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A study of the validity of the Keystone color vision cards as a screening device for color defectives

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Abstract

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By
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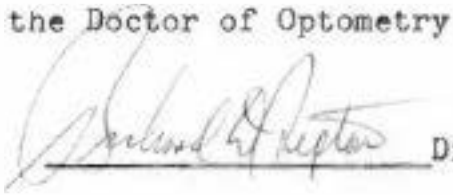
Accepted by the faculty of the College of Optometry, Pacific University, in partial fulfillment of the requirements for the Doctor of Optometry degree.



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INTRODUCTION

Approximately ten per cent of the population of the United States is color deficient. The testing methods used to determine these deficiencies vary greatly. One test is the Keystone Color Screening Cards, derived from the Dvorine Plates. The basic advantage offered by the Keystone Cards over the Dvorine Plates, or any other similar series of plates, is the minimal time spent in administering the test. It is recognized that the Dvorine Plates are of a nigh quality and are an excellent color screening device. The Keystone-Dvorine Cards, two in number, are taken from the series of Dvorine Plates and are the two most difficult for the color deficient to detect.

The Keystone Cards, as they are presently designed, present certain characteristics of a questionable nature, which could result in invalid diagnoses. Two of the characteristics that this study investigated were disparity of the cards and varied overhead illuminations. Disparity is defined as a slightly different stimulus pattern to each eye which elicits a phenomenon of depth, as observed in the stereoscope. One of the Keystone Cards, DB13A, was known to exhibit this phenomenon of

depth, thereby presenting an additional variable.

Our purposes were to investigate the validity of the Keystone-Dvorine Color Screening Cards for screening a selected population for color vision deficiencies, and to investigate the possible differences between monocular and binocular viewing. Our basic hypothesis was that the Keystone screening procedure will fail to detect a significant number of known color defectives.

REVIEW OF LITERATURE

Keystone-Dvorine Color Screening Cards:

Dvorine originally made a two volume set of testing cards in which he selected two color combinations. These colors were selected because they had been proven to be the most confusing to color vision defectives. The colors were orange and green (DB 13A) and blue and purple (DB14A). Dvorine noted in his testing that in no instance did a patient fail his screening plates and later pass a more complicated and lengthy test. We found this to be true, with all our subjects on the two Keystone-Dvorine Cards, however we were unable to find any reference as to whether Dvorine's subjects passed his test and then failed a more "more complicated and lengthy test". The figures on the Keystone Cards were selected on the basis that the purity of these colors were the most difficult for color deficients to detect.

A.O. H-R-R Pseudoisochromatic Plates:

The H-R-R test is unique in certain respects. The plates are made up of a number of different sized dots, some colored and some a neutral gray. The neutral gray background assures that the visual capacity required for reading the characters is not hue discrimination,

but purity sensitivity. As one progresses through the book of plates the colorimetric purities of the colored spots and therefore their saturations for a normal observer increase by steps. The test makes a good qualitative diagnosis of deficiencies; i.e. separates protanopes and protanomals.[1]

Ishihara Pseudoisochromatic Plates:

As in the A.O. H-R-R plates, the purity increases as one progresses through the test booklet. The Ishihara plates test only for red-green deficiencies as opposed to the H-R-R plates which test for blue-yellow deficients as well. It is more difficult to gauge the severity of the defect than with the H-R-R test because there is not such a drastic change in purity.

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[1] Walls, Gordon L.: "How Good Is the H-R-R Test for Color Blindness?", American Journal of Optometry and Archives of American Academy of Optometry, April 1959, Vol. 36, No. 4.

PROCEDURE AND METHODS

The Keystone-Dvorine color screening cards were compared to other color screening tests, the A.O. H-R-R Pseudoisochromatic Plates and the Ishihara Pseudoisochromatic Plates under similar varied conditions of illumination. The Keystone cards DB13A and DB14A were used in a Keystone Stereoscope which was equipped with a new light bulb. The shaft setting was at the far position. The H-R-R and Ishihara Pseudoisochromatic Plates were used under the recommended illumination of the Macbeth easel lamp, and the subjects were tested at their habitual working distance. Thirty-seven male subjects ranging in age from six to sixty-nine were tested with the three tests for color vision deficiencies. Known color defectives were chosen as subjects, and a random selection of subjects made up the remainder of the study.

