MODIFICATIONS IN PRESENTATION OF THE FARNSWORTH-MUNSELL 100-HUE TEST FOR USE IN THE ELEMENTARY SCHOOLS

by

DOROTHY BEATRICE TAYLOR

B.A., University of B.C., 1970

A THESIS SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Arts

in

Educational Psychology

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

August, 1971

ABSTRACT

Because of the increasing use of colour as a primary cue developing concept and as a contextual cue, this study was conducted to modify presentations of the 100-Hue Test for colour discrimination in order to make it a useable instrument for screening the elementary school child who might have difficulties with colour discrimination though he is not a colour defective, which could handicap his school performance.

The subjects were 124 boys, aged 12 years. They were divided into four equivalent groups in relation to I.Q. The Ss were Vancouver, B.C. elementary public school children. The Dvorine Pseudo-Isochromatic plates were shown to each subject as a means of establishing rapport and quickly identifying colour defectives so that they could be excluded from the sample - 4 defectives were found who had congenital anomalies. This percentage of 4.9 was lower than the commonly reported 8.1% for the male population.

Group 1 were read the standard adult instructions from the Farnsworth-Munsell 100-Hue manual, before being asked to complete the test. Group 2 were read the standard adult instructions from the Farnsworth manual for the Panel D-15 (Dichotomous Test for Colour Blindness), before completing this test plus the adult instructions from the 100-Hue manual, before completing

the latter test. Group 3 were read a standardized set of modified instructions which were created for this study. Group 4 were read the same set of modified instructions with the addition of the use of the Panel D-15 as part of the instructions.

Statistical analysis of the mean error scores for the 4 groups revealed, as hypothesized, statistically different means between the groups using the modified and those using the standard instructions. Group 3, using modified instructions without the inclusion of the Panel D-15 performed best, functioning as well with these instructions as do adult subjects.

The results indicate that 12 year olds can function significantly better on the 100-Hue test with modified instruction than other studies with other populations of children, using other types of presentations have indicated.

ACKNOWLEDGEMENTS

The writer wishes to express her gratitude to the Vancouver School Board for their co-operation and support of this research project.

Appreciation and gratitude are also due to the members of her thesis committee - Dr. P. Koopman, Dr. R. Lakowski and Dr. E. D. Allison. Their advice and encouragement were invaluable in the completion of this study.

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CHAPTER I

INTRODUCTION

Interest in colour vision and its development has a long history, being a classical field of inquiry in psychology. The most common deficiency in colour vision, colour blindness, was first described by Tuberville in 1684 (Judd, 1943), first accurately classified in 1837 by Seebeck; intensively investigated by Young, Hemholtz and Maxwell during the nineteenth century; so that as early as 1855 it was known to effect 10% of the male population. Gradually better and simpler tests were devised, by Nagel, Stilling and Ishihara among others.

The demand for such tests in the school population has been felt in some countries. Japan, for example, has made colour vision testing in its schools compulsory for the past twenty years. More recently, Scotland, (1962) has also made colour vision testing a part of school health services. Publicity given in recent years to schemes for teaching reading and mathematics with the use of colour has created widespread interest in North America as to the value of the specific uses of colour in education. However, most educators and researchers have not yet become concerned with the problems for the colour deficient child which increased use of colour in instructional material has created. The need for widespread screening services to aid such children who will otherwise be penalized by such learning procedures will become increasing obvious.

A doctoral dissertation (Prater 1968), investigated colour uses in Primary Instructional materials and the possible implications for colour deficient children. Colour references which were specifically used for instructional purposes were categorized according to function and according to skills receiving emphasis in the classroom. The summary of the total incidence revealed that colour was used 12,067 times for instructional purposes in the five primary reading series in the United States. There were 2,188 references to colour tabulated in the five primary arithmetic series. In arithemetic as in reading, the highest incidence (823 uses) was at the first grade level. At the readiness level, 79.74% of the colour references were used to control the learning situation. Results also showed that the colours which are most frequently confused in colour blindness, red, green and blue, were used more frequently than others in both arithmetic and reading materials. Interviews with colour blind students were conducted to test their reactions to samples from the instructional materials examined. Problems which required students to distinguish between colours did prove difficult. First grade subjects gave the most incorrect responses and college students showed the greatest frustration. Results of interviews also suggested that problems which utilized colour may produce confusion and negative emotional reactions in colour deficient individuals.

In view of the high percentage of colour references used to control the learning situation at the critical levels in school and the results of the interviews, colour usage for instructional purposes should be carefully evaluated, according to the findings of this study, (Prater, 1968).

Researchers, however, have long been interested in the role of colour in learning, and there is a sizeable body of literature on the subject. A recent review of the literature (Otto and Askov, 1968) suggested the current areas of concern. Two general themes emerged, one is the study of colour in developing concepts; the other is the study of colour as a contextual cue, particularly in paired-associate learning.

Results of the studies in concept attainment indicate that younger children use colour as a cue more frequently than do older subjects who tend to use form in preference to colour as a cue, and particularly in matching tasks. Corah (1964) explained this tendency in terms of Piaget's concept of centration. That is, while a young child (whose perception, according to Piaget, is not yet decentered) would attend only to the dominant characteristics of a configuration - i.e., its colour - an older child would be free to attend to all characteristics, including form. Other studies (Gaines 1964 and Suchman and Trabasso 1966) found that colour/form preference is related to ability to discriminate and therefore to performance level. The studies of colour as a contextual cue indicate that colour is a significant factor in learning, particularly paired-associate learning. Saltz (1963) alternated learning and test trials and presented colour cues only during learning or only during testing. He found that colour cues enhanced learning under both conditions. Crannel, (1964) found that colour is utilized as a cue in more difficult learning tasks, that is when the primary stimulus cannot be easily discriminated.

Otto & Askov (1968) also reviewed the literature dealing with the uses of colour in instructional materials. They noted that studies tended to be descriptive rather than experimental. Jones (1965), a notable exception, examined the value of colour as an aid to visual discrimination of words and letters in nursery school children. Jones concluded that: "without colour the tasks were at least three times as difficult even when possible colour matching was considered." He also noted that subjects strongly preferred the coloured test materials.

Gattegno's, (1962), use of a morpho-algebraic approach to teaching reading called, "words in colour" which uses colour as the primary stimuli has been referred to by the authors as gaining in acceptance. A similar method of teaching reading to dyslexics is also in use (Bannatyne, 1966).

Otto & Askov also found in their own studies that good readers tended to utilize colour cues more than poor readers and that grade and developmental level is critical in determining the value of colour cues, so that what works at one level may not work at another. Their conclusions that the use of colour cues in instruction could not be very explicitly prescribed but that the use of colour in instruction is on the increase, concur with Prater's findings.

Although the use of cuissenaire rods in teaching arithmetic in the primary grades is quite widespread, this was not mentioned in any of the studies referred to.

It seems clear in view of the foregoing evidence that not only is the use of colour in instructional materials on the increase but that only limited attention has been paid to the child most likely to be handicapped by excessive use of colour as a primary cue in learning; that is, the child who has some impairment in the ability to discriminate colour.

Identification of the colour deficient child is also important in relation to vocational training. Colour coding in industry increases with the complexity of invention. Complicated and often dangerous procedures can be made safer and simpler (for the colour normal) by colour-coding procedures (Mitchell, 1960). Examples are found in electronics, television, computers, missiles, aviation and in chemical and metallurgical engineering. Individuals who cannot qualify for these professions because of colour deficient vision should be informed at the pre-high school level, in order to prepare for another vocation.

It would seem that, considering the prevalence of colour in learning situations particularly at the elementary school level, adequate screening procedures should be a part of school health services.

Only one study was reported in the literature for the past decade that attempted to evaluate colour vision testing for an entire school district and that was in 1964 in Baltimore, MD. Two other studies which attempted to evaluate colour vision tests for kinder-garten and grade one students have been done by

Gallagher, (1964) and Lampe, (1969). Apart from these there have been evaluations done on the Colour Pyramid test, otherwise the field seems to be a neglected one.

