NPL
National Physical Laboratory

Developments in CIE mesopic photometry: work of JTC-1 and TC2-65

Teresa Goodman

CCPR WG-SP Meeting

22nd April 2013

National Measurement System

NPL National Physical Laboratory

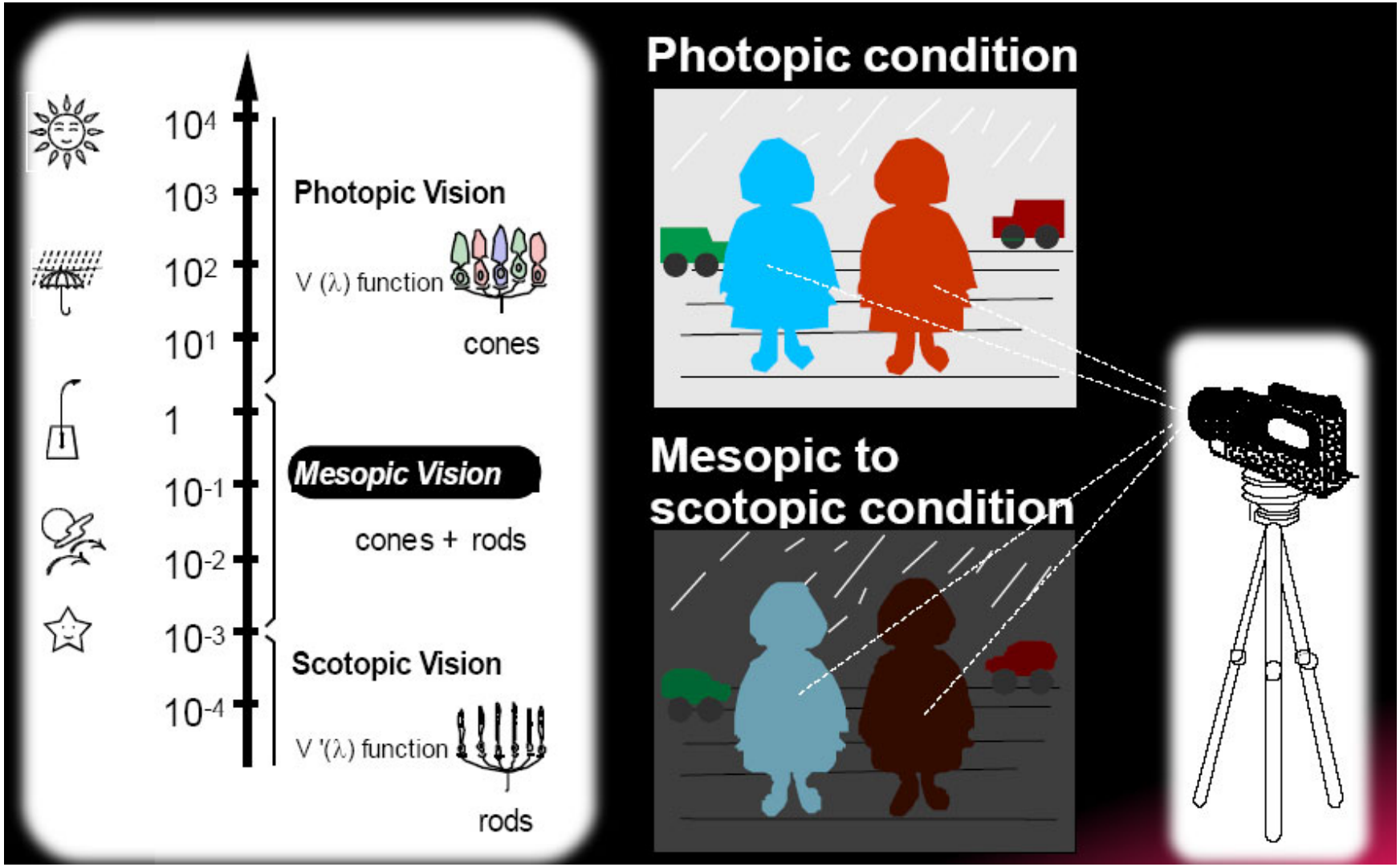
Outline

- Brief review of CIE system for mesopic photometry
- Overview of work of CIE JTC-1
- Outcomes from CIE mesopic photometry workshop 2012
- Review of residential street lighting (publication from CIE TC4-48)
- Overview of work of CIE TC2-65
- Conclusions

