1. WELCOME

The Division Director, Ronnier Luo, welcomed all those present to Weetwood Hall, part of the University of Leeds.

The Division Director invited participants to stand in memory of two colleagues who had died since the last meeting:

Gerhard Rösler (1950 – 2012)
- President Deutsche farbwissenschaftliche Gesellschaft (German Colour Scientific Society)
- D1 Representative of Germany
- Active in CIE Division 2

Pieter Walraven (1930 – 2013)
- Director CIE Division 4
- Associate CIE Director Division 1
- Secretary TC1-36, Member TC1-63
## 2. ATTENDENCE

<table>
<thead>
<tr>
<th>Officers</th>
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<tbody>
<tr>
<td>Ronnier Luo</td>
<td>GB</td>
<td>DD – Director</td>
</tr>
<tr>
<td>Miyoshi Ayama</td>
<td>JP</td>
<td>AD – Vision</td>
</tr>
<tr>
<td>Ellen Carter</td>
<td>US</td>
<td>AD – Colour</td>
</tr>
<tr>
<td>Phil Green</td>
<td>GB</td>
<td>DE – Editor</td>
</tr>
<tr>
<td>Mike Pointer</td>
<td>GB</td>
<td>DS – Secretary</td>
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<table>
<thead>
<tr>
<th>Country</th>
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<tbody>
<tr>
<td>Australia</td>
<td>Peter McGinley</td>
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<td>Belgium</td>
<td>Peter Hanselaer</td>
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<tr>
<td>Canada</td>
<td>Ellen Carter*</td>
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<tr>
<td>China</td>
<td>Ronnier Luo*</td>
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<tr>
<td>France</td>
<td>Françoise Viénot</td>
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<tr>
<td>Germany</td>
<td>Klaus Richter</td>
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<tr>
<td>Great Britain</td>
<td>Mike Pointer</td>
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<td>Hungary</td>
<td>Janos Schanda*</td>
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<td>Italy</td>
<td>Osvaldo da Pos</td>
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<tr>
<td>Japan</td>
<td>Miyoshi Ayama</td>
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<tr>
<td>Korea</td>
<td>Jisoo Hwang</td>
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<td>Netherlands</td>
<td>Esther de Beer</td>
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<tr>
<td>New Zealand</td>
<td>Andrew Chalmers</td>
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<td>Norway</td>
<td>Jan Henrik Wold</td>
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<td>Slovenia</td>
<td>Manuel Melgosa*</td>
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<td>Turkey</td>
<td>Rengin Unver</td>
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<tr>
<td>USA</td>
<td>Ellen Carter*</td>
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In addition, Ana Paula Dornelles Alvarenga (Brazil), Marjukka Puolakka (Finland), John See Keat Siang (Malaysia), Corina Martineac (Romania), Elsie Coetzee (South Africa) and Ludovic Coppel (Sweden) nominated the Division Secretary as their voting representative.

Thus there were 24 countries represented at the meeting for official ballots (23 pm).

<table>
<thead>
<tr>
<th>Technical Committee</th>
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<tbody>
<tr>
<td>Françoise Viénot</td>
<td>TC1-36</td>
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<tr>
<td>Miyoshi Ayama</td>
<td>TC1-42</td>
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<td>Manuel Melgosa</td>
<td>TC1-55</td>
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<tr>
<td>Taiichiro Ishida</td>
<td>TC1-61</td>
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<tr>
<td>Klaus Richter</td>
<td>TC1-63, TC1-81, L1-07</td>
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<tr>
<td>Changjun Li</td>
<td>TC1-71, TC1-73, R1-42</td>
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<td>Janos Schanda</td>
<td>TC1-74, TC1-85</td>
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<tr>
<td>Ronnier Luo</td>
<td>TC1-75, L1-04</td>
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<tr>
<td>Robert Hirschler</td>
<td>TC1-77</td>
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<tr>
<td>Jan Henrik Wold</td>
<td>TC1-82</td>
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<tr>
<td>Dragan Sekulovski</td>
<td>TC1-83</td>
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<tr>
<td>Nana Itoh</td>
<td>TC1-84</td>
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<tr>
<td>Po-Chieh Hung</td>
<td>TC1-89</td>
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<tr>
<td>Hirohisa Yaguchi</td>
<td>TC1-90</td>
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<tr>
<td>Yandan Lin</td>
<td>TC1-91</td>
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<tr>
<td>Kaida Xiao</td>
<td>TC1-92</td>
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<tr>
<th>Reporters</th>
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<tr>
<td>Phil Green</td>
<td>R1-58</td>
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</table>
In addition there were approximately 10 guests present.

Apologies

<table>
<thead>
<tr>
<th>Name</th>
<th>Country</th>
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<tbody>
<tr>
<td>Paula Alessi</td>
<td>US</td>
<td>L1-01</td>
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<tr>
<td>Ana Paula Dornelles Alvarenga</td>
<td>BR</td>
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<tr>
<td>Peter Bodrogi</td>
<td>HU</td>
<td>TC1-68</td>
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<tr>
<td>Elsie Coetzee</td>
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<td>Ludovic Coppel</td>
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<td>Steve Fotios</td>
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<td>Marte K Gunde</td>
<td>SI</td>
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<td>Hillevi Hemphälä</td>
<td>SE</td>
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<tr>
<td>Frédéric Leloup</td>
<td>R1</td>
<td>53</td>
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<tr>
<td>Sharon McFadden</td>
<td>CA</td>
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<tr>
<td>Corina Martineac</td>
<td>RO</td>
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<tr>
<td>Yoshiki Nakamura</td>
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<td>TC1-88</td>
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<tr>
<td>Malcolm Nicholson</td>
<td>SI</td>
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<td>Li-Chen Ou</td>
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<tr>
<td>Marjukka Puolakka</td>
<td>FI</td>
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<tr>
<td>Alan Robertson</td>
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<td>Ken Sagawa</td>
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<td>Thorstein Seim</td>
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<td>R1-57</td>
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<tr>
<td>John See Keat Siang</td>
<td>MY</td>
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<tr>
<td>David Simmons</td>
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<td>R1-50</td>
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<tr>
<td>Michael Stock</td>
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<tr>
<td>Haising Xu</td>
<td>CN</td>
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<tr>
<td>Joanne Zwinkels</td>
<td></td>
<td>L1-03</td>
</tr>
</tbody>
</table>

Total attendance: Approximately 44 persons

3. MEMBERSHIP

The following changes in national representative to Division 1 were noted:
- Croatia: from Miroslav Rasonja to Vladimir Kocet
- Denmark: from Astrid Espenhain to Anne Bay
- Germany: Klaus Richter appointed interim member following the death of Gerhard Rössler
- Israel: from Inna Nissenbaum to Yochanan Di Segni
- Slovakia: from Frantisek Krasnan to Roman Dubnicka

The following additional member countries have appointed a representative to Division 1:
- Romania: Corina Martineac

4. CONFIRMATION OF THE AGENDA

The Agenda, as appended to these Minutes, was agreed.

5. MINUTES

The Minutes of the 2012 meeting held in Taipei, Taiwan, were approved after the following corrections:
6. MATTERS ARISING FROM THESE MINUTES

There were no matters arising not covered by items on the agenda.

7. DIVISION OFFICER REPORTS

7.1 Director
The Director presented a report and highlighted the following points from the activities over the last year:

Terms of Reference
To study visual responses to light and to establish standards of response functions, models and procedures of specification relevant to photometry, colorimetry, colour rendering, visual performance and visual assessment of light and lighting.

Officers
Director Ronnier Luo (GB)
Associate Director (Colour) Ellen Carter (US)
Associate Director (Vision): Miyoshi Ayama (JP)
Secretary: Michael Pointer (GB)
Editor: Phil Green (GB)

Meetings
• The Division last met on 26-27 September 2012 in Taipei, Taiwan.
• Colour Science Symposium, 27 (pm) – 28 (am) September 2012. Co-organised by CIE-Taiwan, CIE-Division 1 and the Colour, Imaging and Illumination Centre, National Taiwan University of Science and Technology.
• Workshop on Colorimetry, Graphic Arts and Colour Management, 4 July 2013, University of Leeds, UK. Organised by the International Color Consortium (ICC), ISO TC130 Graphic Technology and the School of Design, University of Leeds.

Recent Publications: Reports
200:2012: CIE Supplementary System of Photometry
204:2013: Methods for Re-defining CIE D Illuminants

Recent Publications: Standards

New Technical Committees – Taipei
TC1-88 Scene brightness estimation: Yoshiki Nakamura JP
TC1-89 Enhancement of images for colour defective observers: Po-Chieh Hung JP
TC1-90 Colour fidelity index: Hirohisa Yaguchi JP
TC1-91 New methods for evaluating the colour quality of white-light sources: Yandan Lin CN
TC1-92 Skin colour database: Kaida Xiao CN (by email ballot since the Taipei meeting.)
New Reporters – Taipei
R1-58 Liaison with ISO TC130 Graphic Technology: Phil Green GB

CIE Directors and Board Meetings
Held in Paris, France in association with the CIE Centenary meeting, 12-19 April 2013 - main items discussed included:

- Priority projects: to be defined where there is a clear need, the answer can be available in a short time, failure to respond can cause a problem, and there will be well-defined results. Some financial support may be available.
- 2015 is to be designated the International Year of Light by UNESCO. CIE will act as a partner and the concept will be used to raise the profile of CIE in 2015, including at the CIE 2015 21st Session in Manchester, UK.
- The new Technical Committee ISO TC274 Light and Lighting is now established and involves work between ISO, CIE and DIN.
- There is to be a move to improve the quality of CIE conference papers.
- Minority standards (ISO rule: 2/3 vote); Minority TCR (Review panel).
- TC Terms of Reference that include ‘uncertainty’ are to involve a member from D2.
- We must attract new members (young blood), and be more global.
- We must fully utilise the CollTool.
- The next CIE BA meeting will in April 2014 in Malaysia.

Division Strategy
- To smoothly implement the Code of Procedure to be productive for each Technical Committee and Reporter.
- To continue to cover aspects of traditional colorimetry (new colour matching functions to extend to different age observers and viewing fields; new uniform colour space to perform much better than CIELAB and CIELUV; and a more comprehensive colour appearance model than the current CIECAM02).
- To go beyond colour topics (other aspects of appearance such as gloss, texture, translucency; colour emotion and harmony to provide methods to link colour science with colour design); this will extend our understanding the interaction between light, colour and surface.
- To bring theory into practice such as to study visual performance in the real world situation, for example lighting in indoor and outdoor conditions: this will allow us to develop practical tools for real applications.
- To develop an appearance model of lighting.

CIE Midterm Meeting
The CIE meeting in 2014 is to be held in Kuala Lumpur, Malaysia in April 2014.

7.2 Editor
- Produced the Activity Report 2012: reports were received from TCs 1-82, 1-83, 1-89 and JTC-1 in the Vision section, and 1-57, 1-61, 1-63, 1-64, 1-68, 1-71, 1-73, 1-74, 1-75, 1-77, 1-81, 1-86 and 1-91 in the Colour section. Reports were also received from Reporterships 1-42, 1-53, 1-56 and 1-58.
- The following TC reports have been received by the Editor:
  - TC1-42 (Received 15 May 2013 and edits in progress)
  - TC1-68 (Edits completed and returned to TC chair)
  - TC1-74 (Final report approved by D1 and CIE Board of Administration)
  - TC1-76 (Edits completed and returned to TC chair)
  - TC1-80 (Received 19 June 2013 and edits in progress)
7.3 Secretary
- Produced and distributed the Minutes of 2012 Taipei meeting
- Contributed to and distributed the 2013 Activity Report
- Set up the TC1-92 ballot
- Set up the 2013 Leeds Division meeting
- Maintained the CIE D1 website
- Sent/received approximately 1950 emails!

8. TECHNICAL REPORTS VISION: Miyoshi Ayama

TC1-36 Fundamental Chromaticity Diagram with Physiologically Significant Axes:
Françoise Viénot FR
The secretary of the TC, Peter Walraven, has passed away and the TCC praised his contribution to the TC activity and expressed her condolences.

The draft of Part II of the Technical Report has the following chapters:
- Introduction to Part II
- Chapter 6. Photometric aspects; the choice of the spectral luminous efficiency functions $V_{LM}(\lambda)$ and $V_{LM,10}(\lambda)$
- Chapter 7. Chromaticity diagrams
  - 7.1. The MacLeod-Boynton Chromaticity Diagram
  - 7.2. Development of XYZ representations of the cone fundamentals based upon the principles of the CIE standard colorimetric systems
- Conclusion to Part II, including 10 Tables.

