing traffic signals to understanding complex data visualizations and pursuing specific career paths.

Globally, color vision deficiency, commonly known as color blindness, affects a significant portion of the population. While prevalence varies by demographic, it is estimated to affect approximately 8% of males and 0.5% of females of Northern European descent, with slightly different rates in other populations (Birch 2008). The most common forms involve difficulties distinguishing between shades of red and green.

Given its importance and prevalence, accurate and accessible color vision assessment is paramount. This research project at Bindura University will compare the traditional Ishihara handbook with an online Ishihara version to evaluate their respective effectiveness and user experience in diagnosing color vision deficiencies, ultimately aiming to optimize screening methods within the university community.

BACKGROUND

Perception of colour is enabled by the cone photoreceptors cells found in the retina. (Dain 2004). Cone photoreceptors come in three different varieties, each with different spectral sensitivity and containing different photopigment. This corresponds to the three primary colours, namely, red (long wavelength), green (medium wavelength) and blue (short wavelength) resulting in the term trichromacy (Rabin et-al., 2021). Therefore, the interaction of various light energy wavelengths, the absorption of light by photosensitive pigments in the retina's cone cells, and their subsequent neuronal interpretation within the visual system are the sources of colour perception. Not all people possess trichromacy, some are partially colour deficient or completely colour blind (achromatic) perceiving no colour at all. Over the past 100 years, clinicians have used a standard set of colour vision tests including pseudoisochromatic

plate (PIP) tests such as Ishihara or Hardy-Randy-Rittler (HRR), the Farnsworth D-15 and the anomaloscope (Ishihara,2020). The PIP tests are used to detect/screen for colour vision deficiencies (CVDs) whereas the D-15 is used to provide a diagnostic type (such as protan or deutan) and severity grading (such as mild, moderate or severe). The anomaloscope is considered the standard for the most accurate screening and determining the diagnostic type, whereas severity categorization does not have a single standard.

Hardy, Rand and Ritter in 1945 divided or characterised the pseudoisochromatic plates into vanishing, hidden, transformation and classification plates, each with its own technique to enable the identification of a specific colour vision related deficiency (Hardy et-al., 1945). The vanishing plates contain a figure or sign that is easily identified by the normal trichromat but not by the colour-defective individual. Only people with good vision can see the figure but colour-blind people will not see anything. The classification plates allow for the differentiation of a protan from a deutan individual, that is, red- and green-blind persons. A person with a protan defect will see a figure only on the right side, while a person with a deutan defect will see it on the left side. In the hidden plates, normal trichromats will not see the figure but the figure will only be seen by those with a red-green colour deficiency. A person with perfect colour vision will not be able to see the figure. In the transformation plate, two figures are embedded in the background, with the appropriate colour and lightness contrast (Hardy et-al., 1945). An individual with a colour deficiency will see a figure that is different from that seen by an individual with normal trichromatic vision.

In recent years, digital versions of common tests along with newly developed computer-based assessment have surfaced (Goulort et-al., 2018). Computer-based testing offers several advantages; however, it is not widely adopted. In this study we will evaluate the performance of an online version of Ishihara colour vision test with the traditional Ishihara handbook. The extent to which the traditional one will compare to the online is currently unknown. Hence, this study will determine the sensitivity and specificity of the Ishihara Colour deficiency test depending on the presentation mode (that is online or handbook).

PROBLEM STATEMENT

The Ishihara test is used for screening or detecting CVD, whereas the Farnsworth D15 provides a diagnostic classification (such as protan and deutan) and severity grading (mild, moderate or severe). The anomaloscope is considered the standard for the most accurate screening and determining diagnostic type. In recent years, digital versions of the Ishihara have been developed for computer-based assessment. However, producing an accurate digital colour vision test for public use remains challenging as the product must reliably reproduce specific chromaticities across various computer systems and display hardware.

There are currently a number of online versions of the Ishihara color vision tests available, indicating broad implications for public self-screening.

Aim

To compare the traditional Ishihara handbook and an online Ishihara version at Bindura University of Education, assessing the validity, reliability, consistency and accuracy between these two methods of colour vision testing.

Objectives

-Compare the results of the online test with the traditional handbook test among BUSE students between the age of 18-25.

- Determine the prevalence of colour vision deficiencies among BUSE students between the ages of 18-25.

- Assess the effectiveness of the online test as a screening tool for colour vision deficiencies among BUSE students between the age of 18-25.

- To compare the diagnostic accuracy of the online Ishihara test with the traditional Ishihara handbook test among BUSE students between the age of 18-25.

- To identify potential factors influencing the differences in test results between the online and traditional Ishihara tests (e.g., screen resolution, lighting conditions) among BUSE students between the age of 18-25.

Hypothesis

The study hypothesis is that there will be no significant differences between the presentation methods of the online and handbook versions of the Ishihara test.

Research question

Is there a difference in the presentations of the online and handbook version of the Ishihara colour vision test?

Significance of Study

The significance of this study at Bindura University is multi-faceted, impacting individuals, the university community, and broader healthcare practices:

- Optimized Screening Practices for Universities: The study will provide valuable data on the efficacy and user experience of both traditional and online color vision tests within a university setting. This direct comparison will help Bindura University, and potentially other institutions, make evidence-based decisions about adopting the most efficient, accessible, and cost-effective screening methods. It could lead to a more streamlined and student-friendly screening process.J

Contribution to Digital Health and Telemedicine: By evaluating the reliability of an online color vision test, this research contributes to the growing field of digital health. If the online version proves comparable to the traditional method, it could advocate for wider acceptance and use of remote diagnostic tools, especially in contexts where access to specialists or traditional materials is limited.

Conclusion

Color vision is a vital sensory function crucial for daily life and academic pursuits, yet color vision deficiency significantly impacts a substantial portion of the population, particularly males. While traditional methods like the Ishihara test have long been the gold standard for assessment, the advent of digital technologies has introduced online alternatives. This study at Bindura University aims to critically compare the efficacy, usability, and appropriateness of these traditional and digital color vision screening methods. By doing so, we seek to identify the most suitable approach for our university's context, ultimately enhancing student support, informing career guidance, and contributing to more effective diagnostic practices in an increasingly digital world.

CHAPTER 2: LITERATURE REVIEW

Introduction

This chapter provides a comprehensive overview of existing research on colour vision deficiencies, Ishihara tests and online colour vision testing. It synthesises current knowledge, highlighting key findings, methodologies and Gaps that inform the study of the comparative study of online and traditional Ishihara handbook at Bindura University of Science Education.

Colour Vision Deficiencies

The term colour vision deficiency refers to all hereditary or acquired disorders of colour perception, as a result of which the function of the colour-sensitive cones on the retina of the eye is impaired. (Hasrod, Rubin 2023). The consequences are weakness in the perception of individual colours (dichromasia) or all colours (achromasia). The most prevalent type of color deficiency is red-green color deficiency, sometimes known as red-green blindness, which a general name for protanopia (red deficiency), protanomaly (red weakness), deuteranopia (green deficiency), duetaranomaly (green weakness) and tritanopia (blue deficiency) (Gordon 2024). The symptoms of colour vision disorders can range from mild to severe or vary in severity. Achromatopsia (colour blindness) refers to a condition of those who can't/cannot distinguish colours and shades of colours (Dain 2004).

