SOME NOTES ON PHOTOMETRIC UNITS
AND AN ABSTRACT ON BEHAVIORAL PERFORMANCE CRITERIA

John F. Halldane, Ph.D.

Chairman Heins: Our next speaker is Dr. John Halldane. Dr. Halldane has agreed to briefly review the basic measurement concepts of lighting and to emphasize the salient points in his abstract. (A summary of Dr. Halldane's comments and a copy of his abstract are presented on the following pages).

Some Notes on Photometric Units

Dr. Halldane: Before we discuss the merits or shortcomings of any lighting we must be sure that all the measures we use are understood.
Electromagnetic radiant power, P, measured in Watts (W), is based on thermal flow.
Light is radiation that can be seen, either by scotopic or photopic vision. Wavelengths of radiation $\lambda 400$—$\lambda 556$—$\lambda 800$ nm is visible range. Note that plant photosynthesis is more effective about $\lambda 500$ and skin absorption about $\lambda 800$—$\lambda 1{,}000$.
Luminous power is light assuming photopic vision. The measure is a lumen, lm, which is equivalent to about 680 lm/W at $\lambda 556$. An instrument simulating visual responses must be photopically corrected with a **filter.**
Luminous power passing through a unit area or power density, E, is illuminance for incident light. Units—

BRITISH	METRIC
lm/ft^2	lm/m^2
footcandle (fc)	lux (lx)

$$1fc = 10.76\ lx$$

Note that the meter must be **photopically** and **cosine** corrected.
Illuminance has **no** direct correlation with a visual response. It can be shown that the luminance x visual area can relate to the illuminance **on the pupil** of the eye.

Luminous Intensity, I, is the light passing through a unit solid angle. $I = P/\omega$. It only relates to a **point** source of power and has no direct correlation with responses. Units are lumen/steradian (lm/sr) and the candela (cd).
Luminous planar intensity or luminance, L, for light from a surface. This is the orthogonal (at right angles) luminous intensity density measured in

BRITISH	METRIC
$cd/\pi ft^2$	cd/m^2
footlambert (fL)	nit (nt)

$$1fL = 3.43\ nt$$

$$L = I/A\cos\Theta$$

where A = surface area
Θ = angle from normal

Luminance correlates with the visual response of luminosity (apparent brightness, brightness). It can be measured with a telephotometer. The filter and lens system simulates those aspects of vision but not the adaptive and contextural effects. A luminosity response varies as the 0.2 power of the luminance in our design ranges. Standards and performance specifications should always be stated in luminance measures as they relate directly to the human response—luminosity, the magnitude of a color.

A **special case** when the surfaces are **perfectly diffusing** and have a reflection factor or reflectance, K

$$L\ (fL) = K_{reflection} \times E\ (fc)$$

Note the qualifications to this simple expression.

Units in "energy" conservation

Energy (Q)
Joule (J)
1 Btu = 1.052 kJ
1 Therm = 105.2 MJ

$$\text{Power, } P = \frac{dQ}{dt}$$

Watt (W)

1 Btu/hr = 0.2922W

Everything should be converted to the SI metric system for a convenient comparison.

AN ABSTRACT ON BEHAVIORAL PERFORMANCE CRITERIA

Dr. Halldane: There is a growing controversy over what "lighting levels" should be adopted. The political camps are divided; on the one hand, for a universal lowering of task illuminance to meet the demands of power (energy) conservation and on the other, a raising of illuminance to improve visual detection or visibility performances. Government agencies are charged with undertaking conservation measures while maintaining peoples' health and safety. Organizations such as the Illuminating Engineering Society hold themselves responsible for the improvement of lighting systems to the benefit of mankind. My belief is both directions are needed but that more attention should be paid to the lighting design for various visual responses and not to become preoccupied with illumination alone since illumination does not directly relate to human responses.

Conservationists are concerned that lowering illuminances will cause eyestrain, accidents, and errors in responses. Previous minimum codes or recommendations reflected from past lighting experience (Australia's Standard No. C.A. 30–1957—Artificial Lighting of Buildings), were roughly half of what they are now and many other countries still have those criteria. People performed satisfactorily in the past under those conditions and are likely to continue to do so with similar task difficulty. For general activities of moving about buildings, recognizing people, reading signs, and writing, the visual tasks are not demanding. Consequently, a conservative lighting system would be satisfactory. Just decreasing lighting by taking out lamps is not a sufficient consideration alone. The familiar recessed ceiling luminaire is very inefficient in that the ceiling is not illuminated directly. This creates strong contrasts with the diffuser. Previously, and in other countries, luminaires projected below the ceiling or were suspended from it to overcome those difficulties. Substituting reflectors for lamps would increase the luminaire efficiency by about 10% and reduce the glariness caused by the shadows of disconnected lamps under half fluorescent lighting programs.

Clarity of visual forms is important in environmental assessment. This depends on the luminous gradients and the related blur response in the visual field. The function does tend to peak with increasing luminance, particularly in the lower "conservation ranges", and the National Bureau of Standards is studying this. Say NBS does find a maximum range, the response would be appropriate for assessments concerning the formal articulation or clarity of a space but it would not preclude the consideration of visibility in detection-like tasks. An answer here depends on the design goals. In equal interval luminosity (brightness) scaling experiments (Halldane 1968), varying surround lightness and illuminances between 10-90 fc produces the least distortions and variances than outside this range. In another way, the least perceptual variations in viewing the grey Munsell Value color scale against different surrounds would be with illuminances of 10-90 fc. Thus the formal molding and textures of a space become more consistent and clearer. At lower levels, the scale tends to merge into darker tones; at higher levels, into lighter tones.

