How Reliable is the Ishihara Test?

Ishihara Testleri Ne Kadar Güvenilir?

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ABSTRACT

Purpose: Ishihara Pseudoisochromatic-plates first published in 1917 is the most preferred test to diagnose colour-blindness although the test has many drawbacks which may affect test results. The aims are to examine drawbacks of the Ishihara test, to investigate the ophthalmologists' colour vision test usage habits and views, to analyse the result parameters such as individuals' response time for per plate and total test duration.

Methods: To investigate the ophthalmologists' views, a 12-item questionnaire was applied to 140 ophthalmologists who have professional experiences in colour-vision tests in daily practice. To measure response time duration of per plate and total test duration, a brand-new Ishihara 38-plate version has been scanned and applied on 250 individuals through a PC.

Results: Almost all the participants (98.57%) were using Ishihara pseudoisochromatic-plates in their daily routine clinical practice even though 85% of them believe that the Ishihara test does not meet their needs at least partially. They also believe that the plates deform in time and lose their accuracy. The standard deviations of the total test duration of per plate are quite high which means the total test duration for the Ishihara test cannot be standardized.

Conclusions: It is a matter of debate to use the Ishihara test with so many drawbacks which some of them may affect test results directly. Ishihara instruction about time is one of the contentious issues to decide if it should be followed during the test. For more definite results, the study should be applied on more individuals and the results should be compared with Anomaloscope.

Key Words: Biomedical, Colour-blindness, Ishihara.

ÖZ

Amaç: İlk çalışmaları 1917 yılında yapılmış olan ve test sonucunu değiştirebilecek birçok zayıf yönlere sahip Ishihara psödoizokromatik paletleri renk körlüğünün tanısında en çok tercih edilen testtir. Bu çalışmanın amaçları, Ishihara testinin zayıflıklarını analiz etmek, göz hekimlerinin renkli görme testleri hakkında alışkanlıklarını ve görüşlerini incelemek, test uygulamasında her bir test paletinde harcanan süre, toplam test süresi gibi parametreleri analiz etmektir.

Metot: Göz hekimleri görüşlerinin incelenmesi için, 12 soruluk bir anket hazırlanmış ve renkli görme testleri konusunda alanında uzman 140 göz hekimine uygulanmıştır. Deneklerin her bir test paletinde harcadıkları süre ve toplam test süresini ölçmek için, yeni 38-paletlik bir Ishihara testi taranarak bir bilgisayar üzerinden 250 deneğe uygulanmıştır.

Sonuç: Neredeyse ankete katılan tüm göz hekimleri (%98.57) günlük uygulamalarında Ishihara psödoizokromatik paletlerini kullanıyorlar ancak buna rağmen %85'i Ishihara testinin ihtiyaçlarını en azından kısmen karşılamadığına inanmaktadır. Ayrıca bu test paletlerinin zamanla deforme olduğunu ve doğruluklarının azaldığına inanmaktadırlar. Toplam test süreleri standart sapmasının oldukça yüksek olması Ishihara testleri için toplam test süresinin standartlaştırılamayacağını göstermektedir.

Tartışma: Sonuçları doğrudan etkileyebilecek birçok zayıf yöne sahip Ishihara testlerini kullanmak bir tartışma konusudur. Ishihara testinin zaman ile ilgili yönergesine uyup/uymamak ise ayrı bir tartışma konusudur. Daha kesin sonuçlar için çalışma daha fazla denek üzerinde uygulanmalı ve sonuçlar Anamaloskop ile karşılaştırılmalıdır.

Anahtar Kelimeler: Biyomedikal, Renk-körlüğü, İshihara.

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INTRODUCTION

Seeing colourful is one of the vital attributes of visual perception. The colours emerged by perceiving reflected light from objects around us. When the reflected light enters the eye, it is focused on the retina where it is absorbed by photoreceptors. There are two kinds of photoreceptors Rods and Cones.[1-3] Rods are intensively sensitive to light, enabling people to see in very dim conditions, but cannot distinguish colours. Besides, cones are less sensitive. They are responsible for daylight vision and sensitive to colours.[4,5] The cones contain three types of pigments, red, green and blue.[6,7] The reflected light absorbed by three types of cones is transmitted as signals through the optic nerves to the brain. Colour vision is a perception which happens in the brain.[8-10] Any defects at one or more of the three cone types will defect the colour perception process. The defects at the level of perception of the colours called as colour blindness. In other words, colour vision deficiency also called colour blindness is the decreased ability or inability to perceive colour differences or see colours, under normal lighting conditions.[11,18,20]