National Measurement System

NPL National Physical Laboratory

Eye sensitivity and light level



With thanks to Dr Ken Sagawa

National Measurement System

NPL National Physical Laboratory

CIE 191: System for mesopic photometry

- Bridges the gap between the CIE photopic and scotopic standard photometric observer functions
- Defines the spectral luminous efficiency functions to be used in the mesopic region
- Provides a system for precise determination of photometric quantities for all types of luminous source at all levels

$$V_{\mathrm{mes}}(\lambda, m) = \frac{1}{M(m)}\{mV(\lambda) + (1-m)V'(\lambda)\}$$

Normalising factor such that maximum value of $V_{\mathrm{mes}}(\lambda)$ is unity

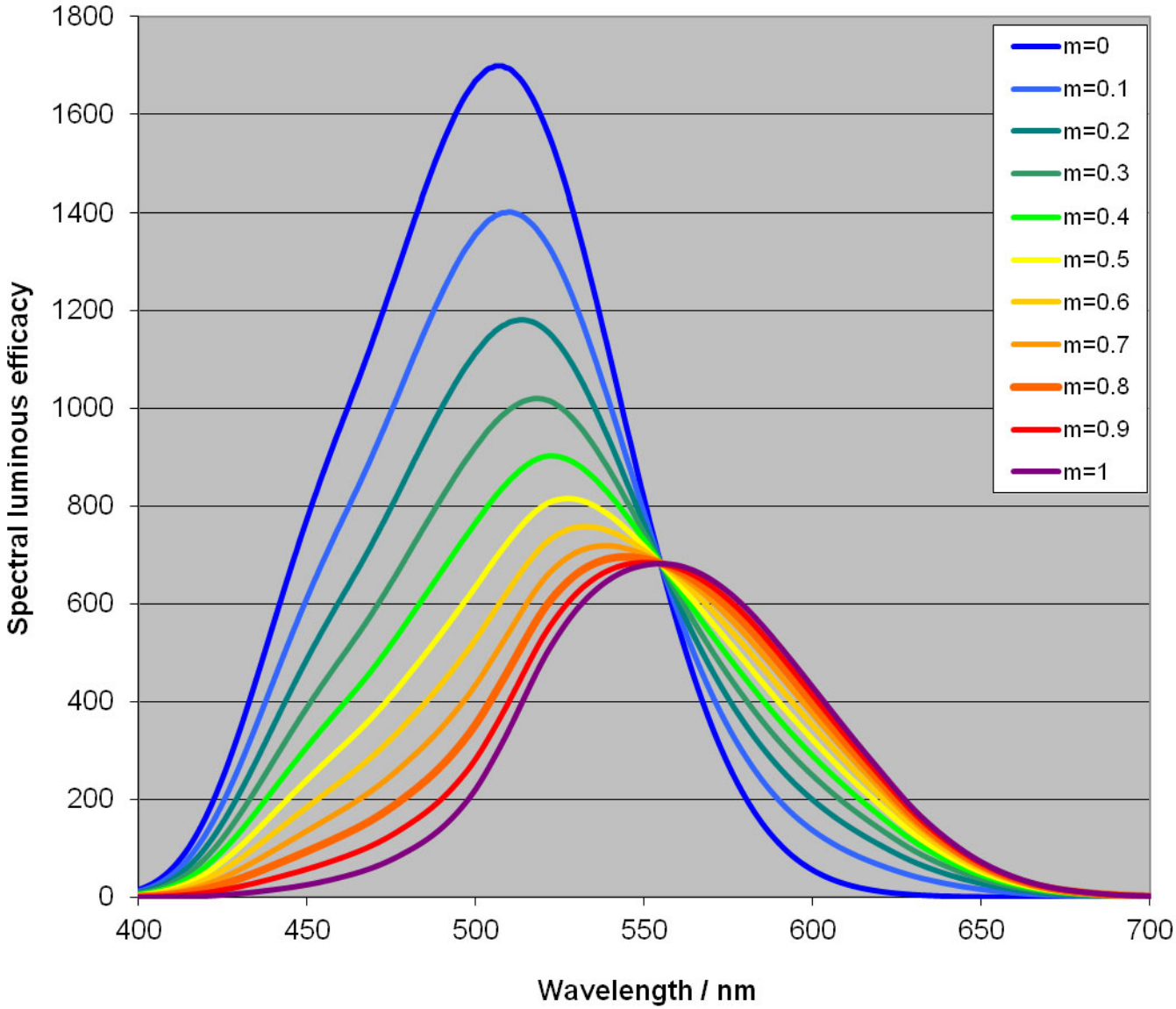
National Measurement System

if $L_{\mathrm{mes}} \geq 5.0$ cd·m^{-2}, then $m = 1$
if $L_{\mathrm{mes}} \leq 0.005$ cd·m^{-2}, then $m = 0$