Prevalence of Colour Vision Deficiencies

Colour vision deficiencies, commonly referred to as colour blindness, affect a significant portion of the global population. The prevalence of colour vision deficiencies varies across different populations, sexes, and ethnicities. According to recent studies, approximately 8% of males and 0.5% of females worldwide have some form of color vision deficiency (Neitz et al., 2011)

The most common type of colour vision deficiency is red-green colour blindness, which affects around 95% of individuals with colour vision deficiencies. This type of colour blindness is more prevalent in males, as it is inherited in an X-linked recessive manner.

Geographically, the prevalence of colour vision deficiencies varies. In Europe, particularly in Northern Europe, the prevalence is around 8% in males, while in Africa, the pooled prevalence is approximately 2.71% (Birch 2012). In Asia, the prevalence ranges from 4% to 6.9% in males (Birch 2012).

The impact of colour vision deficiencies is significant, affecting daily life, education, and certain careers. Individuals with colour vision deficiencies often face challenges in tasks that require colour recognition, such as reading maps, interpreting traffic signals, and recognizing warning signs (National Eye Institute 2020).

Types of Colour Vision Deficiencies

Three terms are used to describe CVD, these are proranopia, deuteranopia and tritanopia. The longer the wavelength cone photo-pigment, which corresponds to the red colors of the visible electromagnetic spectrum, is absent or abnormally functioning in a protanope, while the middle and shorter cone photo-pigments, which corresponds to the green and blue electromagnetic spectrum wavelengths, respectively, are absent or abnormally functioning in deuteranope and tritanope respectively. (Birch 1996).

Protanopia has a significant decrease in sensitivity beyond 600nm (a shortening of the red end of the spectrum), whereas normal observers exhibit maximal sensitivity at a wavelength of 555nm (as measured in a vacuum). In tritanopia and deuteranopia, the maximum shift is less noticeable. The maximum sensitivity in tritanopia is 555nm while in deuteranopia it is 565nm. At the blue end of the spectrum, tritanopes are less sensitive. According to Birch (1996), the relative luminous efficiency of anomalous trichromats is between that of trichromats and the related red-green deficits and blue-yellow dichromats.

The two forms of CVDs are commonly referred to as blue-yellow deficits and red-green deficiencies. (Gouras 2009).

Red-green color deficiencies

According to Cole, red-green color deficits resulting from issues with either the L-cones or M-cones are the most prevalent types of color deficiencies, affecting more men than women (1 in 12 males had red-green CVDs compared to only 1 in 200 women). Individuals that exhibit these kinds of color deficits mix up colors in the red, yellow and green spectrum. (Fairchild

2005).Deuteranopia, a type of dichromatism in which there are only cone pigments, is caused by the lack of M-cones (green-sensitive retinal photoreceptors). CVD is often inherited and sex-linked. An abnormal shift in the green-sensitive retinal receptors causes deurerabomaly, a less severe hereditary and sex-linked form of red-green color deficiency that mildly affects red-green hue discrimination in 5% of European males. Deuteranomaly is characterized by difficulties in differentiating between different shades of the same color in the red- yellow-green spectrum. (Birch 1996), (Francois 1961).

Protanopia affects approximately 1% of men and is inherited and gender-linked. It can be defined as a loss of L-cones caused by the complete absence of red retinal photoreceptors and protanopes confuse colours in the red-yellow-green spectrum (Gouras 2009). A severe form of CVD called protanopia causes a person to only see light wavelengths between 400 and 650 nm rather than the more common 700 nm. Orange-tinted reds may look as very dim yellows, purple colors are indistinguishable from blues, pure reds are invisible and seem black and all orange-yellow green hues appear as yellow hue. (Cole 2007). Protanomaly is a less severe form in which an altered spectral sensitivity of red-sensitive retinal receptors (closer to green receptor response) results in poor red-green hue discrimination and subjects have problems distinguishing different shades of the same colour in the red-yellow-green spectrum (Birch 1991).

Blue-yellow colour deficiency

Tritanopia is a rare chromosome 7 deficiency that affects both men and women equally because it is not sex related. When there are only two cone pigments and no blue-sensitive retinal receptors, this deficiency, which is linked to an absent or abnormal S-cone photo pigment occurs. As a result, blues appear greenish, yellows and oranges appear pinkish and purple colors appear deep red. The condition’s milder version is called tritanomaly. (Birch 1996).

Impacts of Colour Vision Deficiencies

Colour vision deficiencies, commonly referred to as colour blindness, can have significant impacts on an individual's daily life, education, and career choices. People with colour vision

deficiencies often face challenges in tasks that require colour recognition, such as reading maps, interpreting traffic signals, and recognizing warning signs.

In education, colour vision deficiencies can affect a student's ability to understand colour-coded learning materials, graphs, and charts. This can lead to difficulties in subjects like science, art, and design, potentially impacting academic performance. Teachers and educators can help mitigate these challenges by using alternative methods to convey information, such as texture or pattern-based representations.

Career choices can also be limited for individuals with colour vision deficiencies. Certain professions, such as aviation, design, and medicine, require accurate colour recognition, making it difficult or impossible for people with colour vision deficiencies to pursue these careers. For example, pilots need to be able to distinguish between different colours on navigation charts and instruments, while designers rely on colour to create effective visual communications.

In daily life, colour vision deficiencies can lead to misunderstandings or embarrassment in social situations. For instance, an individual with colour vision deficiency may struggle to match clothes or identify ripe fruit. Assistive technologies, such as colour-correcting glasses or smartphone apps, can help alleviate some of these challenges.

Social interactions can also be affected, as people with colour vision deficiencies may rely on others to interpret colour-related information. This can lead to feelings of dependence or embarrassment, highlighting the importance of awareness and understanding.

Traditional Ishihara Handbook Test

The pseudoisochromatic test, which includes the Ishihara test, HRR test, CVTME and Neitz test are all based on colour confusion. These tests have been designed from a known chromatic deficiency and can only reveal the type of dyschromatopsis (deficiency in the perception of colours) for which they were performed (Hardy et-al., 1945). The Ishihara test and CVTME detect only deutan and protan defects by the axes along which confusions are made (Fish et-al.2021), (Birch 2008), (Ionica, Gastaud 2009), (Birch 1989), (Squire et-al., 2005). The Neitz and Richmond HRR tests evaluate defects in all three axes of colour confusion (protan, deutan and tritan) (Neitz, Neitz 2001), (Block et-al., 2004), (Cole et-al., 2006). Although the pseudoisochromatic tests are rapid and easy to perform, they are insufficient for an accurate diagnosis of the axes and degree of chromatic deficiency. It is recommended to repeat the test for greater reliability (Block et-al., 2004).

The Richmond HRR test provides the clinician with more information than the Ishihara test. (Dain 2004). Although the Ishihara test is known because of its superior specificity and high sensitivity in identifying protan and deutan deficits, it has no plates for tritan, and the number of errors that are made gives little indication of severity of deficiency. (Block 2004). Its four protan deutan classification plates are also not very reliable. (Cole et-al., 2006.) The Richmond HRR pseudoisochromatic tests are ideal to evaluate colour vision from 3 years old, (Cole et-al.2006) while the Ishihara test, Neitz test of colour vision and CVTME are adequate for children aged 4–6 years. (Neitz , Neitz 2001).

