A COLOUR-ANOMALOUS FAMILY

By

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1) Preliminary Remarks:

At our Psychological Practum we are used to show the students the Ishihara Test for colour-blindness and to have them tested by one another. Last year among the students a girl turned out who was able to see all those figures which were designed to be seen by normal people as well as those figures which colour-blind people were expected to see.

From the beginning we assumed her to be colour-weak and not colour-blind; one of the aberrations from normal colour-vision with which Pickford\(^1\) dealt so extensively. In the following we do not employ Pickford's nomenclature; but we use Ishihara's.\(^2\)

Our subject may be named Suzan. She is 23 years of age, and studying French philology and psychology.

We first thought that Suzan's performance might be due to differences in colour-vision of both eyes. So we tested each of her eyes separately, but the responses of both eyes were the same, except a very slight difference to which we should come later.

2) Detailed Report:

We first examined each of Suzan's eyes separately with the Ishihara plates. Her left and right eye responses to the various plates were the same except to the IIIrd and IVth plate. While her right eye was covered, her answer to the IIIrd plate was that of a colour-normal person. She read the number 6. With her right eye, however, she

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read 6 as well as 5, which is the reading of colour-blind people. Her answers to the IVth plate were four in number with the left eye, and three with the right eye. With her left eye, the figure which she said "she saw best", was 29 which was the figure designed for normal people, and 79 which was a combination of the normal figure and the figure readily colour-blind people. She saw it second best, this being followed by number 70, the number designed for colour-blinds, and then a fourth one following this third was number 20, another combination of the digits of the two figures given for normal people and for colour-blinds. But when the left eye was covered, in the IVth plate the number she saw best was the combined figure 79, which with her left eye she saw second best, this being followed by the normal number 29 and thirdly by number 70, the number designed for colour-blinds.

We used for our testing the larger 7th edition of the Ishihara Test, consisting of 32 plates. The first and the last plates were 'jokerr', which could be seen by all people including total colour-blinds. Plates (XXVI to XXXI) were used for testing illiterates, each plate containing a certain pattern which was difficult to follow by colour-blinds except plates (XXX and XXXI). We also applied them to Suzan and she succeeded to follow every pattern in each plate. This indicated a normal reaction as well as a colour-blind one.

Following Pickford the remaining plates (II to XXV) may be classified into 6 groups each containing four plates. Plates (II to V) contained pink numbers on green background, each number with an alternative to be read by colour-blind people. Plates (VI to IX) contained green numbers on pink backgrounds again with an alternative to be read by colour-blinds. Plates (X to XIII) contained pink numbers on green backgrounds which were supposed to be seen only by normals, with no alternatives for colour-blinds. Plates (XIV to XVII) contained green numbers on pink backgrounds still easy for the normals to see without any alternatives. Plates (XVIII to XXI) contained grayish figures on multicoloured backgrounds which were supposed to be seen by colour-blinds only. Plates (XXII to XXV) con-

1) Our subject used this phrase extensively throughout her testing without any suggestion or remark by the experimenter.
(2) Ibid.
tained two numbers one being red and the other a darker red on a grey background which were easily read by normal people and by incomplete colour-blind people. But the protanopes whose colour vision was darkened at the red end of the spectrum, could only see the dark red coloured number, and the deuteranopes whose colour vision of red was of normal brightness were able to see the red coloured number.

In the first group of plates, to the second plate Suzan's response was both normal and anomalous with each eye. She was able to read the normal figure 8 as well as number 3 which was designed to be read by colour-blinds. The numbers that were designed for colour-blind people were seen better with both eyes.

Her responses to the (IIIrd and IVth) plates were discussed above. To repeat it shortly we can state that there were two readings of these plates, the normal and the anomalous one. As said above, there was a slight inequality of the eyes. Sometimes one and sometimes the other read the normal figure only. Repeatedly in addition to the normal and the anomalous figure another or even two other figures were read, one digit of which was taken from the normal, the other from the anomalous figure.

In plate V she could both read the normal figure 57 and the anomalous figure 35.

Of the second group of plates (VI to IV), her responses to the VIth, VIIth and VIIIth plates with each eye were both normal and anomalous; in all of them normal figures were clearer. But she gave four different answers to the IXth plate exactly in the same way with both eyes. The first number she saw most clearly was number 74, which was designed for normal people, the second was 71, which was a combination of one of the digits of the two numbers given by Ishihara, the third 24 was another combination like the second, and the last number 21 was the number designed for colour-blinds.

