AN EVALUATION OF COMPUTER BASED COLOR VISION DEFICIENCY TEST: EGYPT AS A STUDY CASE
By

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Overview

- Introduction
- Problem Definition
- Methods of Study
- Experimental Results
- Conclusion
What is CVD?

- **Color Vision Deficiency (CVD)**
  - Congenital color deficiency exists due to a genetic disorder where the color deficient person could miss one or some pigments in the cone cells of the retina.
  - Leads to inability to **distinguish** the differences between certain colors.
What is CVD?

Color normal

Color blind

Blue cones absent in central fovea
Types of CVD

CVD
(Male 10%, Female 0.1%)

Anomalous Trichromacy
(6.3%, 0.37%)
- Deuteranomalous
- Protanomalous
- Tritanomalous

Dichromacy
(2.4%, 0.3%)
- Deutanopia
- Protanopia
- Tritanopia

Monochromacy
0.00001%
- Cone monochromacy
- Rod monochromacy (Achromatopsia)
Types of CVD

Normal Vision

Deuteranopia

Protanopia

Tritanopia
DIAGNOSIS METHODS

- **Anomaloscope**
  - Detects only Red

- **Pseudoisochromatic plates**
  - Detects only Red-Green defect
  - Couldn’t estimate the majority of defect

- **Caps arrangement tests**
  - Complex majority computations
PROBLEM DEFINITION
There is NO medical treatment

Most Diagnosis Methods are specified for Red-Green types only

Traditional diagnosis tools are very expensive and not suitable for kids and non English people.

The awareness about this type of disorder is very limited especially in developing countries.
Objectives: Evaluate the usage of computer systems for CVD screening.

Outcomes: Reliable self-testing and Fast screening in hard testing conditions.
METHODS OF STUDY
SPECIFICATIONS

- The study based on 38-plates brand Ishihara plates.

- A full CVD test has been performed using the first 21 numerical plates.

- 267 volunteers from the Menofia University Campus students, staff members and workers were examined for red green color vision deficiency.
The Volunteers’ personal information were collected using a registration form.

Volunteers’ personal information as well as their test results for both paper-based and computer-based tests were documented in a spreadsheet.
1) PAPER-BASED TEST

- Examinations were done in ordinary day light, with no direct sun exposure, plates were held 75 cm from the volunteer and tilted so that the plane of the paper is at right angle to the line of vision, the numerals seen on the plates were stated within 3 seconds, and recorded by the examiner.
1) PAPER-BASED TEST

Introductory plate

Transformation plates 1

Transformation plates 2

Vanishing figure

Reverse plate

Qualitatively diagnostic
DIAGNOSIS INSTRUCTIONS

- As noted in the instruction sheet of this brand, Volunteers were diagnosed as normal if they were able to read 17 or more plates correctly, and diagnosed as RG-CVD if they were able to read 13 or less plates correctly.
2) COMPUTER-BASED TEST

- The first 21 plates of a brand new Ishihara color vision deficiency examination plates were scanned using HP Deskjet 1050 J410 all in one scanner with 600 dpi resolution, and color adjustment enabled.

- The test program has been written in Matlab R12 and converted to an executable program. The test has been performed on Acer Veriton M 290 PC (Intel Core i3 Processor, 4GB-Ram).
2) COMPUTER-BASED TEST

Ishihara CVD Test

Instructions:
- Write down the number you can see inside the circles within 3 seconds.
- If you couldn't see any numbers, click Nothing button.
- Click Submit button to submit your answer and move to the next plate.
- Click Clear button to erase the editbox.
- You could see your answers and test result under the edit box.

This test is not Authenticated ophthalmology test yet. It depends on your display setting.

User Panel:
- 12
- User Answers:
  - 1 2 3
  - 4 5 6 7 8 9 0
- Clear  Submit

Plate no. 1

12
2) COMPUTER-BASED TEST

Start: \( P = 1 \), Correct = 0

- **P \( \leq 21? \)**
  - **Yes**: Show plate P, Delay 3 s, Hide plate P
    - Correct Answer of plate P = B
    - Manual Input = A
  - **No**: Correct ++

- **Correct \( \geq 17 \)**
  - **Yes**: Normal
  - **No**: Correct \( \leq 13 \)

- **Correct \( \leq 13 \)**
  - **Yes**: RG-CVD
  - **No**: Other Vision Problem

- **P ++**
The test has been performed on Acer Professional 24" Widescreen LCD Monitor with 1920 x 1080 Full HD resolution.

The monitor was kept half an hour in operation at a dark room.
Monitor resolution was set to max.

The sufficient specs for this test are:
- Color temperature 6500 °K, Color intensities of red, green, and blue respectively to 50%.
- Colors set to "true color" (16 million colors).
MONITOR TESTING PROCEDURE

- 11 different gray shades.
- 7 different gray shades.
- Red, Green and Blue should appears in 2 different colors.
ASSESSMENT METHODS

Assessment Methods

- Binary classification functions
- Hypothesis Test
Sensitivity, Specificity, Positive predictive value, negative predictive value, and accuracy were calculated to the answers of the computer-based test using the paper-based Ishihara results as a reference.