Each patient was first tested on a standard Snellen chart for visual acuity in order to eliminate blurred vision as a possible variable. If 20/20 acuity or better was not possible, the best Rx would have been provided for the testing. All of our subjects had 20/20 acuity or better unaided or with their habitual lens Rx.

The subjects were then tested on the Keystone-Dvorine cards DB13A and DB14A with stereoscope illumination on and the overhead room illumination on. Under these conditions there was 115 f.c. of incident illumination at the target plane as measured with a Luckiesh-Taylor foot candle meter. The sequence of testing was first monocular viewing and then binocular viewing. The overhead room illumination was then turned off and the monocular and binocular testing repeated. The stereoscope bulb alone provided 100 f.c. of illumination at the target plane. The room or overhead illumination was turned on and off to simulate the varied testing conditions that could exist when the Keystone screening cards are used clinically. We felt that in clinical situations, not enough attention is paid to room illumination and its effects upon test results.

The A.O. H-R-R Pseudoisochromatic Plates were then administered under the Macbeth illuminant, first with the overhead illumination off and then with the overhead on. With the overhead illumination off, there was 35 f.c. of incident illumination and 15 f.l. of luminance at the target plane. With the overhead on, we had 58 f.c. and 25 f.l. of incident illumination and luminance respectively at the target plane. Because the plates tend

to fade with age and exposure to light, the reflectance values varied slightly from plate to plate but were very close to values stated above. Plates one through six were run on all subjects; if S passed these plates, his color vision was considered to be normal, and further testing on the H-R-R was not indicated. However, if a subject failed one or more of the first six plates, the complete battery of twenty plates was run.

The third test was the Ishihara Pseudoisochromatic Plates. It was administered first with the overhead illumination off, and then with it on. As before, the Macbeth easel lamp was always turned on. The incident illuminations and luminances were the same as on the H-R-R Plates.

The Ishihara Plates are divided into groups of four plates per group. Each group of plates has the same purity, one group being slightly different than the other. We chose representative plates from each group. The Plates used were #1, #4, #9, #12, #17, #19, #25, #27, #29, #31, #33, #35, and #37. All the above plates were presented to each subject.

Following testing, the subjects were diagnosed according to the procedure outlined by the particular test manufacturer. For example, if O-1 figures are

correctly identified on the Keystone-Dvorine card DBl3A, severe color-blindness is indicated. If all three figures on card DBl3A are passed but only one or no number is correctly identified on card DBl4A, mild color-blindness is indicated.

If the subject was found to be color deficient on the H-R-R plates, he was then classified either protan or deutan on the basis of his responses on plates seven through twenty. The severity of the defect was found by noting the smallest numbered card on which he correctly identified the symbol or symbols. This same technique was done on cards seventeen through twenty for a classification of tritan or tetartan. The H-R-R plates classify the defect as mild, medium, or strong.

On the Ishihara plates, all of the selected plates had to be read correctly in order to insure a normal classification. Plates #1, #4, #9, #12, #17, and #19 gave us a differential classification of a red-green deficiency or total color blindness. Plates #25, #27, #29, #31, #33, #35, and #37 enabled us to classify the defect as a strong or mild protan or deutan. This was done by noting what the subject saw on the respective plates and then checking this response to the manual accompanying the test plates.

The same stereoscope, Keystone-Dvorine cards, H-R-R and Ishihara Pseudoisochromatic Plates, Macbeth easel lamp, and testing room were used throughout the study. Every attempt possible was made to insure the same testing situations from subject to subject. This included the same instructions for each subject. The instructions for each test are listed in Appendix I.

RESULTS

The normal typings, binocularly, totaled; (26) Ishihara, (26) H-R-R, and (29) Keystone, with the overhead on and near illumination on. Upon referring to Figure 1., it can be seen that there are more normal typings using the Keystone test. Figure 1. also shows that the severity of the defectives varied from test to test. The deficients typed for the Keystone, under these conditions, were (1) mild and (7) severe red-green deficients. The Ishihara typed (3) mild, (2) moderate, and (6) severe, whereas the H-R-R showed (1) mild, (4) moderate, and (3) severe deficients. There were also (3) unclassified cases with the H-R-R.

