ORIGINAL ARTICLES

Comparison of a Smartphone Application with Ishihara Pseudoisochromatic Plate for Testing Colour Vision

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ABSTRACT

The Eye Handbook (EHB) is the most frequently downloaded smartphone application with diagnostic tools for eye-care providers. However, limited data exists validating the EHB test to gold standard colour vision testing. EHB and Ishihara colour vision tests were evaluated and compared under simulated colour vision loss through use of image processing software. Images of both tests were processed through ImageJ to 32 bit-grey scale and blue channel under split RGB channel to model total colour vision loss and red-green (R-G) deficiency, respectively. Two colour plates differentiated R-G deficiency from total colour blindness in EHB compared with eight Ishihara plates. Without colour information, correct numerals were identified in 3.5/15 EHB plates converted to 32-bit greyscale, versus 1/16 in Ishihara. We conclude EHB may underestimate colour vision loss severity in persons with normal contrast sensitivity compared to Ishihara. Eye-care providers need to be aware of the potential inconsistency compared to standardised methods, including limitations in differentiating patients with R-G colour deficiencies from total colour blindness.

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Introduction

With advancement in smartphone technology and proliferation of medical software applications, physicians are increasingly incorporating smartphones into their daily practice. By 2013, about 80% of physicians reported smartphone use to accomplish their professional responsibilities.¹ The use of smartphone technology in ophthalmology is unique since several testing tools are required for a basic patient exam. Traditional examination tools are often inadequate or unavailable for inpatient consults, emergency room visits and field work.

Smartphone applications offer an affordable and accessible method for colour vision testing. Previous studies report significant delays in patient care while providers searched for an Ishihara booklet, which is commonly shared due to its cost.² An electronic version also helps solve the problem of shifting colourimetric values with aging of the physical colour plates, which can lead to inaccurate results.³

The Eye Handbook (EHB) is a widely used smartphone application containing diagnostic tools for eye-care providers. It is available free of charge for download on iTunes App Store and Android Market and had more than 2 million downloads around the world by September of 2017.⁴ The application contains a colour vision test analogous to the conventional pseudoisochromatic colour vision test, Ishihara, which is one of the most commonly used colour vision test worldwide.⁵

The EHB test differs in several important ways from the more traditional Ishihara. Screen size, resolution, brightness and colour saturation of each smartphone model may impact the accuracy of the EHB colour vision test.⁶ There is limited data validating the EHB test to gold standard colour vision testing. The aim of this study is to evaluate and compare the EHB colour vision test to standardised Ishihara pseudoisochromatic plate under simulated colour vision loss through the use of image processing software.

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Methods

This project did not involve participation of human subjects, and therefore is exempt from Institutional Review Board approval.

Images of the colour vision test from EHB were obtained by screenshots from an iPhone 6s Plus. We utilised a total of 16 colour plates. Images of Ishihara pseudoisochromatic plates (1997 version; Kanehara & Co., Ltd., Tokyo, Japan) were taken from the physical version, captured at a distance of 6 inches using a digital single-lens reflex camera (Canon T5i). A total of 17 images (plate 1–17) were obtained.

Through ImageJ software (version 1.46r; Wayne Rasband, National Institutes of Health, Bethesda, MD, USA), these images were processed to model both total colour vision loss and red-green (R-G) deficiency. First, images were converted to 32 bit-greyscale to remove colour information from the images (Figure 1). Second, split RGB channel was used to separate the red, green and blue colour information from the images (Figure 2).

Unprocessed images with all three colour channels preserved simulated normal colour vision. 32

Figure 1. 32 bit-greyscale of Plate 11 in Eye Handbook. The correct number 16 is visible to the observer despite the lack of colour information, indicating that the image is testing contrast sensitivity rather than perception of colour.

bit-greyscale images are hypothesised to simulate total colour vision loss and blue channel images under split RGB are hypothesised to simulate R-G deficiencies. Each colour plate (unprocessed and processed photos) from EHB and Ishihara was analysed independently by two reviewers with normal colour vision by standard Ishihara testing. For each plate, the numeral (or absence of numeral) seen under three different conditions was recorded.

The first part of the study compared results from the processed photographs of the Ishihara colour plates to the original answer key provided by Ishihara booklet (Figure 3) to evaluate the validity of this image processing method in simulating R-G deficiencies and total colour blindness. The second part of the study compared results from the EHB to the Ishihara test.

Results

Tables 1 and 2 summarise findings from the EHB colour vision and Ishihara test. Plate 1 of both the EHB and Ishihara is a control plate with the number 12, which can be correctly identified by both persons with normal colour vision and those with colour deficiencies. For each table, column 1 states the plate number, column 2 shows the number or the design that is identified by persons with normal colour vision, while columns 3 and 4 state the result identified under blue channel and 32 bit-greyscale, respectively.

There was a high correspondence across the two reviewers interpreting images with 100% interrater correlation.

In plates 2 through 15 of the Ishihara test, both reviewers correctly identified the answer in 12.5 out of 14 plates under simulated R-G deficiency and 13/14 plates under simulated total colour blindness (Table 1).

In the Ishihara test, plates 2–7 and 14–15 are designed so that subjects with R-G colour deficiency detects a number or design different from what a normal person sees, while persons with total colour blindness observe an absence of number or design. Two plates in EHB (Plate 3 and 5) are similarly designed to plates 2–7 in Ishihara.