A significant distinction must be made here in regard to colour vision screening. Even if a more wide-spread use were made of existing tests now available to schools, these would only facilitate the identification of the colour blind persons, that is, those who confuse reds with greens or blues with yellows. By excluding congenital defectives of this type the problem would not be solved. There are an undetermined number of children whose discrimination of colours in the spectrum is impaired. Little data is available on such children. We know relatively nothing about the problems in colour discrimination encountered by such children. The child is usually unaware of deficiency in colour discrimination and the teacher would likely assume that he is unable to learn for other reasons. There is only one test for discrimination surface colour which is available that is fairly simple to administer and which does not require expensive and cumbersome apparatus and would therefore be suitable for the elementary school. This test is the Farnsworth-Munsell 100-Hue (100-Hue).

However, one problem presents itself in recommending the use of this test with elementary school children. The instructions in the Farnsworth Manual are written for adults and application of the present procedures to children have not been notably successful to date. This means that because the difficulty of communicating the concept of a "colour series" to children twelve years and under has not been simplified, the test has not generally been used with elementary school children. It would appear that modifications would be necessary to make it useful to elementary schools. The Farnsworth Dichotomous Test for Colour Blindness - Panel D-15 could be of use in this regard as it is based on a simplified model similar to the 100-Hue and therefore able to present the concept of colour series more simply.

STATEMENT OF THE PROBLEM:

The materials presented in the foregoing suggests the need for an experimental study of the 100-Hue with a normative sample of elementary school children using both the standard instructions for adults, as well as modified presentations for children. One such modification will include the Panel D-15 as part of a teaching method to communicate the concept of "colour series". The procedure in this study will permit a test of the efficiency of the modified presentations with and without the Panel D-15 versus the standard instructions when used with children, and certain related hypotheses.

The aim of the study will be to determine the usefulness of revised methods of administration to children as a test for colour discrimination in the elementary school. It is hoped that in providing a modification of administration of the 100-Hue suitable for diagnosing colour discrimination problems in elementary school children, that this information may aid teachers in establishing learning procedures for colour deficient children which do not rely on colour as the primary stimulus. The following hypothesis will be tested:

1. Error scores on the Farnsworth-Munsell 100-Hue using standard adult instructions should be significantly higher than scores obtained when modified instructions, both with the Panel D-15 or without, are used.

2. Supplementary Hypothesis: The modified instruction which includes also administration of the Panel D-15 prior to the 100-Hue test will produce the most significant reduction in test scores.

CHAPTER II

REVIEW OF THE LITERATURE

Only four previous investigations have been conducted which report results concerning the performance of pre-adult subjects on the 100-Hue test.

Verriest, Vandevyvere and Vanderdonck,(1962)

These investigators were concerned primarily with age changes in colour vision from childhood to old age. Considering the work of, for example, Boice, Tinker and Paterson, (1948), who found no correlation between performance on the Ishihara and age change from 20 to 59 years, it was concluded that ordinary pseudoisochromatic plates are too gross as tests to show any significant changes with age.

In this study therefore, Verriest et al administered the 100-Hue test to 480 subjects aged from 10 to 64 years and comprising 248 men and 232 women. A minimum of 30 subjects were included in each five-year classification more or less equally divided as to sex.

Those subjects were excluded who were discovered to have congenital colour defects, whose co-operation was poor, or who did not complete the test quickly enough. The time allowed for subjects less than 15 years old for completing one box was 2 minutes 20 seconds. The results were classified according to colour, age and sex, and were submitted to an analysis of variance.

The differences in performance due to age were highly significant. The mean total error scores for subjects in the three younger groups (aged from 10 to 24) were as follows:

Table I

	10 - 14 years			15 - 19 years			20 - 24 years		
	M	F	Total	M	F	Total	M	F	Total
No. of subjects	22	27	49	25	31	56	60	34	94
Lowest score	24	16	16	16	8	8	4	4	4
Highest score	160	194	194	124	94	124	162	108	162
Mean	92.5	75.3	83.1	60.1	44.5	51.5	42.3	25.5	36.3

The mean error score achieved by subjects aged from 20 - 24 years was found to be significantly smaller than all other age means. Thus findings reported by other studies are confirmed for the 100-Hue test, namely, that colour discrimination improves gradually until the beginning of adulthood and afterwards deteriorates in the same gradual way. Brown, (1950), Janouskova, (1957), Gilbert, (1957), Lakowski, (1958).

While it seemed reasonable to attribute the general trend of performance on the 100-Hue to genuine physiological differences, Verriest, et al., concede that psychological factors may be partly responsible for the high error scores among the youngest subjects.

Further analysis of the results showed that the deficiency in discrimination of the youngest and oldest subjects was particularly noticeable in the blue-green and reddish hues. In this respect a similarity was noted to the deficiency observed in congenital colour defects of the Tritan type, and also to the losses which can be induced in young adults by their wearing filters which selectively absorb short wave-length radiations.

It must, however, be mentioned that there was an accumulation of errors in these regions even in the case of the 20 - 24 year old age group. Thus it seems that the 100-Hue test is faulty in that discrimination is too difficult relatively in the blue-green and red regions. In view of this fact, it would be misleading to infer too much concerning the nature of colour vision in younger subjects from their performance on this test alone and comparison with that of tritanomalous subjects.

The fineness of discrimination that can feasibly be measured by a test may depend in part on the complexity and conceptual difficulty inherent in its presentation. As such factors are likely to be of greater importance in the case of the youngest subjects, explanation of the observed results in physiological terms may be out of place. If some areas of the test require finer discrimination than others, on the above assumption, the accumulation of errors in these regions should be greater for those subjects who find the test conceptually most difficult.

Finally, although Verriest, et. al. report no test-reliability measure for children under 15, a co-efficient of 0.93 was obtained by the ranking method, for normal subjects between the ages of 15 and 25 who were retested after two or three months.

In addition, no advantage on the test was found due to training or experience in colour discrimination in other contexts.

Subjects whose profession required them to work with colour did not make significantly lower total error scores than non-selected subjects in the same age group, that is, 18 - 24 years.

The second study to be considered seems to be the earliest one to date which as its primary objective investigates the possibility of using the Farnsworth-Munsell 100-Hue test with children.

Lumbroso and Proto, (1963), point out in their paper, that the examination of colour vision in children presents particular problems in that the co-operation of such subjects is often poor. The 100-Hue test has usually been confined for use with adults for it requires the subject's co-operation in performing as well as he can and in carrying out a relatively difficult task without help.

Although Verriest, et. al. had included subjects as young as 10 years in their study, in no previous investigation was the test administered to children younger than 10 years. Lumbroso and Proto were thus the first to provide data as to the performance of such subjects on the 100-Hue.

It was found to be impossible to test children younger than 5 years old as they did not co-operate in the test situation. With the 5 - 6 year olds, the examiner managed to carry on the test in the majority of cases, while in the 7 - 10 age group nearly all the subjects are reported to have co-operated perfectly.

The very young subjects were allowed three to four minutes to arrange the contents of each box but the scores of those who hesitated longer than the allotted time were not included in the results. Children over 7 years were found in general to require no more than the standard time of two minutes to complete each box.

The results reported for twelve normal children from 5 - 6 years old, and 34 from 7 - 10 years are as follows:

Table II

5 - 6 year old group	Minimum error score	100
	Maximum error score	335
	Mean	177
	Standard Deviation	65.7
7 - 10 year old group	Minimum error score	31
	Maximum error score	311
	Mean	138
	Standard Deviation	63.9

If these results are compared with Farnsworth's norms, it can be seen that the mean error scores for both groups are greater than that of the 90th per centile of the adult population (error score of 120) and than that reported by Verriest et. al. for the 10 - 14 age group (error score of 83.1).

It was also found that both groups of subjects showed an accumulation of errors in the green-blue region of the test and also in the red region for the 5 - 6 year olds. This confirms the results reported by Verriest et. al. concerning these areas of the test.

Lumbroso and Proto conclude from these results that the 100-Hue is suitable for use in studying the colour vision of children under 10 years of age. In view of the significance of this statement for further investigations, it is unfortunate that the claim is not further clarified.

It seems that three separate interpretations might be made.

(1) Young children are capable of performing on the 100-Hue test.

(2) The 100-Hue is a suitable instrument for studying the colour discrimination of children.

(3) The 100-Hue is a useful diagnostic test of colour vision in young subjects.

None of these possible interpretations appear to be supported by the experimental evidence as reported.