Fish et al evaluated the validity, reproducibility and feasibility of the CVET for the diagnosis of congenital dyschromatopsia among 155 children using the Ishihara pseudoisochromatic cards, Farnsworth D-15 Hue standard test and the CVET (Fish et-al., 2021). They found that the CVET is a rapid, reliable, reproducible and accessible test for young children to be used for the diagnosis of congenital dyschromatopsia (Cole et-al., 2006). Ideal colour vision testing should reliably detect, categorise and grade the severity of protan, deutan and tritan CVDs. Cole et-al reported results from the new Richmond HRR pseudoisochromatic test for colour vision. The Ishihara, the Farnsworth D-15 test, the Medmont C-100 and the type 1 Nagel anomaloscope were used to diagnose colour vision.

The design of the 2002 HRR test is based on re-engineered principles (Bailey et-al.2004). The test consists of 12 plates that each show one or two symbols, such as a triangle, circle or cross. The patient is asked to identify each symbol's shape and location, which may be one of the plate's four quadrants. The authors concluded that the new HRR test is as good as the Ishihara test for the red–green CVDs, but unlike Ishihara it has plates for the detection of the tritan deficiency. The original HRR sometimes failed tritan, although not always. The colours of tritan symbols in the updated exam is more in line with the tritan confusion and is less saturated.

Development and Effectiveness of Traditional Handbooks

In 1917, Shinobu Ishihara developed 38 colour charts which can review potential red-green colour deficiency (Ishihara 1960). The Ishihara tests set contains a total of 38 test charts with pictures of dots in different sizes and colour shades. The dots and circles in the image are

arranged in a specific pattern to form numbers and figures that people with normal colour vision are able to see. People with colour vision deficiencies or defects (CVD) are only able to recognize the numbers on the Ishihara charts to a limited extent. Some figures and numbers on the Ishihara test charts are only visible to people with CVD and invisible to other people with normal colour vision.

The Ishihara handbook test results give an indication of whether a CVD is present or not, however, a quantification can only be made if the results are cross-checked. The Ishihara test was originally developed for the detection of CVD and is considered the most effective test for the purpose. Birch used 401 participants to assess the Ishihara test effectiveness in identifying red-green colour deficits. (Birch 2012). The 38-plate edition of the Ishihara was found to be an effective screening procedure for protan and dueutan color deficiency based on the combined sensitivity of the transformation and disappearance plates.

Limitations of the Traditional Handbook

It must be pointed out that the test is time-consuming especially when examining a large group of populations and is not able to recognize the severity of visual impairment. (Van Staden et al, 2018). The Ishihara Pseudo-isochromatic plate test has been compared to modified electronic equivalents in a number of investigations. The effectiveness of projected colour slides in identifying colour deficiencies was compared to the traditional Ishihara pseudo-isochromatic plate approach (Gündogan et al, 2005). The authors concluded that using projected slides was a quick and efficient way to identify colour deficiencies.Ganley et al conducted a study in which a similar method of projected colour slides were used as a method of mass screening of red-green colour deficient individuals. The sensitivity of the screening system was 100%, with authors suggesting that projected colour slides are potentially useful as a screening method to detect individuals with red-green color deficiencies (Ganley et al, 1997). Hoffmann and Menozzi used ten patients who were normal and ten who were colour deficient to compare the conventional Ishihara test to computer-based screening approach. The computer-based approach accurately distinguished people with color deficiencies from those without, according to the results, even if the spectral emission of the monitor and the reflected daylight using traditional Ishihara plates differed. (Hoffmann and Menozzi, 1998). However, 20% of normal trichromats fail the test, according to Rodriguez-Carmona et-al., indicating limitations in its applicability (Rodriguez-Carmona et al, 2012).

Online Colour Vision Tests

The online Ishihara test for color vision is a digital adaptation of the traditional Ishihara plates, designed to screen for red-green color deficiencies. Users are presented with a series of plates, each containing a circle of dots appearing in various colors and sizes. Within this circle, a number or a path is embedded, formed by dots of a different color. (Ishihara 1917). Individuals with normal color vision can easily discern the embedded number or path, while those with certain types of color blindness (protanopia or deuteranopia) will have difficulty or be unable to see it. The online version typically requires users to input what they see, and the results are then interpreted to indicate the presence and, sometimes, the type of color deficiency.

Development and effectiveness of online Ishihara

The development of the online Ishihara test marks a notable digital leap from Shinobu Ishihara's foundational 1917 creation. Initially, these digital versions often directly replicated the static images of the physical plates. However, contemporary online tests have evolved to include interactive features, such as direct on-screen input or timed responses, which can refine the diagnostic process (Cole, Lian 2018).

Regarding effectiveness, online Ishihara tests generally show strong reliability in identifying red-green color deficiencies, maintaining the core principles of the original test (Birch, 1997). Their benefits are that they offer accessibility, convenience, and instant results, making them excellent tools for initial self-assessment or widespread screening. Nevertheless, their accuracy can be swayed by variables like monitor calibration, ambient light conditions, and image resolution, which may not perfectly mimic the color fidelity of printed plates (Almutairi et al., 2022).

Conclusion

Given the limitations, there is a need to improve and standardize the Ishihara test. Several authors have modified its presentation format by using projected slides for mass screenings achieving a specificity and sensitivity of 100%. Campbell et al (2016) investigated the effectiveness of printed and digital iPad versions of the Ishihara charts in screening CVD charts and found that electronic presentation forms produced comparable results to traditional printed formats.

CHAPTER 3: RESEARCH METHODOLOGY

Introduction

Research methodology refers to specific procedures or techniques by which the research was conducted their study. This chapter addresses the research design, setting, sampling procedure, research instruments, ethical considerations, data collection and analysis. All the procedures by which the study was conducted are explained in this chapter.

Study Design

This was a comparative study using convenient, non-probability sampling of undergraduate student participants from the Bindura University of Science Education community. Visual acuity at distance and near was assessed and ophthalmoscopy was performed to rule out the presence of ocular pathology.

Study Period

The study period was from October 2025 to June 2026 at Bindura University of Science Education by researchers in collaboration.

Study population

The population of the study was all students who are 18-25 years from Bindura University of Science Education as they are representative of the total population for the study.

Reseach Instruments and materials

- Online Ishihara test platform

- Traditional Ishihara handbook (38-plate edition, only plate 1-12 used in the research)
- Data collection sheets for manual recording
- Demographic questionnaire (e.g., age, sex, Family History of CVD)

Validity and Reliability of Instruments

Reliability refers to the degree to which an instrument can be dependent upon to yield consistent results if used repeatedly over time on the same participant or if used by different researchers (Creswell and Creswell, 2018). The researcher used instruments which were valid and reliable that is a standard Snellen's chart for Visual Acuity measurement, a standard Ophthalmoscopy to rule out pathologies, a standard Ishihara book and a computer with standard settings

Sampling Method

Convenient sampling was used to recruit equal numbers of male and female.

Sample Size

The sample size for this comparative study was determined using a formula for estimating proportions. With a desired precision of 5%, confidence level of 95%, and estimated prevalence of color vision deficiency of 8% (sensitivity and specificity of the online Ishihara color vision test in detecting color vision deficiencies), the required sample size was approximately 113 participants. To account for potential dropouts and ensure sufficient power, 150-200 participants were aimed. This sample size allowed for reliable comparisons between online and traditional Ishihara tests.

Inclusion Criteria

Students from Bindura University of Science Education aged 18 to 25 years were recruited to the study and they signed a consent form.