For plates (X to XIII) her responses were those expected from normal people, except those to the XIth plate. There also she gave the normal readings with either eye. But to that normal figure 97 she
added another one-place figure 5, which Ishihara designed neither for normals, nor for colour-blinds.

As to the plates (X to XIII) and the following plates (XIV to XVII) it might be useful to remind the reader that there were no alternative figures to be read by colour-blinds. All these plates ordinarily are not read at all by colour-blinds. Our subject behaved as colour-normal. It was the case at plates (X to XIII) as well as at the plates (XIV to XVII).

Plates (XVIII to XXI), grayish figures on multicoloured backgrounds to be read by colour-blinds only, were read by our subject correctly without difficulty with each of her eyes.

Plates (XXII to XXV), designed to distinguish the protanopic type of redgreen blindness from the deuteranopic type, contains a two-place figure legible to colour normals and incomplete colour-blinds, whereas either of the two types of colour-blindness can read only one digit of the figure. Our subject was able to read the whole both figures in all of the four plates, with each of her eyes in the same way.

So, as is seen above, the results of the Ishihara testing were extraordinary with our subject.

On the base of his "item-analysis" of the Ishihara plates Pickford distinguishes plates more or less reliable in detecting colour-blindness and colour-anomalies. Choosing the most reliable ones he "proposes plates X, XI, XIV, XV, XVIII, XXIII". To these he adds plate I in order to have a 'joker'. According to him this "version of the test would tend to do less injustice to all classes of subjects than the 25-plate version, but it would still be of no use in distinguishing any particular type of defective either major or minor". He gives a mean value of 0.29 errors per subject per plate, for the absolutely normal type. The achievement of our subject was higher than that. She gave only one colour-blind answer for the XVIII th plate, the answers to all the remaining five plates being correct; and the XVIII th is considered by Pickford himself, as the most unreliable plate for normal subjects.

(1) Ibid.
So, if we agreed with Pickford we would have to consider from
the beginning the colour-vision of our subject as completely normal.

That it is not normal, may be seen from the fact that among 250
to 300 students tested at our Practicum in the course of time we have
found the usual proportion of red-green blinds and a number of cases
of colourweakness, but not another single case showing the properties
of Miss Suzan. Her anomalous colour vision will be seen to turn up
with other members of her family. Also the experiments to be des-
cribed later on will prove it.

3) The Family:
The family of our subject consisted of five persons alive, and we
tested each of them with the Ishihara Test, and found that none of them
were absolutely normal according to Ishihara's norms.

Her mother's responses to the first group of plates (II to V) were
normal. Like her daughter she gave the anomalous reading beside
the normal one to the second group of plates (VI to IX). Only in plate
VIII instead of the anomalous number 17 she read number 11, beside
the normal reading 15. In the next two groups of plates (X to XIII)
and (XIV to XVII) her responses were those of a person with nor-
mal colour-vision. In the next group of plates where normal people
were expected to read nothing, but the red-green blind people could
read certain numbers, Suzan's mother was able to read the figures
designed for colour-blinds. In plates (XXII to XXV) she could read
the numbers as the people with normal colour vision or the people with
incomplete red-green blindness were expected to do. In plates (XXVI
to XXXII) where there were certain patterns to be traced, she suc-
cceeded in all including those which were hard for people with normal
colour-vision to follow.

So, the total of dubious and anomalous responses of our sub-
ject's mother in 31-plates was 10.

The responses of her father to the various groups of plates were
also partly normal, partly anomalous. In plate II, he could read both
the normal and anomalous number, In the Vth plate he could read
the normal number 57 and also 55, which was a combination of the
second place digit 5 of the normal number, and the first plate digit
5 of the anomalous number. In the IIIrd and IVth plates he only could read the normal numbers.