With the overhead illumination off, the Keystone cards elicited (33) normals, while the H-R-R and Ishihara remained at (26) as demonstrated in Figure 2. Under these conditions, the Keystone showed more normals than with the overhead illumination on and all color deficients found were classified as severe. Ishihara's typings of defectives, as well as normal typings, remained the same as when the lights were on. The H-R-R typing changed, as compared with the overhead on, to (2) mild, (3) moderate, (3) severe, and (3) unclassified. With the H-R-R

plates there was an identical number of normals and deficients in the two conditions; the typings of the deficients showed a trend toward more milds and fewer moderates.

In the Keystone sequence, comparing binocular to monocular viewing, the binocular findings tallied (29) normals with the overhead on and (33) with it off, whereas monocularly it found (26) normals with the overhead on, and (28) with it off, showing a trend for less normal typings monocularly, both on and off (Figure 3.). The deficient typings showed more severe classifications monocularly with the lights on, and a decrease in severe classifications with the overhead off.

RESULTS

TABLE I

SUBJECT CLASSIFICATION

Sex	Name	On-Off	Keystone BINOC.	Keystone MONOC.	H-R-R	Ishihara
M.	W.R.	on	severe R.G.	severe R.G.	strong protan	strong prot.
		off	severe R.G.	severe R.G.	strong protan	strong prot.
M.	T.M.	on	normal	severe R.G.	unclass. R.G.	mild deut.
		off	normal	severe R.G.	unclass. R.G.	mild deut.
M.	D.B.	on	severe R.G.	severe R.G.	medium deutan	strong deut.
		off	normal	normal	medium deutan	strong deut.
M.	D.W.	on	normal	*severe R.G.	unclass. R.G.	strong deut.
		off	normal	*severe R.G.	unclass. R.G.	strong deut.
M.	O.R.	on	severe R.G.	severe R.G.	medium deutan	strong deut.
		off	normal	severe R.G.	medium deutan	strong deut.
M.	K.M.	on	severe R.G.	*severe R.G.	medium deutan	mild deut.
		off	normal	normal	mild deutan	mild deut.
M.	G.M.	on	mild R.G.	severe R.G.	mild protan	mild prot.
		off	normal	severe R.G.	mild protan	mild prot.
M.	C.S.	on	severe R.G.	severe R.G.	unclassified	medium deut.
		off	severe R.G.	severe R.G.	unclassified	medium deut.
M.	P.F.	on	severe R.G.	severe R.G.	strong deutan	strong deut.
		off	severe R.G.	severe R.G.	strong deutan	strong deut.
M.	J.R.	on	normal	severe R.G.	medium deutan	medium deut.
		off	normal	severe R.G.	medium deutan	medium deut.
M.	K.G.	on	severe R.G.	severe R.G.	strong protan	strong prot.
		off	severe R.G.	*mild R.G. *severe R.G.	strong protan	strong prot.
M.	J.L.	on	normal	normal	normal	normal
		off	normal	normal	normal	normal
M.	J.H.	on	"	"	"	"
		off	"	"	"	"
M.	R.Z.	on	"	"	"	"
		off	"	"	"	"
M.	B.W.	on	"	"	"	"
		off	"	"	"	"
M.	B.P.	on	"	"	"	"
		off	"	"	"	"