Exclusion Criteria

Participants who presented with ocular pathology or VA worse than 6/6 (corrected) were excluded from participating in the study.

Data collection

The data of this research was collected at Bindura University of Science Education from April 2026 to May 2026.

Questionnaire

The Data collection instrument comprised of 4 sections.

A pilot study was conducted to validate the questionnaire. A sample size of 20 BUSE students who did not participate in the study, meeting the inclusion criteria participated in the pilot study.

Section A: Demographic information

Age, gender, faculty and any known history of color vision deficiency (CVD).

Section B: Recording Sheet

A standard Ishihara recording sheet was the tool used to document raw data for both the traditional Ishihara handbook and the online Ishihara. It comprised of the following columns:

Plate Number:

Identifying each plate (e.g., Plates 1–12).

Target Response:

The number or line path that a person with normal vision should see.

Participant Response (Handbook): What the participant identified while viewing the physical handbook.

Participant Response (Online): What the participant identified while viewing the digital screen.

Error Classification: A binary "Correct/Incorrect" marker for each plate to calculate total scores.

Section C: Environmental and Hardware variables (Online Ishihara)

Device specifications -Screen type

-Resolution

-Screen Size

Display settings -Brightness

-Colour Temperature

-Blue light filters

Section D: Final clinical interpretation based on standard protocols:

Passing Score: Typically, 3 or more correct out of 12 red/green test plates for the concise edition.

Clinical examination

Clinical test procedures

The two tests, online and handbook Ishihara colour vision, were carried out sequentially in a monocular manner beginning with the right eye for uniformity followed by the left eye after 30-minute intervals. The Ishihara manual and online edition were distributed in a random order. Testing began with the demonstration plate (plate 1) which is designed to be visible to all individuals. The transformation plates (2-9), where a person with normal colour vision sees the intended image while someone with colour vision impairment sees a different image, came next. and finally, the participant read the 3 remaining plates.

The online version of the Ishihara that was used (https://colormax.org/color-blind-test/) as it replicates the 38-plate handbook version. Participants were seated in front of a laptop at a test distance of 50-70cm with the researcher controlling the transition of the slides in sequential

order on the monitor. The researcher recorded the participants' spoken responses on a typical Ishihara recording sheet.

Data analysis

Statistical analysis of the data was performed using the IBM SPSS version 27 for windows (IBM Corporation., Armonk, NY). Data of all participants was scored and the percentage of incorrect responses was evaluated for both presentation methods (handbook or online). The normality of the variables was analysed. Descriptive statistics will be performed using the mean ±SD. The level of significance was set at 95% (p-value < 0.05).

ETHICAL CONSIDERATION

Ethical clearance

The proposal of this study was submitted to the Bindura University of Science Education Research Board Committee for approval. The ethical clearance-approval number: BUSEREC/0191/2026.

Permission to conduct study

Upon receiving the ethical clearance, the formal letter was submitted to the Students Affairs to seek permission to conduct the study at BUSE.

Anonymity and confidentiality

The process of ensuring confidentiality refers to a researcher's responsibility to prevent data from being linked to participants or being divulged for purposes other than research. The researcher kept participants' identities, anonymous and confidential and data was not linked to individual participant.

Informed consent

Participants received a comprehensive information about the study and they provided written consent prior to participation.

Principle of justice

The principle of justice refers to a participant's right to fair selection and treatment. The researchers selected study participants fairly for reasons directly related to the research problem. Participants' privacy was respected including the extent and circumstances to which their information is shared. The researcher respected and honoured all agreements made with participants. Participants' privacy rights were upheld. The participant had the right to determine the extent to and circumstances under which their private information will be shared.

Principle of beneficence

The researcher secured the participant's well-being protecting them from discomfort and harm. The study was non-invasive and posed no foreseeable risks.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter presents the findings of the study comparing the traditional Ishihara handbook and the online Ishihara colour vision test among students aged 18–25 years at Bindura University of Science Education (BUSE). The results are presented using descriptive statistics in tables and narrative form.

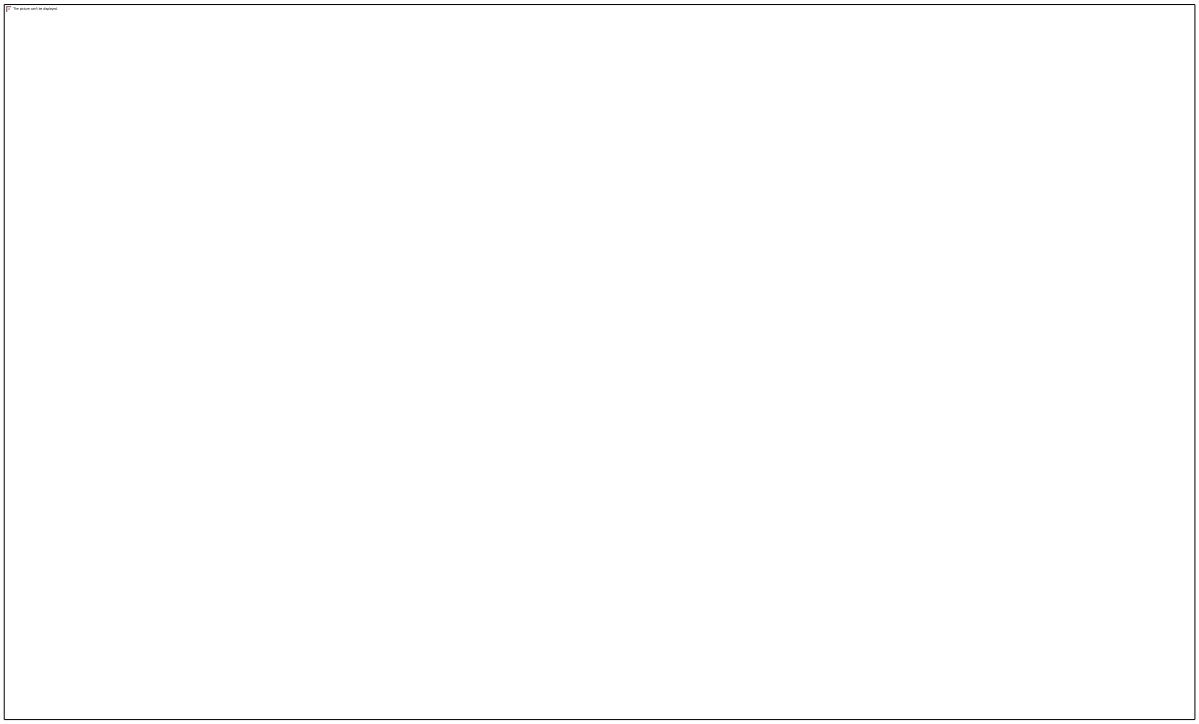
4.2 Demographic Characteristics of Participants

A total of 180 participants were recruited into the study. Of these, 105 (58.3%) were female and 75 (41.7%) were male.