In the second group of plates (VI to IX) his response to VIth plate was that of a colour-blind person. He read number 2 which was designed for red-green blinds. In plate VII his answers were both normal and anomalous. The number 5 which was designed for red-green blinds was seen more clearly than the normal number 3. His answers to the VIIIth plate were also normal and anomalous. In the IXth plate he could only read the anomalous figure 21. In the next two groups his responses were all that of a person with normal colour-vision. His responses to plates (XVIII to XXI) were also mixed. To the XVIIIth and the XXIst plate his responses were those of a colour-normal person, while the responses to the two other plates of the group were those of a colour-blind person. The responses to the next group of plates were normal, and as were also the responses to plates (XXVI to XXIX). To plates XXX and XXXI, however, they were anomalous. Thus the dubious and anomalous responses of the father were also 10 in number, the same as with the mother.

Suzan's sister's answers to plates (II to IV) were normal, but in the Vth plate she could read the normal number 57 and the anomalous number 35. In addition she also read number 55, a figure combining one digit of the normal reading with one of the anomalous reading.

For plates (VI to IX) her answers were both normal and anomalous. In the IXth plate in addition to the normal number 74, she read number 24 again combined from the normal number 74 and the anomalous 21. In the next two groups her responses were normal. In plates (XVIII to XXI) she could see the figures designed for red-green blinds. In the last group of plates where a path was to be followed she succeeded in completing the path of the XXVIth plate which was expected to be done by normals but she could not trace out the path in the XXVIIth plate which was an anomalous reaction. In the plates XXVIII and XXIX her responses were anomalous.

The total of dubious and entirely anomalous responses of Suzan's sister were 12 in number.

Lastly, we tested Suzan's grandmother from her mother's side.
All her responses to the 32 plates were normal but those to the VIHth and the IXth plate. In the VIIIth plate she could read the normal number as well as the anomalous one. In the IXth plate she read only number 71 which combined from the normal number 74 and the anomalous number 21. Thus, the grandmother had less dubious and anomalous responses than any other members of the family, the total of her dubious and anomalous responses being only 2.

The frequency of the various kinds of responses given by all members of the family to 31 plates may be seen on Table I. on the XIIth plate Suzan, beside the normal reading 97 also added number 5 with both her eyes, number which was not mentioned by Ishihara. Since there was no alternative figure to be read by colour-blinds we classified this reading as “Normal?” Under the heading “Normal and Anomalous” we put the cases where our subjects gave the normal reading and the anomalous reading. Also cases in which one or two more combined readings were added, to these two given by Ishihara, as explained above, were placed under this heading. Under the heading “Partly normal, partly anomalous” we placed a single case, where the grandmother on plate IX read a combined number which consisted of the second place digit of the normal number and the first place digit of the anomalous number. As “Normal” we have classified the cases in which of the two alternative readings, the normal and the anomalous, the normal only was given, and those in which the number recognizable by normals only, according to Ishihara, was read, as “Anomalous” we have classified readings which, according to Ishihara, can be given by anomalous subjects only.

The Table shows most frequent anomalies with our original subject Suzan, particularly at her reading with her right eye. Nearest to her in frequency of anomalous reading is her sister. Her mother and father with an equal number of anomalous readings stand somewhat back. Her grandmother from mother’s side show only slight traces of anomaly.

4) Experiments on the Recognition of Faintest Colour Hue:

The following experiments were made with Miss Suzán, and with three other subjects whose colour vision was accepted absolu-
Table 1.
Frequency of Responses to all Ishihara charts, except Chart I.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Normal</th>
<th>Normal and Anomalous</th>
<th>Partly normal, Partly Anomalous</th>
<th>Anomalous</th>
<th>Total</th>
<th>Total of Dubious and Anomalous Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suzan (Right eye)</td>
<td>17</td>
<td>1</td>
<td>7</td>
<td>—</td>
<td>6</td>
<td>31</td>
</tr>
<tr>
<td>Suzan (Left eye)</td>
<td>16</td>
<td>1</td>
<td>8</td>
<td>—</td>
<td>6</td>
<td>31</td>
</tr>
<tr>
<td>Mother</td>
<td>21</td>
<td>—</td>
<td>4</td>
<td>—</td>
<td>6</td>
<td>31</td>
</tr>
<tr>
<td>Father</td>
<td>21</td>
<td>—</td>
<td>4</td>
<td>—</td>
<td>6</td>
<td>31</td>
</tr>
<tr>
<td>Sister</td>
<td>19</td>
<td>—</td>
<td>5</td>
<td>—</td>
<td>7</td>
<td>31</td>
</tr>
<tr>
<td>Grand Mother</td>
<td>29</td>
<td>—</td>
<td>1</td>
<td>1</td>
<td>—</td>
<td>31</td>
</tr>
</tbody>
</table>