M.	D.C.	on	normal	normal	normal	normal
		off	normal	normal	normal	normal
M.	C.S.	on	"	"	"	"
		off	"	"	"	"
M.	M.O.	on	"	"	"	"
		off	"	"	"	"
M.	J.S.	on	"	"	"	"
		off	"	"	"	"
M.	E.S.	on	"	"	"	"
		off	"	"	"	"
M.	C.W.	on	"	"	"	"
		off	"	"	"	"
M.	S.W.	on	"	"	"	"
		off	"	"	"	"
M.	J.B.	on	"	"	"	"
		off	"	"	"	"
M.	D.B.	on	"	"	"	"
		off	"	"	"	"
M.	K.B.	on	"	"	"	"
		off	"	"	"	"
M.	L.F.	on	"	"	"	"
		off	"	"	"	"
M.	J.J.	on	"	"	"	"
		off	"	"	"	"
M.	L.L.	on	"	"	"	"
		off	"	"	"	"
M.	D.S.	on	"	"	"	"
		off	"	"	"	"
M.	K.B.	on	"	"	"	"
		off	"	"	"	"
M.	J.B.	on	"	"	"	"
		off	"	"	"	"
M.	S.O.	on	"	"	"	"
		off	"	"	"	"
M.	S.S.	on	"	"	"	"
		off	"	"	"	"
M.	R.P.	on	"	"	"	"
		off	"	"	"	"
M.	V.N.	on	"	"	"	"
		off	"	"	"	"
M.	M.B.	on	"	"	"	"
		off	"	"	"	"

* Denotes monocular disorders not detected with the binocular presentation of the Keystone Cards.

Data compilation of Keystone, H-R-R, and Ishihara color screening tests, as shown in Figure 1. The distribution shows that Keystone types more normals than the other two tests with the overhead illumination on.