Consider FPA to refer to false positive answers, FNA is for false negative answers, TPA is for true positive answers and TNA is for true negative answers.
1) BINARY CLASSIFICATION FUNCTIONS

- Screening Inefficiency (SI) measures the quality of the discriminating ability of each plate

\[ SI = \frac{\sum(FPA) + \sum(FNA)}{\sum(Answers)} \]

- Minimum \( SI \) refers to Higher Accuracy
1) BINARY CLASSIFICATION FUNCTIONS

- Sensitivity (Sen) is defined as the proportion of volunteers classified as having CVD among those with Ishihara plates proven CVD

\[
Sen = \frac{\sum(TPA)}{\sum(TPA) + \sum(FNA)}
\]

- Higher Sen refers to higher performance of CVD cases classification.
Specificity ($Spc$) is the proportion of volunteers classified as not having CVD among those in whom the disease was excluded by Ishihara plates.

$$Spc = \frac{\sum(TNA)}{\sum(FPA) + \sum(TNA)}$$

Higher $Spc$ refers to Higher performance of Normal cases classification.
2) HYPOTHESES TEST

- Student t-test was used to calculate the statistical difference between numerical variables. Assume $H_0$ for null hypothesis and $H_1$ for alternative hypothesis

$$H_0: \mu = \mu_0, H_1: \mu \neq \mu_0$$

- The one-sample t statistic is:

$$t_{stat} = \frac{\bar{x} - \mu_0}{sem}$$

- where $\bar{x}$ represents the sample mean, $\mu_0$ represents the expected value under the null hypothesis, and

$$sem = \frac{s}{\sqrt{n}}$$

- with $(n - 1)$ degrees of freedom
2) HYPOTHESIS TEST

- Screening Inefficiency (SI) was calculated for each plate independently, and the mean and the standard deviation for all plates were calculated.

- P-value and conclusion: The $t_{stat}$ is converted to a $p$ value with $t_{table}$.

- Small values of $P$ provide evidence against $H_0$. 
2) HYPOTHESIS TEST

- When \( p \text{ value} > .10 \) → the observed difference is “not significant”
- When \( p \text{ value} \leq .10 \) → the observed difference is “marginally significant”
- When \( p \text{ value} \leq .05 \) → the observed difference is “significant”
- When \( p \text{ value} \leq .01 \) → the observed difference is “highly significant”

- Use of “significant” in this context means “the observed difference is not likely due to chance.”
The study included 267 volunteer, 240 males (89.9%), and 27 females (10.1%) with an age range from 19 to 23 years, with a mean 20.7 years, and standard deviation 1.34 years.
## 1) RESULTS OF PAPER BASED TEST

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Plates answered correctly</th>
<th>Number of volunteers</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>RG-CVD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>246</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>225</td>
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</table>
## 2) RESULTS OF COMPUTER BASED TEST

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Plates answered correctly</th>
<th>Number of volunteers</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>RD-CVD</td>
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<td></td>
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</tr>
<tr>
<td>6</td>
<td>3</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not diagnosed</td>
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<td></td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
<td>243</td>
</tr>
<tr>
<td>17</td>
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<td>18</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>24</td>
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<tr>
<td>20</td>
<td>57</td>
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<tr>
<td>21</td>
<td>141</td>
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<td></td>
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</table>
The same number of volunteers (21) were diagnosed as red green CVD by both tests, with 100% sensitivity of the computer based test compared to the paper based test.

While 243 volunteers were diagnosed as normal in computer based test, when compared to the 246 volunteers diagnosed as normal by the paper based test gave a 98.78% specificity for the computer based test.
## Difference Between Both Tests Regarding the Number of Correct Answer in Each Test

<table>
<thead>
<tr>
<th>Two test difference</th>
<th>Number of two test difference</th>
<th>Type of difference</th>
<th>Number of volunteers</th>
<th>Total number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correct answers in paper based test</td>
<td>Correct answers in computer based test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No difference</td>
<td>0</td>
<td>0</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Number of correct answers more in the computer based test</td>
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<td>12</td>
<td>13</td>
<td>6</td>
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<tr>
<td></td>
<td>11</td>
<td>12</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>21</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Number of correct answers more in the paper based test</td>
<td>1</td>
<td>21</td>
<td>20</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>19</td>
<td>19</td>
<td>33</td>
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<td>21</td>
<td>3</td>
</tr>
<tr>
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<td>20</td>
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<tr>
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<td>16</td>
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<tr>
<td></td>
<td>6</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>
The categorization of normal/RG-CVD, and the total number of answers in each test have been formulated using *Chi square* test.

<table>
<thead>
<tr>
<th>Variance</th>
<th>Paper based test</th>
<th>Computer based test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screening inefficiency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.04</td>
<td>0.05</td>
<td>0.092</td>
</tr>
<tr>
<td>STD</td>
<td>0.02</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Categorization into</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>247</td>
<td>243</td>
<td>0.0912</td>
</tr>
<tr>
<td>RG-CVD</td>
<td>21</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Total number of answers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct</td>
<td>5376</td>
<td>5310</td>
<td>0.004</td>
</tr>
<tr>
<td>Wrong</td>
<td>231</td>
<td>297</td>
<td></td>
</tr>
</tbody>
</table>
Discussion & Conclusion

- The prevalence of RG-CVD was 8.75% of male participants, no female participants were diagnosed, both in the paper based test, and in the computer based test, which is very close to the predictable value in the world.

- Computer based test gave 100% sensitivity and 98.78% specificity, which makes the use of the computer based test convenient for screening RG-CVD without losing any positive cases.
Discussion & Conclusion

- Comparing the number of volunteers diagnosed as normal or RG-CVD by both test, resulted in statistically insignificant difference ($P = 0.0912$), this adds to the reliability of the computer based test, so, it can be used in screening of RG-CVD.
Discussion & Conclusion

- Although comparing the total correct and wrong answers in both tests resulted in a significant difference ($P = 0.004$), however this did not affect the reliability of the computer based test, as the total number of correct and wrong answers did not diagnose RG-CVD from normal, where it depends on the number of correct and wrong answers in all plates for each participant.
Test Yourself

- Enjoy our Free **Color Blindness Self-Test** App on Google Play:
Thank You

For further questions:

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