8% percent of male[14-16,19] and 2% percent of female[17] in today's population suffer from colour blindness. Colour blindness is one of the most common genetic disorders observed in the human population.[12,13]

In the related literature, there are many tests to determine if an individual is colour blind or not. Ishihara pseudoisochromatic test is the most commonly used test to diagnose colour deficiency[21-23] and it has almost a century background. The Ishihara test plates have shown to be successful in an early diagnosis of colour vision defects. This commonly used colour vision test was initially intended to identify those who suffered from red-green aspect of congenital colour blindness however, it may be of use to reveal acquired colour vision defects as well.[24]

AIMS

Ishihara Pseudoisochromatic plates first published in 1917[25] is the most widely used test to diagnose colour blindness.[28,38-40] The Ishihara test has many drawbacks besides some of them are so significant which can cause to produce inconsistent result.

The listed drawbacks in the Conclusion section of The Ishihara test arise a question that "Why the Ishihara test is the most preferred test for colour blindness since the last century?". An even more fundamental question is "Do the ophthalmologists consider these drawbacks during the test?"

In this paper, our main aim is to answer these questions through the objectives listed,

- to examine drawbacks of the Ishihara test.
- to investigate the ophthalmologists' colour vision test usage habits and views if it meets the needs of their demands in clinical practice.
- to analyse time duration of the Ishihara plates by measuring every individuals' response time to per plate and calculating total test duration. By this means, to determine if the test instruction about time condition should be followed or not. There are no papers in the related literature about measuring time consumption of the plates.

IMPLEMENTATION OF THE QUESTIONNAIRE

Table 1. *The Questionnaire.*

1	Which colour test do you usually prefer in your daily practice?
2	Why do you use your preferred colour test?
3	Do you think the colour test you apply to the colour-blind patients, give you detailed information and meet to your needs (ex. Type of the colour blindness, which wavelength was confused etc.)?
4	Do you consider about ambient light while applying colour test?
5	Do you consider about finger prints, dusts, wear and tear on the plates?
6	Do you think the Ishihara Colour Plates are deformed in time? (ex. Colour saturation, contrast lost etc.)
7	Do you think the Ishihara Colour Plates lose their accuracy in time?
8	Do you think applying Ishihara Colour Plates in different clinics can produce some discrepancy in the results?
9	Do you think is there a need for standardized a test which offer colour blindness type and the confused wavelength?
10	Do you want to use a test which is developed by computerized methods, fast and easily applicable, can analyse the related colour blindness type and wavelength?
11	Do you think this program developed by computerized methods can be more objective while ensuring the professional standardizations (ex. Pilot, military personal, police, driver etc.)?
12	How much budget do you prefer to devote for this program developed by computerized methods?

140 ophthalmologists (112 Male and 28 Female) have participated in a 12-item questionnaire shown in Table 1. Participation in the questionnaire was only allowed by an invitation sent by email. The invitation has been only sent to ophthalmologists who have professional experiences in colour vision tests in daily practice. Table 2 shows the descriptive statistics of the participants. The mean age of the participants is 37.47 years and mean experience year of the participants is 10,67 years.

Table 2. *Descriptive Statistics of Participants.*		
Participants (n=70)		
	n (%)	**Description**
Age (Years)	66 (47.1)	30 ± 5
	52 (37.1)	40 ± 5
	16 (11.4)	50 ± 5
	6 (4.3)	60 ± 5
Sex	112 (71.4)	Male
	28 (28.6)	Female
Institution	50 (35.7)	University Hospital
	52 (37.1)	State Hospital
	24 (17.1)	Training and Research Hospital
	12 (8.6)	Military Hospital
	2 (1.4)	Private Hospital
Experience (Years)	50 (35.7)	0 - 5 years
	52 (37.1)	6 - 10 years
	14 (10)	11 - 15 years
	24 (17.1)	≥16 years

IMPLEMENTATION OF THE ISHIHARA TEST

Marey et al. scanned the first 21 plates from a brand-new Ishihara test with 600 dpi scanner and applied on their subjects with the traditional Ishihara plates in their study. They have achieved 100% sensitivity and 98.78% specificity.[41] Isik et al. applied scanned images to their participants. They made no adjustments or modifications on their scanned images. They have achieved 100% sensitivity and 100% specificity through the traditional Ishihara plates in their study.[42] In related literature, there are other similar papers that show the test results gathered from scanned Ishihara plates are extremely enough to diagnose if an individual is colour blind or not. Therefore, for this study, we have used scanned Ishihara plates by means of computer screens instead of traditional Ishihara plates.