Under 32 bit-greyscale, which removes all colour information, the number was identifiable in

Figure 2. Split RGB Channel of Plate 5 in Eye Handbook. The number 74 is visible in (A) Normal Plate and can be discerned in (B) Red channel and (C) Green channel. In contrast, the Blue channel (D), which simulates red-green colour blindness, reveals the number 21.

Answers to each plate

Plate	Normal Person	Person with Red-Green Deficiencies		Person with Total Color Blindness and Weakness	
1	12	12		12	
2	8	3		X	
3	29	70		X	
4	5	2		X	
5	3	5		X	
6	15	17		X	
7	74	21		X	
8	6	X		X	
9	45	X		X	
10	5	X		X	
11	7	X		X	
12	16	X		X	
13	73	X		X	
14	X	5		X	
15	X	45		X	
		Protan		Deutan	
		Strong	Mild		
16	26	6	(2) 6	2	2 (6)
17	42	2	(4) 2	4	4 (2)

The mark X shows that the plate cannot be read. Blank space denotes that the reading is indefinite. The numerals in parenthesis show that they can be read but they are comparatively unclear.

Figure 3. Ishihara instruction demonstrating the number that should be identified by normal person, person with red-green deficiency and person with total colour blindness.

Table 1. Results of Ishihara test, showing numeral that is visible under blue channel and 32 bit-greyscale. (-) means no numeral was detected.

Plate	Number or design on the plate	Blue Channel	32 bit-Greyscale
1	12	12	-
2	8	3	-
3	29	70	-
4	5	5	-
5	3	5	-
6	15	15	-
7	74	21	-
8	6	-	6
9	45	-	-
10	5	-	-
11	7	-	-
12	16	-	-
13	73	-	-
14	Wiggly line	5	-
15	Wiggly line	45	-
16	26	-	-
17	42	-	-

Table 2. Results of Eye Handbook, showing numeral that is visible under blue channel and 32 bit-greyscale. (-) means no numeral was detected.

Plate	Number or design on the plate	Blue Channel	32 bit-Greyscale
1	12	12	12
2	8	-	-
3	5	8	-
4	29	29	29
5	74	21	-
6	7	-	16
7	45	-	-
8	2	-	-
9	Wiggly line	-	-
10	Wiggly line	-	-
11	16	-	16
12	Wiggly line	-	-
13	35	-	5
14	96	-	-
15	26	-	26
16	Wiggly line	-	-

3.5 out of 15 plates in the EHB test versus 1 out of 16 in the Ishihara test.

Discussion

In this study, we demonstrate that the colour vision testing methodology in the most frequently downloaded mobile application for eye-care utilises a different rate of R-G colour assessment and contrast assessment than the Ishihara test. Specifically, the data reveal that the EHB test does not contain as many specially designed plates as Ishihara for differentiation of R-G deficiency

from total colour blindness; Notably, EHB seems to be more affected by contrast-related effects when compared to Ishihara testing.

We also demonstrate that image processing using ImageJ software is an adequate method for modelling R-G deficiency and total colour blindness. Similar methods have been described in the literature to simulate colour vision loss using Adobe Photoshop.⁷

A recent study by Ozgur *et al*⁶ sought to validate EHB colour vision test by comparing results from the EHB application to standard Ishihara colour plates. Patients were recruited with varying types of ocular pathology including, non-glaucomatous optic neuropathy, glaucoma, corneal and/or ocular surface pathology, retinal pathology, cataracts and thyroid eye disease. 11% of subjects in this study were characterised as colour vision deficient, defined as missing more than 2 of 11 plates on either the EHB and/or Ishihara test. Their results within the colour vision deficient group showed variability of scores obtained by EHB and Ishihara, limits of agreement ranged from -4.64 to 3.64. This raises question of the level of variability that is acceptable for mobile application.

We have previously demonstrated contrast-related effects of pseudoisochromatic plate testing, raising the possibility that its test results may not only reflect colour identification but also testing of contrast sensitivity.^{8,9} Hardy-Rand-Rittler was the most affected compared to Ishihara.⁸ In this study, more plates under 32 bit-greyscale were identifiable in EHB compared to Ishihara test. The ability to see the correct number in 32 bit-greyscale depends on contrast sensitivity alone. This finding suggests that results from the EHB may underestimate the severity of colour vision loss in persons with normal contrast sensitivity compared to Ishihara. This theory is supported by Ozgur *et al*⁶ in which more patients with ocular pathology were able to correctly identify all 11 colour vision plates with EHB (85%) compared to Ishihara (69%). This further suggests colour vision testing with the EHB may be easier with the risk of not identifying individuals with colour vision deficiency. We postulate that this discrepancy is likely related to stronger contrast sensitivity effect with EHB colour vision testing.

Study limitations include the use of computer software to model R-G colour blindness and total colour blindness. This method was not able to

discriminate the two different types of R-G colour deficiencies, protanopia and deutanopia.

This study highlights the disparity between colour vision tests using a high resolution smart phone screen versus Ishihara pseudoisochromatic plates. Eye-care providers need to be aware of the potential inconsistency between data obtained by the EHB compared to standardised methods. Similar to a recommendation provided by Tofigh *et al*¹⁰ regarding visual acuity testing, documentation of the techniques used for colour vision assessment needs to be done to avoid misinterpretation of possible variances between results from different testing methods.

Financial disclosure

None.

Conflicts of interest

Authors have no relevant conflicts of interest.

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