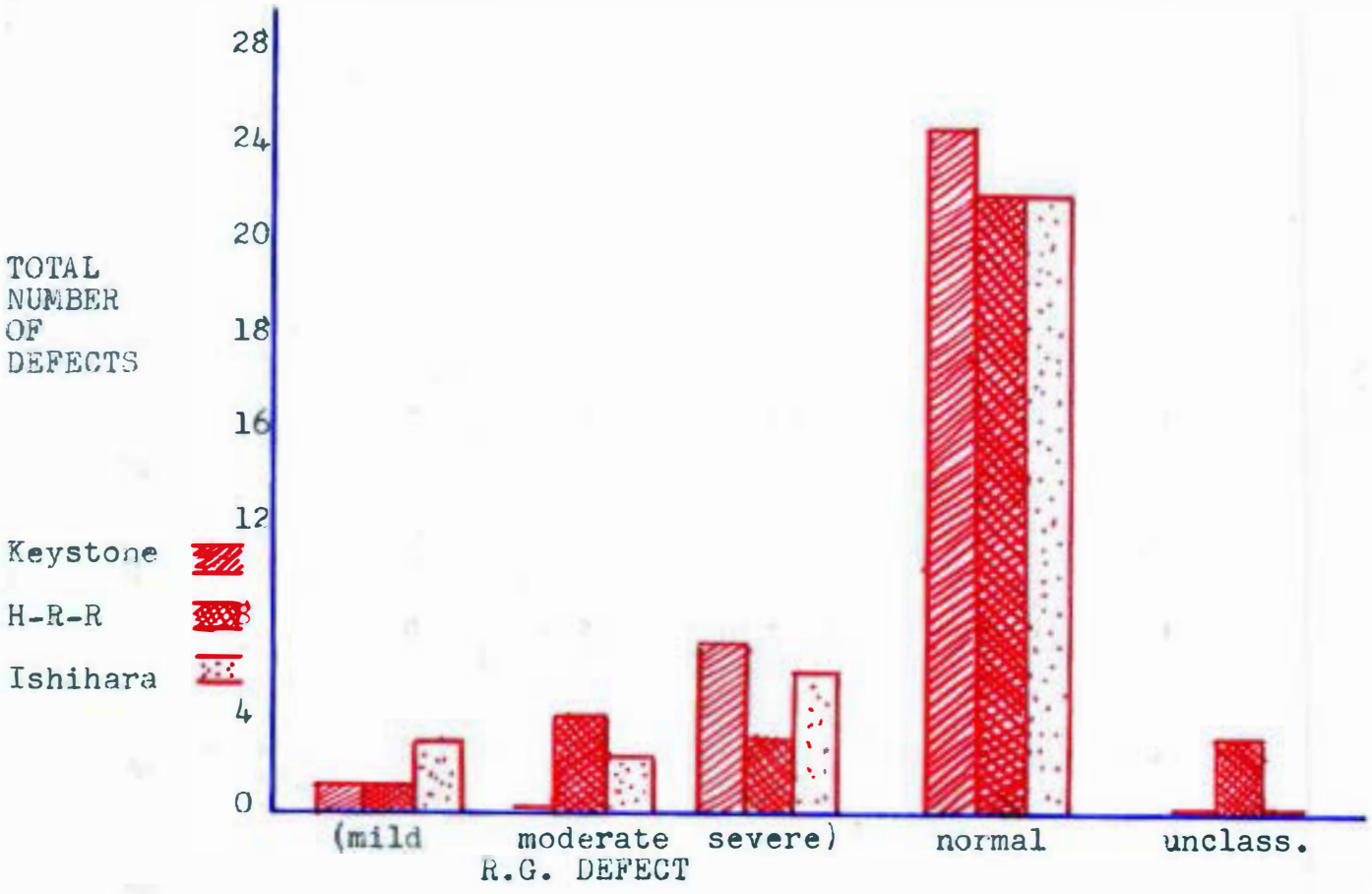
