



An Optional Method for **Adjusting the Recommended Illuminance for Visually Demanding Tasks Within IES Illuminance Categories P through V Based on Light Source Spectrum**

Currently in preview, click buy full version

**An Optional Method for Adjusting the Recommended
Illuminance for Visually Demanding Tasks
Within IES Illuminance Categories M through Y
Based on Light Source Spectrum**

Publication of this Technical
Memorandum has been approved
by the IES. Suggestions
for revisions should be directed
to the IES.

Prepared by:
IES Visual Effects of Lamp Spectral Distribution Committee

Copyright 2013 by the Illuminating Engineering Society of North America.

Approved by the IES Board of Directors, August 18, 2012, as a Transaction of the Illuminating Engineering Society of North America.

All rights reserved. No part of this publication may be reproduced in any form, in any electronic retrieval system or otherwise, without prior written permission of the IES.

Published by the Illuminating Engineering Society of North America, 120 Wall Street, New York, New York 10005.

IES Standards and Guides are developed through committee consensus and produced by the IES Office in New York. Careful attention is given to style and accuracy. If any errors are noted in this document, please forward them to Rita Harrold, Director of Technology, at the above address for verification and correction. The IES welcomes and urges feedback and comments.

ISBN # 978-0-87995-275-4

Printed in the United States of America.

DISCLAIMER

IES publications are developed through the consensus standards development process approved by the American National Standards Institute. This process brings together volunteers representing varied viewpoints and interests to achieve consensus on lighting recommendations. While the IES administers the process and establishes policies and procedures to promote fairness in the development of consensus, it makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

The IES disclaims liability for any injury to persons or property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document.

In issuing and making this document available, the IES is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the IES undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

The IES has no power, nor does it undertake, to police or enforce compliance with the contents of this document. Nor does the IES list, certify, test or inspect products, designs, or installations for compliance with this document. Any certification or statement of compliance with the requirements of this document shall not be attributable to the IES and is solely the responsibility of the certifier or maker of the statement.

IES Visual Effects of Lamp Spectral Distribution Committee**B. Liebel, Chair****D. DeGrazio, Secretary**

S. Berman	S. Fotios	J. Waymouth
J. Brodrick*	R. Heller	M. Whitney
J. Bullough	K. Houser	H. Wiig*
X. Chen*	P. Kistler*	T. Tolen (deceased)
J. Cyre	M. Lambert	
M. Duffy	R. Lee*	*Advisory
R. Dunlap*	R. Levin*	
J. Fetters	S. Walerczyk	

Figure 1 on page 2 reproduced with permission from Elliott DB, Yang KC, Whitaker D. Visual acuity changes throughout adulthood in normal, healthy eyes: seeing beyond 6/6. Optom Vis Sci 1995;72:186-91. ©The American Academy of Optometry 1995.

Contents

1.0	FOREWORD	1
2.0	SCOPE AND LIMITATIONS	1
2.1.	Scope	1
2.2.	Limitations	1
3.0	OVERVIEW: CONCEPTS AND DEFINITIONS	1
3.1.	The Role of Spectrum in Defining Photometric Quantities	1
3.2.	The Photopic Luminous Efficiency Function, $V(\lambda)$	2
3.3.	Pupil Size, Retinal Image Quality and Visual Acuity	2
3.4.	Visual Efficiency and Visual Effort	3
3.5.	Visually Demanding Tasks	3
3.6.	Visual Acuity, Visual Efficiency, and Visual Performance of Visually Demanding Tasks	4
3.7.	Light-Level/Spectrum Tradeoff for Visually Demanding Tasks	5
4.0	SUMMARY OF RESEARCH	6
4.1.	Overview	6
4.2.	Pupil Size Does Not Follow $V(\lambda)$	6
4.3.	Physiological Mechanism Explaining Spectrally-Driven Pupil Size Change	6
4.4.	Empirical Formula Correlating Pupil Size Variation Including Both $V\lambda$ and Lamp SPD	7
4.5.	Pupil Size and Visual Acuity	8
4.6.	Lamp Spectrum and Visual Acuity / Visual Performance Studies	9
4.7.	Current Status, 2011	13
5.0	EQUIVALENT VISUAL EFFICIENCY (EVE) CALCULATION	13
5.1.	Overview	13
5.2.	Basis for Calculation: Equivalent Visual Efficiency (EVE)	13
5.3.	EVE Calculations	14
5.4.	The EVE Calculation and the Illuminance Determination System	15
5.5.	Summary of the EVE Calculation	16
6.0	DESIGN CONSIDERATIONS	17
6.1.	Overview	17
6.2.	Acceptance of High CCT Ambient Lighting at Lower Light Levels	17
6.3.	Color Appearance and Lighting Quality	18
6.4.	Brightness Perception	18
6.5.	Daylighting	18
6.6.	Age	18
7.0	CONCLUSIONS	19
	REFERENCES	20
	Annex A – Discussion of Various Studies Claiming an Absence of Spectral Effects on Visual Acuity and/or Visual Performance	24
	Annex B – Discussion of Various Studies on the Relationship of Pupil Size to Visual Acuity (VA)	32
	Annex C – EVE Table of Illuminance Modifying Factors	39
	POSITION STATEMENT	41