In our test setup, we have used an Acer monitor which has a resolution of 1920 x 1080-pixel, the brightness of 200 cd/m2 and the contrast ratio of 600:1. The screens have been used at a maximum level of illumination. The test room is 52 square meters and illuminated by both sufficient sunlight and sixteen cool white Philips fluorescent tubes (16 x 40W). The light level near the screens is measured as between 682 – 736 lumens during the study. In this study, the colours emerge by the screen not the reflected light, so the ambient light will not affect the results. Isik et al. applied scanned plates with different ambient lights and reached the same diagnostic results with very close sensitivity and specificity.[42]

A brand-new Ishihara 38 plate version test has been scanned with 1000 dpi resolution scanner. No adjustments or modifications have been made on the scanned plates. A program has been developed in JAVA platform to apply all the scanned plates to the individuals. Time consumption of the per plates has been measured and recorded to the database through the designed program. Figure 1 shows some of the scanned pictures from the designed program.

The subject group consists of 250 voluntary individuals who are at the students at a vocational school and aged from 18 to 21. All individuals have been chosen from students who successfully completed ‘basic computer training course’. In this way, it can be assumed that proficiency in the use of computers does not affect the test results. Because of the Ishihara plates is in a certain order, it can be easily memorized and answering the memorized plates will affect the test results unfavourably. Because of that, the individuals have been chosen who never took any colour vision test and did not aware of their colour vision situation before the study.

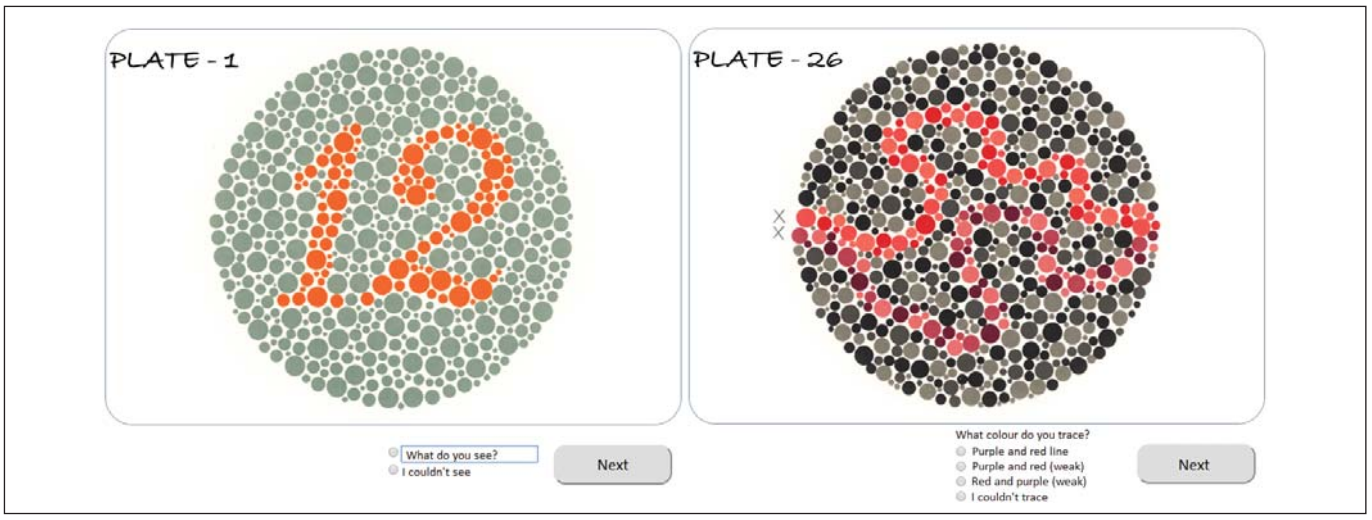

Figure 1. *Scanned plates from the designed program.*

The individuals are separated randomly in groups of five and each group consists of 32 individuals. Before the study, they have put on notice that the test duration will be recorded, and they also have been informed about the process & application of The Ishihara test which took approximately 1 minutes. This time consumption has been excluded from the total test duration. The individuals have been positioned 75-centimeter distance of the monitor and their sitting position has been arranged to be perpendicular to the test screens. A numpad and a mouse have been given to every individual to enter their answers. As soon as an individual press any button on the numpad to write his/her answer or click on the mouse to choose their answer for winding lines between two X, the program blurs the test plate and records the measured time into the database.