NPL National Physical Laboratory

Spectral luminous efficacy functions

- Spectral weighting function depends on visual adaptation (determines value of *m*)
- Mesopic system provides method for calculating *m* from values of L_p and L_s for the adaptation field



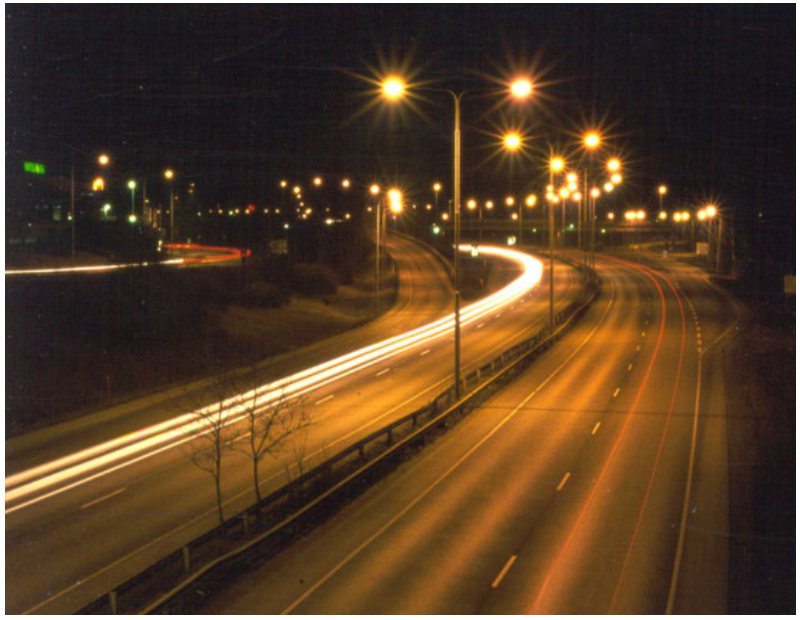
National Measurement System

NPL National Physical Laboratory

Step 1 – determine adaptation conditions

$$L_{\text{mes}} = \frac{683}{V_{\text{mes}}(555)} \int L_{\text{e}}(\lambda) V_{\text{mes}}(\lambda) \mathrm{d}\lambda$$

$$V_{\text{mes}}(\lambda, m) = \frac{1}{M(m)} \{ m V(\lambda) + (1-m) V'(\lambda) \}$$



- Must determine *m* before can calculate any mesopic quantity
- *m* depends on the visual adaptation of the eye, which varies with:
  - luminance of the adaptation field
  - spectral characteristics of the adaptation field (S/P ratio, R_{SP})

National Measurement System

Step 2 – calculate *m* and L_{mes}

Two methods are given in CIE 191:2010:

1.Iterative approach

$$m_0 = 0.5$$

$$L_{mes,n} = \frac{m_{(n-1)}L_p + (1-m_{(n-1)})L_s(683/1700)}{m_{(n-1)} + (1-m_{(n-1)})(683/1700)}$$

$$m_n = 0.7670 + 0.3334\log_{10}(L_{mes,n})$$

Repeat until *m* converges

2.Tables giving values of *m* and L_{mes} as a function of photopic luminance and light source S/P-ratio (R_{SP}= L_s/L_p)

NPL National Physical Laboratory

Step 3 – calculate other mesopic quantities

Other mesopic quantities can be calculated using the adaptation coefficient *m*

$$Q_{\text{mes}} = \frac{683}{V_{\text{mes}}(555)} \cdot \frac{1}{M(m)} \cdot \left[m \int Q(\lambda) V(\lambda) d\lambda + (m-1) \int Q(\lambda) V'(\lambda) d\lambda \right]$$

$$Q_{\text{mes}} = \frac{683}{V_{\text{mes}}(555) \cdot M(m)} \cdot \left[m Q_{\text{P}} + (m-1) Q_{S} \right]$$