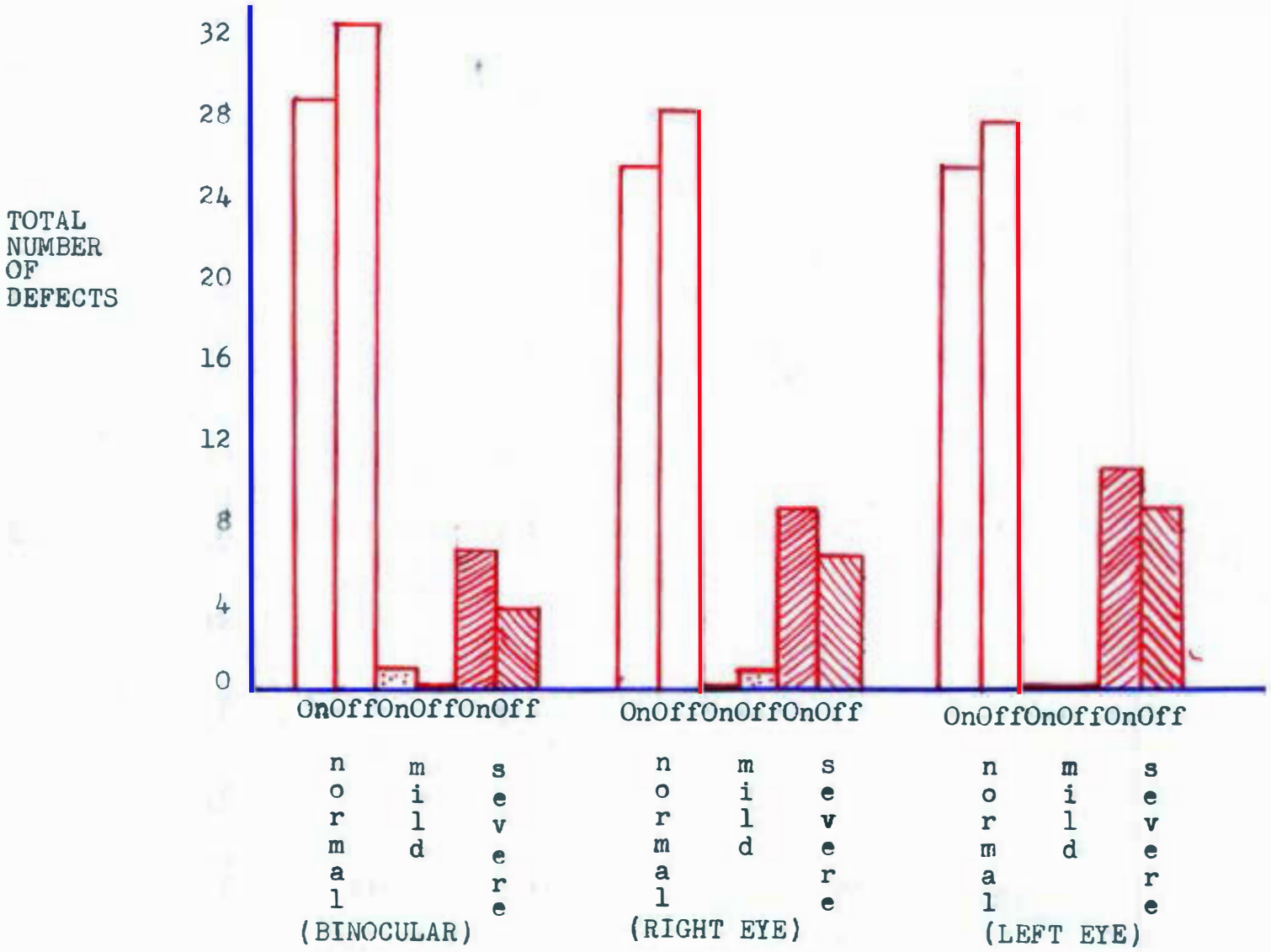