The draft has been agreed among the TC members, and it will proceed to the TC vote after minor editorial revisions.

TC1-42 Colour Appearance in Peripheral Vision: Miyoshi Ayama JP
A TC vote for the TR has been completed and the draft TR has been submitted to the Division and the BA.

TC1-67 The Effects of Dynamic and Stereo Visual Images on Human Health: Hiroyasu Ujike JP
The circulation of the latest draft of a TR on photosensitive seizures was delayed, but done recently. The draft TR was also sent to Division 6 because they are interested in the work dealt with by the draft report.

The title of the TR is: Undesirable Biomedical Effects of Photosensitive Seizures - Effects of Flash and Pattern, Their Measurements and Countermeasures

Tentative schedule for the processing of the draft is as follows:
- The deadline for comments on the draft TR is 31 July.
- The draft will be revised by the mid August.
- The TC ballot will start and be completed by the end of August.

TC1-78 Evaluation of Visual Performance in the Real Lit Environment: Monica Billger SE
Following the resignation of the TCC, Monica Bilger, the DD received responses from some of the TC members indicating the importance and validity of the work of the TC. Taking this into consideration, the DD will take over the TCC: see item 11.1 below.
**TC1-80 Research Methods for Psychophysical Studies of Brightness Judgements: Steve Fotios GB**

A draft TR has been approved by the TC members and sent to the DE.

**TC1-82 The Calculation of Colour Matching Functions as a Function of Age and Field Size:**

Jan Henrik Wold NO

A TC meeting was held in Paris on 17 April 2013 where one new member, Lee Chan-Su, joined the TC. He has programming skills to converge the present web application in Python to provide a Matlab version.

Suggestions from TC meetings in Taipei and Paris are as follows:

- Restrict the age parameter to 20–70 (or 20–60) years
- Include tables and plots for
  - CIE 1931 Standard colorimetric observer
  - CIE 1964 Standard colorimetric observer
- Include data for stimuli represented on the purple line, i.e.
  - XYZ tristimulus values as a function of complementary wavelength
  - xy chromaticity coordinates as a function of complementary wavelength
- Include option for choice of wavelength domain (used in tabulations)
- Facilitate saving (of plots and tables) in different file formats

Issues below were discussed at the TC meeting in Leeds.

- Need to investigate data for elderly people in order to determine the cut-off with respect to age.
- Contact will be made with some people in Division 6 from the Department of Ophthalmology, Glostrup Hospital, University of Copenhagen, who are involved in the research on age-related changes in transmission properties of ocular media.
- In addition to the Matlab application, an Excel application is highly desirable. Lee Chan-Su commented that there exists some difficulty in the optimization process to convert the present Python version to an Excel application. An attendee of the meeting said that he might be able to introduce volunteers to help.

**TC1-83 Visual Aspects of Time-Modulated Lighting Systems: Dragan Sekulovski NL**

After the Division 1 Meeting in Taipei, the membership of the TC was finalized. A publication with the definitions of different temporal artifacts and comparison of models for their visibility is in preparation. Links were made to the IEEE PAR1789, IEC and Energy Star. Experiments have been carried out at Philips Research Europe (Sekulovski, Perz) and at the South East University (Wang). Matlab and Excel programs to compute the Strobo Visibility Measure are being written.

Issues below were discussed at the TC meeting in Leeds:

After discussion, the words “ghosting, and digital artifacts” in the first Term of Reference were changed to “the phantom array effect.” This was approved by the TC.

To investigate and report on current research on the perception of visual artifacts of temporally modulated lighting systems, including flicker, the stroboscopic effect, and the phantom array effect.

The working plan of the TC is as follows:

- Write up literature study (Summer 2013)
- Agree on best practices for methodologies (before end of 2013)
- A paper with definitions and best practices on methodologies (before end of 2013)
• Reconcile data and identify where more data are needed (before end of 2013)
• Agree on sensitivity curves for simple stimuli (before end of 2014)
• Agree on the methods to extend to complex stimuli (before end of 2014)
• Write up the TC Report (2015)

The TCC plans to have a web meeting in August 2013, and physical meeting in November 2013, in Taipei.

**TC1-84 Definition of the Visual Field for Conspicuity: Nana Itoh JP**

The membership of the TC was finalized and the TC was officially activated in July 2013. The TC had a meeting in Leeds. The TCC introduced that there exist two ways to represent the visual field function, one is by depicting the functional property as a function of eccentricity, and the other is by showing the value of functional field size. She showed Table 1 below, for the classification of visual field function, and Table 2 below, for the effective factors relevant to visual field for conspicuity.

**Table 1**

<table>
<thead>
<tr>
<th>Function</th>
<th>Static/dynamic</th>
<th>Specification</th>
<th>Important factors to effects size of visual field</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Detection</td>
<td>Observer &amp; Target : Static</td>
<td>Light sensitivity, Color</td>
<td>Adaptation level of Observer, Target size</td>
</tr>
<tr>
<td>2 Discrimination</td>
<td>Observer &amp; Target : Static</td>
<td>Spatial: Colour, Luminance</td>
<td>Adaptation level of Observer, Target size</td>
</tr>
<tr>
<td>3 Resolution</td>
<td>Observer: Static Target: Static or dynamic</td>
<td>Spatial: Visual acuity, Temporal: Critical flicker frequency (CFF)</td>
<td>Target size, Contrast between target and background</td>
</tr>
<tr>
<td>4 Recognition</td>
<td>Observer &amp; Target : Static</td>
<td>Legibility of letters, Shape, Conspicuity, Color appearance</td>
<td>Adaptation level of Observer, Target size, Target background: Complexity</td>
</tr>
<tr>
<td>5 Motion</td>
<td>Observer: Static Target: Dynamic</td>
<td>Motion</td>
<td>Projection duration, Distance to move</td>
</tr>
<tr>
<td>6 Visual performance</td>
<td>Observer: Dynamic Target: Static</td>
<td>Reading sentences, Pattern recognition</td>
<td>Target size, Contrast between target and background</td>
</tr>
<tr>
<td>7 Behavior</td>
<td>Observer: Dynamic</td>
<td>Reaching, Grasping, Driving, Walking</td>
<td>Target (or objects in environment) size, Contrast between target (or objects in environment) and background</td>
</tr>
</tbody>
</table>
The method of classification and aspects of classification were discussed and the following suggestions were given in the TC meeting:
1. Consider some other aspects of two different groups of visual field function.
2. Add “adaptation” as an important factor for the all functions of visual field.

Work for the next meeting is as follows:
1. Modify Table 1 and Table 2.
2. Preparation for guidelines for visual signs, displays, markings.
3. Point out the important considerations for guidelines.
4. Collect more references.

**Table 2**

<table>
<thead>
<tr>
<th>1. Target background</th>
<th>2. Subjective attributes</th>
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</thead>
<tbody>
<tr>
<td>1. Luminance</td>
<td>1. Contrast of different age group (e.g. older-younger)</td>
</tr>
<tr>
<td>2. Size</td>
<td>2. Longitudinal change by age</td>
</tr>
<tr>
<td>3. Shape</td>
<td>1. Low vision</td>
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<td>4. Color</td>
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</table>

<table>
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<th>2. Subjective attributes</th>
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<td></td>
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<tr>
<td>2. Visual Impairments</td>
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<td></td>
</tr>
<tr>
<td>3. Subjective attributes</td>
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**TC1-88 Scene Brightness Estimation: Yoshiki Nakamura JP**
The working program is as follows:
In 2013, 2014, all members will investigate current research on brightness estimation methods using a calibrated luminance image of a real indoor scene, will list them, and provide explanatory descriptions of each of them.
In 2015, several members in different laboratories will carry out experiments to compare brightness estimations of real indoor scenes with those predicted by different estimation methods.
In 2016, the TC will finalize the activity and recommend a method to predict the brightness of specified regions of a scene from a luminance image of that scene.
Because the TCC could not yet join the training program by CB, real activity has not been able to start yet.

**TC1-89 Enhancement of Images for Colour Defective Observes : Po-Chieh Hung JP**
The TC was proposed and accepted in Division 1 in 2012, and had 4 Web meetings from February to June, further it is going to have the 5th Web meeting in August 2013. The TC had a physical meeting
in Leeds.

The TCC showed highlights of presentations in the past meetings from the TC members.
- Exact Compensation of Color-Weakness with Discrimination Threshold Matching (R. Mochizuki)
- An Efficient Naturalness-Preserving Image-Recoloring Method for Dichromats (G. Kuhn, M. Oliveira, and L. Fernandes)
- Proposal of Real-time and Bi-directional Color Simulator for Dichromacy and Trichromacy on Smartphones (S. Ohtsuka)
- Real-Time Temporal-Coherent Color Contrast Enhancement for Dichromats (G. Machado and M. Oliveira)
- A Colour Conversion Method Which Allows Colourblind and Normal-Vision People to Share Documents With Colour Content (P. Hung)
- An Analytical Strategy for Color Vision Deficiency Using a Digital Color Vision Test Plate (H. Chen)

It was agreed that the Terms of Reference be changed to those below:
To study, evaluate and recommend image enhancing techniques for colour defective observers and to provide test procedures for the evaluation of those techniques.

The working plan of the TC is as follows:
2013: Introduction of member’s work, List up the requirements

### JTC-1 Implementation of CIE 191: Mesopic Photometry in Outdoor Lighting: Liisa Halonen FI

This TC had a meeting on 8 April 8 2013 in Paris where 22 members and 22 observers attended.
Seven presentations below were given as contributions to the work of the TC:
- Alternative approaches in defining visual adaptation field, Marjukka Puolakka, FI
- The effect of local adaptation luminance on the Purkinje phenomena, Yukio Akashi, JP
- How a high luminance source affects the adaptation state in the mesopic range? Tatsukiyo Uchida, JP/US
- Typical Eye Fixation Areas of Car Drivers in Inner-City Environments at Night, Jan Winter, DE
- Eye glance behaviour at rotaries, Ron Gibbons, US
- Study on visual field of drivers in China, Haldun Demirdes, CN
- Darmstadt University of Technology, DE

The 5th meeting will be held at the time of the CIE 2014 Lighting Quality & Energy Efficiency Conference, 23-26 April 2014 in Kuala Lumpur, Malaysia.

### R1-40 Scene Dynamic Range: Jack Holm US

No report from this Reporter again. Ballot to close this reportership was approved.

### R1-49 Above-threshold Pulsed Lights: Malcolm Nicholson UK & Dennis Couzin US

Malcolm Nicholson submitted a report written by Dr. Peter Rhodes entitled “Apparent Intensity of Flashing Light.” This report is appended to these Minutes.

The report was written independently from Dennis Couzin, and his comments will be sent to Malcolm Nicholson and the Division officers.
R1-51 Reconciling Maxwell vs Maximum Saturation Colour Matches: Mike Brill US
No report to this meeting. This Reporter continues this work, and thus the Division gave the Reporter a one-year extension again.

R1-57 Border between Luminous and Blackish Colours: Thorstein Seim NO
The Reporter submitted a report, which will be circulated and uploaded to the Division website. Ballot to close this reportership approved.

9. TECHNICAL REPORTS COLOUR: Ellen Carter

TC1-55 Uniform colour space for Industrial Colour-Difference Evaluation: Manuel Melgosa ES
This TC met July 5 2013 with 24 people attending. The main conclusions were:
1. Amongst noteworthy developed colour spaces (e.g. DIN99, CAM02, OSA-GP, IPT-based spaces, etc.), at this moment we cannot recommend just one colour space for industrial colour-difference evaluation. From existing experimental datasets, none of the formulas associated with such colour spaces is statistically significantly better than CIEDE2000.
2. We can produce a Technical Report focusing on the STRESS method to assess the merit and statistical improvement of any colour-difference formula with respect to a given set of visual data, as well as the intra- and inter-observer variability associated with visual experiments. On the conclusion of this Report (first draft: October 2013) this TC will be disbanded.
3. Research in colour-difference evaluation must be continued. To follow-up advances in this field and give advice on possible new TC/TCs I think that nomination of a Reporter may be highly useful.

Technical Report (TCR) Proposal

METHOD FOR EVALUATION OF THE PERFORMANCE OF COLOUR-DIFFERENCE FORMULAS

SUMMARY: A method is proposed to evaluate the strength of the relationship between visually-perceived colour differences in a given set of colour pairs and their corresponding predictions by a colour-difference formula. This method is based on the standardized residual sum of squares (STRESS) index used in multidimensional scaling, and it allows to test if two colour-difference formulas are or are not statistically significantly different. The same index can be also used to compute intra- and inter-observer variability. Using different highly reliable visual datasets, the results from this method indicate that most recent colour-difference formulas (e.g. DIN99d, CAM02, OSA-GP-Euclidean, etc.) perform well but they are not significantly better than CIEDE2000.