Or

$$Q_{\text{mes}} = \frac{m Q_{\text{P}} + (1-m) \cdot Q_{\text{S}} \cdot \left(\frac{683}{1700} \right)}{m + (1-m) \cdot \left(\frac{683}{1700} \right)}$$

National Measurement System

NPL National Physical Laboratory

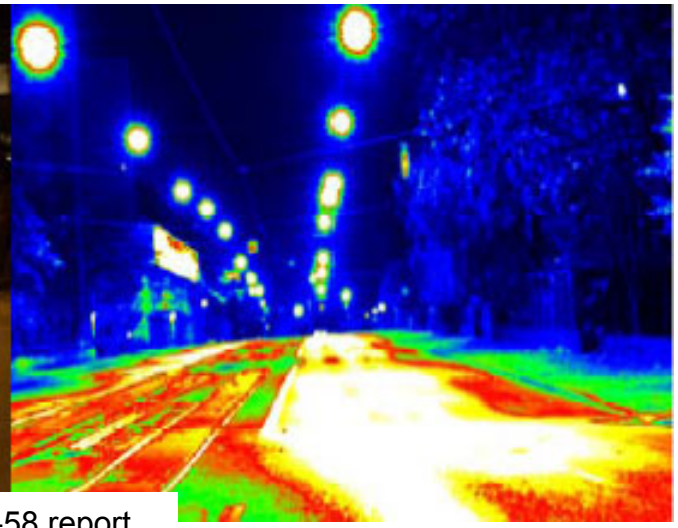
Issues for implementation of mesopic photometry

- System provides photometric values in mesopic region based on visual adaptation (photopic luminance and S/P ratio of adaptation field)
- Does NOT state what is relevant adaptation field
  - Depends on application?
  - JTC-1 working on this for outdoor lighting
- Does NOT state how measurements should be made, how quantities other than luminance should be calculated or how measurement results should be expressed
  - TC2-65 working on this
- Does NOT state how the system fits within the SI system
  - JTC-2 (CCPR-CIE) working on this
- Does not indicate what other considerations are important for key applications, especially road lighting
  - TC4-48 report on this (under ballot)

National Measurement System

NPL National Physical Laboratory

Issues for JTC-1 (1)



© CIE, TC1-58 report

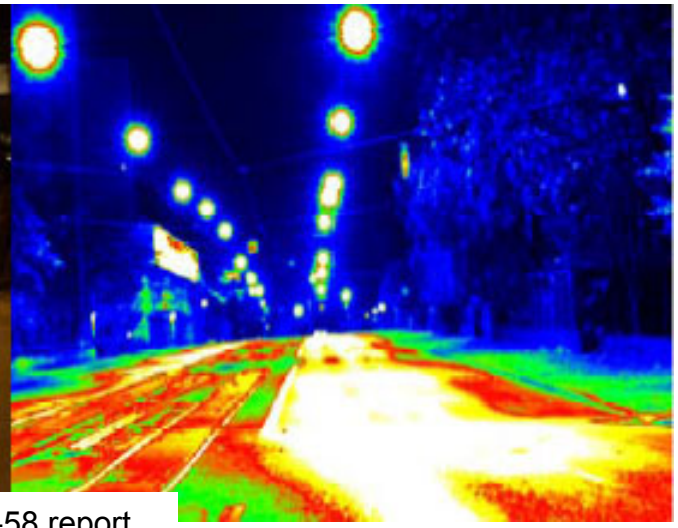
- What is the size, shape and position of the adaptation field?
  - Where is attention concentrated?
  - How much of the visual scene should be considered?
  - Does luminance of area surrounding fixation area influence adaptation?

Eye tracking studies for drivers and pedestrians
Lab-based experiments to evaluate effect of surround luminance

National Measurement System

NPL National Physical Laboratory

Issues for JTC-1 (2)