Figure 1. Bar graph of classifications with overhead illumination on.

Data compilation of Keystone, binocular versus monocular viewing condition, overhead illumination on and off. Monocular conditions with overhead illumination on showed the correct number of normals (26).

Figure 3. Binocular versus monocular classifications with the Keystone color vision cards.



Data compilation of Keystone, H-R-R, and Ishihara color screening tests, as shown in Figure 2. The distribution shows that Keystone typed more normals than the other two tests with the overhead illu ination off. It also typed more normals than any of the tests with the illumination on.

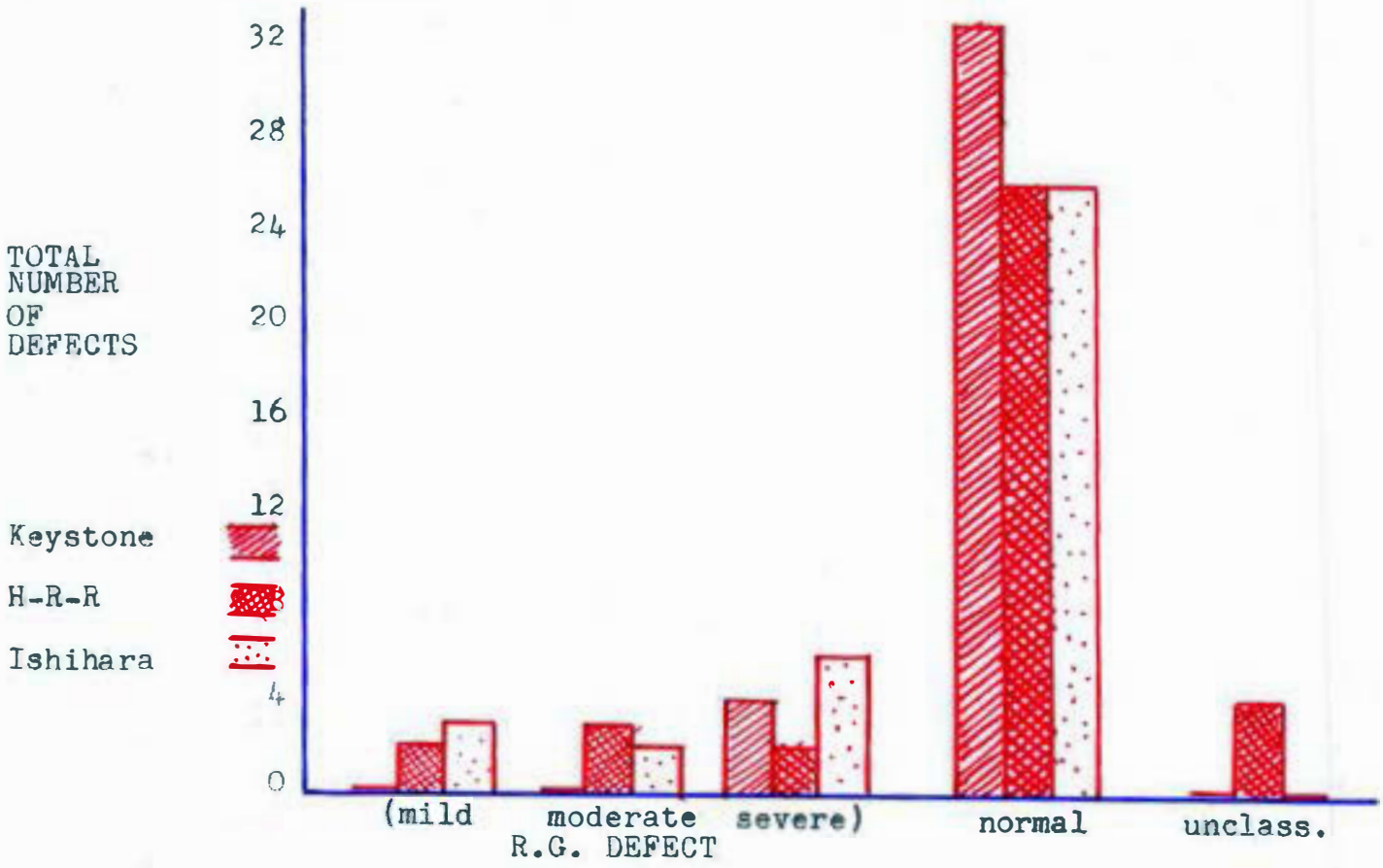


Figure 2. Bar graph of classifications with overhead illumination off.

TABLE II

CLASSIFICATION UNDER BINOCULAR VIEWING CONDITIONS WITH OVERHEAD ILLUMINATION ON AND OFF

	Normal		Mild		Moderate		Severe		Unclassified	
	on	off	on	off	on	off	on	off	on	off
Keystone -	29	33	1	0	0	0	7	4	0	0
H-R-R -	26	26	1	2	4	3	3	3	3	3
Ishihara -	26	26	3	3	2	2	6	6	0	0

TABLE III

KEYSTONE CLASSIFICATION UNDER BINOCULAR AND MONOCULAR VIEWING CONDITIONS-OVERHEAD ILLUMINATION ON AND OFF

	Binocular		Monocular	
	on	off	on	off
Normal -	29	33	26	28
Mild -	1	0	0	1*
Severe -	7	4	11	8

* One subject showed mild R.G.(O.D.) and severe R.G.(O.S.), whereas in "on" sequence (O.U.) was severe.

TABLE IV

PERCENTAGES OF CLASSIFICATIONS UNDER BINOCULAR VIEWING CONDITIONS WITH OVERHEAD ILLUMINATION ON AND OFF

	Normal		Mild		Moderate		Severe		Unclassified	
	on	off	on	off	on	off	on	off	on	off
Keystone	-78.4	89.2	2.7	0.0	0.0	0.0	18.4	10.8	0.0	0.0
H-R-R	-70.2	70.2	2.7	5.4	10.8	8.1	8.1	8.1	8.1	8.1
Ishihara	-70.2	70.2	8.1	8.1	5.4	5.4	16.2	16.2	0.0	0.0

TABLE V

PERCENTAGES OF KEYSTONE CLASSIFICATIONS UNDER BINOCULAR AND MONOCULAR VIEWING CONDITIONS

	Binocular		Monocular	
	on	off	on	off
Normal -	78.4	89.2	70.2	75.6
Mild -	2.7	0.0	0.0	2.7
Severe -	18.9	10.8	29.7	21.6

Tables VI and VII group the test classifications of the Keystone, H-R-R, and Ishihara respectively and list the number of defectives that type a particular classification in each of the three tests. With the overhead illumination on, (4) of the color defectives typed the same on all three tests. Of these, (3) typed severe and (1) typed medium. The remaining (7) color deficient subjects typed differently on one or more of the tests. Of the known color defectives, (3) typed normal on the Keystone. There was a trend for the Keystone and Ishihara tests to type the same, as opposed to the H-R-R. The above information may be found in Table VI.

With the overhead illumination off (Table VII), there were (3) defectives who typed the same on all three tests. These (3) typed severe on each test. Under these conditions, (8) defectives typed differently on one or more of the tests. Of the known color defectives, (7) typed normal on the Keystone. There was no trend for one test to type similarly to another, as was found with the overhead illumination on.