CONTENTS

INTRODUCTION including: What is a colour-difference formula? CIE-recommended colour-difference formulas. Advanced colour-difference formulas / associated colour spaces.

MEASURING THE RELATIONSHIP BETWEEN PERCEIVED AND COMPUTED COLOUR-DIFFERENCES.

PF/4 and PF/3. STRESS and WSTRESS. Observer variability and uncertainty.

RESULTS FROM SOME SPECIFIC DATASETS.
COM-weighted and individual datasets employed for CIEDE2000. Others.

RECOMMENDATIONS: FUTURE WORK to include further examination of DIN99, CAM02, OSA – GP – Euclidean, IPT.

**TC1-57 Standards in Colorimetry: Alan Robertson CA**

This TC was established in 2000 and since then the following standards have been published:


Since the work of the TC is now completed with the publication of Part 6, the TC was closed at this meeting.

**TC1-61 Categorical Colour Identification: Taiichiro Ishida JP**

This TC met July 5 2013 to discuss the third draft of the TR. Suggestions from the previous meeting in Taipei were that the report should include:

1. Colour categorization data obtained by Sturges and Whitfield (1995) in the final data section
2. Final data mapped on to CIELAB colour space
3. Summary and recommendation section.

Thus the contents of the TR would be as follows (with the new sections marked in yellow)

1 INTRODUCTION
   1.1 Colour categorization
   1.2 Objective

2 COLOUR CATEGORIZATION AT PHOTOPIC AND MESOPIC ILLUMINANCES
   2.1 Psychological studies on categorical colour identification
   2.2 Categorical colour identification study at Kyoto University
      2.2.1 Background of the study
      2.2.2 Methods
      2.2.3 Results
   2.3 Data comparison

3 COLOUR CATEGORIZATION MAP
   3.1 Munsell Colour Space (add Sturges and Whitfield data)
   3.2 CIELAB colour Space (add Sturges and Whitfield data)
   3.3 CIECAM02 Colour Space (add Sturges and Whitfield data)

4 SUMMARY and RECOMMENDATION

REFERENCE

APPENDIX
   1. Table of colour categorization data
   2. Table of colour specification

**Discussion of the Sturges and Whitfield data**

A consensus colour is when all subjects named that sample consistently with the same colour term. There were 102 consensus colours named using the 11 basic colour terms.
Data plot

Ishida (2002)+
- test color
- most frequently answered color term
- ≥ 70% agreements
- ≥ 90% agreements

Sturges and Whitfield (1995)
- 100% agreements

Sturges and Whitfield data added on Munsell Color Space
Colorimetry of Munsell Colour sample under D65

JIS : Japanese Industrial Standards
Z 8721-1993

附属表付表 1 三属性による表色系の基準（有彩色）

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AIST offers a web site with the values: [http://riodb.ibase.aist.go.jp/ssrdoc/soba_e.html](http://riodb.ibase.aist.go.jp/ssrdoc/soba_e.html)
### CIECAM02 input data

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<td>Yw × 0.2</td>
<td>Yw × 0.2</td>
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<tr>
<td>relative luminance of the surround</td>
<td>average</td>
<td>average</td>
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<td>C</td>
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<td>relative luminance of the background</td>
<td>20% (N5)</td>
<td>40.7% (N7)</td>
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### Color Identification data on CIECAM02 Color Space

![Color Identification data on CIECAM02 Color Space](image)
Next steps for the TC
1. to complete the 3rd draft report ... by the end of July 2013
2. to circulate the 3rd draft to the TC members
3. if acceptable, proceed to the CIE publication process

TC1-63 Validity of the Range of CIEDE2000: Klaus Richter DE
While there was no progress in this TC over the last year, a first draft is intended to be completed by the end of 2013.

TC1-64 Terminology for Vision, Colour and Appearance: Sharon McFadden CA
This TC has been collecting terms that were suggested to be added to the ILV. Progress that has been made in the past year includes:
1. During the past year, two drafts of a Technical Report were prepared and reviewed by members.
2. The drafts contained the terms and definitions that had been accepted by TC members.
3. Although members supported the form of the report, there was continuing concern about a few of the terms. These concerns will be addressed in the third draft.
4. Once members have approved this report, it will be submitted to the Division 1 Editor.
5. At the same time, Division 2 will be asked to review and comment on a subset of the terms.

Some of the terms and definitions still under discussion require input from experts in vision. If Division members are willing to provide input in this area, please contact the Chair. The vision terms include:
1. Colour vision: The capacity of an organism or machine to distinguish objects based on wavelengths (or frequencies) of the light they reflect, emit or transmit.
2. Contrast
   i. in the perceptual sense: assessment of the difference in appearance of two or more parts of a field seen simultaneously or successively (hence: brightness contrast, lightness contrast,
colour contrast, simultaneous contrast, successive contrast, etc.)

ii. in the physical sense: quantity intended to correlate with perceived contrast

3. Contrast sensitivity

i. qualitatively: the ability to perceive differences between an object and its background or between two or more objects

ii. quantitatively: the reciprocal of any of a number of measures of sensitivity to luminance contrast measured across a range of spatial frequencies.

4. Vision (suggestions to date)

i. Sensation and perception to recognize brightness, colour, shape, movement, etc. of the external world as a result of radiation entering the eye.

ii. Sense which perceives the form, colour, size, movement, and distance of objects.

iii. Perception of the environment through the visual system

iv. Ocular perception

v. Visual function – basic capabilities of the visual system including light and dark adaptation, colour vision, spatial and temporal resolution, and stereopsis

vi. Visual properties – parameters of an object that have direct, measurable visual correlates

The TC continues to monitor new Division 1 reports for additional terms that should be added to the ILV.

TC1-68 Effect of Stimulus Size on Colour Appearance: Peter Bodrogi HU

The TC has agreed upon the text of the Technical Report of CIE TC 1-68 and the document has been edited by the Division Editor, Phil Green. Now the minor editorial changes must be incorporated, and then the TR will be sent to the CB for ballot.

TC1-69 Colour Rendition of White Light Sources: Wendy Davis US

The TR from this TC is in the writing stage. The report will summarize the main work that has occurred but will issue no recommendations. The two new TCs will take up the work where this TC has left off. Once the report is completed the plan is to close the TC.

TC1-70 Metameric Samples for Indoor Daylight Evaluation: Balázs Kranicz HU

No report.

TC1-71 Tristimulus Integration: Changjun Li CN

Various methods of tristimulus integration have been selected and compared in the past year. These include the following:

1. Direct Selection,
2. CIE-R method (interpolating measured reflectance into 1nm data and then use the 1nm summation formula),
3. ASTM Table 5,
4. ASTM Table 6,
5. Optimum Method (Li-Luo-Rigg),
6. Least Square Method (Li-Wang-Luo),
7. Zero-Order method (based on Oleari’s work), and
8. Second-Order method (based on Oleari’s work).

1096 Pantone reflectance values over the range of 360-780nm at 1nm intervals were used. Six illuminants were used: D65, A, D50, F2, F7 and F11. The test procedure was: a) Use 1 nm Refs to get
standard XYZS values; b) get the simulated measured RefM using 1nm data; c) use RefM to compute test XYZT values using different methods; d) Compute the colour difference CD between XYZS and XYZT. The smaller the value of CD the better the corresponding method.

Median values of CIELAB colour difference for Illuminants F11/64 and D65/64.

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<th>10nm</th>
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Median values of CIELAB colour difference at various integration intervals for D65/64.

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<td>0.0079</td>
<td>0.0142</td>
<td>0.1626</td>
</tr>
<tr>
<td>LLR</td>
<td>0.0045</td>
<td>0.0045</td>
<td>0.0045</td>
<td>0.0045</td>
<td>0.0044</td>
<td>0.0042</td>
<td>0.0036</td>
<td>0.0083</td>
</tr>
<tr>
<td>LWL</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0005</td>
<td>0.0017</td>
<td>0.0108</td>
</tr>
</tbody>
</table>

Median values of CIELAB colour difference at various integration intervals for F11/64.

<table>
<thead>
<tr>
<th>F11/64</th>
<th>2nm</th>
<th>3nm</th>
<th>4nm</th>
<th>5nm</th>
<th>6nm</th>
<th>7nm</th>
<th>10nm</th>
<th>20nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_s$</td>
<td>0.2556</td>
<td>0.4481</td>
<td>0.2630</td>
<td>0.0530</td>
<td>0.1857</td>
<td>0.4983</td>
<td>10.1768</td>
<td>22.7151</td>
</tr>
<tr>
<td>$D_{ss}$</td>
<td>0.2522</td>
<td>0.4572</td>
<td>0.2387</td>
<td>0.0066</td>
<td>0.1244</td>
<td>0.4818</td>
<td>10.0927</td>
<td>22.5813</td>
</tr>
<tr>
<td>CIE-R</td>
<td>0.0070</td>
<td>0.0187</td>
<td>0.0348</td>
<td>0.0556</td>
<td>0.0814</td>
<td>0.1101</td>
<td>0.2238</td>
<td>1.2043</td>
</tr>
<tr>
<td>CIE-Rss</td>
<td>0.0023</td>
<td>0.0024</td>
<td>0.0027</td>
<td>0.0044</td>
<td>0.0075</td>
<td>0.0165</td>
<td>0.0682</td>
<td>0.4292</td>
</tr>
<tr>
<td>Ct5ss</td>
<td>0.0023</td>
<td>0.0024</td>
<td>0.0027</td>
<td>0.0044</td>
<td>0.0075</td>
<td>0.0165</td>
<td>0.0682</td>
<td>0.4292</td>
</tr>
<tr>
<td>O0</td>
<td>0.0916</td>
<td>0.1427</td>
<td>0.0468</td>
<td>0.0566</td>
<td>0.0642</td>
<td>0.2131</td>
<td>1.8205</td>
<td>3.9149</td>
</tr>
<tr>
<td>O2</td>
<td>0.0467</td>
<td>0.0555</td>
<td>0.0282</td>
<td>0.0080</td>
<td>0.0459</td>
<td>0.0589</td>
<td>0.8764</td>
<td>1.9568</td>
</tr>
<tr>
<td>O2ss</td>
<td>0.0945</td>
<td>0.1299</td>
<td>0.0607</td>
<td>0.0027</td>
<td>0.0595</td>
<td>0.1337</td>
<td>1.9306</td>
<td>3.7979</td>
</tr>
<tr>
<td>LLR</td>
<td>0.0047</td>
<td>0.0047</td>
<td>0.0046</td>
<td>0.0047</td>
<td>0.0038</td>
<td>0.0042</td>
<td>0.0178</td>
<td>0.1992</td>
</tr>
<tr>
<td>LWL</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0016</td>
<td>0.0025</td>
<td>0.0157</td>
<td>0.2003</td>
</tr>
</tbody>
</table>
Preliminary results have shown that the LWL method is the best when the interval length is not greater than 10nm (shown in red in the above tables). When the interval length is 20nm, the LLR method is the best and LWL is competitive with the LLR method and is the second best.

It is hoped that the TC work can be completed by the end of 2014. It would be nice to recommend a single method (LWL) for computing the tristimulus values no matter what the measured interval length. It is also hoped that the results are valuable to CIETC1-85 for the revision of CIE Publication 15:2004 Colorimetry.

**TC1-73: Real Colour Gamut: Changjun Li CN**

Firstly, reflectance data were accumulated [1]. This set of data has 85,879 reflectance functions representing natural and man-made object colours. The available 3D gamuts were compared, which shows the available gamuts do not represent real data well and a new gamut in terms of reflectance functions is necessary. Based on the accumulated data, a new gamut [2] named as the object colour gamut (OCG) was developed. This set of data has $36 \times 19 = 684$ points with hue, $h$, sampling from 0° to 350° at 10° intervals and $L^*$ sampling from 5 to 95 at 5 $L^*$ unit intervals. In addition, there are two common extreme points with $L^* = 97$, $C^* = 0$, and $L^* = 2.5$, $C^* = 0$. The OCG is not only defined in terms of CIELAB coordinates $L^*$, $C^*$, $h$ under D50/2°, but also in terms of reflectance functions [2].

Here the reflectance functions for the Spectral Gamut at 12 hue planes are shown below:
The newly developed OCG [2] will be further evaluated. It is hoped that the OCG will provide the starting point for a CIE recommendation, once sufficient testing has been completed and perhaps further refinements are completed. Finally it hoped the TC work will be completed by the end of next year, 2014.