(1) Apparently only a 'majority' of the 5 - 6 year olds and 'nearly all' of the 7 - 10 year old group co-operated in the test situation. No figures are given concerning the numbers who failed, but it seems that in neither age group were all children capable of performing the test. Unfortunately no assessment of the intelligence of the subjects is reported. It might be supposed that the more intelligent children may be capable of co-operating in the test situation at a younger age. Without such knowledge about the group of subjects used, it is impossible to consider the findings of this investigation as having general application.

(2) The degree to which measurement of colour discrimination as such is contaminated by general learning factors and level of mental development, is not considered in this study, although the observed improvement of performance with age would seem to suggest their relevance.

(3) The scores obtained by children in this study were greater than those of 90% of the normal adult population. The implication of this finding is that pre-adult subjects should be considered as forming a different population whose performance must be assessed with reference to separate norms.

If factors such as intelligence are of great importance in determining performance on the test, it may prove that control for stabilizing age norms alone is not sufficient for an adequate assessment of the child's visual ability. Until such aspects of the test are investigated, it cannot be considered as a useful diagnostic instrument.

In addition, it appears that not all the children tested by Lumbroso and Proto, (1963), were able to perform the test under the standard conditions specified by Farnsworth.

For example, the younger children could not fulfil the time requirement and approximately 14% were unable to complete one box even after four minutes. Unfortunately no information is given as to the instructions used. However, it appears that the conditions of the test would have to be altered if it is to be used with children.

Another study, Luscombe, (1966), was the first experimental study to attempt to modify the presentation of the 100-Hue test with children.

The 100-Hue, as well as the Ishihara Pseudo-Isochromatic Plates were administered to 174 boys aged 7 - 15 years. Subjects were grouped and three stages of presentation were used. Results on the Ishihara need not concern us here as it was used primarily as a means of comparing the performance of normals on tests which differ in nature and construction. All subjects were tested twice on the Ishihara and the 100-Hue, identical instructions being given on both occasions.

This investigation was concerned primarily with maturation factors effecting colour vision from 7 - 15 years, intelligence affects on colour test scores and effect on test scores with a modification in presentation.

Results confirmed the findings of other studies (Verriest et. al., 1962, Lumbroso and Proto, 1963, Brown, 1950, Janouskova, 1955, Gilbert, 1957, Lakowski, 1958) that colour vision tends to improve with age. Scores of the oldest group of subjects were inferior on both tests to those reported for adults in other investigations.

According to the findings, lack of comprehension of the standard instructions was not significantly related to age; 7 - 9 year olds performed better than the 11 - 13 year old group with the modified presentation however.

The modified presentation was limited to 40 subjects 7 - 15 years of age. A perceptual device was used as an aid to understanding the instructions. This was a white card with Munsell coloured papers attached, identically coloured to match the colour caps contained in one section of the 100-Hue. Subjects were told to follow the same pattern with the colour caps of the test as they saw on the card. However, direct matching of caps to papers was not permitted. When subsequent sections of the tests were administered, subjects were no longer permitted to see the demonstration card but were told to 'make the same kind of pattern' as they had before. Purportedly all the subjects in this group of subjects 'understood the test correctly'.

Mean error scores for all subjects, even when those who misinterpreted the instructions were excluded, were considerably greater than those reported by Lumbroso and Proto, (1963), for 7 - 10 year olds, and by Verriest et. al. (1962) for 10 - 14 year olds.

Intelligence affect on colour vision tests such as the 100-Hue was indicated by the sample of 10 subjects who differed in being 15 I.Q. points higher than the other subjects and who scored significantly better on the 100-Hue test. Since this variable was not controlled for in the previous two studies under review no valid comparisons can be made. Retest scores showed negligible improvement, much less than those reported for adults in other studies (Farnsworth, 1943, Lakowski, 1965).

In summary, this study indicated that the modification of the instructions for the 100-Hue could be an important variable in determining scores on the 100-Hue with children. However, the experimental evidence presented showed no improvement in the scores of children who were given the modified presentation that could not be accounted for by chance.

A recent study (Lakowski and Montgomery, 1968), on deaf children, introduced another modification of the 100-Hue which would seem to be more effective as a means of making the instructions more understandable to younger children, even those with a severe handicap.

The deaf children were given the Farnsworth Panel D-15, a test which parallels in presentation and test material used, the 100- Hue. There is one exception, however; the colour difficulty on the Panel D-15 is much smaller as there are larger differences between the neighbouring colour caps. The Panel D-15 was administered before the 100-Hue since no verbalization to the subjects of the instructions was possible. By this means, the experimental results indicate that the subjects were enabled to comprehend the concept of "colour series" which made administration of the 100-Hue not only possible but successful to a significant degree with children.

Due to the limited and specialized nature of the sample used in this study, further corroboration with larger, normal populations would seem to be necessary to verify the findings.

The studies reviewed in the foregoing, indicate the need for more evidence as to the effectiveness of the use of the 100-Hue with normal children at the elementary school level and the utilizing of even more effective modifications in presentation to aid in their understanding of how to perform on this test.

CHAPTER III

METHODS & PROCEDURES

SAMPLING AND SUBJECTS:

The subjects were 24 boys, aged 12 years, from Vancouver, B.C. elementary schools that comprised the sample. They were divided into four equivalent groups in relation to I.Q. Equivalence of groups was obtained by the following method: The groups were checked and matched by inspection for I.Q. and then the significance of the difference between the mean I.Q. scores of these groups was tested by computing *t*-scores. A statistical computation of the significance of the means using *t*-scores as the method resulted in the following table:

Table III

t-scores on I.Q.s

I	II	III	IV
	.39 .30 df	.12 .29 df	.83 .30 df
II		.26 .29 df	.52 .30 df
III			.71 .29 df

None of the above *t*-scores are statistically significant as the score has to be of 1.645 value (df 30) to be significant at the 0.05 level.

Table IV

Means and Standard Deviations

on I.Q. Scores

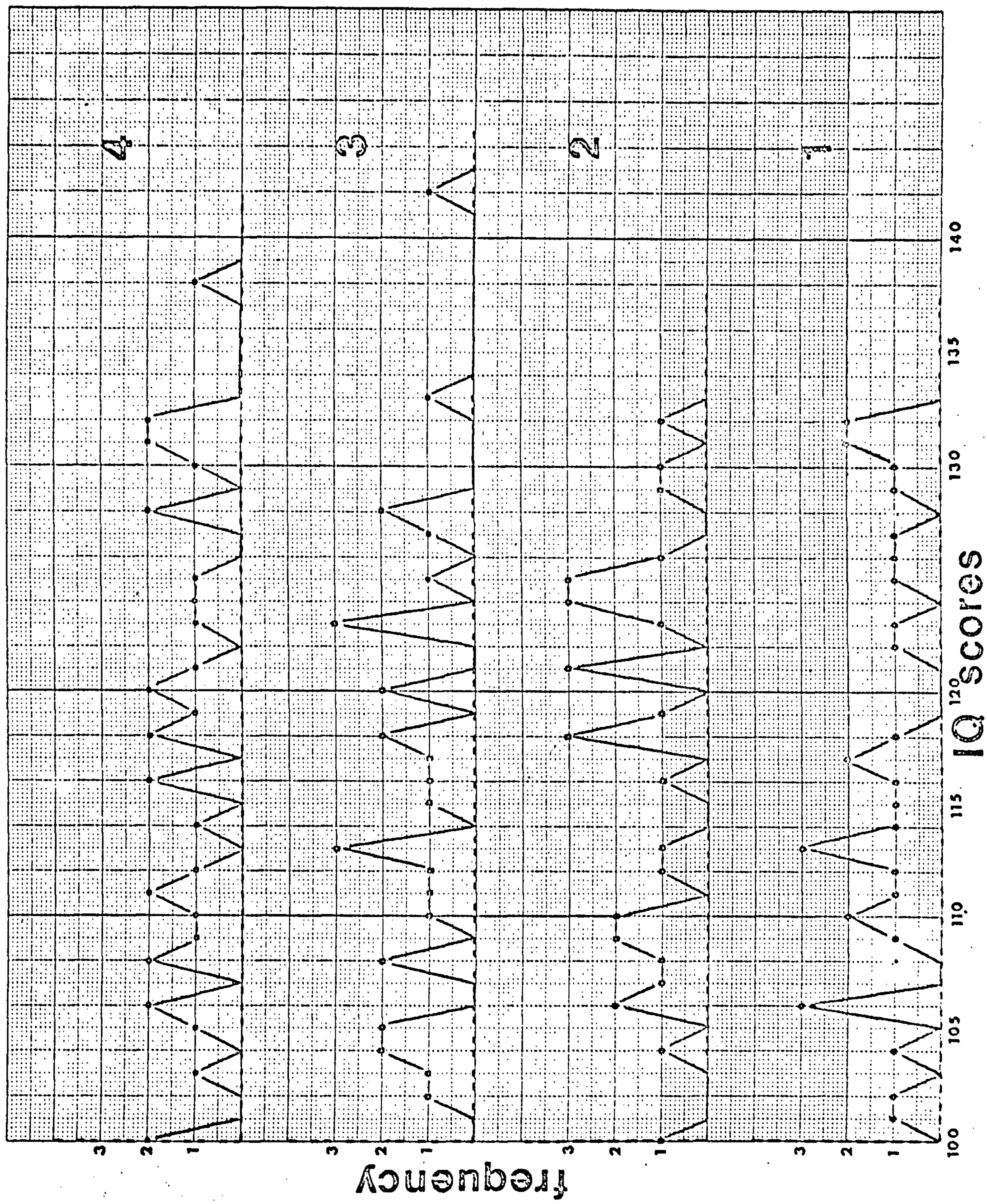
Group	N	Mean I.Q.	Standard Deviations
I	31	116.6	9.4
II	31	117.2	8.5
III	30	116.8	9.5
IV	32	118.0	10.3