© CIE, TC1-58 report

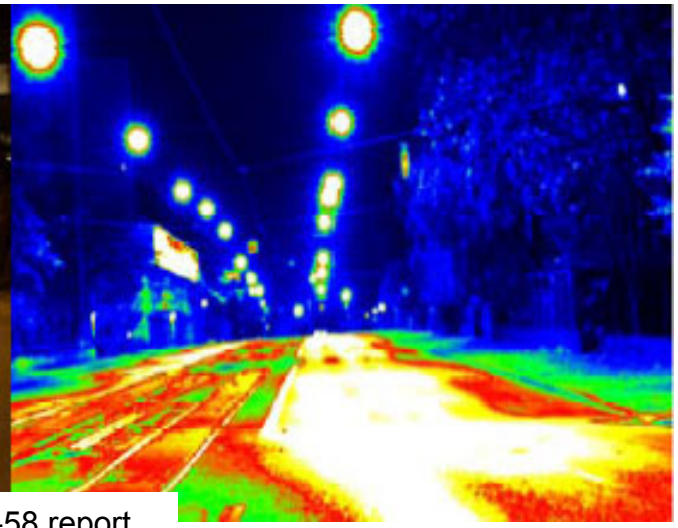
- Are all areas within (or surrounding) the defined adaptation field equally important?
  - Do non-uniformities within the defined field have an impact?
  - Do small, intense sources outside main area of fixation influence adaptation?

Pupil size studies when driving at night
Measurements of luminance at fixation point when driving at night
Lab-based experiments to determine influence of glare sources

National Measurement System

NPL National Physical Laboratory

Issues for JTC-1 (3)



© CIE, TC1-58 report

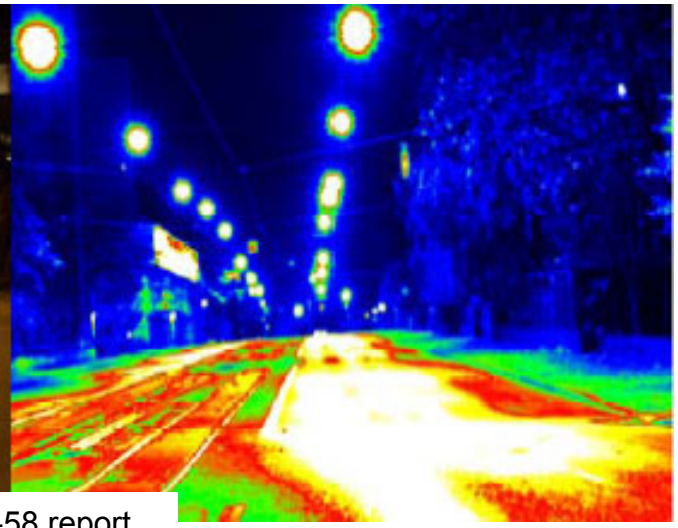
- How do transient effects affect adaptation?
  - How to allow for fact that conditions change as observer moves (e.g. oncoming headlights when driving)?
  - How to allow for fact that gaze is constantly shifting?

Eye tracking experiments for different types of road
Pupil size studies when driving

National Measurement System

NPL National Physical Laboratory

JTC-1 results to date



© CIE, TC1-58 report

- Most eye fixations in 20° x 10° ellipse centred in front of driver
- Type of road / driving situation has large influence on fixation points
- Local adaptation dominates over surround luminance
- Glare sources also have an influence on adaptation
- Large luminance variations occur in real driving situations
- Large changes in pupil size occur in real driving situations

National Measurement System

NPL National Physical Laboratory

CIE mesopic photometry workshop Sept 2012

- Agreement that reasonable and acceptable to determine the adaptation field as the average over a 'fairly wide field of view'
  - Strong support for use of 20° x 10° ellipse centred in front of driver
- Discussion regarding conversion between luminance and illuminance
  - When making measurements, illuminance and luminance can/should be independently measured
  - At design stage, standard values for road reflectance should be used
- Concern that increased use of high S/P ratio ('bluer') lighting might be disadvantageous for older road users
  - Contrary view also strongly held that current lighting levels are too high, so reduction will have no adverse impacts for any group
- Mesopic system may need to be coupled with other metrics for street lighting for pedestrians (TC4-48)

National Measurement System

$$L = q_0 E = \frac{\rho}{\pi} E$$

NPL National Physical Laboratory

Street lighting requirements

- Aid safe movement (⇒ aid detection of obstacles)
- To enhance pedestrian perception of safety (⇒ increase brightness)
- Increase ability to make informed decisions on intent of other street users (⇒ recognition of facial expressions)
- To improve visual appearance (⇒ visual acceptability / preference)

National Measurement System

NPL National Physical Laboratory

TC4-48: Metrics for implementation of mesopic lighting

	Obstacle detection	Perceived brightness	Assessing intent	Acceptability
CIE mesopic photometry or S/P ratio	✓	✓	✓	
R_a			✓	✓
Further research			✓	✓

Proposed metrics for quantifying street lighting performance: CIE mesopic photometry combined with high R_a

National Measurement System

NPL National Physical Laboratory

Work of TC2-65

Practical implementation of mesopic photometry from a measurement perspective

Two initial priorities:

- To ensure correct use of terms and units for mesopic photometry.
- To provide guidance for manufacturers regarding the specification of product performance in the mesopic range.