RESULTS

In the Ishihara test instruction, each answer to the numerical plates which are plate1 to 21 should be given without more than three seconds delay. In respect of the plates 26 to 38 which are for winding lines between two X, the answer should be given within ten seconds.[26,27] So, it means that if an individual response time is more than instructed, it should be accepted that the individual couldn't see the test plate.

In this study, no test plate has been skipped depending on the time delay. Ishihara instructions except time condition have been complied to determine if an individual is colour blind or not. The readings of the plates 1 to 21 has been used to determine the normality or defectiveness of colour vision as Ishihara user manual instructed.[26,27] If 17 or more plates are read normally, the colour vision is regarded as normal. If only 13 or less than 13 plates are read normally, the colour vision is regarded as deficient.

Table 3 and 4 show the mean, median, standard deviations of the measured time duration as seconds for per plate. The table also shows, on the contrary of the Ishihara test instruction, most of plates 1 to 25 couldn't be answered under three seconds by persons who have normal colour vision. Persons having colour vision deficiency spend more time on the plates as expected. On the contrary, persons having normal colour vision spend more time on the plate 18 and 26. Because on those plates, they try to read a number or trace a line even they are not supposed to.

Table 3. *Time duration results of the test (Plate 1 to 25).*

	Colour Blind			Normal Vision		
Plate No	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
1	4,98	4,26	2,19	5,91	5,53	2,19
2	7,65	6,79	4,13	4,40	3,47	2,50
3	6,73	4,89	4,36	3,87	3,16	2,08
4	5,76	4,58	3,29	4,26	3,52	2,05
5	6,84	4,63	4,42	4,14	3,23	2,25
6	8,13	8,32	3,33	3,40	2,66	1,82
7	8,97	5,84	7,02	4,37	3,26	2,88
8	8,37	7,21	4,66	3,73	3,15	1,90
9	6,34	5,89	2,69	4,73	4,02	2,44
10	6,73	6,31	3,00	3,49	2,84	1,66
11	6,72	6,52	3,43	3,45	2,80	2,06
12	6,22	5,83	3,14	4,23	3,52	1,75
13	5,60	4,23	3,38	3,82	3,10	1,84
14	6,30	5,12	3,20	3,34	2,57	2,18
15	6,93	5,72	3,64	3,33	2,65	1,87
16	5,83	4,27	3,83	3,75	3,18	1,95
17	6,27	6,29	2,94	5,80	4,93	3,08
18	8,50	8,01	5,58	10,97	9,33	7,45
19	6,98	5,41	6,72	7,65	6,44	5,54
20	7,54	6,88	4,01	7,95	5,79	6,16
21	7,17	5,18	5,42	7,42	5,33	6,27
22	8,70	6,94	4,87	5,46	4,56	3,23
23	6,39	5,70	3,57	3,63	3,15	1,69
24	7,05	5,25	4,57	3,74	3,10	1,96
25	5,44	5,11	2,30	3,84	3,11	2,25

Table 4. *Time duration results of the test (Plate 26 to 38).*

	Colour Blind			Normal Vision		
Plate No	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
26	16,33	14,87	9,36	21,60	16,18	18,51
27	11,93	9,64	8,55	8,89	6,85	6,29
28	11,93	9,64	8,55	8,89	6,85	6,29
29	10,92	5,89	9,25	8,33	5,69	8,69
30	10,04	6,79	7,55	10,48	7,83	7,84
31	12,64	5,89	16,84	6,17	4,80	4,29
32	10,29	5,50	13,64	5,88	5,13	3,29
33	10,51	6,31	9,77	4,73	3,93	2,60
34	12,81	9,12	10,99	9,42	6,20	8,05
35	14,36	8,83	16,24	6,34	4,92	4,46
36	11,40	5,67	11,45	7,64	6,76	4,22
37	8,56	5,41	9,34	6,01	4,84	3,66
38	6,14	5,19	3,13	5,61	4,12	8,83

Table 5. *Comparison of diagnostic results with/without following the instructions.*

	Ishihara Results	
	Colour deficiency	Normal vision
compliance with the time condition	113	137
noncompliance with the time condition	51	199

It has been observed that the individuals spent more time on the plates than recommended. Table 5 shows the comparison of diagnostic results between compliance and noncompliance with the time condition in the instruction during the test. If the Ishihara instruction about time condition were followed, most of the individuals including the ones who answered the plates correctly would be diagnosed as a colour blind.