LIST OF ABBREVIATIONS

EVE	Equivalent Visual Efficiency
fc	Footcandles
IES, IESNA	The Illuminating Engineering Society
IES Handbook	Refers to the 10th Edition of the IES Lighting Handbook, unless specifically noted otherwise
ipRGC	Intrinsically Photosensitive Retinal Ganglion Cells
min	Minutes of arc
nm	Nanometers
PS	Pupil Size
S/P	Scotopic to Photopic Ratio
SPD	Spectral Power Distribution
TM	Technical Memorandum
VA	Visual Acuity
VL	Visibility Level
$V(\lambda)$	Photopic Luminous Efficiency Function
$V'(\lambda)$	Scotopic Luminous Efficiency Function

1.0 FOREWORD

This Technical Memorandum (TM) addresses how the Spectral Power Distribution (SPD) of light sources can be incorporated into the IES Illuminance Determination System for visual tasks that are categorized as P through Y within interior lighting applications. The summary of research investigations included in this TM describes how light spectrum affects pupil size, visual acuity, and visual efficiency under the conditions of interior lighting conditions, and concludes that light source SPD can be factored into lighting calculations for interior lighting applications under limited conditions when visual tasks require the ability to discern visual detail to ensure speed and/or accuracy in the performance of the visual task. These tasks are defined in this TM as visually demanding tasks and are a subset of visual tasks within IES Category P through Y of the Illuminance Determination System. This TM introduces the Equivalent Visual Efficiency (EVE) calculation and provides general guidelines and relevant caveats for its use. The calculation is optional and its use should be balanced with other lighting design criteria and objectives.

2.0 SCOPE AND LIMITATIONS

2.1 Scope

Applications and tasks are limited to:

1. Visual tasks for which the IES has designated Categories P through Y as the Recommended Illuminance Target (Refer to Table 4.1, IES Handbook); and
2. Visual tasks that are Visually Demanding Tasks, as defined in this Technical Memorandum; and
3. Interior lighting applications in which the conditions of performing the task are under a full-field-of-view, with relatively uniform lighting (luminance ratios do not exceed the Default Luminance Ratio Recommendations (Table 12.5, IES Handbook); and
4. Visual tasks for which the task background luminance is 50 cd/m² or greater.

Applications and Tasks Not Included:

The methods described in this TM do not apply to applications and tasks that have been designated

as IES Illuminance Categories A through O as the Recommended Illuminance Target, are exterior lighting applications, or are non-visual tasks. Other tasks that are excluded are noted in **Section 3.5** under the definition of visually demanding tasks.

The methods described in this TM are based on how light source SPDs affect the ability to discern visual detail. Light spectrum can also impact brightness perception, color rendering, discomfort glare, circadian rhythm and other possible health issues, but these issues are outside the scope of this TM.

2.2 Limitations

In publishing TM-24, the IES acknowledges that light source SPD can affect vision in the design of interior lighting applications. This Technical Memorandum includes the Equivalent Visual Efficiency (EVE) calculation, which can result in the use of design light levels that differ from published IES recommendations.

The methods described in this TM can be applied to lighting applications where the population is known to have generally good ocular health. In applications where it is known that there is a proportionally high number of occupants with abnormal vision or poor ocular health, care should be taken to ensure that the principals of spectrally-driven pupil size visual effects apply.

3.0 OVERVIEW: CONCEPTS AND DEFINITIONS

3.1 The Role of Spectrum in Defining Photometric Quantities

The quantification of the effects of lighting on human vision is one of the fundamental requirements of illuminating engineering. This quantification is accomplished through the use of photometric quantities derived by converting light as an electromagnetic quantity defined in radiometric values to units that have some relationship to human vision. This conversion is accomplished by using the spectral power distribution (SPD) of light sources as a radiometric quantity, and weighting that SPD against a spectral response of the human visual system.

The visual response to spectrum that is used to define illuminating engineering metrics is the photopic luminous efficiency function, $V(\lambda)$. All lighting metrics (illuminance, luminance, etc.) are based on the $V(\lambda)$ response and are sometimes referred to as "photopic" quantities.