I.Q. scores were obtained from the Henman-Nelson, Form B, group test (P.14, table IX) manual, which gives the mean value for this test as 105.82 and the standard deviation as 14.12 for students in grades 3 to 6.

Students were selected with I.Q. scores of 100 or more due to experimental evidence that a significant correlation exists between I.Q. and the ability to discriminate colour (Lakowski, 1969).

Boys were used as subjects as they are usually later in maturing than girls (Verriest, 1962) and because previous research indicates that colour deficiency in females is far less common than it is in males (less than 0.5% of females are colour blind compared to 8.1% of males).

COMPARISON OF GROUPS



To keep the age variable controlled subjects were chosen to have variance in age of less than 12 months. This control was excercised because age has been shown to be a significant variable in colour vision tests. (Lakowski, 1958, Verriest, 1962). Age was therefore held constant in each of the four groups.

PROCEDURE:

The Dvorine Pseudo-Isochromatic plates were shown to each subject in each of the four groups as a means of establishing rapport. It was also a means of quickly identifying possible colour defectives so that they could be excluded from the sample.

The four groups were divided up as outlined in the Method Section. Each group was given four variations in instructions. Group one received the manual instructions for the 100-Hue. Group two received the Panel D-15 manual instructions and test and the manual instructions for the 100-Hue. Group three received the standardized modified instructions, and group four received modified instructions which included the Panel D-15 as part of these instructions. The following is the procedure:

Step 1 - Group 1:

Administration of the 100-Hue to one group of 31 subjects. Each subject was given the standard adult instructions from the Farnsworth manual. These read as follows:

"The object of this test is to arrange the caps in order according to colour. Please transfer them from this panel (indicate) to this panel (indicate) and place them so that they form a regular colour series between these two caps (indicate). It should take you about two minutes. However, accuracy is more important than speed - so you will be told when the two minutes are up, but the panel won't be taken away from you. Arrange them as best you can and don't dawdle."

Step 2 - Group 2:

Administration of the Farnsworth Panel D-15 and the 100-Hue to each of 31 subjects, individually, using the standard manual instructions only for each of the two tests. The Panel D-15 manual instructions read as follows:

"The object of the test is to arrange the buttons in order according to the colour. Take the button from this panel (indicate) which looks most like this button and place it here (indicate space next to the fixed reference cap). Take the button which looks most like that and place it here; continue doing this until all the buttons are arranged in order."

If the subject does not seem to grasp the problem, further help is given:

"After each button is placed it may be necessary to say, 'Now which of these buttons (indicate) is most like the last one? (indicate) (one alteration was made; substitution of the words "colour cap" in place of the word "Button" in order to make the instructions more uniform with the instructions for the 100-Hue)."

The manual instructions for the 100-Hue were used (see step 1 - group 1).

Step 3 - Group 3:

The modified instructions were standardized as follows and were read to each subject:

"First of all, what colour is this cap (Motioning)? Now choosing one colour cap from all these (scanning finger across top of tray) I'd like you to find one that's almost exactly the same colour as this one you've called "blue" (or colour name given) and place it right here (point). You may try several caps until you're satisfied its the closest in colour."

"Now I'd like you to pick the very next closest cap in colour to this last one you've just put down. Remember, it must be the very next closest colour, almost exactly the same but not quite. Place it right beside the last one (point). (Use this one at a time procedure for first two caps of tray #1. For the presentation of tray #2, say, "Remember, find the very next closest colour to this cap (point to stationary cap), almost exactly the same, but not quite."

"Continue doing this until all the caps are in order. They will form a colour series between these two caps (motioning). It usually takes about two minutes to arrange them in sequence, but accuracy is more important than speed. Do you understand?"

(When presenting trays #3 and #4, say, "Run your finger along the edge here (motioning) to make sure they are in the correct order. You may make any changes you wish.

Step 4 - Group 4:

Administration of modified instructions which included the Panel D-15 as part of the teaching method to each of a group of 32 subjects.

The Panel D-15 was administered first with the following instructions:

"The object of this test is to arrange the colour caps in order according to colour. Take the cap from this panel (indicate) which looks the most like this cap and place it here beside it (wait until selection is made and placed correctly). Now take the cap which looks the most like the one you've just put down and place it here (indicate). Continue doing this until all the caps are arranged in order."

After the Panel D-15 is arranged by subjects, if there are any very great differences in hue between the arranged colour caps, as, "Is this one (motioning) the very next closest in colour to this one beside it?" If the answer is "yes", and subjects do not attempt to rearrange caps then the order is accepted and no further inquiry is made. This is because the subject may be colour defective and therefore unable to perceive the difference between the hues.

When the Panel D-15 was completed the first tray of the 100-Hue was presented with the following instructions:

"This is the same kind of test as the one you've just finished; that is, you arrange the caps in order according to colour."

Then the exact wording of the "modified" instructions was read to the subjects with no variations. (See Step 3-Group 3).

INSTRUMENTS:

A. The 100-Hue

The Farnsworth Munsell 100-Hue test for colour discrimination was devised by Farnsworth for the purpose of measuring hue discrimination with samples with constant value and chroma but varying only in hue. Test materials sample all the hues quantified according to Munsell's specifications and under standard conditions of lighting, all the papers appear equal in chroma and value to normal subjects.

Its primary uses are; first, to separate persons with normal colour vision into classes of superior, average, and low colour discrimination, and second, to measure the zones of colour confusion of colour defective persons.

The diagnostic properties of the test stem from the fact that defective subjects will be unable to arrange the hues in perfect order but will make mistakes in those regions of colour space affected by the defect. The defective will not be able to make use of cues from chroma or value as all the papers are similar to them.

One of the great merits of the 100-Hue is that those elements suitable for detecting small variations in colour discrimination are also suitable for detecting colour confusion. As the coloured caps were chosen to cover the entire colour circle it happens that in some areas certain consecutive caps follow the confusion lines of all known dichromats. It is also possible to estimate which of the caps are confused by deutans, protans, tritans and tetartans. In addition to detecting classical types of dichromats, Verriest, (1964), has recently shown that the 100-Hue can detect the so-called scotopic type of confusion characteristic of many subjects with acquired colour defects.

The colour circle encompasses 85 hues in all which indicates the minute differences in colour discrimination which can be detected by the 100-Hue.