The experiments were carried on, in daylight in a sufficiently light room, at almost the same time of the day. We used an electrically driven colour-wheel. The discs, 11 cm in diameter, were cut from Hering's colour-papers. As grey we used a mixture of 180° white and
180 black. Procedure ascending by steps of 2° colour immixion up to that amount of colour which in three successive experiments was judged as a certain hue, was used. Experiments from 5 to 35 was needed to reach the threshold. We also inserted trick experiments to control our results, by adding black to the white disc in every third or fourth experiments. At each step a judgement was given by the subject, and it was noted down. The subjects used the term grayish very much in almost every beginning of every part of the experiments. In the immixion of white, the subjects used the term pinkish, and of red to blackthey used purplish extensively. As an example of the procedure let us give a full protocol of one sitting of Suzan's.

**Subject: Suzan Time: 25 m.**

**PART V: Gray mixed with green.**

1 — 2° green 179° white-179° black the answer is light grayish.
2 — 4° green 178° white 178° black - the answer is grayish.
3 — 6° green 177° white 177° black - the answer is grayish.
4 — 8° green 176° white 176° black - the answer is grayish.
5 — 60° black 300° white - the answer is gray.
6 — 10° green 175° white 175° black - the answer is grayish.
7 — 12° green 174° white 174° black - the answer is gray.
8 — 14° green 173° white 173° black - the answer is gray.
9 — 180° black 180° white - the answer is gray.
10 — 16° green 172° white 172° black - the answer is pinkish gray.
11 — 10° green 171° white 171° black - the answer is gray.
12 — 20° green 170° white 170° black - the answer is gray.
13 — 22° green 169° white 169° black - the answer is gray.
14 — 60° black 300° white - the answer is gray.
15 — 24° green 168° white 168° black - the answer is greenish gray.
16 — 26° green 167° white 167° black - the answer is greenish gray.
17 — 28° green 166° white 166° black - the answer is greenish.

With every subject six sittings were needed and one sitting took
approximately half an hour. This description of procedure with all
the items pointed out, applies equally to all six experiments.

The results of the three normal subjects were different from one
another in the same experiments. But, in spite of all these differen­
ces, one could say there was some nearness in their results when com­
pared with those of Suzan's. When we took the averages of the diffe­
rrent responses of the three subjects to the different parts, the diffe­
rences between them and Suzan's responses were very great, espe­
cially in the first four parts of the three experiments.

In the first part of our experiments, where we used white as
"base", and added red, the First Subject was able to perceive red at 84° red mixed with 276° white. The Second Subject perceived it
at 44° red and 316° white. And the Third Subject at 36° red and 324°
white. The average of these three reactions was 54.7° red. But Suzan
was able to perceive red already when we mixed 18° red to 342°
white. Suzan in the very beginning of these experiments used to see
a dark gray line revolving on a dirty white disc, which she continued
to see the disc as pinkish for the first time. She also used to see this
way in the beginning of the second part of the experiments, before
seeing the disc at uniform colour. This sort of answer was not met
with any other of our experiments.

In the second part, where again white was used as base and green
was mixed in, the First Subject could perceive green at 54° green and
306° white, the Second Subject at 36° green 324° white and the Third
Subject at 90 green and 270° white. The average of these answers was
at 60° green. Suzan was able to perceive green when 20° was mixed
with 340° white. So that, Suzan's threshold of colour was again at
a very low degree in comparison with normal subjects.

In the third part of the experiments we used black as base to which
we mixed red. The First Subject was able to perceive red when 8° of
red was mixed with 352° of black. The Second Subject could perceive
it at 6° red 354° black, and the Third Subject at 26° red and 334° black.
All our subjects were able to perceive red on the black base at a much
smaller immixion of red than on the white base. Suzan's threshold
was still lower. She could perceive red in the very beginning of the
experiment where we mixed 2° red to 358° black.
In the fourth part of our experiments again black was used as base and green was mixed to it. The First Subject could perceive green at 2° of green and 358° of black. The Second Subject’s reaction was just the same as the First Subject’s. The Third could perceive it when 10° of green was mixed with 350° of black. The average of these reactions was at 3.7°. Suzan was also able to perceive green at the mixture of 2° green and 358° of black. So that, Suzan’s threshold when compared with the first two subjects was exactly the same, but when we compared it with the average threshold of the three normal subjects it was again lower.