3.2 The Photopic Luminous Efficiency Function, $V(\lambda)$

The $V(\lambda)$ function was determined in the 1920s using psychophysical methods where the testing visual field was restricted to the central 2 degrees of view in order to confine the spectral response to the fovea. This restricted central 2-degree field of view represents less than one percent of the solid angle of the full field of view that eyes are normally exposed to in most interior lighting applications, and as a result, $V(\lambda)$ excludes the possible contributions of photoreceptors whose concentrations are primarily peripheral to the central 2-degree limitation. These include a portion of the S cones, the rods, and the recently discovered intrinsically photoreceptive retinal ganglion cells (ipRGCs). The photopic luminous efficiency function may therefore not fully account for responses of the visual system applicable under the more common and relevant condition where eyes are naturally exposed to a full field of view. Despite the industry-wide acceptance of $V(\lambda)$, the IES recognizes that it represents a compromise in assuming a predictable correlation of physical measurements with visual response, and that there are some circumstances where the system works poorly. (IES 2000)

One example of how $V(\lambda)$ works poorly is in its failure to predict changes in pupil size when different spectra are compared under the conditions of equal light level. The current status of research indicates that, at photopic levels and when the eyes are exposed to a full field of view, the principal control of pupil size variation is provided by input from the ipRGCs (Gamlin et al., 2007; Markwell, et al. 2010; McDougal and Gamlin 2010), whose melanopsin photopigment spectral sensitivity function has a peak wavelength at around 480-490 nm, as compared to the $V(\lambda)$ function that peaks at 555 nm. As a result, the SPD of light sources can affect pupil size based on the relative amount of short wavelength content in ways that are not accounted for in $V(\lambda)$. Sections 4.2 and 4.3 provide a more detailed discussion on these issues.

3.3 Pupil Size, Retinal Image Quality and Visual Acuity

The importance of pupil size for vision is that it can affect visual acuity, depth of field and accommodation effort (Ward & Charman 1985, Loewenfeld & Rowe 1993). Of particular concern to lighting practice is the effect of pupil size on retinal image quality and, consequently, visual acuity.

Visual Acuity (VA) refers to the minimum size that can be visually resolved under specific viewing conditions,

such as luminance, contrast, and distance. Visual acuity is a variable unique to each person and also varies with age. Elliott et al. (1995) performed VA testing on a large number of subjects ranging in age from 18 to 80, and compared these results with several other studies. (Figure 1). Differences in the average VAs between studies are generally attributable to the types of subjects tested, and in some cases the range of task sizes used in the VA tests. Some studies reviewed by Elliott included only healthy eyes with optimal correction, while other studies were not as strict and included the subjects' habitual correction (rather than their optimal correction). Habitual correction is the vision that people have on a habitual, or daily basis, and is more representative of the general population.

The average VA for the general population is slightly better than 20/20 prior to age 50, and worsens with age from that point. Figure 1 shows how optimum refraction for subjects up to approximately 60 years of age is improved over habitual correction by about one line on the Snellen VA chart (0.1 logMAR units). The best average VA of approximately 20/14 occurs in the group that is under 30 years of age with optimal correction, based on light levels of 160 cd/m² and 85% contrast.

An individual's VA is evaluated under prescribed conditions of task luminance and contrast. However,

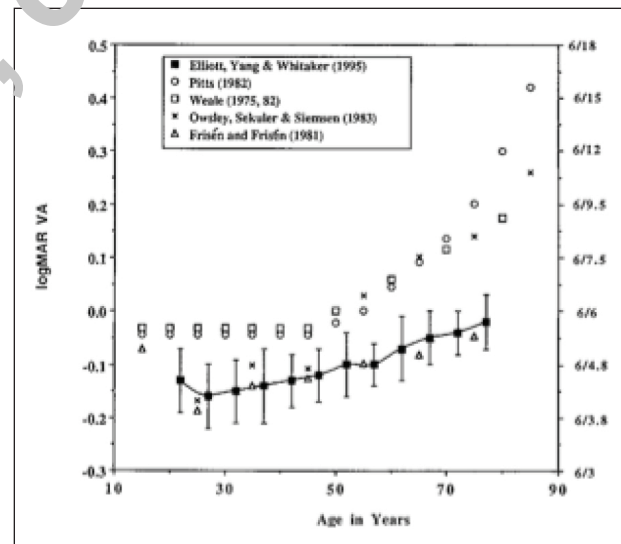


Figure 1: Comparison of the mean logMAR visual acuity (VA) data as a function of age. (Elliott,1995). The data show a wide variation of VA within age groups and a gradual decline with increasing age; the best mean VA shown is 20/14 with optimum correction. The solid line is for optimally corrected vision, and the data approximately 0.1 logMAR units above this line is from the general population with their habitual refraction.