The test consists of a scoring sheet and four wooden boxes that together hold the 85 movable caps, in which Munsell colours are mounted. The caps were divided into four groups of about 21 in order to subdivide the large number of stimuli into smaller task units. The arbitrarily chosen groups became the four series of the test, one red to yellow, a second from yellow to blue-green, a third blue-green to blue and the fourth

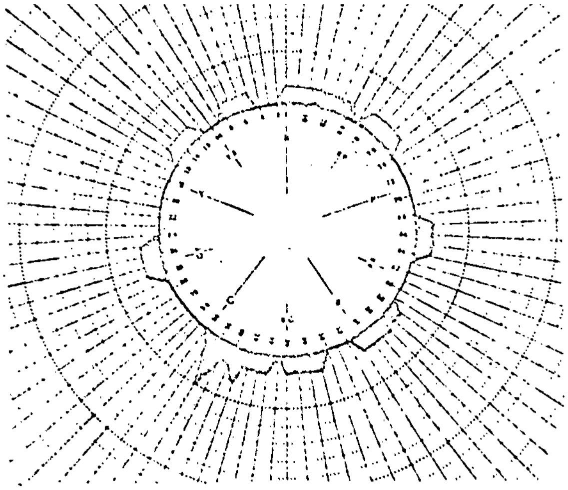


Fig. 2. Specimens of normal, average, discrimination patterns, 2 trials.

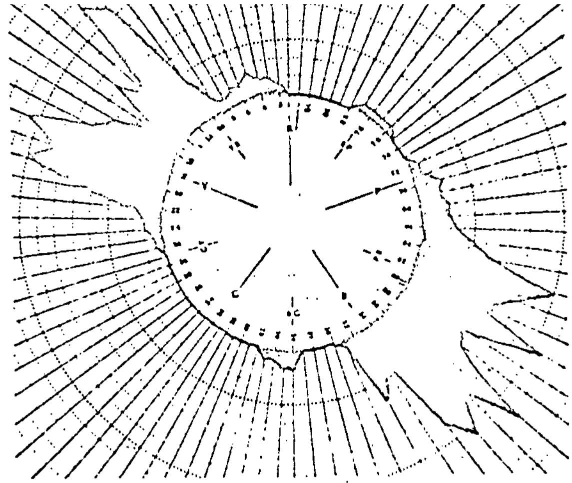


Fig. 5. Specimen of color defective pattern: Deutan. Average of 2 trials.

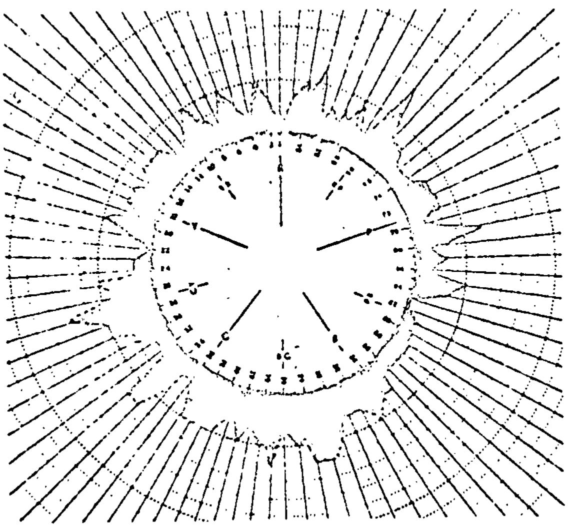


Fig. 3. Specimens of normal, low discrimination pattern, 2 trials.

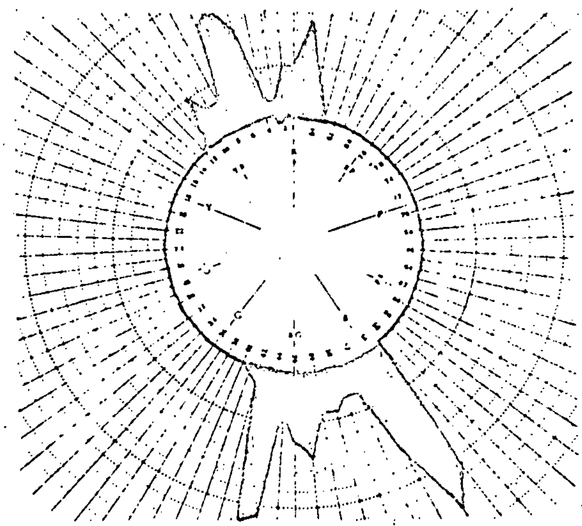


Fig. 6. Specimen of color defective pattern: Tritan. Average of 2 trials.

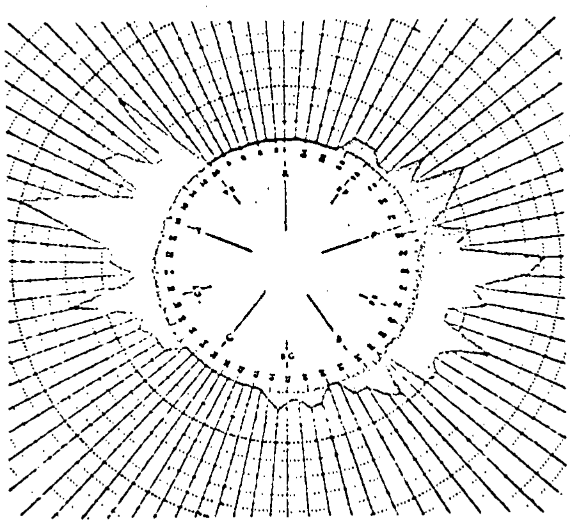


Fig. 4. Specimen of color defective pattern: Protan. Average of 2 trials.

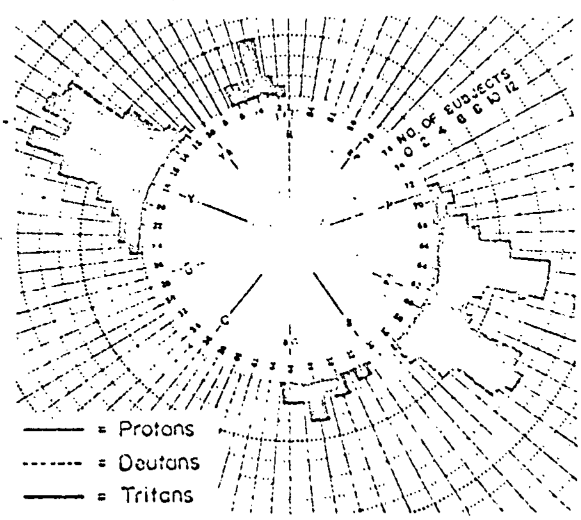


Fig. 7. Distribution of mid-points from 112 tests on color defective subjects: 50 protans, 50 deutans and 12 tritans.

FIGs 1.

from blue to purple-red. The different coloured caps each numbered on the back can be moved about freely during the performance. Each box also contains two extra immobile caps, the first and last of the neighbouring series.

LIGHTING:

For the administration of the test, standard illumination is required of about 25 foot candles provided by Illuminant C type of lamp.

SCORING:

The underside of the caps are numbered to allow the examiner to score the test. If a perfect arrangement has been made the numbers are consecutive. If not, the numbers are noted on a scoring sheet, and an error score calculated for each cap by adding the differences between the number of the cap and the number of the caps placed adjacent to it. These error scores are plotted on the circular abscissa of a graph (see Fig. 1), the radial lines of which carry the numbers of the colour caps. The first inner abscissa is number 2, the lowest possible score and the one which represents perfect serial order. The second is numbered 3, the lower error score, representing transposition of adjacent caps. The points plotted on the graph for the error score of each cap are connected to show a profile clearly. Axes of confusion characteristics of colour defective subjects emerge when error scores are plotted in this way.

A total error score is obtained by subtracting two from each cap error score and adding the resultants together. A perfect arrangement gives a total error score of zero.

INTERPRETATION:

Variations in discriminative ability as tested by the 100-Hue are found by Farnsworth to be approximately normally distributed. About 68% of the adult population excluding defectives make a total error score of between 20 and 100 on the first test. The errors are random, seldom occur on retest, and are not bunched in any one region of the colour space. This is taken to be indicative of normal competence. 10% of the population score between 0 and 16, showing superior discrimination. 16% of the population show low discriminative ability but have normal colour vision. This group make a total error score of more than 100. This group shows no improvement on retests but have no area of minimum sensitivity as in defectives.