**TC1-74 Methods for Re-defining CIE D Illuminants: Janos Schanda HU**

The Division and BA ballot have been conducted with all comments and questions answered. The TR has been published as CIE Publication 204:2013: Methods for Re-defining CIE D Illuminants. Thus the TC has completed its work and was closed at this meeting.

**TC1-75 A Comprehensive Model of Colour Appearance: M. Ronnier Luo GB**

The 2010 work plan for this TC proposed that the TR be completed by June 2012. It turned out not to be so simple. Thus it is that the Forward Model was complete by July 2013. The problems that remain are:

1. The Size Effect for the Forward Model – there is a discrepancy between the CIECAM02 (already 2° observer) and the Xiao et al. model (which has its own 2° observer);
2. Unrelated colours for the forward model – the system is now only dealing with 0.5° and 10° observers;
3. For the Inverse Model, Brightness QUN, Colourfulness, MUN and Hue, HUN attributes are insufficient, the Y tristimulus of the sample, L, also needs to be known.

The problems solved are:
So the plan is to complete the forward model in July 2013. To submit the paper and to circulate the first version of the Technical Report to TC members in September 2013.
TC1-76 Unique Hue Data: Sophie Wuerger GB

There have been no changes since last year’s report. However, the next step is that the chair, Sophie Wuerger, is meeting with Renzo Shamey in July at ICVS in Winchester, GB. Hopefully there will be time to discuss if he can provide data for surface colours. She has provided data for self-luminous stimuli.

TC1-77 Improvement of the CIE Whiteness and Tint Equations: Robert Hirschler HU

This technical committee met July 5 2013 in Leeds. The following on-going research was reviewed at the meeting:

1. David Chen (PhD student) and Ronnier Luo (supervisor) (University of Leeds): Colour Measurement of Sample Containing Fluorescent Whitening Agent (PhD thesis submitted to the University of Leeds)
2. Dan Fleming et al. (Western Michigan University): research focused on the visual-numerical correlation of whiteness formulas and on the development and verification of a new whiteness formula. One paper published, two more submitted for publication.
5. Katayama et al.: Comparison of various whiteness formulae based on results of whiteness evaluation experiments (AIC 2012)
7. Danny Rich (SunChemical ): Research in preparation on the performance of whiteness formulae under D50 illumination
8. Renzo Shamey at NCSU
   a) Lin, Shamey et al. (NCSU): Factors Affecting the Whiteness of Optically Brightened Material (JOSA 2012)
   b) Assessment of Whiteness of a Series of Wool and Cotton Fluorescent Brightened Material (to be published)
   c) Ongoing research on the assessments of a range of whites in terms of P/F ratings for about 90 samples.

TC1-81 Validity of Formulae for Predicting Small Colour Differences: Klaus Richter DE

This TC met July 5 at Leeds. According to the result of the thesis of Kittelmann (2009) and of CIE TC1-57 (Melgosa) both CIELAB and CIEDE2000 fail to describe small colour differences. For example for small colour differences with $\Delta E^*_{ab}<2$ the yellow-blue weighting constant had to be reduced for all formulae by about a factor three compared to red-green. According to the optimized weighting constants of Kittelmann, see page 115, the threshold formula LABJNDS 1985 is better compared to six other formulas including CIELAB. The formula LABJNDS uses the chromaticity coordinates $(a, b)$ in relative luminance units. The chromaticity coordinates $(a, b)$ are similar to the cone excitation coordinates $(l, s)$ of CIE 171-1.

It is therefore appropriate to study the coordinates $(a, b)$ and the corresponding colour space YABCh (in addition to LabCh* of CIELAB) further for threshold applications. Fig. 1 to 4 show the basis and
some properties of these coordinates for applications including image technology.

Colours we perceive are usually dependent on the reflection of light on surfaces (Fig. 1, top left and right) and the opponent evaluation of the human observer (Fig. 1, bottom left and right). In an ideal case the reflections of surface colours lead to a rectangular shape. This creates optimal colours of different bandwidth (Fig. 1, top left and right).

There are many pairs of optimal colours which mix to white. Fig. 1 (top middle) shows special optimal colours with complementary wavelength limits $\lambda_1$ and $\lambda_2$ which are on a line in any chromaticity diagram through the achromatic point. They are called Ostwald colours, and create a colour half, and have the largest chromatic value among all (ideal) surface colours, see $C_{AB}$ in Fig 2. Many of these colours have a bandwidth of 100nm, for example $\lambda_1=475$ nm and $\lambda_2=575$ nm. The elementary colours yellow and blue with the dominant wavelength $\lambda_d=570$ nm and $\lambda_d=470$ nm are created by dividing the spectrum at $\lambda=520$ nm in two parts.

Visually the spectrum is divided by colour vision in the parts blue and yellow and in addition the yellow part is divided in the parts green and red. Therefore we have the four elementary colours red, yellow, green, and blue. In image technology three basic colours are sufficient as red and green mix to yellow.
Fig. 2 shows a table for the calculation of the chromaticity \((a, b)\) and the chromatic values \(A, B, C, AB\) and \(h_{AB}\). The Ostwald colours are located approximately on a triangle in the CIE \((x, y)\) chromaticity diagram, and on a hexagon in the \((a, b)\) chromaticity diagram. All the Ostwald colours are located approximately on a circle (with the chromatic value \(C_{AB}=35+/-3\) for CIE illuminant D50 and \(C_{AB}=35+/-5\) for CIE illuminant D65), see Fig. 3 top left. For all the Ostwald colours the CIELAB chroma \(C^{*}_{ab}\) differs

<table>
<thead>
<tr>
<th>Colour Value Metric (Colour Data: Linear Relation to CIE 1931 Data)</th>
<th>Linear Colour Terms</th>
<th>Name and Relationship to CIE Tristimulus or Chromaticity Values</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminous Value (Y = y(X + Y + Z))</td>
<td>(Y = y(X + Y + Z))</td>
<td>(Y = y(X + Y + Z))</td>
<td>Notes</td>
</tr>
<tr>
<td>Chromatic Value (A = [X/Y - X_0/Y_0] )</td>
<td>(A = [X/Y - X_0/Y_0] )</td>
<td>(A = [X/Y - X_0/Y_0] )</td>
<td>Notes</td>
</tr>
<tr>
<td>(B = -0.4(Z/Y - Z_0/Y_0) )</td>
<td>(B = -0.4(Z/Y - Z_0/Y_0) )</td>
<td>(B = -0.4(Z/Y - Z_0/Y_0) )</td>
<td>Notes</td>
</tr>
<tr>
<td>(C_{AB} = [a_a - a_b] + [b_a - b_b]^{1/3} )</td>
<td>(C_{AB} = [a_a - a_b] + [b_a - b_b]^{1/3} )</td>
<td>(C_{AB} = [a_a - a_b] + [b_a - b_b]^{1/3} )</td>
<td>Notes</td>
</tr>
</tbody>
</table>

**Fig. 2: Calculation of chromatic values; Ostwald colours in chromaticity diagrams \((x, y)\) and \((a, b)\).**

**Fig. 3: Chromatic value \(C_{AB}\); CIELAB chroma \(C^{*}_{ab}\); Hue diagram \(C_{AB}\); Y; Black \(n\) and threshold \(t\).**
for example by a factor 2 for blue and yellow. CIELAB is based on an empirical optimization and equal 
\( C_{AB} \) seems more appropriate. The chromatic value \( C_{AB} \) may be the basis for an alternate description 
for the human chroma perception. This is supported by experimental results of Holtsmark and 
Valberg (1971). According to these results the wavelength discrimination of the Ostwald and other 
complementary optimal colours is constant. The property of equal coordinates \( C_{AB} \) for these colours is 
a necessary basis to describe these results, and the CIELAB chroma \( C^{*}_{ab} \) fails.

Fig. 3 (bottom left) shows colour triangles with the hues \( Y_m \) and \( B_m \) of equal chromatic value \( C_{AB} \). 
Further studies show that the chromaticity difference \( c_{AB} \) between the colour and the achromatic 
point differs for the colours \( Y_m \) and \( B_m \) by a factor 4 (Fig. 3 bottom). The luminance factor changes in 
the opposite direction. Therefore the chromatic value \( C_{AB} = c_{ab} Y \) is equal for \( Y_m \) and \( B_m \) and in addition 
approximately constant for all other hues.

Colours of equal grey value \( n=\text{constant} \) are on red lines according to Fig. 3 (left bottom). Colours of 
the equal grey value \( n=0 \) are located on the lines between \( Y_w=100 \) and \( Y_m \) or \( B_m \). CIE R1-57 Border 
Between Blackish and Luminous Colours is expected to define the CIE tristimulus values for any hue. 
The model here gives one solution. In the Natural Color System (NCS) this border has been defined 
experimentally and the CIE tristimulus values are available. Fig. 3 (right bottom) shows by green lines 
the visual discrimination in the luminance direction. For threshold colour differences (\( \Delta L^*<1 \)) the 
Weber-Fechner law is assumed to be appropriate. Therefore the ratio \( Y/\Delta Y \) is assumed to be constant 
along the luminance direction for any colour. For example the ratio \( Y/\Delta Y \) is approximately four times 
less for blue \( B_m \) compared to \( Y_m \). The sRGB colour space defined in IEC 61966-2-1 uses a hue specific 
relative luminance \( l_p=Y/ Y_B \). Then for example \( l_p/\Delta l_B \) is equal for thresholds at blue \( B_m \). Yellow \( Y_m \) and 
White \( W \) of Fig. 3 (bottom left), and in addition on the red lines with the grey value \( n=0 \) between \( W \) 
and \( B_m \), and \( W \) and \( Y_m \). Fig. 3 (bottom right) use the Weber-Fechner ratio \( Y/\Delta Y \), and calculates values 
which are by a factor 4 smaller for blue \( B_m \) compared to the results of the sRGB colour space.

The scaling property of SRGB is in addition in agreement with experimental results produced by Hard 
(1985) for the definition of the NCS color system (1985). According to Hard the discriminability is 
equal for the visual blackness \( n^*=0 \). In addition according to Hard the discriminability \( l_p/\Delta l_B \) decreases 
for relative luminances larger than one and has a maximum for \( n^*<0 \).

Fig. 4 (top left and right) shows physiological \( l \)-signals (\( l=\text{Increment} \)) for colours of increasing relative 
luminance \( L \), and of different chromaticity. Different chromaticity between \( x_p=0 \) and 1 (\( p=\text{purity} \)) 
produce a shift of the \( l \)-signals towards the left, compared to the achromatic signals (black and 
white). Yellow, red, green, and blue \( l \)-signals are shifted towards the left. In addition for blue of 
increasing purity there is an increasing shift towards the left. All response curves have the same 
S-shape property. Therefore for example the slope is largest and equal for a series of blue colours 
with the luminance factor between \( Y=90 \) (for \( x_p=0 \) of white) and \( Y=9 \) (for \( x_p=1 \) of blue with maximum 
chromatic value \( C_{AB} \)).

Fig. 4 (bottom left and right) shows that the calculated luminance discriminability \( L/\Delta L \) has the 
maximum at the luminances between \( Y=90 \) and \( Y=9 \) for the blue series and similar for the other 
colours depending on their hue specific purity.

Summary: 
The coordinates \( Y_{AB} C_{AB} h_{AB} \) of the opponent colour space and the vision model with physiological 
\( l \)-signals of relative luminance \( L \), and of different chromaticity \( x_p \) create new possibilities to describe 
The first full meeting was held in Paris April 17, 2013. The following are the agreed main parts of the Colorimetry document and leading authors:

1. CIE Observers: Jan Henrik Wold (CIE standards and TC 1-36 XYZ observers)
2. CIE illuminants and sources: J Schanda (include indoor daylight and smoothed illuminants)
3. Information on simulators: R Hirschler
4. Reflectance standards: D. Rich (include available information from TC 2-70)
5. Geometric conditions for colorimetry: D. Rich
6. Calculation of tristimulus values: E. Carter, Dr. Li, Y Ohno
7. Uniform color spaces and colour difference formulas: M Melgosa
8. Color appearance model: R Luo
9. Dominant wavelength, purities, CCT: Y Ohno, M Rea
10. Whiteness: R. Hirschler

The second full meeting was held in Leeds, July 5, 2013. Progress on each section was discussed.