Guidance relating to measurement procedures and instrumentation requires recommendations from JTC-1 on the size, shape and location of the adaptation field to be used

- Work on these aspects should wait for recommendations from JTC-1

National Measurement System

NPL National Physical Laboratory

Mesopic quantities and units (1)

Technical Note on photometric units

- Photometric units DO NOT depend on spectral luminous efficiency function used
- Qualifying descriptors MUST NOT be added to units
- Qualifying descriptors MUST be used with quantities to identify spectral luminous efficiency function used
- If a qualifying descriptor is not used, $V(\lambda)$ applies
- For quantities evaluated using $V'(\lambda)$ function, descriptor “scotopic” is sufficient, but must always be used
- For mesopic quantities, spectral luminous efficiency function described by specifying (1st approach is simplest):
  - value of adaptation coefficient, *m*, or
  - photopic adaptation luminance, L_{adapt} and S/P ratio of adaptation field, R_{SP}

National Measurement System

Key message: Must not use “mesopic lumen”, “mesopic candela” etc!

NPL National Physical Laboratory

Mesopic quantities and units (2)

Technical Note on photometric quantities

- Different quantities relate to different geometries
- Qualifying descriptors must be used with quantities to identify spectral luminous efficiency function used
- If a qualifying descriptor is not used, $V(\lambda)$ applies
- For quantities evaluated using $V'(\lambda)$ function, descriptor “scotopic” is sufficient, but must always be used
- For mesopic quantities, spectral luminous efficiency function described by specifying (1st approach is simplest):
  - value of adaptation coefficient, *m*, or
  - photopic adaptation luminance, L_{adapt} and S/P ratio of adaptation field, R_{SP}
  - Subscripts and brackets used with symbols for photometric quantities to identify relevant spectral luminous efficiency function (see JTC-2)

National Measurement System

NPL National Physical Laboratory

Technical Note on Specifying Product Performance

- Intention is to provide guidance on how to specify product performance
- Need to avoid misleading information
  - ➢ It is not possible to specify a unique value for quantities such as the mesopic luminous flux of a lamp; such quantities depend on visual adaptation and are not an intrinsic property of the lamp, luminaire etc.
- Standardised approach needed, especially for luminous flux

Φ_v	1000 lm	$\Phi_{mes}(0.2)$	1616 lm
R_{SP}	2.0	$\Phi_{mes}(0.3)$	1484 lm
$\Phi_{mes}(0.1,2.0)$	1310 lm	$\Phi_{mes}(0.4)$	1376 lm
$\Phi_{mes}(0.3,2.0)$	1198 lm	$\Phi_{mes,}(0.5)$	1287 lm
$\Phi_{mes}(1.0,2.0)$	1101 lm	$\Phi_{mes}(0.6)$	1211 lm

Nati
Measurement
System

NPL National Physical Laboratory

Other issues for TC2-65

- Should this TC provide guidance on the conversion between luminance and illuminance for applications such as residential street lighting **design** (not measurement) in the context of mesopic photometry?
- Some guidance on use of CIE system for mesopic photometry in road and street lighting already appearing (e.g. TC4-48, UK ILP and BS, IES-TM-12, ….)
  - Need for this TC to review this published guidance to identify any potential measurement issues?
- Measurement instrumentation is already being developed
  - Need to develop recommendations for calibration and use now, before JTC-1 completes work?

National Measurement System

NPL National Physical Laboratory

Conclusions

- More research needed to determine optimum size, shape and position of adaptation field
  - 20° x 10° ellipse centred in front of driver most likely
- Existing standards for street lighting need revision for mesopic system
  - Follow TC4-48 approach?
- Transient effects and glare need to be considered in lighting design but are difficult to predict or allow for in real driving situations
- Guidance on quantities and units to be published shortly
- Calculations of illuminance from luminance should use q_0=0.07
- Guidance on calibration and use of new instrumentation likely to be required before JTC-1 completes work

Measurement System

NPL
National Physical Laboratory

teresa.goodman@npl.co.uk

National
Measurement
System