Colour vision defects are thus identified by the clustering of maximum errors in two regions of the colour circle which are nearly opposite. The type of defect is inferred from the direction of the axes shown on the graph and the degree of defect from the extent of the distortion. Individual degrees of superiority of discrimination are, on the other hand, more simply assessed by referring to the total error score. General colour discrimination and colour anomaly are factors independent of each other. It is possible that anomolous trichromats may do well on the 100-Hue whereas normal trichromats may do poorly.

TEST RELIABILITY:

Performance on the 100-Hue for adults improves considerably between first test and retest. An average of 30% reduction in total error score is reported by Farnsworth. Scores on third testing show little further improvement. Correlation between first test and retest is .82, and with the third .67.

Farnsworth suggests that experience in handling test material may explain improvement on retest measures since the initial improvement on retest is considerable it may be inferred that the format of the test presents and unfamiliar and difficult task even for adults. These conceptual difficulties affect performance. This conceptual as opposed to perceptual difficulty of the

100-Hue might be expected to be of even greater importance when the performance of children is considered.

FARNSWORTH DICHOTOMOUS TEST FOR COLOUR BLINDNESS: (PANEL D-15)

The Panel D-15 is designed to indicate colour blindness clearly and quickly, i.e. to distinguish dichromats, the functionally colour blind from the moderately colour defective and the normal (normal and anomalous trichromats). As a vocational test it can be used to eliminate with certainty those who cannot distinguish between such colours as red and green, green and blue, blue and pink, yellow and blue or between green and brown (or tan or amber). It is not intended to distinguish degrees of colour aptitude to normals.

PRESENTATION:

Test materials consist of a rack of 2 hinged panels, scoring sheets, 15 colour caps, placed in the rack, contain pigments on upper surface and scoring numbers on the under side. Two numbered diagrams are provided on the scoring sheets to use in constructing the pattern that shows the type of colour defect.

At the beginning of the test the colour caps No. 1 to No. 15 are arranged in a row in random order in the cover panel of the rack, so that the subject can easily select them for placement in the lower panel.

The standard adult instructions are as follows:

> "The object of the test is to arrange the buttons in order according to the colour. Take the button from this panel (indicate) which looks most like this button and place it here (indicate space next to the fixed reference cap). Take the button which looks most like that and place it here; and the button most like that, and place it here; continue doing this until all the buttons are arranged in order."

If the subject does not seem to grasp the problem, further help is given.

> "After each button is placed it may be necessary to say, Now which of these buttons (indicate) is most like the last one? (indicate)"

To prevent dawdling subjects may be told they will be limited to two minutes, but should not be held to it. Subjects who rush may be asked to review it and make changes to "get them all in order".

LIGHTING:

While this test is less dependent on quality of illumination than most tests of colour vision reliable results require average daylight or an Illuminant "C" lamp.

SCORING:

By closing the cover on the colour cap case and turning it over the scoring numbers on the underside are revealed. The examiner is merely required to record the numbers on the scoring sheet in the order in which they were arranged by the subject. If there are no errors in placement a plotting of it the diagram is not required. If there is any divergence from the correct arrangement a ruler or card should be used to connect the points on the diagram in the order in which they were recorded beginning with the point marked "Reference Cap".

INTERPRETATION:

The test is scored as a unit, either "passing" or "failing". A circular pattern indicates "passing"; a parallel or lacing pattern indicates "failing". See (Fig. II). Patterns of normal and colour-weak vision are shown in Figures 1, 2 and 3 (passing scores). The patterns of colour blind subjects are shown in Figures 4, 5, and 6 (failing scores). The three typical axes are indicated on the chart as "protan", "deutan" and "tritan". The type of deficiency is indicated by the index line most nearly parallel to the crossover lines.

RELIABILITY:

The test-retest reliability is as stated in the manual indicated by the following figure drawn from 163 subjects.

TEST

Passed	Failed
733	1
1	28

The Panel D-15 as well as the 100-Hue test involve the concept of "colour series" but the 100-Hue detects small differences in hue whereas the D-15 has large colour differences in the series which are generally much more easily discerned. It is because of this similarity in utilizing the same concepts that it is suggested that the D-15 be used as a teaching device for children before administering the 100-Hue in order to communicate the "colour series" concept more readily. Some further explanation may be necessary than that found in the manual instructions in administering the Panel D-15, and these changes in administration, if they arise, will be reported.

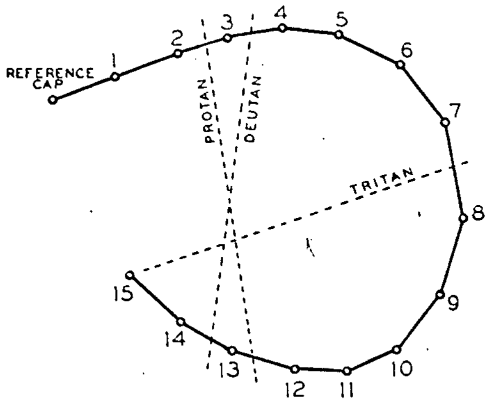


Figure 1—NORMAL VISION—NO ERRORS

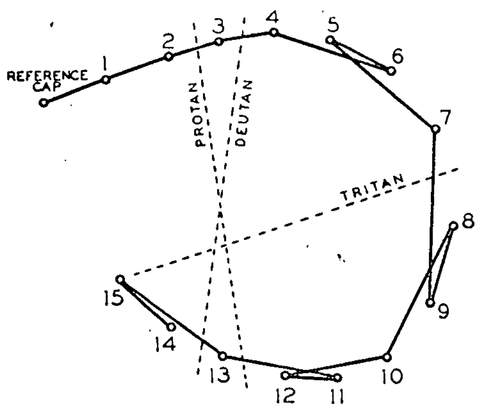


Figure 2—NORMAL VISION—MINOR ERRORS

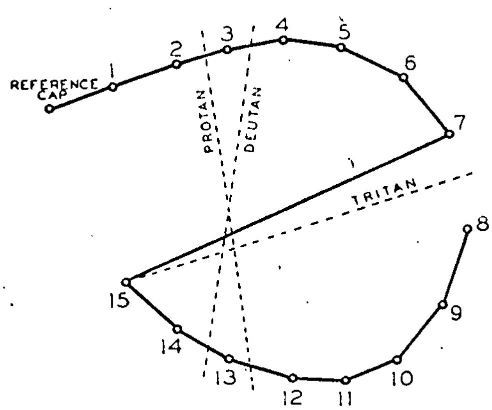


Figure 3—NORMAL VISION—ONE ERROR (SEE TEXT)

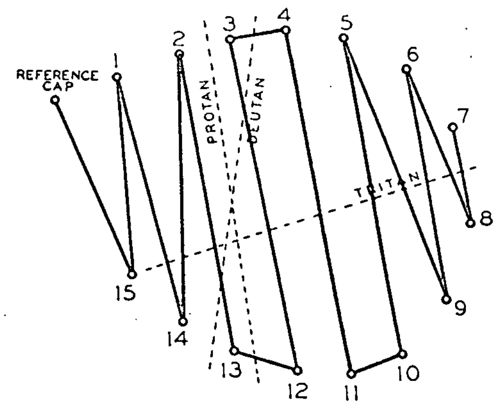


Figure 4—DEFECTIVE VISION—RED BLINDNESS (PROTANOPIA)

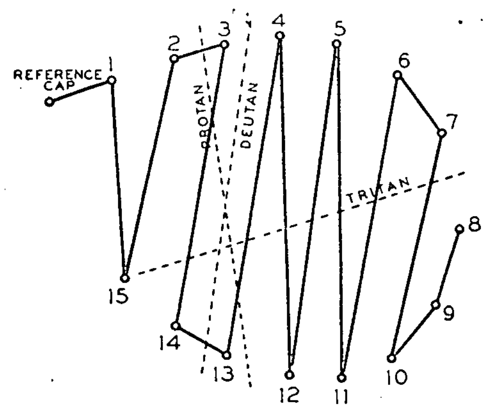


Figure 5—DEFECTIVE VISION—GREEN BLINDNESS (DEUTERANOPIA)