**TC1-86 Models of Colour Emotion and Harmony: Li-Chen Ou TW**

The meeting of this TC scheduled for July 5, 2013 was cancelled. The following review of work so far was sent by the chair. Psychophysical data has been collected (using the following key - a: single-colour chips, b: colour-pair chips, c: 2D/3D images, d: typeface colours) on colour emotion includes: British (a, b) Chinese (a, b), Taiwanese (a, b, c, d), Spanish (a, b), Iranian (a, b), Argentinean (a, b), French (b), German (b), and Swedish (b). Data from semantic scales for colour emotions using colour chips (a, b) for Warm/cool, Heavy/light, Modern/classical, Clean/dirty, Active/passive, Hard/soft, Tense/relaxed, Fresh/stale, Feminine/masculine, and Like/dislike. Semantic scales for colour emotion using 2D/3D images (c) include: Active/passive, Heavy/light, New/old, Feminine/masculine, etc.

Existing psychophysical models include:

1. Sato et al.

\[ WC = -0.5 + 0.02(C_{ab})^{1.07} \cos(h_{ab} - 50^\circ) \]

\[ HL = -2.1 + 0.05(100 - L') \]

\[ AP = -1.1 + 0.03[(C_{ab}^*)^2 + (L' - 50)^2]^{1/2} \]

2. Ou et al. 2004

For the models applicable to the first half of hue angles, that is, \(0^\circ \leq h < 180^\circ\), we obtain the following:

\[ \text{CEI}_{0^\circ \leq h < 180^\circ} = x_1L^* + y_1(C^*)^a + z_1/h + c_1 \]

For the models applicable to the second half of hue angles, that is, \(180^\circ \leq h < 360^\circ\), we obtain the following:

\[ \text{CEI}_{180^\circ \leq h < 360^\circ} = x_2L^* + y_2(C^*)^b + z_2(360^\circ - h) + c_2 \]

For the models applicable to all hue-angles, we obtain the following:

\[ \text{CEI} = x_3L^* + y_3(C^*)^d + z_3h + c_3 \]
Additivity of Colour emotion

Data collected for colour harmony using the key of (a): colour-pair chips, and (b): 2D/3D images includes: Chinese (a), Taiwanese (a, b), Spanish (a), Iranian (a), Argentinean (a), and Thai (a). Existing psychophysical models for colour harmony are:

1. (Ou & Luo 2006)

\[ CH = H_C + H_L + H_H \]

where

\[ H_C = 0.04 + 0.53 \tanh(0.8 - 0.045 \Delta C) \]

\[ \Delta C = [(\Delta H_{ab})^2 + (\Delta C_{ab} / 1.46)^2]^{1/2} \]

\[ H_L = H_{L_{sum}} + H_{\Delta L} \]

\[ H_{L_{sum}} = 0.28 + 0.54 \tanh(-3.88 + 0.029 L_{sum}) \text{ in which } L_{sum} = L^*_1 + L^*_2 \]

\[ H_{\Delta L} = 0.14 + 0.15 \tanh(-2 + 0.2 \Delta L) \text{ in which } \Delta L = |L^*_1 - L^*_2| \]

\[ H_H = H_{SY1} + H_{SY2} \]

\[ H_{SY} = E_C(H_S + E_I) \]

\[ E_C = 0.5 + 0.5 \tanh(-2 + 0.5 C_{ab}) \]

\[ H_S = -0.08 - 0.14 \sin(h_{ab} + 50^\circ) - 0.07 \sin(2h_{ab} + 90^\circ) \]

\[ E_I = \left[ (0.22L^* - 12.8) / 10 \right] \exp \left( (90^\circ - h_{ab}) / 10 - \exp \left( (90^\circ - h_{ab}) / 10 \right) \right] \]
2. (Szabó et al. 2009)

\[ CHF_{2M} = 0.283 \cdot (3.275 \ CHF_{2M,J_{diff}} - 0.643 \ CHF_{2M,J_{sum}} + 2.749 \ CHF_{2M,C_{diff}} + 4.773 \ CHF_{2M,HP}) - 5.305 \]

where:

\[ CHF_{2M,HP} = 0.361 \sin(1.511h) + 2.512 \]

\[ CHF_{2M,J_{diff}} = 2.33 \cdot 10^{-5} |\Delta J|^3 - 0.004 |\Delta J|^2 + 0.211 |\Delta J| + 0.246 \]

\[ CHF_{2M,C_{diff}} = 3.87 - 0.066 |\Delta C| \]

\[ CHF_{2M,J_{sum}} = 0.0268 J_{sum} - 0.656 \]
\[ CHF_{2D} = 0.47 \]
\[
\left( 0.515 CHF_{2D,\text{Jdiff}} + 0.391 CHF_{2D,\text{Jsum}} + 0.205 CHF_{2D,\text{Cdiff}} + 1.736 CHF_{2D,\text{Csum}} + 2.187 CHF_{2D,\text{bdiff}} + 5.104 CHF_{2D,\text{HP}} \right) \]
\[
-2.283
\]

where:
\[
CHF_{2D,\text{Jdiff}} = 2.5 \cdot 10^{-5} |\Delta J|^3 + 3 \cdot 10^{-3} |\Delta J|^2 - 2.2 \cdot 10^{-2} |\Delta J| + 0.158
\]
\[
CHF_{2D,\text{Jsum}} = 0.027 J_{\text{sum}} - 0.656
\]
\[
CHF_{2D,\text{Cdiff}} = -0.053 |\Delta C| + 1.172
\]
\[
CHF_{2D,\text{Csum}} = -0.051 C_{\text{sum}} + 2.36
\]
\[
CHF_{2D,\text{bdiff}} = 8 \cdot 10^{-5} (h_1 - h_2)^2 - 0.0279 |h_1 - h_2| + 2.3428
\]
\[
CHF_{2D,\text{HP}} = \frac{-0.0127 h_2 + 1.4035}{2}
\]

3. (Ou et al. 2011)

\[
CH = \frac{1}{n + m} \left[ \sum_{j=1}^{n} (CH_{A,j}) + \sum_{j=1}^{m} (CH_{N,j}) \right]
\]

where
\[
CH_{N} = 0.2 + 0.65 \tanh(1.7 - 0.045 \Delta C')
\]
in which
\[
\Delta C' = \left[ (\Delta H_{ab}^*)^2 + (\Delta C_{ab}^*/1.30)^2 \right]^{1/2}
\]
The research questions include:
  1. Universal colour emotion scales,
  2. Colour emotion modelling,
  3. Additivity of colour emotion,
  4. Colour harmony modelling, and
  5. Additivity of colour harmony.

TC1-90 Colour Fidelity Index: Hirohisa Yaguchi JP

The first TC1-90 Meeting was held April 17 2013 in Paris, France. The work plan was 1) to gather reliable experimental data assessing colour fidelity by the time of the Division 1 Meeting in 2014, 2) to analyze the data by proposed colour fidelity indices by the end of 2014, then 3) to write a report to propose the new CIE CRI by the middle of 2015. The currently proposed colour fidelity indices are 1) Hirohisa Yaguchi: Current CIE CRI; 2) Ronnier Luo: nCRI, and 3) Lorne Whitehead: Supplement the general discussion of the CRI2012.

Evaluation experiments, which have been currently carried out are:
  • Lorne Whitehead: Summary of the recent work in making real printed samples based on the HL17 mathematical sample set.
  • Ronnier Luo: A recent experimental result on colour fidelity.
  • Janos Schanda: A recent experimental result.
  • Yoko Mizokami: Evaluation of uniform colour spaces for calculation of colour difference.

The topics of discussion that followed were 1) Reference light sources, 2) Reference colour samples, 3) A proposal by K. Richter to use the same test charts for colour rendering for both lighting and image technology, 4) Colour spaces for calculation of colour difference, and 5) Formula or class of colour fidelity index.

The second meeting of the TC was held July 5 2013 in Leeds. It included the following presentations:
  • Proposed CFI and related visual experiments (15min) by R. Luo (15min)
  • Calculation of nCRI with various light sources (10min) by A. Tsukitani (5min) and Y. Mizokami (5min)
- Visual experiment of CFI (15min) by J. Schanda (5min), T. Fuchida (5min), O. da Pos (5min)
- Test color samples (5min)
- H. Yaguchi (Kobayashi & Komatsubara) (5min)

The discussions following covered the Visual experiments
- How? - Prepare methods, test color samples, test light sources
- Who? - About 8 groups including non-member
- When? - Till the next Division 1 meeting at NIST, June 2014
- What? - Test color samples

It ended with a plan to continue the discussion using the TC1-90 mailing list.

**TC1-91 New Methods for Evaluating the Colour Quality of White-Light Sources: Yandan Lin CN**

The activities of this TC in its first year included a call for members. Thirteen members and 3 observers had signed up by May 19 2013. The TC chair finished Colltool Webex training and the TC1-91 room on CIE Colltool was activated on May 7 2013. The TC held its first meeting in Paris on April 18 2013. The second meeting was on July 5 2013 at the University of Leeds.

Altogether 24 people participated in the first TC meeting, including 8 members, 1 observer and 15 guests. The current colour quality metrics that were reviewed, included Peter Bodrogi: Visual Assessment of Light Source Color Quality, Kevin Smet: MCRI, Ayako Tsukitani: FCI, and Yoshi Ohno: CQS (reviewed by Lin). Other discussions included Peter Karp’s suggestion emailed on April 5 2013; PS presented by Ayako Tsukitani, a review by Minchen Wei, and a discussion of the data and format that should be used when submitting metrics for consideration.

The TC work plan proposes gathering reliable experimental data assessing colour quality by June 30 2013. Then analysis of the data from proposed methods should be completed by the end of 2013. In 2014 some parallel experiments for comparison of the indices will be carried out. Then a report to propose the methods for industrial use will be written in 2015.

**TC1-92 Skin Colour Database: Kaida Xiao CN**

This TC was formed by email ballot earlier this year, 2013. The Terms of Reference for this TC are:

1. To investigate the uncertainty in skin colour measurement and to recommend protocols for good measurement practice, and
2. To tabulate skin colour measurements that accord with these protocols covering different ethnicity, gender, age and body location.

The TC held its first meeting on July 5 2013 in Leeds. The plan is to target skin colour spectral reflectance data. The methods for measurement will include both conventional skin colour measurement (using spectrophotometers and spectroradiometers) and skin imaging with spectral estimation (using RGB cameras, multi-spectral cameras, hyper-spectral cameras). The work plan time table is to investigate uncertainty of skin colour measurements (1-12 months), to recommend the protocol for skin colour measurements (13-18 months), to combine the existing skin colour database (19-36 months), to conduct skin colour measurement (19-36 months), and development of skin colour database (37-42). Finally then write the TC report (42-48 months).

**R1-42 Extensions of CIECAM02: Changjun Li CN**

TC8-11 had a meeting on Thursday, Nov 15 2012 during CIC 2012. In the meeting, Changjun Li, the Chair of the TC, gave a presentation to summarise what has been achieved since TC8-11 was formed.
Mike Brill also gave a presentation on the Oleari’s approach about the chromatic adaptation [Michael H. Brill, Claudio Oleari, Chromatic Adaptation by Illuminant MatrixProducts: An Alternative to Sharpened Von Kries Primaries, Color Res Appl, 14 MAR 2013 | DOI: 10.1002/col.21799].

In the meeting the following actions were planned:
1. Further modify CIECAM02 by removing the HPE matrix and adopting new chromatic-adaptation primaries that are HPE-like (i.e., enclose the spectrum locus) and fit corresponding-colour data.
2. Compare the result in 1 with those using the HPE matrix.
3. Evaluate Oleari’s approach.

It is expected that the next meeting will be held during CIC2013 in November 2013.

R1-50 3D Aspects of Visual Appearance Measurement: David Simmons GB
A report was submitted earlier in the year and this reportership was closed at this meeting.

R1-51 Spectral Data Interpolation: Hugh Fairman US
Reporter Fairman wrote that he expects to complete the report by the end of 2013.

R1-53 Gloss Perception and Measurement: Frédéric Leloup BE
The completed report has been submitted to Color Research and Application as a Review Article and is currently in the review process. When a decision has been made on publication the report can also be submitted to Division 1.

R1-56 Skin Colour Database: Kaida Xiao CN
The report was completed and a new TC (TC 1-52) was established in 2013. Thus this Reportership was closed at this meeting.

R1-58 Liaison with ISO TC130 Graphic Technology: Phil Green GB
This reportership was formed in Taipei last year and the major effort of the reporter during this year was to organize the workshop that was held prior to this year’s Division 1 meeting. The Workshop on Colorimetry in Graphic Arts and Colour Management was held on July 4 2013, with participation from CIE, ISO TC130 and ICC. The topics covered were CIEDE2000 applications in graphic arts (including neutrals), Progress on CIE colour rendering indices, Colour gamuts, and Over-range L* values on fluorescent substrates.