Table 4.2 Distribution of Participants by Faculty and Gender

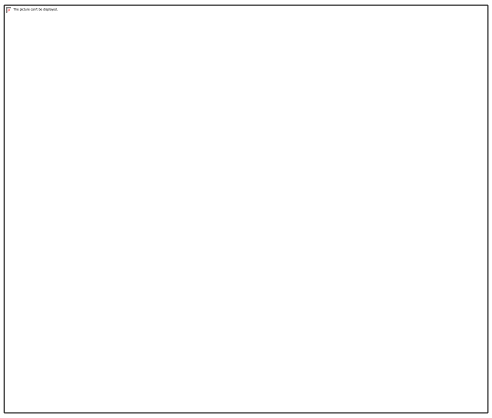
Faculty	Female	Male	Total
Science	14	7	21
Engineering	10	15	25
Commerce	38	15	53
Social Science	32	28	60
Education	11	10	21

Figure 4.2Faculty distribution of respondents.



The largest proportion of participants came from the Faculty of Social Sciences (33.3%), followed by Commerce (29.4%). Science and Education each contributed 11.7% of the participants, while Engineering contributed 13.9%.

Figure 4.2.1 Gender distribution of participants (58.3% female; 41.7% male).



4.2.3 Family History of Colour Vision Deficiency

Participants were asked whether they had a family history of colour vision deficiency.

Table 4.2.3 Family History of Colour Vision Deficiency

Response	Frequency	Percentage
Yes	5	2.8%
No	50	27.8%
Not Sure	125	69.4%

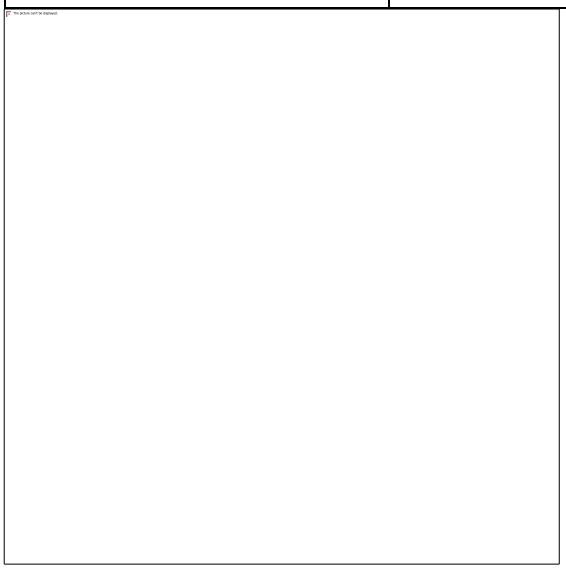


Figure 4.2.3 Family history of colour vision deficiency.

Most participants (69.4%) were unsure whether colour vision deficiency existed in their families. Only 2.8% reported a positive family history of colour vision deficiency.

4.3 Objective 1: Evaluate the Sensitivity and Specificity of the Online Ishihara Test

Table 4.3 presents the comparison of participants identified with red-green colour vision deficiency using the traditional Ishihara handbook and the online Ishihara test. Both methods identified the same number of deficient participants for most plates. For Plate 2, both methods identified 10 participants with colour vision deficiency. For Plate 3, the handbook identified 8 participants while the online test identified 9 participants. Minor differences were observed for Plate 5, where the handbook identified one participant with colour vision deficiency while the online test identified none. Across the remaining plates, no differences were observed between the two methods, indicating a high level of agreement in the identification of red-green colour vision deficiency.

Table 4.3: Comparison of Colour Vision Deficiency Detection Between the Handbook and Online Ishihara Tests

Ishihara Plate	Handbook Deficiency (n)	Online Deficiency (n)	Difference
Plate 1 (12)	0	0	0
Plate 2 (8)	10	10	0
Plate 3 (6)	8	9	1
Plate 4 (29)	3	3	0
Plate 5 (57)	1	0	1
Plate 6 (5)	2	2	0
Plate 7 (74)	6	6	0
Plate 8 (6)	0	0	0
Plate 9 (45)	0	0	0
Plate 10 (5)	0	0	

Figure 4.3: Comparison of Handbook and Online Red-Green Colour Vision Deficiency Frequencies across Ishihara Plates

Figure 4.3: Comparison of handbook and online red-green colour vision deficiency frequencies across Ishihara plates. The x-axis represents the Ishihara plate number, while the y-axis represents the number of participants identified with red-green colour vision deficiency. The graph shows a high level of agreement between the handbook and online Ishihara tests, with only minor variations observed for Plates 3 and 5.



C

4.4 Objective 2: Compare Results between the Online and Traditional Ishihara Tests

Comparison of the handbook and online results showed a high level of agreement. Similar frequencies of colour vision deficiency were recorded across the tested Ishihara plates for both methods, with only slight variations observed on a few plates.

Comparison of Handbook and Online Ishihara Results for the Right Eye (OD)

The results obtained using the traditional Ishihara handbook and the online Ishihara test were highly comparable.

Table 4.4. Ishihara Handbook vs. Online Results for OD

Plate	Number	Handbook Normal (F/M)	Handbook Red-Green Deficiency (F/M)	Handbook Other (F/M)	Online Normal (F/M)	Online Red-Green Deficiency (F/M)	Online Other (F/M)
Plate 1	12	180 (105/75)	0	0	180	0	0
Plate 2	8	165 (102/63)	10 (2/8)	5 (1/4)	164 (102/62)	10 (2/8)	6 (1/5)
Plate 3	6	172 (103/69)	8 (2/6)	0	170 (101/69)	9 (3/6)	1 (1/0)
Plate 4	29	175 (104/71)	3 (0/3)	2 (1/1)	175 (104/71)	3 (0/3)	2 (1/1)
Plate 5	57	179 (105/74)	1 (0/1)	0	180 (105/75)	0	0
Plate 6	5	178 (104/74)	2 (1/1)	0	178 (104/74)	2 (1/1)	0
Plate 7	74	165 (97/68)	6 (2/4)	9 (5/4)	164 (68/96)	6 (2/4)	10 (4/6)
Plate 8	6	165 (100/65)	0	15 (5/10)	163 (98/65)	0	17 (7/10)
Plate 9	45	150 (95/55)	0	30 (10/20)	150 (95/55)	0	30 (10/20)
Plate 10	5	179 (105/74)	0	1 (0/1)	180 (75/105)	0	0
Plate 11	7	175 (103/72)	0	5 (2/3)	173 (103/70)	0	7 (2/5)
Plate 12	16	172 (102/70)	0	8 (3/5)	170 (101/71)	0	10 (5/5)

Selected Findings

Plate 1 correctly identified all participants (100%) in both the handbook and online tests. For Plate 2, both testing methods identified 10 participants with red-green colour vision deficiency. For Plate 3, the handbook identified 8 participants with red-green colour vision deficiency, while the online test identified 9 participants. Across the remaining Ishihara plates, only minor differences were observed between the handbook and online versions. Overall, the frequencies obtained from both methods were very similar, indicating a high level of agreement between the traditional Ishihara handbook and the online Ishihara test.

4.4.1 Comparison of Handbook and Online Ishihara Results for the Left Eye (OS)

The comparison between the handbook and online tests for the left eye also showed similar findings.