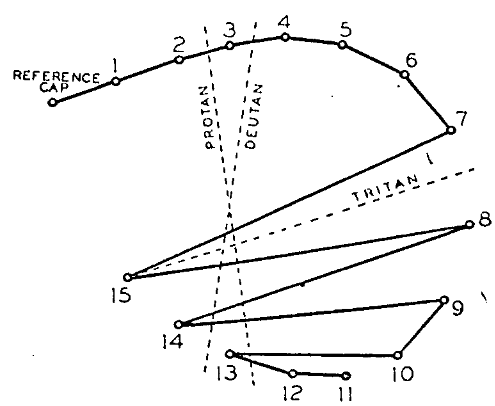


Figure 6—DEFECTIVE VISION—BLUE BLINDNESS (TRITANOPIA)

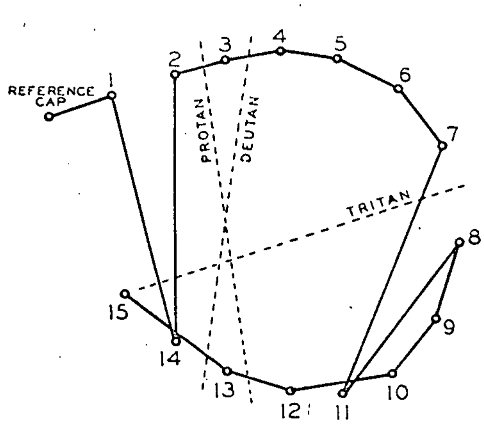


Figure 7—ANOMALOUS TRICHROMATIC VISION

CHAPTER IV

RESULTS

ANALYSIS OF THE DATA:

The U.B.C. Computing Centre Triangular Regression Programme Packe (TRIP) was implemented to find means, standard deviations and correlation co-efficients between the variables involved. Since no significant correlations were found, this statistic was discounted and all further analysis was done on the simpler statistics, mean and standard deviations (see Table V).

Table V

Means and S.D. for the Four Groups

Group	N.	Mean	S.D.
I	31	99.55	51.25
II	31	74.74	39.22
III	30	55.00	30.28
IV	32	70.44	32.97

Two-tailed *t*-tests were used to determine whether the difference in means between the various experimental groups were significantly different. Table VI gives the *t*-scores at the indicated degrees of freedom.

Table VI

t-Scores between Groups

	I	II	III
II	2.56 30 df		
III	4.76 29df	2.78 29 df	
IV	3.11 30df	0.6 30df	3.41 29df

The levels of significance of the t-scores for each of the groups is shown in Table VII.

Table VII

Levels of Significance

	I	II	III
II	.01		
III	.005	.01	
IV	.005	n.s.	.005

Table VIII

Comparison of Means between Average and High I.Q. Subjects

	Means I.Q. Average	High	Standard Deviations I.Q. Average	High
Gp. I	102.4	96.5	59.2	42.9
Gp. II	69.2	80.6	37.6	41.2
Gp. III	56.9	53.1	39.4	18.3
Gp. IV	81.1	59.7	34.6	28.3
t-scores:	3.02 significance to .01 at 15d.f. (Group IV, average vs high)			

Results show that:

a) From Table V it can be seen Group 3 has the lowest mean score, 55.00 indicating the method of presentation involved here has elicited the best response. It is also of interest to note the high s.d. 51.25 in Group One as compared to the others, 30.28, 32.97, and 39.22, respectively. These results can be interpreted as supporting the first hypothesis and do not appear to support the supplementary hypothesis.

b) In Table VI all of the t-scores except for that between Groups II and IV are large enough to be significant. This relationship is borne out in Tables VI and IV where there is, respectively, no significance and little visible difference, the means being 70.44 and 74.74. This would indicate a lack of support for the supplementary hypothesis.

In Table VII very good significance is evidenced in all comparisons except that as already mentioned, with levels of significance at .01 or higher. These results can be interpreted as supporting hypothesis one and as not supporting the supplementary hypothesis.

In Table VIII by inspection one can see that there is little difference between the I.Q. range for all but Group IV. In this group the average I.Q. subjects have a mean score of 59.7. This group difference, when a t-score was computed, was found to be significant to the .01 level.

CHAPTER V

SUMMARY AND DISCUSSION

The aim of this study was to determine the efficaciousness of revised methods of presentation of the Farnsworth-Munsell 100-Hue test for colour discrimination, rendering it suitable for use in the elementary school.

It was hypothesized that error scores on the 100-Hue would be significantly higher when the standard adult instructions were used than when modified instructions more suitable for elementary school children, both with the Panel D-15 and without were used.

It was also hypothesized that the most significant reduction in scores would occur when the modified instructions included use of the Farnsworth Dichtomous Test for Colour Blindness - Panel D-15 as part of the instructions.

Four groups of 124 twelve year old boys were compared using four different presentations of instructions for the 100-Hue. Group one was given the standard adult instructions from the Farnsworth manual only. Group two was given the standard adult instructions from the Farnsworth manual for the Panel D-15 which was completed before being given the standard adult instructions for the 100-Hue. Group three received modified instructions for the 100-Hue. Group four received the modified instructions which also included the Panel D-15 as part of the modified presentation.

As the results already shown indicate, the first hypothesis was substantiated. Scores for group one were significantly higher at the .01 level of significance in relation to the other three groups.

The second hypothesis was not supported by the data. The most significant reduction in the scores occurred for the group which received the modified instructions only (Group 3). Group four which had the same instructions as group three but also had the Panel D-15, had a mean error score of 70.4. When this compared to the group three mean of 55.0 and a t-score is computed, it is found to be significant beyond the .01 level, with a t-score of 3.41.

The overall results indicate that 12 year olds can perform as well as adult subjects on the 100-Hue when the instructions are modified, implying that they now understand the test better than the other studies with children shown, because of lower scores compared to all the other populations.

The lowest scores in this study, that of group three with a mean of 55.00 are significantly similar to those reported by Verriest, (1963), for adults in the prime of understanding, the 30-34 year age group which had a mean error score of 54.7.

DISCUSSION

The results in group 4 were quite surprising in that the inclusion of the Panel D-15 as part of the modified instructions did not result in lower scores than did Group 3's with the modified instructions alone. This is interesting in that the use of the Panel D-15 with the adult instructions previous to administering the 100-Hue in group 2 resulted in significantly lower scores than with the 100-Hue alone.

Thus it seems that a model which incorporates the concept of "colour series" in a simpler form had a definite effect in aiding the child to understand what was expected of him. The results in Group three indicate that modified instructions more accessible to the elementary school child's level of understanding were significantly more efficacious for grasping the "colour series" concept and producing better scores.

It seems that once the child has grasped the concept,inclusion of Panel D-15 did nothing to aid him, in fact was detrimental to the more average I.Q. boys. For example, although the inclusion of the Panel D-15 in group four did not effect the scores of the above average I.Q. subjects (they did almost as well in group four as did the same I.Q. level child in group three), it was the average I.Q. child that found additional instruction with the Panel D-15 detrimental to performance.

This more average subject scored appreciably lower in Group 4 than did his I.Q. peer in Group 3. (See Table V.) It would appear that the inclusion of the Panel D-15 was somehow slightly confusing, perhaps in the sense that too much data was included in the presentation. This was not a great handicap to the above average child but was appreciably more so for the normal.

Since I.Q. was held constant for all groups by matching, intelligence did not appear in this study as a variable. However, in Group 4 where Panel D-15 was used and a comparison was made between high and low I.Q. groups it was of some significance.

DISCUSSION OF EARLIER STUDIES:

In the study by Verriest, Vandevyvere and Vanderdonck, (1962), in which ages ranging from 10 to 64 were administered the 100-Hue using the standard adult instructions it was found that the group of boys aged ten to fourteen years had a mean error score of 92.5. This is not significantly different to the results in Group one of the present study whose mean error was 99.55. It also indicates how significant in the present study the scores between Group 1 with the highest mean error score, and Group 3 with the modified instructions and the lowest mean error score is, in relation to this age group. I.Q.'s were not reported

for the Verriest study so that this is a possible significant variable which needs to be considered when the results of the studies are compared.
Lumbroso and Proto, (1963), study deal with children under 10 years of age and involved only 46 children, which is a very limited sample. The mean error score for the 7 - 10 year age group (N = 34) of 138 would be directly comparable to Group one of the present study with its mean of 99.55. A t-score of 4.14 for this comparison shows our group is significantly different beyond th .01 level. Again standard adult instructions were used in both cases. Also, again no control for I.Q. was done in the Lumbroso and Proto study.