In the 5th part of our experiment we mixed red with gray. The First Subject could perceive it when 32° of red was mixed with 164° white and 164° black, the Second Subject saw it at the mixing of 34° of red with 163° black and 163° white, and the Third Subject perceived it at the mixing of 30° of red with 165° black and 165° white. Thus, all of our subjects could perceive the colour on a gray base at almost the same degree. Suzan saw it at 26° of red and 167° of black and 167° of white. The average of the thresholds of the three normal subjects was 32° of red. So, Suzan’s reaction was again lower than the normal responses, but this time it was nearer to theirs.

In the last of our experiments we used green on the gray base. The First Subject perceived green when 22° of green was mixed with 169° of black and 169° of white. The Second Subject saw it at 30° of green, and the Third at 24° of green. The average of these responses was 25.3° of green. Suzan perceived it when 24° of green was mixed with 167.5° of black 167.5° of white. So, this time, her response was very near to the average normal responses. In fact, her threshold was equal to that of the Third Subject and even higher than that of the First Subject.

To survey Suzan’s thresholds in the six parts of the experiments we compare them on Table II with the lowest thresholds obtained from one of our three normal subjects. From the preceding figures it may be seen that it has not been always the same normal subject who has shown the lowest threshold. In the first, and fifth part it was the Third Subject, in the second and third part the Second Subject, in the sixth part the First Subject. In the fourth part the First and the Second Subject showed equally low thresholds. In Table II, there-
fore, we compare Suzan’s thresholds with those of the Third Subject in the second and third part, with that of the First Subject in the sixth part, and with those of the First and Second Subject in the Fourth part.

The Table reveals two facts:

1) Suzan’s superiority in recognizing the faint colour immixion is largest at the base white and smallest at the base gray. At the base gray Suzan is nearest to the normal threshold.

2) If green is the colour mixed to the base, Suzan always approaches more the normal threshold than if red is mixed to the base,

\[ \text{Table 2.} \]

\emph{Normal and Anomalous Colour Thresholds:}

<table>
<thead>
<tr>
<th></th>
<th>Part I White-red</th>
<th>Part II White-green</th>
<th>Part III Black-red</th>
<th>Part IV Black-green</th>
<th>Part V Gray-red</th>
<th>Part VI Gray-green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Subject</td>
<td>36</td>
<td>36</td>
<td>6</td>
<td>2</td>
<td>30</td>
<td>22</td>
</tr>
<tr>
<td>Suzan</td>
<td>18</td>
<td>20</td>
<td>2</td>
<td>2</td>
<td>26</td>
<td>24</td>
</tr>
<tr>
<td>Difference in Percentage of Normal</td>
<td>$-50%$</td>
<td>$-44%$</td>
<td>$-67%$</td>
<td>$+9%$</td>
<td>$-13%$</td>
<td>$+9%$</td>
</tr>
</tbody>
</table>

At green mixed to black there is no difference at all between her threshold and the normal, whereas red mixed to black shows a large difference in favour of Suzan’s sensitivity. If green is mixed to gray Suzan is even inferior to the normal, whereas at red mixed to gray still a slight superiority of Suzan is seen.

What the first of these two facts means we shall try to explain later on. The second fact seems to show that Suzan’s anomaly predomi-
riantly refers to her vision of red, but other results to be seen in the following paragraph do not confirm that.

5) *Experiments on Different Colour-Thresholds on the Same Disc*:

These experiments originally aimed at finding out whether a mixture of gray with a very small sector of red could be made appear equal for our subject Suzan to a mixture of gray with a small sector of green. To check the results obtained from Suzan we wanted to carry the same experiments with our three colour-normal subjects. On a large gray-green disc of 19 cm diameter we superposed a smaller gray-red disc of 11 cm diameter and asked the subjects to compare the centre of the revolving disc (composed of gray and red), with its periphery, (composed of gray and green). The subjects should state whether centre and periphery appeared equal or different and what kind of difference they saw. But it turned out that centre and periphery did not fuse into one another with our subjects and they did not compare properly, but made separate statements on them either. Thus the experiments differed from the previous ones in that only that two colour thresholds on the same revolving disc were found instead of a single one.