Table 4.4.1 Ishihara Handbook vs. Online Results for OS

Plate		Handbook Normal (F/M)	Handbook Red-Green Deficiency (F/M)	Handbook Other (F/M)	Online Normal (F/M)	Online Red-Green Deficiency (F/M)	Online Other (F/M)
Plate 1	12	180 (105/75)	0	0	180 (105/75)	0	0
Plate 2	8	165 (102/63)	10 (2/8)	5 (1/4)	164 (101/63)	10 (2/8)	6 (2/4)
Plate 3	6	172 (102/70)	8 (3/5)	0	170 (101/69)	9 (3/6)	1 (1/0)
Plate 4	29	175 (104/71)	3 (0/3)	2 (1/1)	175 (104/71)	3 (0/3)	2 (1/1)
Plate 5	57	179 (105/74)	1 (0/1)	0	179 (105/74)	1 (0/1)	0
Plate 6	5	177 (104/73)	3 (1/2)	0	176 (104/72)	3 (1/2)	0

Plate 7	74	166 (98/68)	5 (2/3)	9 (4/5)	165 (69/96)	5 (2/3)	10 (4/6)
Plate 8	6	164 (99/65)	0	16 (6/10)	164 (99/65)	0	16 (6/10)
Plate 9	45	151 (96/55)	0	29 (9/20)	149 (94/55)	0	31 (11/20)
Plate 10	5	178 (104/74)	0	2 (1/1)	179 (75/104)	0	1 (0/1)
Plate 11	7	174 (102/72)	0	6 (2/4)	174 (103/71)	0	6 (2/4)
Plate 12	16	171 (101/70)	0	9 (4/5)	171 (102/69)	0	9 (4/5)

Selected Findings

Plate 1 showed complete agreement between the handbook and online Ishihara tests, with all 180 participants correctly identifying the plate. For Plate 2, both testing methods identified 10 participants with red-green colour vision deficiency. For Plate 3, the handbook identified 8 participants with red-green colour vision deficiency, while the online test identified 9 participants. Across the remaining Ishihara plates, only minimal differences were observed between the two methods, indicating a high level of consistency in the results obtained from the handbook and online versions of the Ishihara colour vision test.

4.5 Objective 3: Determine the Prevalence of Red-Green Colour Vision Deficiency

Table 4.5 shows the frequency of participants identified with red-green colour vision deficiency across the Ishihara plates. The highest frequencies were recorded on Plate 2, where 10 participants were identified with colour vision deficiency by both the handbook and online tests. Plate 3 identified 8 participants using the handbook and 9 participants using the online test, while Plate 7 identified 6 participants using both methods. Lower frequencies were recorded on Plates 4, 5 and 6. No participants were identified with colour vision deficiency on Plates 1, 8, 9 and 10. Overall, red-green colour vision deficiency was detected in a relatively small proportion of the study population.

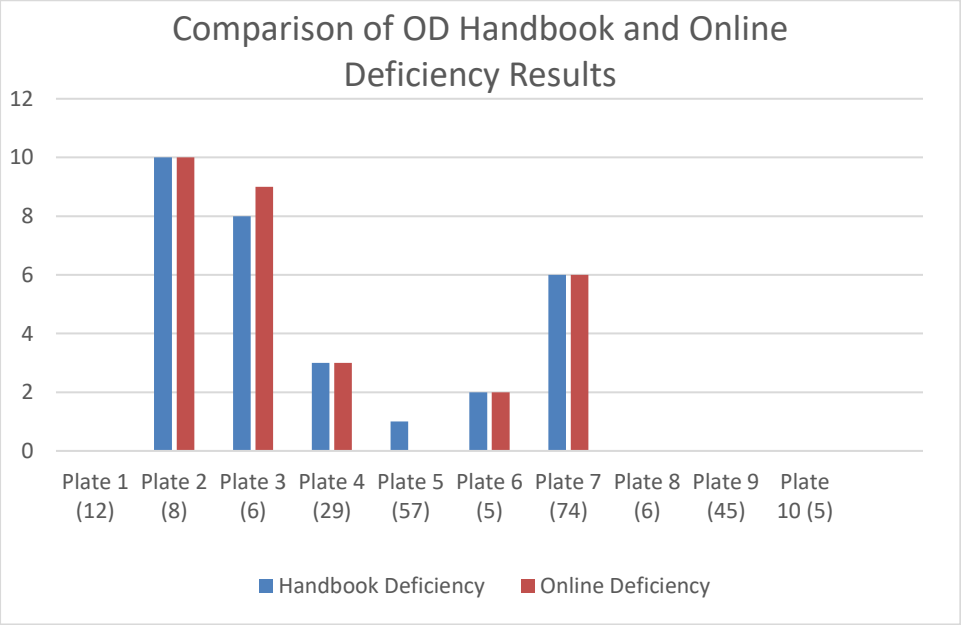
Detection of Red-Green Colour Vision Deficiency

The majority of red-green deficiencies were detected on Plates 2, 3, 4, 6 and 7.

Table 4.5: Participants Showing Red-Green Deficiency (OD)

Plate	Handbook Deficiency	Online Deficiency	Number They Saw
Plate 1 (12)	0	0	
Plate 2 (8)	10	10	3
Plate 3 (6)	8	9	5
Plate 4 (29)	3	3	70
Plate 5 (57)	1	0	
Plate 6 (5)	2	2	6
Plate 7 (74)	6	6	21
Plate 8 (6)	0	0	
Plate 9 (45)	0	0	
Plate 10 (5)	0	0	

Figure 4.5: OD handbook versus OD online deficiency frequencies.



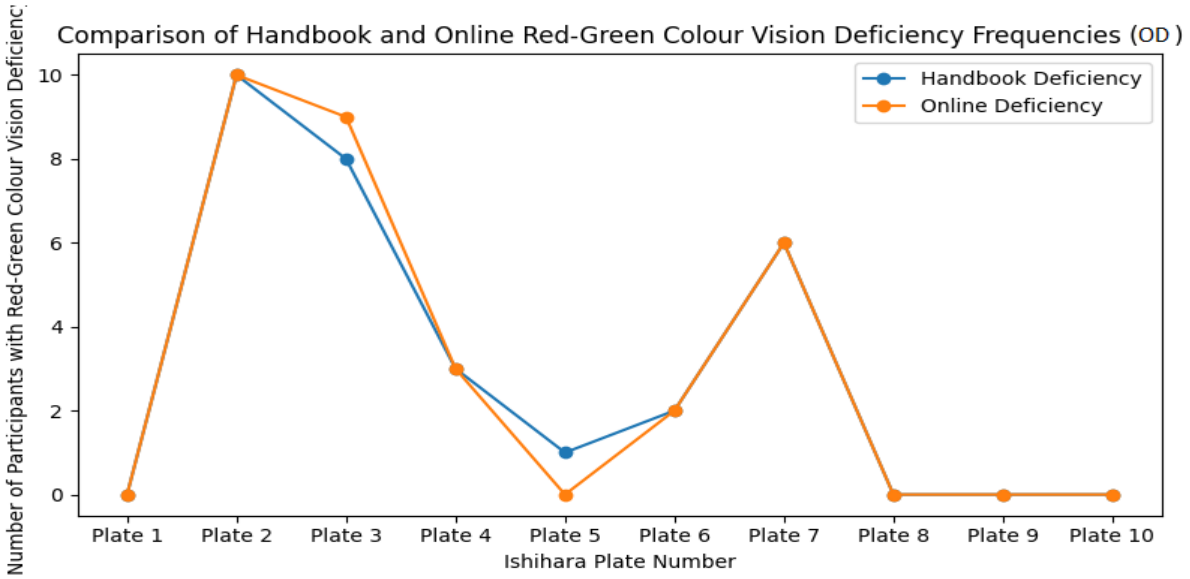


Table 4.5.1: Participants Showing Red-Green Deficiency (OS)