The most interesting contrast in results emerge when the present study is compared to results found by Luscombe, (1966) which is the only other study with young children using the 100-Hue and a modified presentation of instructions. The model or modified instructions Luscombe used with one group of 40 subjects aged 7 - 15 years has already been described in cpater two. The scores for this group who fell into the 11 - 13 year old age bracket were not significantly different from the same age group having standard adult instructions only. The mean error scores for the 11 and 13 year olds averaged 161.1 and 187.9. This is considerably greater than the findings of both previous staudies, Verriest et al and

Lumbroso and Proto which have been cited and certainly considerably greater than the mean error scores for those receiving adult instructions only (Group 1) 99.5 and dramatically greater than the group receiving modified instructions (Group 3) 55.0 in the present study. Even with the group of ten subjects with higher I.Q. scores in relation to the other subjects a mean average error score of 220.5 was recorded.

DEFECTIVES:

Four of the 124 subjects tested were found to have congenital anomalies. The percentage was thus 4.9 which is considerably lower than that commonly reported of 8.5%.

It was possible to quickly identify these subjects with the use of the Dvorine Pseudo-Isochromatic plates and to double check these results using the Panel D-15. They were of course excluded from the sample and reults reported to the school nurse.

CONCLUSIONS AND IMPLICATIONS

Implications for further Research:

Although the results of this study indicate that the 100-Hue using modified instructions can be successfully used to detect variations in colour discrimination with twelve year olds of normal intelligence, further studies would be necessary on younger populations within the elementary school to indicate whether some other modifications might be necessary to ensure understanding of the test and gain co-operation in younger children.

For example, with the present age group of 12 year olds, a definite attitude of independence toward completing the test successfully was observed after the first tray had been completed. Although initial instructions were reviewed briefly with the presentation of tray 2, (i.e. "now remember to find the cap that is almost exactly the same as this one - motioning to demonstration cap - but not quite"), the majority of the boys showed noticeable impatience and resorted to remarks like, "Yes, I know", or, "Its the same as the last one, isn't it?" In the experimentor's judgement this would not be the case with younger subjects whose attention span is considerably shorter and who would likely have more difficulty retaining the concept of "sameness" and remembering what was required of them. It seems this sort of reminder might be necessary throughout the test and certainly as each individual tray was presented.

It also remains to be demonstrated whether or not children with an I.Q. of below 100 or in the low average range and lower could successfully complete the 100-Hue with the modified instructions thus encompassing the more total elementary school population.

Of all the methods the one that uses the modified instructions seems to get the best results and the fact that the Panel D-15 did not prove efficacious would not necessarily hold for younger groups. Perhaps manipulation as with Panel D-15 as well as oral instruction would prove to be more effective with a younger population.

CONCLUSIONS

Because of the increasing use of colour as a primary cue in developing concepts and as a contextual cue, this study was conducted to modify presentations of the 100-Hue test for colour discrimination in order to make it a useable instrument for screening the elementary school child who might have difficulties with colour discrimination though he is not a colour defective, which could handicap his school performance.

The subjects were 124 boys, aged 12 years. They were divided into four equivalent groups in relation to I.Q. The subjects were Vancouver, B.C., elementary public school children. The Dvorine Pseudo-Isochromatic plates were shown to each subject as a means of establishing rapport and quickly identifying colour defectives so that they could be excluded from the sample - 4 defectives were found who had congenital anomalies. This percentage of 4.9 was lower than the commonly reported 8.1% for the male population.

Group 1 were read the standard adult instructions from the Farnsworth-Munsell 100-Hue manual, before being asked to complete the test. Group 2 were read the standard adult instructions from the Farnsworth manual for the Panel D-15 (Dichotomous Test for Colour Blindness), before completing this test plus the adult instructions from the 100-Hue manual, before completing the latter test.

Group 3 were read a standardized set of modified instructions which were created for this study. Group 4 were read the same set of modified instructions with the addition of the use of the Panel D-15 as part of the instructions.

Statistical analysis of the mean error for the 4 groups revealed, as hypothesized, statistically different means between the groups using the modified and those using the standard instructions. Group 3, using modified instructions without the inclusion of the Panel D-15 performed best, functioning as well with these instructions as do adult subjects.

The results indicate that 12 year olds can function significantly better on the 100-Hue test with modified instruction than other studies with other populations of children, using other types of presentations have indicated.

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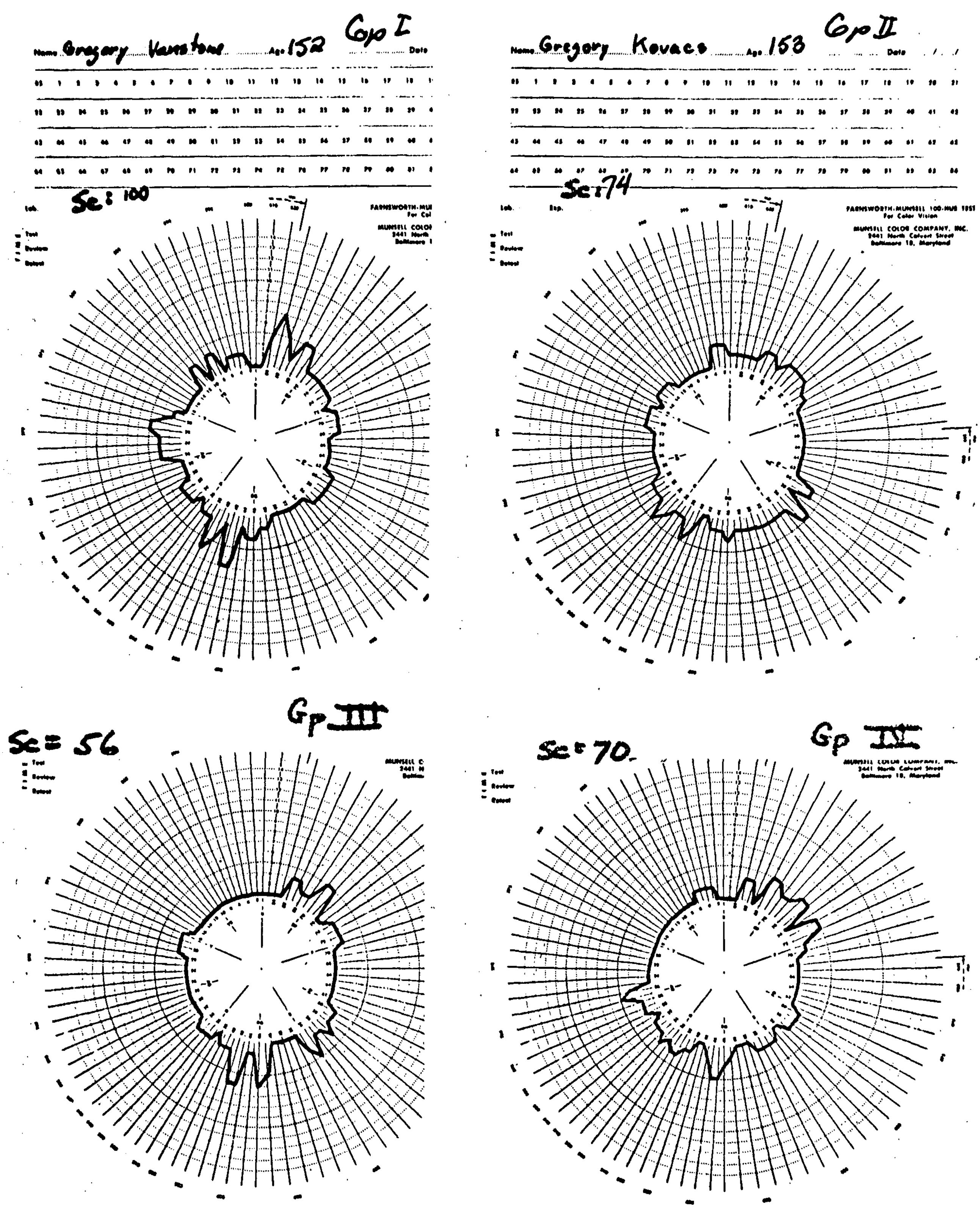
APPENDIX



Profiles on 100-Hue
Groups I, II, III, IV