Therefore, this study has shown that the Ishihara instruction about time is one of the contentious issues to decide if it should be considered or not during the test. Besides, table 3 and 4 also shows that the standard deviations for per plate are different from each other additionally they are high values so the total test duration couldn't be standardized for the Ishihara test. The time limit should not be under six seconds for the plates 1 to 26. Before the test, the individual should be informed that it's ok unable to read some plates, to prevent time delay on the plates 18 and 26.

A total of 140 participants (112 male, 28 female) with a mean age of 37.47 years have completed the questionnaire. Figure 2 shows that almost all the participants (98,57%) were using Ishihara pseudoisochromatic plates in daily clinical practice. However, Table 6 shows that 83% of the participants believe that Ishihara pseudoisochromatic plates do not meet their needs and do not give any detailed diagnostic results at least partially (Question number 3).

Table 6. *The questionnaire results.*

Question Number	Results			
	Yes	No	Partially	Other
3	22 (16.92%)	66 (50.77%)	42 (32.31%)	0 (0.00%)
4	68 (48.57%)	38 (27.14%)	32 (22.86%)	2 (1.43%)
5	8 (5.71%)	86 (61.43%)	43 (30.71%)	3 (2.14%)
6	106 (75.71%)	22 (15.71%)	12 (8.57%)	0 (0.00%)
7	72 (51.43%)	10 (7.14%)	53 (37.86%)	5 (3.57%)
8	71 (50.71%)	54 (38.57%)	13 (9.29%)	2 (1.43%)
9	104 (74.29%)	10 (7.14%)	22 (15.71%)	4 (2.86%)
10	126 (90.00%)	2 (1.43%)	6 (4.29%)	6 (4.29%)
11	126 (90.00%)	6 (4.29%)	4 (2.86%)	4 (2.86%)

Table 6 shows the questionnaire results. Although the ambient light is the vital factor for colour formation, only 48.57 percent of the ophthalmologists take it into consideration during the test. Surely this is a flaw in practice, but the test is very prone to cause misdiagnosis. Using Ishihara Plates over time can cause wear and tear, fingerprints and dust because of that seeing the colours on the plates will be more difficult even for persons having normal colour vision. Most of the ophthalmologists do not consider this fact. 75.71 percent of the ophthalmologists believe that the plates are deformed in time and most of them think that the plates lose their accuracy in time. Of course, these flaws can be overcome by replacing the test book with a new one. But how often the clinics change the test book in practice is another subject to analyse. At least half of the ophthalmologists specified that the plates in different clinics can produce some discrepancy in the results.

Figure 3 shows that why Ishihara is the most preferred colour test. As it can be seen in the figure, the ophthalmologists