In a second group of these experiments we reversed the order of the colours on the disc, using a large gray-red disc of 19 cm diameter and superposing on it a small gray-green disc of 11 cm diameter. As gray we used a mixture of white and black at equal parts. When, for instance we showed gray with $10^\circ$ red, the gray was mixed of $175^\circ$ white and $175^\circ$ black. We used the same ascending procedure, but this time we began with mixing $5^\circ$ of chromatic colour to gray and ascending by steps of $5^\circ$ colour immixion up to that amount of colour which in three successive experiments was recognized correctly. From 6 to 17 experiments were needed to reach the thresholds. We also inserted trick experiments by placing only gray on one of the parts of the disc, or, sometimes on both. One sitting was needed for each part of the experiments with every subject, and each sitting with one subject took about 15 and 20 minutes. As an example the full protocol of one sitting with one of our subjects is given in the following.
PART II. Large disc: Gray-red.
   Small disc: Gray-green.

1 — Large disc. 5° red 177.5° black 177.5° white - the answer is gray.
   Small disc. 5° green 177.5° black 177.5° white - the answer is gray.

2 — Large disc. 10° red 175° black 175° white - the answer is gray.
   Small disc. 10° green 175° black 175° white - the answer is gray.

3 — Large disc. 15° red 172.5° black 172.5° white - the answer is gray.
   Small disc. 15° green 272.5° black 172.5° white - the answer is greenish gray.

4 — Large disc. 20° red 170° black 170° white - the answer is gray.
   Small disc. 20° black 340° white - the answer is grayish.

5 — Large disc. 20° red 170° black 170° white - the answer is gray.
   Small disc. 20° green 170° black 170° white - the answer is greenish gray.

6 — Large disc. 25° red 167.5° black 167.5° white - the answer is gray.
   Small disc. 25° green 167.5° black 167.5° white - the answer is greenish.

7 — Large disc. 30° red 165° black 165° white - answer is grayish violet.
   Small disc. 30° green 165° black 165° white - the answer is greenish.

8 — Large disc. 35° red 162.5 black 162.5° white - the answer is reddish violet.
Small disc. 35° green 162.5° black 162.5° white - the answer is light green.

9 — Large disc. 40° black 320° white - answer is gray.
Small disc. 40° white 320° black - the answer is dark gray.

10 — Large disc. 40° red 160° black 160° white - the answer is reddish.
Small disc. 40° green 160° black 160° white - the answer is greenish.

11 — Large disc. 45° red 157.5° black 157.5° white - the answer is reddish.
Small disc. 45° green 157.5° black 157.5° white - the answer is greenish.

In these nine experiments two trick experiments were inserted. The red-threshold at these experiments was at 35°, the green-threshold at 15°.

In the First Part of the experiments where on a large gray-green disc, we superposed a smaller gray-red disc, the First Subject perceived green at 40° of green mixed with 160° of black and 160° of white, and red at 5° of red mixed with 177.5° of black and 177.5° of white. The Second Subject at the mixture of 30° of green with 165° of black and 165° of white, and at 5° of red mixed with 177.5° of black and 177.5° of white. The Third Subject at 10° of green mixed with 175° of black and 175° of white, and 10° of red mixed with 175° of white and 175° of black. The average degree of perception at the periphery was at 26.6° and in the centre 6.6°. Suzan perceived green at the mixing of 60° of green with 150° of black and 150° of white, and red at 25° of red mixed with 167.5° of black and 167.5° of white. She, therefore, needed considerably more green and red to recognize these colours in the mixture.

In the second group of these experiments where we reversed the order of the colours on the disc, using a large gray-red disc and superposing on it a small gray-green disc, the First Subject could perceive red when 65° of red was mixed with 147.5° of black 147.5° of white and green at 10° of green mixed with 175° black and 175° white. The
Second Subject at 55° of red mixed with 152.5° of black and 152.5° of white, and green at 5° of green mixed with 177.5° of black and 177.5° of white. The Third Subject at the mixture of 35° of red to 162.5° of white and 162.5° of black, and 15° of green mixed with 172.5° of black and 172.5° of white. The average degree of perception in the periphery was at 51.6°, and in the centre, at 10°. Suzan was able to perceive red when 90° of red was mixed with 135° of white, and 135° of black, and green at 5° of green mixed with 177.5° of black and 177.5° of white. She, therefore, had a green-threshold as low as the lowest met with the normal subjects but a red-threshold much higher than any of the other subjects.