Visibility of detection-like tasks has been clearly demonstrated by the Blackwells and others to increase with illuminance. With older age and the increasing demand for detail nowadays in specific visual tasks, this concern is justified. My argument is that the general lighting of spaces should not be expected to provide the higher illuminances for the detailed tasks. There are various control systems for resolving the problems including worn, fixed, or portable lenses; luminaires proximate to the task surfaces like desk or reading lamps; more contrasting stimuli; daylight; magnifiers; larger print; lamp shielding; TV image enhancement; and equipment to avoid detailed tasks like a needle threader, etc. There is considerable scope for innovation. It should be remembered that the limiting criteria are based on the luminous visual field impeding the activity, such as the photic, flicker, phototropic, after image, pain responses.

The significant concept in evaluating be-

havioral problems is that it can not be based on one parameter alone or a single behavioral response. It is not a matter for compromise but rather a satisfaction within limiting criteria for each of the evaluative parameters according to their intended design goals.

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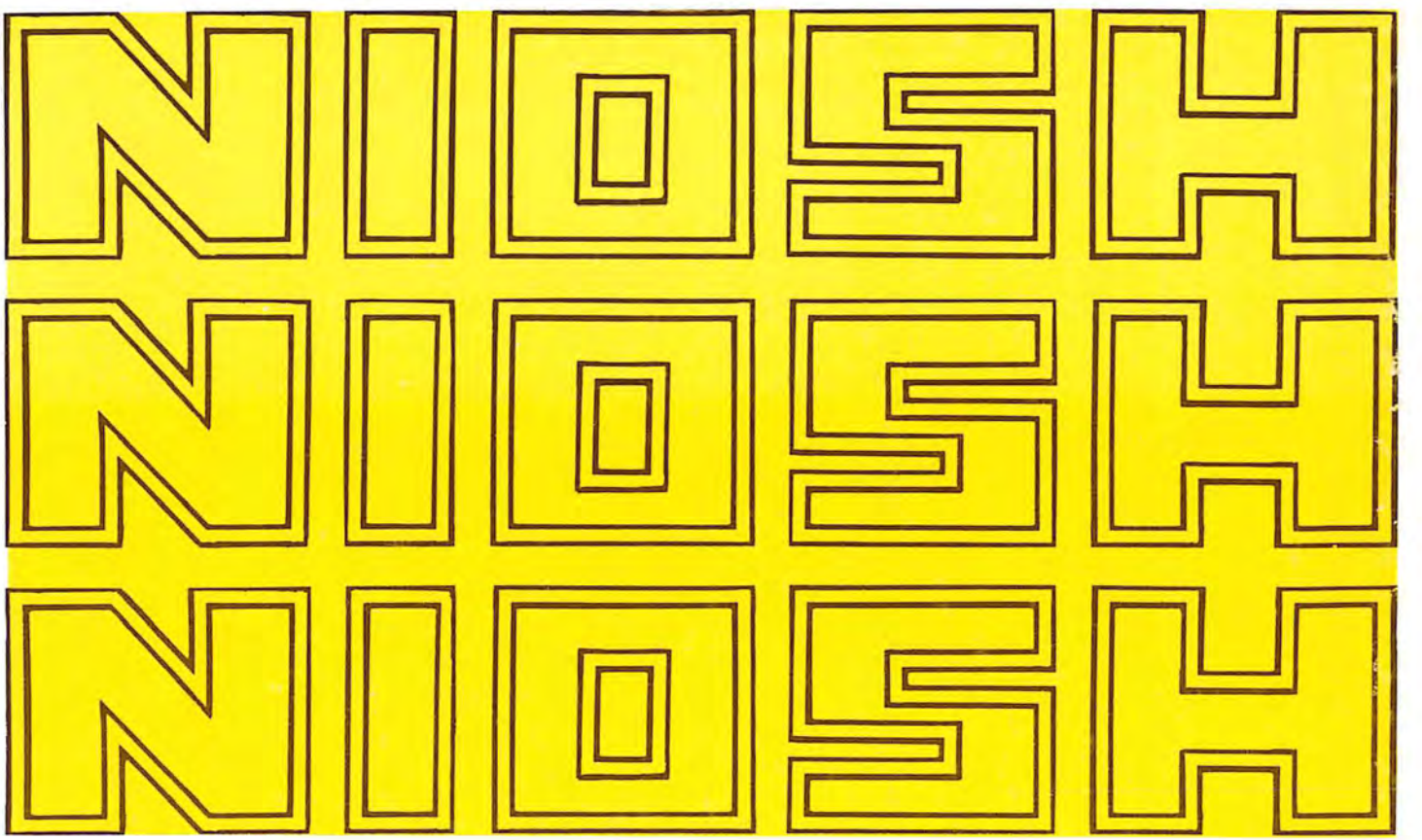

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