Plate	Handbook Deficiency	Online Deficiency	Number They Saw
Plate 1 (12)	0	0	
Plate 2 (8)	10	10	3
Plate 3 (6)	8	9	5
Plate 4 (29)	3	3	70
Plate 5 (57)	1	0	
Plate 6 (5)	2	2	6
Plate 7 (74)	6	6	21
Plate 8 (6)	0	0	
Plate 9 (45)	0	0	
Plate 10 (5)	0	0	

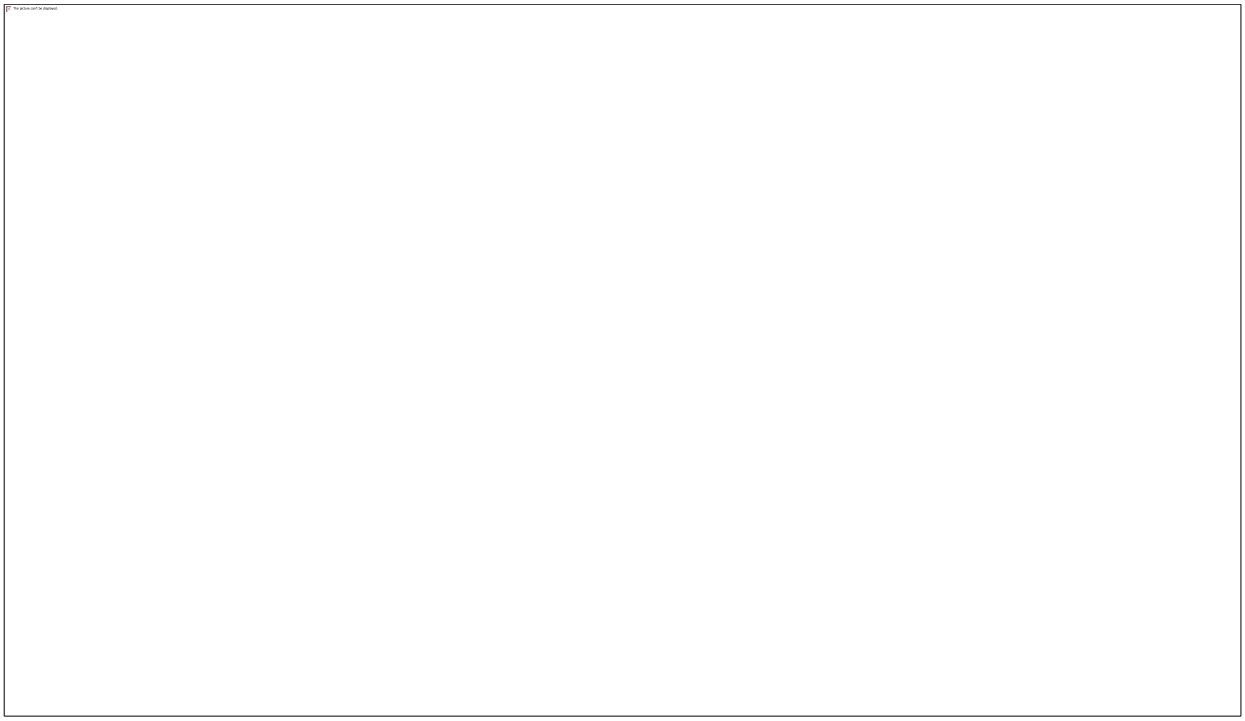


Figure 4.5.1. OS handbook versus OS online deficiency frequencies.

4.6 Objective 4: Assess the Effectiveness of the Online Ishihara Test

Table 4.6 presents a comparison of the frequencies of participants identified with red-green colour vision deficiency by the online Ishihara test and the traditional Ishihara handbook. The frequencies were identical for most plates, with only minor differences observed for Plates 3 and 5. Overall, the results obtained from the online Ishihara test closely matched those obtained from the traditional handbook, indicating comparable performance between the two testing methods.

Ishihara Plate	Handbook Deficiency (n)	Online Deficiency (n)	Difference
Plate 1	0	0	0
Plate 2	10	10	0
Plate 3	8	9	1

Ishihara Plate	Handbook Deficiency (n)	Online Deficiency (n)	Difference
Plate 4	3	3	0
Plate 5	1	0	1
Plate 6	2	2	0
Plate 7	6	6	0
Plate 8	0	0	0
Plate 9	0	0	0
Plate 10	0	0	0

4.7 Objective 5: Compare Diagnostic Accuracy between the Two Methods

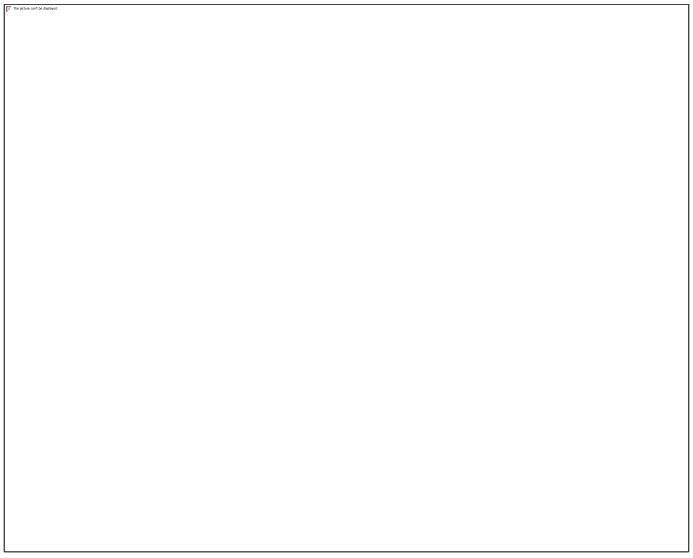
Table 4.7 presents the correlation and regression analysis between the online Ishihara test and the traditional Ishihara handbook. For the right eye (OD), a Pearson correlation coefficient of 0.995 and a coefficient of determination (R^2) of 0.989 were obtained. For the left eye (OS), a Pearson correlation coefficient of 0.998 and a coefficient of determination (R^2) of 0.995 were obtained. The results indicate a strong relationship between the online and handbook Ishihara test results for both eyes.

Table 4.7

Eye Tested	Pearson Correlation (r)	Coefficient of Determination (R^2)
Right Eye (OD)	0.995	0.989
Left Eye (OS)	0.998	0.995

Figure 4.7: Coefficient of Determination (R^2) for OD and OS

Figure 4.7: Coefficient of determination (R^2) & Pearson correlation (r) values for the right eye (OD) and left eye (OS). The high R^2 values indicate a strong relationship between the online Ishihara test and the traditional Ishihara handbook results.



OS Regression Analysis

Pearson correlation (r) = 0.998

Coefficient of determination (R^2) = 0.995



Conclusion

The results suggest that the online Ishihara colour vision test performs similarly to the traditional Ishihara handbook in detecting red-green colour vision deficiencies among BUSE students. Therefore, the online version may serve as a reliable screening tool where access to the traditional handbook is limited.

CHAPTER 5: DISCUSSION OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses the findings presented in Chapter 4 in relation to the objectives of the study and the literature reviewed in Chapter 2. The discussion focuses on the sensitivity and specificity of the online Ishihara test, comparison of results obtained using the online and traditional Ishihara tests, prevalence of red-green colour vision deficiency, effectiveness of the online Ishihara test, and diagnostic accuracy of the online version. The chapter also presents the conclusions, recommendations, limitations of the study, and suggestions for future research.