10. LIAISON REPORTS

L1-01 AIC: Paula Alessi
A report is attached to these Minutes.

L1-02 CCPR (Consultative Committee for Photometry and Radiometry): Michael Stock
A report is attached to these Minutes.

A report is attached to these Minutes.
Nothing to report.

L1-05 ISO/TC42: Photography: Jack Holm
No report. Klaus Richter has been appointed as this Liaison in place of Jack Holm.

L1-06 ISO/TC130: Graphic Technology: Danny Rich
A report is attached to these Minutes.

L1-07 ISO/IEC JTC1/SC28 Office Equipment: Klaus Richter
Klaus Richter informed the Division that he has resigned as this liaison as he is no longer active on the ISO TC. Hirohisa Yaguchi has been formally appointed as liaison by ISO.

L1-08 International Association of Lighthouse Authorities: Malcolm Nicholson
A report is attached to these Minutes.

L1-09 ISO/TC159/WG2 Ergonomics: Ken Sagawa
A report is attached to these Minutes.

ISO Steering Committee for Image Technology (SCIT)
Klaus Richter has indicated that he would like to act as a liaison from ISO SCIT to CIE D1: formal appointment is awaited.

ISO TC159/SC4/WG2 Visual Display Requirement
Klaus Richter has indicated that he would like to act as a liaison from ISO TC 159/SC4/WG2: formal appointment is awaited.

11. CHANGES TO CURRENT WORK PROGRAMME

11.1 Changes to Technical Committees

TC1-78 (V) Evaluation of Visual Performance in the Real Lit Environment
Terms of Reference: To investigate and report on current research on visual performance that relates to psycho-physical and physiological measurements in the real lit environment, and to produce a plan for future work.
Chairman: Monica Bilger SE
Action: Change Chairman from Monica Bilger to Ronnier Luo
Rationale: Original chairman resigned in 2012

TC1-83 (V) Visual Aspects of Time-Modulated Lighting Systems
Terms of Reference: 1. To investigate and report on current research on the perception of visual artifacts of temporally modulated lighting systems, including flicker, the stroboscopic effect, ghosting, and digital artifacts.
                            2. Design methodology and gather data on the visibility of temporal artifacts.
                            3. Build a model for the visibility of temporal artifacts and their dependence on environmental, demographical and lighting parameters.
Chairman: Dragan Sekulovski NL
Action: Change the first Term of Reference to:
       1. To investigate and report on current research on the perception of visual artifacts
of temporally modulated lighting systems, including flicker, the stroboscopic effect, and the phantom array effect.

Rationale: Minor changes to Terms of Reference

**TC1-89 (V) Enhancement of Images for Colour Defective Observers**

Terms of Reference: To study, evaluate and recommend image enhancing techniques for colour defective observers and to provide a test procedure for the evaluation of those techniques.

Chairman: Po-Chieh Hung JP

Action: Change the Terms of Reference to:
To study, evaluate and recommend image enhancing techniques for colour defective observers and to provide **test procedures** for the evaluation of those techniques.

Rationale: Minor changes to Terms of Reference

11.2 Changes to Reporters

None.

12. NEW WORK ITEMS IN WORK PROGRAMME

12.1 New Technical Committees

**TC1-93 (V) Calculation of Self-luminous Neutral Scale**

Terms of Reference: To recommend a formula or computational method for an achromatic, neutral or gray scale for self-luminous (i.e. non-reflective) surfaces. (This computation complements CIE Lightness, L*, which serves a similar purpose for reflective surfaces.)

Chairman: Robert Carter US

Work plan: In R1-59 proposal report: see below

Timeline: 4 years

Members: Phil Green GB, Elizabeth Krupinski US, Robert Marcus US, Claudio Oleari IT, Kevin Smet BE

Actions: Approved 23 for: 0 against: 0 abstentions

**TC1-94 (V) Visually Meaningful Spectral Luminous Efficiency Functions**

Terms of Reference: To propose new 2 degree and 10 degree photometric observers based on the work described in CIE Publications 086-1990 and 165:2005, as well as that of CIE TC1-36 Fundamental chromaticity diagram, and study their use in practical photometry.

Chairman: Janos Schanda HU

Work plan: To be provided

Timeline: 4 years

Members: Mark Rea, Andrew Stockman, Ferenc Szabo, Françoise Viénot, Jan Henrik Wold

Actions: Approved 23 for: 0 against: 0 abstentions

12.2 New Reporters

**R1-59 (V) Calculation of Self-luminous Neutral Scale**

Chairman: Robert Carter US

Action: Opened and closed
Rationale: Since the previous meeting in Taipei, Robert Carter wrote a report recommending the establishment of a Technical Committee. In order to put this report into the CIE system, this reportership was approved, the report accepted and then the reportership closed. A new TC is to be established: see TC1-93 above. The report is available on the CIE D1 website.

R1-60 (C) Future Colour-Difference Evaluation
Terms of Reference: To report on publications that relate to colour-difference evaluation and uniform colour spaces.
Reporter: Guihua Cui CN
Rationale: To continue the work of TC1-55
Timeline: Two years
Action: Approved 23 for: 0 against: 0 abstentions

Secretary’s Note
The Division Secretary received notice that the CIE Board approved the change to the Chairman of TC 1-78, and the changes to the terms of reference of TC1-83 and TC1-89 on 29 August 2013.

The CIE Board also approved the title, terms of reference and chairman of the two new technical committees: the TC numbers were allocated as shown above.

Note that new Reporters do not need Board approval to start their work.

13. NEXT MEETING

The Division had received two invitations to hold its 2014 meeting:
i. In the USA, at the invitation of the Inter-Society Color Council (ISCC) and jointly with the ASTM International (ASTM).
ii. In Kuala Lumpur, Malaysia, jointly with Division 2.

After discussion the Division Officers proposed that the next meeting of CIE D1 be in the USA in June 2014.

The Division meeting in 2015 will be at the University of Manchester, Manchester, UK as part of the 28th Session of CIE.

14. ANY OTHER BUSINESS

None.

15. CLOSE OF MEETING

The Director thanked everyone for attending and declared the meeting closed.

Dr Michael R Pointer
Secretary – CIE Division 1
01 September 2013
AGENDA

Saturday 6th July

AGENDA – Division Meeting – Opening Session
09:00 – 09:30
1. Opening and welcome by Director, Ronnier Luo
2. Apologies for absence
3. Membership
4. Attendance
5. Approval of agenda
6. Approval of minutes of Taipei meeting
7. Matters arising from those minutes
8. Report from the Director: Ronnier Luo
9. Report from the Editor: Phil Green
10. Report from the Secretary: Mike Pointer

AGENDA – Division Meeting – Business Session
09:30 – 10:30 Vision Section: Report – Miyoshi Ayama
10:30 – 11:00 Vision Section: New work items
11:00 – 13:00 Colour Section: Report – Ellen Carter

14:00 – 15:00 Colour Section: Report – Ellen Carter – continued
15:00 – 15:30 Colour Section: New work items
15:30 – 16:00 Liaison reports
16:00 – 16:30 Any other business: Location of next meeting
16:30 Close of meeting

All times are flexible - there will be a break for coffee/tea during the sessions.

Mike Pointer
Division Secretary
Additional Attachments: Division 1 Liaison Reports

L1-01 International Color Association (AIC)
L1-02 CCPR (Consultative Committee for Photometry and Radiometry)
L1-03 ISO/TC6/WG3 Paper, Board and Pulp – Optical Properties
L1-06 ISO/TC130 Graphic Technology
L1-08 International Association of Lighthouse Authorities
L1-09 ISO/TC159/WG2 Ergonomics for People with Special Requirements, and related WGs

R1-49 Above-threshold Pulsed Lights: Interim Report
The Color Association of Taiwan hosted the AIC 2012 Interim Meeting in Taipei from September 22-25. The venue for the meeting was the Chinese Culture University. The topic of the meeting was “In Color We Live – Color and Environment”. The purpose of the meeting was to explore the colors of human living spheres on a daily basis. The meeting was very successful in that it helped us understand the physiological and psychological effects of man-made and natural environments that contribute to healthier living through the use of color. We also learned how hue, vision, light and color temperature affect human bio-energetic response. The meeting was attended by more than 250 participants from 34 countries around the world. There were about 60 oral presentations with pre-conference lectures and workshops, a poster exhibition, and a color market.

The 12th AIC quadrennial Congress will be hosted by The Colour Group (Great Britain) from July 8-12, 2013. The venue is The Sage Gateshead located on the River Tyne by the city of Newcastle, UK. The Congress theme will be “Bringing Colour to Life”. Papers have been submitted according to the following topics:

- Lighting and colour
- Colour vision
- Colour science
- Colour imaging
- Digital colour
- Colour measurement
- Colour appearance
- Colour communication
- Colour in art and design
- Colour in environmental design
- Sustainable coloration
- Color in conservation
- Colour in nature
- Colour psychology
- Colour education
- Colour in forensics and medicine

The Congress will feature 6 symposia:

1. Lighting: New Technologies and Colour Rendering
2. Colour Harmony: From Perception to Built Environment
3. Colour in Fashion and Textile Design
4. Multispectral Colour Science
5. Colour Vision: Perception and Neuroscience
6. Museum Lighting: Conservation and Appearance

New officers for the Executive Committee will be elected at the General Assembly to be held on July 10, 2013.

During the Congress the coveted AIC Deane B. Judd Award will be presented to Dr. Roy S. Berns from The Munsell Color Science Laboratory at Rochester Institute of Technology. Dr. Berns will give a special talk after receiving the Award.

The AIC 2014 Interim Meeting will be held in Oaxaca, Mexico from October 21-24 2014. It will be hosted by Asociación Mexicana de Investigadores del Color. The theme will be Colors, Culture, and Identity: Past, Present and Future. Please see www.aic2014.org or www.amexinc.org.mx for more details.

The AIC 2015 Midterm Meeting will be held in Tokyo, Japan from May 19-22 2015. It will be hosted by The Color Science Association of Japan. The theme will be Color and Image. Please see www.aic2015.org or office@color-science.jp for more details.

The AIC 2016 Interim Meeting will be held in Santiago, Chile from October 18-22 2016. It will be hosted by The Chilean Color Association. The theme will be Color in Urban Life: Usability in Images,
Objects, and Space.
Please see www.aic2015.org or diffusion@asociaciondelcolour.cl for more details.

The AIC 2017 13th Congress will be held in Jeju, Korea from October 16-20 2017. It will be hosted by The Korea Society of Color Studies. The venue will be the International Convention Center Jeju. Please see www.color.or.kr for more details.

The AIC Annual Report (formerly known as the AIC Newsletter) is available online at www.aic-colour.org. Please visit the website for all the latest news in the international color world.

Respectfully submitted,
Paula J. Alessi
The CCPR meets about every two years at the BIPM in Sèvres, France, bringing together some 30-40 experts from its member NMIs (National Metrology Institutes). The last meeting took place on 23-24 February 2012. The CCPR working groups met during the same week and again on 22 and 23 April 2013. The next meeting of the CCPR is planned for June/July 2014. On 1 January 2013, Dr. Takashi Usuda from the National Metrology Institute of Japan (NMIJ) became the new President of the CCPR, following Dr. Franz Hengstberger. General information on the work of the CCPR can be found on www.bipm.org/en/committees/cc/ccpr.

The CCPR Key Comparison Working Group has set up a schedule for the second round of key comparisons, which are the technical basis for the CIPM Arrangement on Mutual Recognition of National Measurement Standards and of Calibration and Measurement Certificates issued by National Measurement Institutes. The key comparisons demonstrate the technical capabilities of the participating NMIs. The first comparisons to be repeated are for spectral regular transmittance (start in 2011), for luminous intensity and luminous flux (start in 2012) and for spectral responsivity in the visible and infrared regions (start 2013). The results of the completed key comparisons of the first round can be found in the Key Comparison Data Base, held at the BIPM (kcdb.bipm.org/appendixB). They cover the fields of spectral irradiance, spectral responsivity, luminous intensity, luminous flux, spectral diffuse reflectance (to be completed very soon) and spectral regular transmittance.