A rather strange fact at the two parts of our experiments was that at the large gray-green disc, the green-threshold with two of our normal subjects and with Suzan was higher than at the small gray-green disc and the red-threshold at the large gray-red threshold with all normal subjects and with Suzan was higher than at the small gray-red disc.

Table III shows Suzan's thresholds in the two parts of the experiments compared with the lowest thresholds obtained from one of our three normal subjects. In the large disc of the First Part and the large disc of the Second Part it was the Third Subject who has shown the lowest thresholds. In the small disc of the First Part the First and the Second Subjects showed equally low thresholds, of the Second Part the Second Subject and Suzan showed equally low thresholds. So that, in Table III we compare Suzan's thresholds with those of the Third Subject.

### Table 3.

**Normal and Anomalous Different Colour Thresholds on the Same Disc.**

<table>
<thead>
<tr>
<th></th>
<th>Part I</th>
<th></th>
<th>Part II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large Disc Gray-green</td>
<td>Small Disc Gray-red</td>
<td>Large Disc Gray-red</td>
</tr>
<tr>
<td>Normal Subject</td>
<td>10</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td>Suzan</td>
<td>60</td>
<td>25</td>
<td>90</td>
</tr>
</tbody>
</table>
at the large discs in the First and Second Parts, and with those of the First and Second Subjects at the small disc of the First Part, and with those of second Subjects in the Second Part.

The Table, once more, shows what has been stated above. In all but one figure Suzan's sensibility proves as being inferior. The exception is the green-threshold at the small disc. It is as low as the lowest threshold found with the normal subjects. But we cannot take this exception as more than a matter of chance. At the large disc Suzan's green-threshold is six times as high as that of the normal Subject. And when we look at the figures given in the previous chapter, we see that Suzan's green-threshold there neither has been markedly higher nor lower than that of the normal subjects. But her red-threshold was a little bit lower. Thus the instability of our results does not allow to draw any conclusion. Suzan's inferiority seen at Table III may be due to confusion in face of the task to observe two juxtaposed colour mixings. In any case, Suzan's thresholds of colours arising from gray discs were higher in some cases, equal in other cases, never lower than the corresponding thresholds of normal subjects. Contrary to these results her thresholds of colours arising from white or black discs were lower, mostly considerably lower than those of normal subjects.

6) A Hypothesis:

The anomalus of colour-vision shown by Suzan and her family seem to be understandable from a hypothesis which may be sketched in its barest outlines.

It is more than probable that the red-green blind sees red and green as different shades of gray and that protanopes and deutera-nopes differ in the brightness of gray they see instead of the chromatic colours.

We now assume that colour anomalous or colour-weak individuals see red and green chromatic colours, but not in the saturation seen by colour-normals, but veiled with gray. When fully saturated colours are presented to them they recognize them, as colour-normals do. Faced with highly unsaturated colours however, they may recognize a shade of chromatic colour the easier, the more the achromatic colour in which the chromatic is
embedded differs from medium gray, i. e. from the gray veiling up even the most saturated colour. The difference is greatest in white and in black. Therefore Suzan recognizes the slight immixon of red or green in white and in black at a lower level than the normal subjects do. Immixed in gray, however, the colour is seen by Suzan in one part of our experiments at almost the same level as by normals, in another part of our experiments at a considerably higher that the normal level.

On Ishihara's test-charts the figures seen by colour-blinds and not seen by colour-normals may show such difference in achromatic colour which colour-blinds are able to recognize, whereas the normals are not. Suzan sharing the higher brightness-sensitivity of colours or approaching it recognizes, therefore these figures. In the same time she recognizes the figures seen by normals, because their chromatic colour is saturated enough to be seen even under gray veil.

EDITORS POSTSCRIPT. The author of this paper was on the way to the United States, when the proofs arrived. In looking them through we soon saw that quite a number of expressions were not clear or even wrong. It seems that in typing the handwritten manuscript various errors have slipped in. Due to administrative obstacles we were not able to withdraw the paper from its immediate publication.