A New Approach to Establishing Colour Vision Limits for Use in Occupational Environments

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Examples of past & present practices

- The Ishihara Test is used to set minimum colour vision requirements in various occupational environments.

- The normal practice is to allow a small number of errors when screening for ‘functionally safe’ colour vision. The exact number depends on the assessment of colour-related visual demands within a given occupation.

<table>
<thead>
<tr>
<th>Professional environment</th>
<th>Edition</th>
<th>38-plate no errors</th>
<th>24-plate no errors</th>
<th>1-15 plates &lt;=8 errors</th>
<th>1-10 plates &lt;=5 errors</th>
<th>1-17 plates no errors &amp; &lt;=3 mr*</th>
<th>24-plate no errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAA</td>
<td>N (236)</td>
<td>191 (81%)</td>
<td>213 (90%)</td>
<td>236 (100%)</td>
<td>236 (100%)</td>
<td>229 (97%)</td>
<td>235 (99.6%)</td>
</tr>
<tr>
<td></td>
<td>D (340)</td>
<td>2 (0.6%)</td>
<td>5 (1.5%)</td>
<td>68 (20%)</td>
<td>64 (18.8%)</td>
<td>5 (1.5%)</td>
<td>24 (7%)</td>
</tr>
<tr>
<td></td>
<td>P (166)</td>
<td>0</td>
<td>0</td>
<td>10 (6%)</td>
<td>10 (6%)</td>
<td>1 (0.6%)</td>
<td>2 (1.2%)</td>
</tr>
</tbody>
</table>

*mr = ‘misreadings’ or errors on specified plates
Background

- Many subjects with reduced red-green (RG) chromatic sensitivity can carry out visually-demanding, colour-related tasks encountered in occupational environments with the same accuracy as normal trichromats.

Ishihara results:
- 100% of normals make ≤ 4 errors
- 80.9% (191) normals make no errors
- 10% deutans (34) make ≤ 4 errors
- 1% protans make ≤ 4 errors

- Mild deuteranomalous subjects tend to make less errors than dichromats – it is probably this observation that has prompted the use of the plates failed as a direct measure of the severity of colour vision loss.
- In addition to discovering those that are colour deficient, there is a need to quantify accurately the severity of colour vision loss providing fairer colour vision standards that are specific to the occupational environment.

Analysis of Ishihara test

- Examine whether the plates can be ranked in order of difficulty and whether this order remains unchanged for deutans and protans – this would validate to some extent the practice of allowing a k number of errors on the Ishihara as a pass depending on the colour vision requirements in the specific occupation.

- Examine whether appropriate ‘weights’ to reflect the likelihood of a correct response within each class of colour deficiency improves Ishihara’s description of severity of colour vision loss.

- Compare the measure of colour vision loss of the Ishihara test against the CAD (Colour and Assessment and Diagnosis) test.
**CAD test**

**Colour Assessment & Diagnosis**

1. **CAD measure of chromatic sensitivity**

- Deuteranope
- Protonope
- Tritanope
- 2.5% < P < 97.5%
- "Standard Observer"
- subject's data

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Colour vision deficiencies

CAD test measurements in over 500 observers reveals a large variability in RG colour vision loss

- Subjects with RG congenital colour deficiency can exhibit an almost continuous loss of chromatic sensitivity
- The loss of RG chromatic sensitivity is greater in subjects with protan- when compared to deutan-like deficiency.

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Acquired loss of chromatic sensitivity

Hereditary/acquired diseases causing loss or damage to photoreceptors / ganglion cells /optic nerve fibres:

- Autoimmune related retinopathy & neuropathy
- Melanoma associated retinopathy
- Enhanced S-cone syndrome
- Newfoundland rod-cone dystrophy
- Retinitis pigmentosa
- Age Related Macula Degeneration
- Glaucoma
- Optic Neuritis
- Diabetic retinopathy
- Vitamin A deficiency
CLINICAL APPLICATIONS OF COLOUR VISION ASSESSMENT: EXAMPLES OF ACQUIRED LOSS OF COLOUR VISION

Normal subject

Minimal congenital deficiency

Asymptomatic AMD?

Congenital & Acquired

AMD patient

Diabetes

High IO Pressure (Glaucoma?)

Direct sun viewing

RG versus YB loss

Optic Neuritis

Diabetes

AMD

Congenital-Acquired

Optic Neuritis

Diabetes

AMD

Congenital-Acquired

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Ishihara: study design

Methods:
Ishihara 38-plate ed. (1-25 plates)

Subjects:
236 normals
340 deutsans
166 protans

Ishihara: plate-specific errors

Weights:
\[ W_i = 1 - P_{N_i} \]
\[ W_i = 1 - P_{D_i} \]
\[ W_i = 1 - P_{P_i} \]

hence 'weight' for plate \( i \) is given by:
\[ W_i = k(1 - PE_i) \]
where,
\[ k = \frac{100}{\sqrt{\sum_{i=1}^{25} (1 - PE_i)}} \]

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Plate and subject group specific weights

\[ W = k^* (1 - PE_i), \text{ where, } k = 100 / \sum_{i=2}^{25} (1 - PE_i) \]

Severity Index (SI) is defined as:

\[ SI = \sum_{i=2}^{25} W_i^* R_i \]

(Where, \( R_i = 1 \) indicates an error on plate, \( i \), and \( R_i = 0 \), indicates a correct response)

Ishihara measure of colour vision loss

- Extremely poor correlation between the measured RG colour detection thresholds and the number of errors the subjects make on the Ishihara plates within each subject group.
**Ishihara measure of colour vision loss**

- In order to examine how the mean errors subjects with similar RG thresholds make on the Ishihara plates, the subjects were grouped according to their RG thresholds into bins of width 2.5 CAD SN units.

\[
\text{Severity Index (SI): } SI = \sum_{i=2}^{25} W_i R_i
\]

Error bars show ±2s.

**Conclusions**

- The number of errors on the Ishihara test does not reflect the same severity of colour vision loss for deutan and protan colour deficient.
- The computation of the SI for the Ishihara test failed to show a significant improvement.
- The number of errors the applicant makes on the Ishihara plates should not be used by occupational medical advisors to judge suitability for the job.
- There is a need for a new approach in colour vision assessment in occupational medicine that provides evidence-based guidelines specific to the occupational environment.