It is expected that in the near future four of the seven base units of the SI system will be redefined: the kilogram, the ampere, the kelvin and the mole. Each of these units will be based on a fixed numerical value of a fundamental constant: the Planck constant, the elementary charge, the Boltzmann constant and the Avogadro constant. The impact of these changes on the candela will be insignificant. To give guidance on how the units can be realized in practice, a so-called mise en pratique (French for “practical realization”) will be published for each base unit. The candela will not be redefined, but it is planned to change the wording of its definition. An important development in the field of photometry is the introduction of the spectral luminous efficiency functions for mesopic vision. For these reasons, the Strategic Planning Working Group of the CCPR held in 2012 a workshop on the mise en pratique of the candela to which representatives of the CIE had been invited. The workshop had the objective to guide the direction and to coordinate possible joint work between the CIE and the CCPR to prepare a new mise en pratique for the candela. The final decision was that a concise mise en pratique would be written by experts from the CCPR and that an additional more extensive document Principles Governing Photometry should be published by a joint CCPR-CIE task group, which should be chaired by Dr. Ohno (NIST).

Another workshop was organized on 22 April 2013, on SI units for Photometry and Radiometry, again with representation from the CIE. One of the topics was a discussion of the proposal to replace the candela as the photometric SI base unit by the lumen. The CIE Division 2 Director, Dr Peter Blattner presented the outcome of discussion within CIE which resulted in the recommendation that “in the absence of compelling reasons to change from the candela to the lumen as the base SI unit, it is highly recommended to maintain the status quo.” The participants at the workshop agreed with this recommendation. Other topics were the status of the mise en pratique of the candela and of the Principles Governing Photometry. Work on both documents is well advanced and it is planned to have final versions for the CCPR meeting in 2014.
The following recent activities of ISO TC6 WG3 (Optical properties), may be of interest to CIE D1:

- ISO 11476 Paper and board – Determination of CIE whiteness, C/2° (indoor illumination conditions) and ISO 11475 Paper and board – Determination of CIE whiteness, D65/10° (outdoor daylight) – the New Work Item proposals to update Annex A, Section A.2 of both of these Standards to allow for calculations using ASTM E308 for instruments that have bandpass correction and still maintain the non-bandpass correction procedure (Tables 5 and 6, respectively). Whiteness measurement has become of fundamental importance in the description of many commercial papers. This amendment provides the ability to measure the property on a wider range of instruments.

- ISO DIS 2469 Paper, board and pulp – Measurement of diffuse radiance factor (diffuse reflectance factor) – a new DIS version of this Standard was prepared for ballot. The main changes from the previous FDIS stage are: 1) removal of the requirement to reduce the UVB with insertion of a filter (based on a decision made at the 2012 WG3 meeting in Montreal, where round-robin measurement results testing this modified procedure showed no improvement in inter-instrument variability agreement); 2) changes in terminology as a consequence of a two day meeting in March 2013 between executive members of ISO TC6 and the ISO Committee on conformity assessment (CASCO) to discuss changes in ISO 4094 to meet the ISO/IEC Directives on conformity assessment (see below). Notably the transfer standards that are used in this ISO TC6 calibration hierarchy (IR1, IR2, IR3) are now referred to as international (not ISO) reference standards of levels 1, 2 and 3, respectively. Any usage of “ISO standards” was deemed not permissible. However, the use of “ISO brightness” is permissible since it refers to an ISO standard measurement method and not an ISO authorized physical standard.

- ISO 4094: 2005 Paper, board and pulps – International calibration of testing apparatus – Nomination and appointment of standardizing and authorized laboratories is scheduled for normal systematic review in October 2013. As a proactive measure, in response to concerns from CASCO, the members of the ISO TC6 representatives of the authorized laboratories for optical property measurement (Opal-group) prepared a revised version of ISO 4094 with the same structure as ISO/IEC 17025. This revised draft of ISO 4094 was used as a starting point for the meeting with CASCO, where remaining conformity assessment issues were resolved. Notably, this requires the establishment of a scheme committee with strict separation from ISO TC6. This scheme committee is responsible for defining and verifying the set of requirements for a laboratory to be named and to maintain authorized laboratory status.

- The new Ad hoc group on the Measurement and Characterization of Nanocellulose (AHG1), under the chairmanship of Dr. Lyne Cormier of FPInnovations (Canada) has held two Web-Ex meetings. This group has completed a survey of its 11 member countries on the priority needs for Standards for two different forms of nanocellulose (crystalline and fibrils). The members are currently identifying existing standards or methods for the five physical and chemical properties of these materials that were ranked highly; this included colour/brightness.

Respectfully submitted,
Joanne Zwinkels
National Research Council of Canada
ISO TC 130 held its spring meeting at the Venice Hotel, Shenzhen, China 19 May to 24 May 2013.

The spring meeting did not include a plenary session but I have included relevant actions and advances from ISO TC 130 in this report.

The following were topics of discussion carried over from the fall meetings that are still open.

1. ISO TC 130 was still looking for guidance on how to move forward from the older CIE standard CIELAB to adoption of the new standard CIEDE2000. The American National Standards Institute Committee on Graphic Arts Standards and Professor Robert Chung had prepared a report in which a large number of color readings from print runs for press certifications had been sent in to RIT. In that report Professor Chung attempted to use the method developed by Roy Berns for the CIE TC that developed CIEDE2000 in which he compared the cumulative distribution of measured values and the cumulative distribution of visual judgments. The point at which the two distributions crossed would then be considered the point of equivalence and the CIEDE2000 value at the point would be recommended as the tolerance. The methodology seemed to be well accepted but requires the use of a large number of actual print run data. TC 130 will now seek to acquire such a set of measurement data.

2. When characterizing materials that are luminescent it is possible to obtain CIELAB L* values greater than 100. But there is no guidance as to the relevance of these values, since the CIE Publication 15:2004 defines the range of L* as 0 to 100. ISO TC 130 is still waiting for guidance from CIE Division 1 as to the applicability to the power function of Y/Yn for Y values greater than Yn?

3. Standards ISO 12646 and ISO 14861, the standards that documents the processes for calibrating self-luminous displays for simulating the proof of a print job using flat panel displays, have moved forward and should be balloted for release as a draft international standard in late 2013. The publication has stalled due to uncertainty about how to specify tolerances in CIEDE2000 for soft proofing displays. Perhaps CIE Div 1 would care to comment on the applicability of CIEDE2000 and CIELAB L* for use in characterizing the visual color and lightness of self-luminous graphic displays?

4. The use of LED sources that produce some form of “white” light is increasing. ISO TC 130 is still concerned that there is no agreed method on how to assess and rank the quality of LED lamp light, particularly as it impacts both publication and packaging printing. Since graphic reproduction relies on achieving a controlled level of metamerism, uncontrolled sources provide unnecessary business risks. Additionally, as shown in the workshop earlier in this meeting, neutral or gray reproduction is critical to the appearance of a process printed image and the LED lamps impact the metamerism of 3-color overprinted neutrals in a very different manner than more traditional lamps and D50 simulators.

5. A further revision to the draft new standard ISO 15397 was recommended and is being undertaken. This standard addresses, for the first time, the properties of paper substrates from the perspective of the printer. This allows the printer to review and specify optical properties in terms of CIE D50, and the ISO 5 recommended 45:0 instrument geometry.

Dr. Danny Rich represented ISO TC 130 at a workshop held on 4 July 2013 prior to the CIE Division 1 meetings hosted by the School of Design at the University of Leeds in Leeds, United Kingdom. All of the issues listed above were discussed in the meeting. The presentations on the needs of ISO TC 130 were deemed very helpful by the members of CIE Division 1 in attendance.

Respectfully submitted,
Dr. Danny C. Rich
1 Introduction
IALA is a non profit, non governmental international technical association. Established in 1957, it gathers marine aids to navigation authorities, manufacturers and consultants from all parts of the world and offers them the opportunity to compare their experiences and achievements. IALA’s aim is to harmonize aids to navigation worldwide and to ensure that the movements of vessels are safe, expeditious, cost effective and harmless to the environment.

Taking into account the needs of mariners, developments in technology and the requirements and constraints of aids to navigation authorities, a number of technical committees have been established bringing together experts from around the World.

The work of the committees is aimed at developing common standards through publication of IALA Recommendations and Guidelines.

This work ensures that mariners have aids to navigation which will meet their needs both now and in the future. IALA is therefore contributing to the reduction of marine accidents and to the increasing safety of life and property at sea, while protecting the marine environment.

Visual aids to navigation have been used by mariners for centuries; these include daymarks, such as beacons and buoys, and lights for use at night. Recommendations for visual aids, published by IALA, rely greatly on information from standards and guides published by CIE.

2 CIE TC’s of Interest to IALA
Division 1: Vision and Colour
TC1-84 (NEW TC) Definition of Visual Field for Conspicuity (N. Itoh)

Division 2: Metrology
TC2-28 Methods of characterizing spectrophotometers (T. Goodman)
TC2-70 Standards for the Measurement of Reflectance and Transmittance Properties of Materials (D. Rich)
TC2-49 Photometry of Flashing Light (Y. Ohno)
TC2-65 Photometric Measurements in the Mesopic Range (T. Goodman)
TC2-71 CIE Standard on Test Methods for LED Lamps, Luminaires and Modules (Y. Ohno)
TC2-74 Goniospectroradiometry of Optical Radiation Sources (J. Pan)

Division 4: Lighting and Signalling for Transport
TC4-47 Application of LEDs in Transport Signalling and Lighting (S. Jenkins)
TC4-32 Revision of Publication CIE 39-2:1983: Surface Colours for Visual Signalling

3 Publications
The output from the above mentioned Technical Committees will impact the following IALA Publications:

Recommendations:
E200-1 On Marine Signal Lights – Colours
E200-2 On Marine Signal Lights – Calculation, Definition and Notation of Luminous Range
E200-3 On Marine Signal Lights – Measurement
E200-4 On Marine Signal Lights – Determination and Calculation of Effective Intensity
E-108 For the Surface Colours used as Visual Signals on Aids to Navigation

Guidelines:
1041 On Sector Lights
1048 On LED Technologies and their use in Signal Lights
1073 On Conspicuity of Aid to Navigation Signal Lights at Night
A new publication of interest to CIE is IALA Guideline 1094 On Daymarks for Aids to Navigation is available to download from the IALA website www.iala-aism.org

4 Events
IALA is preparing for its quadrennial conference in A Coruna, Spain in May 2014. The author will be presenting two papers. One on ‘effective intensity’ and one giving an overview on the above mentioned E-200 series. The author will also be presenting results from a field light measurement of the Torres de Hercules Lighthouse, conducted during the conference.

5 Committee Activity
The Aid-to-Navigation Management (ANM) and Engineering, Environment and Preservation (EEP) Committees of IALA are coming to the end of their four year work programmes with work on ‘Sector Lights’ and ‘Illumination of Structures’ Guidelines still to be completed. Any input from CIE members would be welcomed.

6 Other Items of Interest
The GLAs R&RNAV Department has made its “Marine AtoN Light Calculator” available to download on the R&RNAV website. www.gla-rrnav.org

The GLAs R&RNAV Department in collaboration with Leeds University is in the process of repeating the experiment of Toulmin-Smith and Green, originally carried out in 1933, with a view to extending the illuminance range covered.

M. Nicholson  Date: 28/06/13
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L1-09: ISO/TC159/WG2 and related WGs: Ken Sagawa

1. Work items in TC159/WG2 “Ergonomics for people with special requirements”
ISO/TC159/WG2 has only one work item for developing 2nd version of ISO/TR22411:2008 “Ergonomic data and guidelines for the application of ISO/IEC Guide 71 to products and services to address the needs of older persons and persons with disabilities”. The work started in 2009 but had been paused after a while because revision of the ISO/IEV Guide 71 had been taken place meanwhile. Recognizing the revision task almost comes to the final stage of the work now, the editing task on the TR22411 has been restarted again. The 2nd edition of the TR will contain more relevant ergonomic data including vision and lighting that are useful for designing products, services, and environments for older people and people with disabilities.

2. Other related work items in TC159 “Ergonomics”
TC159/SC5/WG5 “Physical environment for people with special requirements” is discussing a work item related to conspicuous colour combinations for older people, that is ISO/WD 24505 “Ergonomics - Accessible design - Method for creating colour combinations taking account of age-related change of human colour vision”. This work item is now in voting for CD approval which will be closed in June, 2013.

Meanwhile, TC159/SC4/WG10 “Accessible design for consumer products” has also an item related to accessible design in the field of vision but now in the preliminary stage. The title of the work item is “ISO/PWI Ergonomics - Accessible Design - Minimum legible font size for people at any age”. Recently, a new work item concerning indicator lamps was raised in also this working group (SC5/WG5) and being voted for approval with a deadline in August 2013.

3. CIE actions needed
CIE and CIE/Division 1 will have to send their comments to those work items when asked at appropriate times such as voting for CD/DIS/FDIS to contribute scientifically and to share the knowledge on accessible design in the field of vision and lighting.