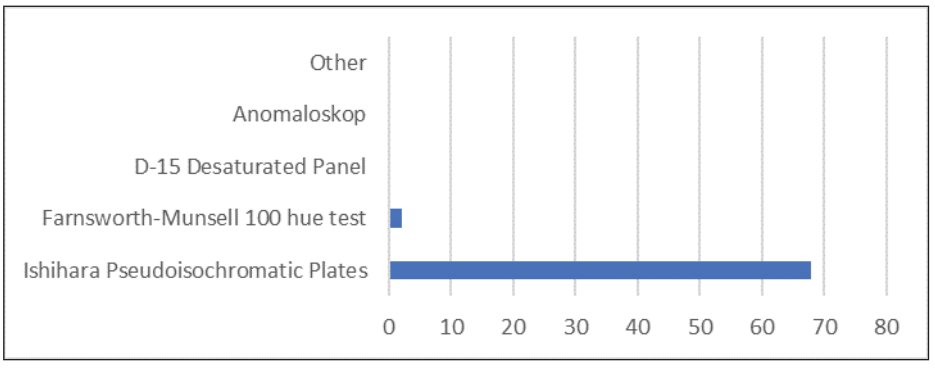

Figure 2. *Which colour test do you usually prefer in your daily practice?*

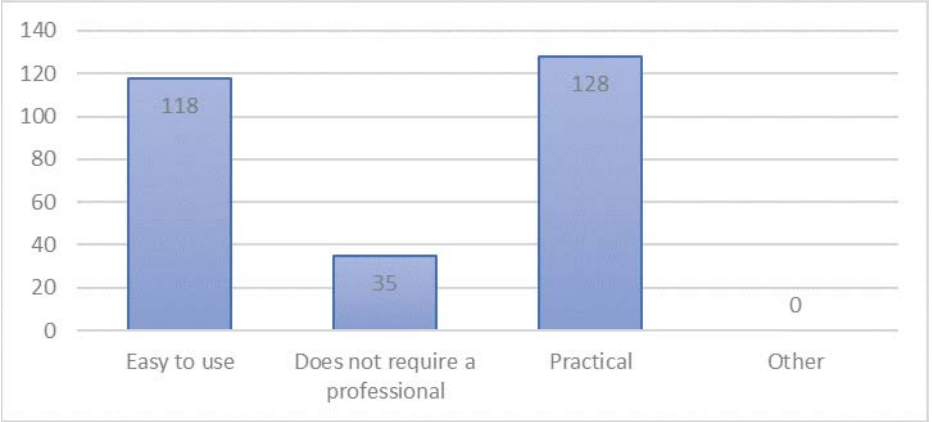

Figure 3. *Why do you use your preferred colour test?*

use The Ishihara test because it is easy to use, practical and does not require any professional. Anomaloscope is known as a golden standard to diagnose colour vision.[29,33,43,44] But it is not practical to use and does require a professional to apply.

The ophthalmologists stated that for colour vision assignment there is a need for a new computerized test which can also give detailed diagnostic results.

CONCLUSIONS

The Ishihara test which has almost a century background does not fit today's technology and has many drawbacks as listed below:

- Using the plates over time causes wear and tear, dust, fingerprints[26-29] therefore the colours on the plates will be more difficult to see, so the test accuracy will be reduced.
- There is no established standard for the papers used in the plates. Therefore, the brightness levels and qualities of the colours used in the plates are also dependent on the quality of the paper used.[30]
- There is a risk that the output printer cannot achieve the same required level of sharpness and clarity at all the time.[31]
- The introduction of direct sunlight or the use of electric light may produce some discrepancy in the results.[26,27]
- The colours used in the plates are applied to the persons without measuring their accuracy.[29,32]
- The test cannot determine a person's stability/instability to choose.[30]
- For colours to occur, the ambient light is one of the vital conditions which can also cause misleading results if it is not observed.
- Daylight enters the test room with different angles at different times in a day can cause different test results.[32]
- Total test duration is ambiguous.
- The Ishihara test does not give detailed results, so it is very difficult to carry out further scientific studies with the results.
- Because of the Ishihara plates is in a certain order, an individual may memorize all the answers.
- There are no plates to diagnose Tritanopia colour blindness in The Ishihara test,[33] so it impossible to diagnose if an individual suffers from Tritanopia colour blindness.[34]
- There may be severity differences which even can be seen between Ishihara tests.[31,35,36]
- Ishihara plates fade when exposed to sunlight.[26,27]
- Occasionally, some Ishihara plates could not be identified correctly by subjects deemed to have normal colour vision.[37]

It is a matter of debate that the accuracy of the results from the Ishihara test with the drawbacks listed. Of course, some of the drawbacks caused by practitioner in practice but it doesn't change the fact that the test is so prone to cause misdiagnosis. The questionnaire has proved that most of the ophthalmologists do not entirely follow the test instructions and still use Ishihara pseudoisochromatic plates for colour vision assessment in their routine practice. However, they thought that it does not meet their needs and believe that a new computer-based colour vision test is essential for the detailed examination of the patients with colour vision deficiency. Although some of the drawbacks can be accepted as an implementation flaw, these flaws may cause different results. Ishihara instruction about time is one of the contentious issues to decide if it should be followed during the test. For more definite results, the study should be applied on more individuals and the diagnostic results should also be compared with Anomaloscope which is known as a golden standard for colour vision assignment. The questionnaire used in this paper is a preliminary study. The questionnaire

can be expanded with more questions and applied to more ophthalmologists.

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