5.2 Discussion of Findings

5.2.1 Sensitivity and Specificity of the Online Ishihara Test

The sensitivity and specificity of the online Ishihara test in detecting red-green colour vision deficiency was evaluated among university students. The results demonstrated a high level of agreement between the online and traditional Ishihara tests. Both methods identified the same participants with colour vision deficiency on most plates, with only minor differences observed on a few plates. For example, both methods identified ten participants with red-green colour vision deficiency on Plate 2, while a slight difference was observed on Plate 3, where the handbook identified eight participants and the online test identified nine participants.

These findings indicate that the online Ishihara test possesses a high level of sensitivity in identifying individuals with colour vision deficiency while also maintaining specificity by correctly classifying participants with normal colour vision. The high level of consistency observed suggests that the online test can effectively distinguish between colour-normal and colour-deficient individuals.

The findings agree with Cole and Lian (2018), who reported that online colour vision tests can provide diagnostic outcomes comparable to traditional colour vision screening methods. Similarly, Almutairi et al. (2022) found that online colour vision tests demonstrated high effectiveness in detecting colour vision deficiencies when administered under controlled conditions.

One possible explanation for the small differences observed between the two methods may be variations in screen brightness, colour calibration, and display quality across different devices. Despite these factors, the online test maintained a high level of consistency with the handbook, suggesting that modern digital devices are capable of accurately reproducing Ishihara pseudoisochromatic plates.

5.2.2 Comparison between the Online and Traditional Ishihara Tests

A comparison between the online Ishihara test and the traditional Ishihara handbook revealed very little variation between the two methods. Most participants produced identical responses regardless of the testing method used. The close similarity between the two methods demonstrates that the online version can replicate the diagnostic performance of the traditional handbook. This finding is particularly important because it suggests that colour vision screening can be conducted using digital platforms without significantly compromising accuracy.

The results are consistent with Hoffmann and Menozzi (1998), who found that computer-based colour vision testing systems accurately identified red-green colour vision defects. The findings also support those of Gündogan et al. (2005), who reported that projected and computerised colour vision screening systems produced results comparable to conventional testing methods. The increasing use of digital technologies in healthcare and education makes online colour vision testing increasingly relevant. The ability to conduct colour vision screening remotely may improve accessibility, particularly in resource-limited settings where traditional Ishihara handbooks are not readily available.

5.2.3 Prevalence of Red-Green Colour Vision Deficiency

The prevalence of red-green colour vision deficiency among students at Bindura University of Science Education. The findings showed that only a small proportion of participants demonstrated red-green colour vision deficiency, while the majority correctly identified the Ishihara plates.

This finding agrees with Birch (2012), who reported that congenital red-green colour vision deficiency affects a relatively small percentage of the population worldwide. The low prevalence observed in this study therefore reflects the expected distribution of colour vision deficiency within the general population.

The observed prevalence may also be influenced by the demographic characteristics of the study population. Since the participants were university students aged between 18 and 25 years,

the sample represented a relatively healthy and educated population. Similar prevalence patterns have been reported in previous studies conducted among students and young adults.

Although the prevalence was low, the findings remain important because undetected colour vision deficiency can influence academic performance and career choices, particularly in fields that require accurate colour discrimination such as medicine, engineering, aviation, graphic design, and laboratory sciences.

5.2.4 Effectiveness of the Online Ishihara Test

The findings demonstrated that the online test produced results that closely matched those obtained using the traditional handbook. The frequencies of participants identified with colour vision deficiency were highly comparable across both methods. These findings support the conclusions of Almutairi et al. (2022), who found that online colour vision tests can function as effective screening tools for detecting colour vision deficiencies. Likewise, Cole and Lian (2018) reported that online colour vision testing systems can provide reliable and clinically useful screening outcomes.

The effectiveness observed in this study suggests that online Ishihara testing may serve as a practical alternative in situations where access to traditional testing materials is limited. Educational institutions, occupational health departments, and community screening programmes may benefit from adopting validated online screening approaches.

An additional advantage of online testing is convenience. Participants can complete screening procedures quickly using devices that are readily available, reducing the costs associated with purchasing and maintaining traditional testing materials.

5.2.5 Diagnostic Accuracy of the Online Ishihara Test

Correlation and regression analyses demonstrated extremely strong relationships between the two methods. Pearson correlation coefficients of 0.995 and 0.998 were obtained for the right and left eyes respectively, while the coefficients of determination were 0.989 and 0.995. These values indicate that almost all variation in handbook results could be explained by the online test results. Such high correlations suggest that the online Ishihara test accurately predicts outcomes obtained using the traditional handbook.

The findings support previous studies that have demonstrated the reliability of digital colour vision testing systems. Hoffmann and Menozzi (1998) reported that computer-based colour vision tests can accurately classify individuals with colour vision deficiencies. Similarly, Block

et al. (2004) found strong agreement between alternative colour vision testing methods and established colour vision assessment tools.

The exceptionally high R^2 values observed in this study provide strong evidence supporting the use of online Ishihara testing as a reliable screening method for red-green colour vision deficiency.

5.2.7 Gender Distribution of Colour Vision Deficiency

The findings showed that colour vision deficiency occurred more frequently among males than females. Across the deficient plates, males consistently accounted for the majority of affected participants.

This observation agrees with Birch (1997), Cole (2007), Francois (1961), and Neitz and Neitz (2001), who reported that red-green colour vision deficiency is inherited through an X-linked recessive genetic pattern. Because males possess only one X chromosome, they are more likely to express the defective gene when inherited.

The higher prevalence among males observed in this study therefore reflects the established genetic basis of congenital colour vision deficiency and further supports existing scientific evidence regarding the inheritance pattern of red-green colour vision deficiency.

5.3 Conclusion

The study successfully evaluated the effectiveness of the online Ishihara colour vision test in comparison with the traditional Ishihara handbook. The findings demonstrated high sensitivity, specificity, effectiveness, and diagnostic accuracy of the online version. Strong correlations were observed between the two testing methods, indicating that the online test can accurately predict results obtained using the traditional handbook. The study therefore concludes that the online Ishihara test is a reliable and practical tool for screening red-green colour vision deficiency among university students.

5.4 Recommendations

1. Universities should incorporate colour vision screening into routine student health assessments.
2. The online Ishihara test should be adopted as an alternative screening tool where traditional handbooks are unavailable.

3. Occupational health programmes should utilise online screening methods to improve accessibility.
4. Public awareness campaigns should be conducted to promote early detection of colour vision deficiencies.
5. Further validation studies should be undertaken in different populations and age groups.

5.5 Limitations of the Study

The study was conducted among students from a single university, which may limit the generalizability of the findings. Variations in screen quality, device specifications, colour calibration, and ambient lighting conditions may also have influenced online test performance. In addition, the study focused exclusively on red-green colour vision deficiency and did not assess other forms of colour vision impairment.

5.6 Areas for Further Research

Future studies should investigate the effectiveness of online colour vision testing among larger and more diverse populations. Research should also evaluate the impact of different digital devices, screen technologies, and environmental conditions on test performance. Further studies comparing online Ishihara testing with other colour vision assessment tools such as the HRR test, Farnsworth D-15 test, and anomaloscope are also recommended.

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ADDENDUM 1: Data collection sheet (See attached)

ADDENDUM 2: Consent form (See attached)