Ken Sagawa, Liaison officer to TC159/WG2
7th June, 2013
1. Introduction

Flashing lights are widely used at sea for navigation and to mark hazards. Due to the limited response of the human visual system, it has proven necessary to increase the brightness of flashing sources. A century of research has led to various attempts to model the effective luminous intensity of flashing light to provide a fixed-light equivalent, as summarised by Tutt (2010). Several problems remain, however, including the models being valid only at the achromatic threshold of vision. In addition, technology has rapidly advanced during the last century resulting in changes to the spectrum, flash profile and rival lighting.

The aims of this work are to repeat, verify and extend Toulmin-Smith and Green’s [TSG] fundamental work on the relationship between the perceived intensities of steady and flashing light sources.

2. TSG Experiment

The original experiments conducted by Toulmin-Smith and Green (1931a and 1931b) consisted of two phases. The first of these attempted to establish whether there was any difference between observations made with one or two eyes (Figure 1). From the outset it should be noted that there is a degree of ambiguity in their descriptions and also a lack of detailed raw data reported in their results.
The second phase used a clockwork-driven sector disc mechanism to generate a series of light pulses. The observer was able to alternate between flashing and steady light by pressing a key. The intensity of the flashing source was then manipulated by adjusting the position of a variable transmission wedge until a visual match was obtained. A block diagram (Figure 2) illustrates the main elements.

![Figure 2: TSG second experimental phase](image)

According to their results, TSG involved only a very limited number of observers (possibly as few as two or three) and many of their smooth curves which plot apparent intensity mask experimental noise. The mechanical set up as described would certainly lead to variations in timing and there was insufficient data to reach a conclusion over the typical variability of observers and the robustness of the conclusions.

3. Apparatus

3.1 Hardware

Due to the unique nature of this experiment, no off-the-shelf solution was available. With the assistance of Bentham Instruments, bespoke apparatus was designed to reproduce similar conditions to those used by TSG but using updated technology. A cross-sectional view of the resulting ILFD20QH unit is shown in Figure 3. Not shown here is the photopic matched photodiode at the surface of the integrating sphere which was used to measure light output.
The switching characteristics of the electromechanical shutter used to module the flashing light were assessed by Bentham prior to supplying the finished apparatus. A typical 20 ms pulse is shown in Figure 4 which exhibits a rise/fall time of within 2 ms. The shutter itself is capable of operating over sustained frequencies ranging from 10 Hz to dc.

Bentham also estimated the measurement uncertainty as being 2.5% on average during the unit’s spectral calibration.
3.2 Software

A PC linked to the ILFD20QH source via USB ran software provided by Bentham (2013) having the following functionality:-

- **calibration** – to manually set the slit width or aperture, select or measure the light source (flashing or steady) and to re-calibrate the slit
- **flashing profiles** – graphically configure the duration in ms of the on and off times within a cycle for the flashing source
- **experiment profiles** – set the steady light intensity and assign multiple flash profiles which are to be used as stimuli in an experimental session
- **run experiment** – begin, pause or abort the execution of an experimental profile

Once an experiment had begun, each observer was then able to interact via a game controller (see Figure 6) which had buttons for toggling between the steady and flashing sources and also for changing the brightness of the flashing source. The brightness of the steady source was always that specified in the experiment profile. Each new stimulus began with a zero intensity flashing light. It was not possible for observers to adjust this to the same level each time simply by tapping the up button a certain number of times.

![Controller Diagram]

**Figure 6: controller used by observers**

Based on experience from the pilot study, the “next” button was disabled as it proved all too easy to press this by mistake with no easy way of recovering. Instead, the experimenter advanced stimuli via the PC user interface once the observer was satisfied with the match. After a session, the results were stored to a CSV file which included the date, observer name (if recorded), measured illuminances of the steady and flashing sources (in μlux) together with details of the flashing profiles used.
4. Experiment

Due to ambiguities in the description of the original TSG study, a small-scale pilot study was completed to validate the set up. Both experiments were conducted in complete black out conditions with observers seated 2.2 m away from a pinhole aperture, leading to a < 1’ arc visual angle. The pinhole was positioned at roughly the same height as observers’ eyes. The ILFD20QH unit’s two integrated 30W quartz halogen lamps required a ten-minute warm up before beginning and observers typically needed at least 15 minutes to acclimatise to the darkness – longer if coming from a bright environment. A further refinement was added to the software to add a switching delay, preventing instantaneous toggling between steady/flashing lights.

4.1 Pilot Study

Achieving a completely black environment initially proved challenging, in part because the equipment emitted stray light from power indicators, etc. These were concealed, however it soon became apparent that total darkness created significant problems for observers. Without anything else to look at, the visual system rapidly “lost interest” in between flashes, and most people found it difficult to locate and re-focus the eyes during the brief instant that a flash was emitted. To remedy this, a very dim “reference” light was added so that they had something else to fixate on in between viewing the pinhole source. This reference light was constructed by shining a Kingbright L-7113SEC-E 5 mm orange LED light driven at 1.83 V into a 10 cm integrating sphere having a 2 cm aperture which was positioned at the same distance but above and to the right of the pinhole. The final set up is shown in Figure 5. Even with this light, the conditions were close to the limits of vision leading to the potential for considerable visual fatigue. To minimise this, each session was limited to around 45 minutes (excluding acclimatisation).

For this experiment, only one brightness level was used for the steady light: 0.2 μlux. Using a fixed off-time of 1000 ms, the following 19 different on-time flash profiles were used as stimuli (in ms units).

<table>
<thead>
<tr>
<th>50</th>
<th>75</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>175</th>
<th>200</th>
<th>225</th>
<th>250</th>
<th>275</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>325</td>
<td>350</td>
<td>375</td>
<td>400</td>
<td>425</td>
<td>450</td>
<td>475</td>
<td>500</td>
<td>×</td>
</tr>
</tbody>
</table>

The results from this experiment were eventually combined with those of the main experiment, and so will be discussed in the next section. Some adjustments were subsequently made to the range of flash durations in light of the initial findings.
4.2 Main Experiment

Extending the groundwork laid in the previous section, a further four off-time flash durations were added covering intervals both longer and shorter than the pilot. Each of these four phases included the following sixteen flash durations (in ms) which were again compared with the same 0.2 μlux steady reference:

<table>
<thead>
<tr>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>175</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>250</td>
<td>275</td>
<td>300</td>
<td>350</td>
<td>400</td>
<td>450</td>
<td>500</td>
</tr>
</tbody>
</table>

A total of six observers took part in each phase, although not all observers took part in all phases. Each observer was required to make four observations of each set of stimuli, this being done on different occasions. A new visual acuity test was added based on a modified Snellen chart (1862) which was redesigned to be viewed at the same 2.2 m distance as the light sources. Observers attained scores equivalent to the range 20/16 to 20/25 with vision corrected where applicable.
A list of the participants and the phases they took part in is given below. They were a mixture of professional staff from Trinity House and the University of Leeds.

<table>
<thead>
<tr>
<th>Observer</th>
<th>Flash Duration (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>250</td>
</tr>
<tr>
<td>Chris</td>
<td></td>
</tr>
<tr>
<td>David</td>
<td>✓</td>
</tr>
<tr>
<td>Gavin</td>
<td>✓</td>
</tr>
<tr>
<td>Link</td>
<td>✓</td>
</tr>
<tr>
<td>Malcolm</td>
<td>✓</td>
</tr>
<tr>
<td>Neal</td>
<td>✓</td>
</tr>
<tr>
<td>Peter</td>
<td>✓</td>
</tr>
<tr>
<td>Sophie</td>
<td>✓</td>
</tr>
<tr>
<td>Travis</td>
<td></td>
</tr>
</tbody>
</table>

Before their first session, observers were allowed to practice with a few test stimuli to familiarise themselves with both the task and the controls. They were instructed to make the match in the central part of the vision. Although flashing lights are significantly more conspicuous in peripheral vision, early findings from the pilot study showed that this was not a reliable way of judging brightness. Observers were also encouraged to rest their eyes whenever vision became “fogged” with after images. The reference light proved to be very helpful in this regards.

5. Results and Discussion

After some practice, the majority of observers seemed to adopt the strategy of increasing the brightness of the flashing stimulus until it was just visible before comparing it with the steady light and then switching back to fine tune the match. Several cycles of toggling back and forth between steady and flashing stimuli were usually required; however it should be noted that if a match could not be obtained within a few minutes, the task became progressively harder due to visual fatigue.

Two other observers were excluded from the experiments because their results were found to be highly non-repeatable and “noisy”. Performance did not appear to be related to age, experience or visual acuity; although further work would be needed to establish this conclusively. A key finding from this work is the typical variability of observers, which is important in establishing tolerances around the overall trends that were uncovered. The TSG experiments seemed to pay very little attention to this aspect.

† Experiments for the 1500 and 2000 ms phases are still ongoing.
Based on the matching data recorded by the experimental software, the ratios of steady to flashing intensity were calculated. These were plotted against flash duration for each of the phases. To better understand the robustness of the results, standard error bars were included. Since the occasional incorrect result was inevitable due to the highly challenging nature of the task, the median was used when averaging an observer’s results as this statistic is not influenced by outliers.

5.1 Observer Reliability

A comparison was made between individual observer’s results and the mean results from all observers. These are plotted in detail in Appendix A where the size of the error bars signifies the magnitude of individual variation (i.e. precision). For an observer to be accurate, their error bars should encompass the mean overall data (red bars) for a given stimulus.

From these graphs, the following points can be identified:

- qualitatively, the spread of results seems greater than that found by TSG
- the typical standard error for observers was around 0.06 however certain individuals (i.e. Chris and Sophie) exhibit a very much greater variation
- some observers produce either higher matches (e.g. David) or lower matches (e.g. Peter) than average, whilst for others (e.g. Malcolm) this seems to vary according to the interval between flashes
- contrary to expectations, shorter flashes seem to be judged more consistently than brighter ones

To improve overall precision, either more observers would need to be used or alternatively the existing observers could complete more repeat judgements. It is also possible to selectively exclude some observers or specific observer data, however this would need to be justified on the basis of it being anomalous as opposed to representative of the typical human variation for this task.

5.2 Overall Results

Figure 6 summarises the overall results from each of the three phases that have been completed. It can be seen quite clearly that the flash duration time has the biggest impact on apparent intensity, with flashes lasting 250 ms or more being perceived in the same manner as steady sources. This does not seem to be affected significantly by the interval between flashes, although observers found longer off periods much harder to judge. Separate plots for each of the three phases are given in Appendix B in which the spread of individual observer median results can be seen.
6. Conclusions

The findings presented here reveal a definite trend from the observers: for durations of less than 250 ms, flashing stimuli are perceived to be dimmer than steady lights. This means that a flashing light needs to be made progressively more intense as it becomes shorter in duration in order for it to be judged as equivalent in brightness to a steady light. In addition, it has been possible to fully define the experimental procedure and investigate observer variation – both of which go beyond the results of Toulmin-Smith and Green.

Aside from the number of observers used, one possible limitation here is that stimuli were always presented in the same order (i.e. ascending flash length). While this could potentially lead to bias, the intention here was to help reduce the considerable visual fatigue by making the task seem progressively easier. Judging the brightness of such brief and dim sources is at the limits of human vision and not a task that most of us are used to doing. It would therefore be interesting to invite the participation of astronomers as their assessment of the magnitude of stars is probably the closest real-world task.

Within this study, data still needs to be collected for the 1500 and 2000 ms flash duration. Further work should then be considered to look at different intensities for the steady light before moving on to the impact of colour of light. In the longer term, the further complexity could be added by adding different coloured (or even moving) backgrounds together with rival lights. This would closely mimic the real world scene experienced by mariners close to land.
References

- Toulmin-Smith A.K., Green H.N. The Fixed Light Equivalent of Flashing Lights. *RAE Electrical and Ignition Department* 1933; Memo 94.
- Snellen H. *Probabilistchen zur Bestimmung der Sehschärfe*, Utrecht 1862
Appendices

A1. Observer Spread for the 250 ms Phase

Red bars signify the average over all observers, blue bars represent the median observer result and errors bars show the spread.
A2. Observer Spread for the 500 ms Phase

Red bars signify the average over all observers, blue bars represent the median observer result and errors bars show the spread.
A3. Observer Spread for the 1000 ms Phase

Red bars signify the average over all observers, blue bars represent the median observer result and errors bars show the spread.
B1. Overall Results for the 250 ms Phase

250 ms @ 0.2 μlux
B2. Overall Results for the 500 ms Phase

500 ms @ 0.2 μlux
B3. Overall Results for the 1000 ms Phase

1000 ms @ 0.2 μlux

Flash Duration (ms)