TABLE VI

DIFFERENTIAL GROUP CLASSIFICATIONS
WITH OVERHEAD ILLUMINATION ON *

#	Keystone	H-R-R	Ishihara
3	severe	strong	strong
2	severe	medium	strong
1	severe	medium	medium
1	severe	unclass.	medium
1	medium	medium	medium
1	normal	medium	medium
1	normal	unclass.	strong
1	normal	unclass.	medium

TABLE VII

DIFFERENTIAL GROUP CLASSIFICATIONS
WITH OVERHEAD ILLUMINATION OFF *

#	Keystone	H-R-R	Ishihara
3	severe	strong	strong
3	normal	medium	medium
2	normal	medium	strong
1	severe	unclass.	medium
1	normal	unclass.	strong
1	normal	unclass.	medium

* - Denotes tests under binocular conditions.

DISCUSSION

As has been previously discussed, the percentages of subjects with color deficiencies passing the respective color tests is higher on the Keystone Color Screening Test. This was found under both testing conditions, overhead illumination on and illumination off. The Ishihara plates and H-R-R Pseudoisochromatic plates detected all the color defectives, both with overhead illumination on and off, and thus demonstrated their excellence in anomalous color vision detection.

The Keystone Color Screening procedure detected fewer color deficients with the overhead illumination off than with it on, which would indicate that if the test were to be used by an individual he should maintain full room illumination. A possible explanation for this observance might be that the flourescent tube in the overhead illuminant gives off more of the blue end of the visable spectrum, thus more closely approximating daylight conditions. With the overhead illuminant off, the red-green cards become easier for the anomalous trichromat since the blue end of the spectrum is reduced. The Macbeth easel lamp makes sure this added variable does not enter into the test with the H-R-R and Ishihara.

Also, our data shows that more valid findings may be elicited if the Keystone cards are presented monocularly rather than binocularly. Monocular findings on the Keystone with the overhead illumination on were, in fact as precise in detection as the H-R-R or Ishihara plates.

A part of the Keystone Screening test's invalidity is linked to the presence of disparity between corresponding portions of card DB13A. There was here a disparity of .25 mm between portions of number 79 and its background. This produces quite a sizable stereoscopic clue to the binocular subject. All of our subjects, both normal and color deficient, reported this stereopsis, with the number 79 appearing closer than the background or card itself. This factor in itself would allow some color deficients to pass that card.

CONCLUSIONS

In summary, we feel that the Keystone Color Screening Cards, as they are normally presented, are not an accurate or reliable color screening test. The H-R-R Pseudoisochromatic Plates and the Ishihara Plates are much better tests both from the viewpoints of detection and classification, and are only slightly less convenient to use.

However, should some naive or unsuspecting examiner elect to use the Keystone Cards for color screening, he should be aware that for most accurate results, the test should be made with illumination on, both in the instrument and overhead, and the cards should be presented monocularly.

Above all, he should be aware that the system he is employing in color screening is, at best, effective in detecting only severe color deficiencies to any reliable degree.

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APPENDIX I

Instructions For The Keystone-Dvorine Cards:

DB13A:

Clinician: Here we have a group of circles. How many circles are there?
Subject: Three!

Clinician: In the top circle, do you see any figures?
Subject: _____

Clinician: In the lower left (pointing) #2?
Subject: _____

Clinician: In the lower right (pointing) #3?
Subject: _____

DB14A:

Clinician: And again, the top.
Subject: _____

etc.

Instructions For The A.O. H-R-R Pseudoisochromatic Plates:

Instruction Plates:

Clinician: (Hands paint brush to patient): "Take this brush and trace lightly over symbol or symbols which you see; like this: (Clinician does it.. ...Patient does it.)

Plate #1:

Clinician: "And now do just as you did before.

etc. (with the rest of the plates.)

Instructions For The Ishihara Pseudoisochromatic Plates:

Plate #1:

Clinician: In this test we want you to trace over the symbols or numbers which you see, as you did in the previous test.

etc.