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COLOR OF ILLUMINANT AND EFFICIENCY OF THE WORKER

This bureau has not carried on any research connecting color of illuminant with efficiency of the worker. It is believed that the connection is not very important, not nearly as important as the amount and angular distribution of the light.

The following rules for efficient lighting are given in Recommended Practice of Industrial Lighting, Trans. Illum. Eng. Soc. 34, 369 (1939): Minimize glare, hang lights high up out of the field of vision, use luminaires which limit the quantity of light emitted in directions just below the horizontal. Avoid high brightness contrasts. Supplementary lighting sources should illuminate only the immediate working area. Consult a competent illuminating engineer regarding diffusion and distribution of light. Use light-colored walls and ceilings. Get enough light for the task to be done; minimum illuminations vary from 5 foot-candles for aisles and stairways up to 100 foot-candles for tasks involving severe eyestrain such as discrimination of extremely fine details.

The color of the illuminant of the work room may have some effect, however, on the efficiency with which work may be conducted. The following bibliography serves not only to indicate some of the sources of information on this effect but also to give a brief summary of the several conclusions, some of which apparently contradict others.

1. A. Broca and F. Laporte, Étude des principales sources de lumière au point de vue de l'hygiène de l'oeil, Bull. de la Soc. Int. des Electriciens (2nd series) 8, 277 (1908). The carbon-filament lamp and the mercury-arc lamp, adjusted to give equal illuminations, also yield the same visual acuity. Speed of reading is the same regardless of kind of illumination. Photometric measurements of industrial light sources determine very satisfactorily the practical value of the lights.

2. S. W. Ashe, The Bearing of Modern Illumination upon Physiological Optics, Electrical World, 53, 495 (1909). Illumination from a carbon-filament lamp was found to yield better visual acuity than an equal amount of blue illumination, which, in turn, is better than green or red. The failure of Broca and Laporte to detect these differences is ascribed to their failure to use a flicker photometer for measurements of illumination.

3. J. S. Dow, The Effect of Light of Different Colours on Visual Acuity, The Illuminating Engineer (London) 2, 233 (1909). Red light is slightly better for distinguishing detail at a distance than blue-green light, but for close work blue-green light is somewhat more advantageous.

4. L. Bell, Chromatic Aberration and Visual Acuity, Electrical World, 52, 1163 (1911). Light from the low-pressure mercury-arc lamp yields a visual acuity significantly better than that from the incandescent lamp. The inferiority of the latter is ascribed to the chromatic aberration of the eye which is unable to focus both short-wave and long-wave light at the same time.

5. M. Luckiesh, The Influence of Spectral Character of Light on the Effectiveness of Illumination, Trans. Illum. Eng. Soc. 7, 135 (1912). Spectrally homogeneous light produces a more well-defined image on the retina than light of extended spectral character. For illuminations of 3 or 4 foot-candles, visual acuity is greatest for spectrum light of about 580 mμ; unfortunately homogeneous light distorts the colors of objects so badly that its practical use is limited.

6. M. Luckiesh, Color and Its Applications, Van Nostrand, New York, p. 135; 1915. For discrimination of fine detail spectrum yellow light is best.

7. C. E. Ferree and G. Rand, The Effect of Visual Angle, Intensity, and Composition of Light on Important Ocular Functions, Trans. Illum. Eng. Soc. 17, 69 (1922). Speed of discrimination and acuity are best for daylight, poorest for blue. The order is: daylight (artificial), pale yellow (gas-filled incandescent lamp), spectrum yellow, spectrum yellow-green, medium reddish yellow (incandescent lamp at voltage considerably under rating), spectrum orange, spectrum green, spectrum red, spectrum blue-green, spectrum blue. These results may be accounted for by two opposing principles: (1) light of highly saturated color is not favorable; (2) spectrum light is favorable because the retinal image is free from chromatic aberration. Power to sustain acuity is similar to the above except that spectrum green is inferior to spectrum red.

8. M. Elliott, Comparative Cognitive Reaction-Time with Lights of Different Spectral Character and at Different Intensities of Illumination, Am. J. Psychol. 33, 97 (1922). For reduction of the time required to recognize printed characters, less mercury-arc light is required than daylight, and slightly less daylight than incandescent-lamp light. The superiority of the mercury-arc is ascribed to reduction of the effect of chromatic aberration within the eye.

9. C. E. Ferree and G. Rand, Further Studies on the Effect of Composition of Light on Important Ocular Functions, Trans. Illum. Eng. Soc. 19, 424 (1924). Yellow light is less fatiguing and more comfortable for reading than red, blue, or green light, saturation and brightness being equalized. Daylight is still better.

10. M. Luckiesh and F. K. Moss, The Effect on Visual Acuity of Shortening the Spectrum at the Blue End, J. Opt. Soc. Am. and Rev. Sci. Instr. 10, 275 (1925). Acuity is slightly increased by using a yellow filter (potassium dichromate) over an incandescent lamp in spite of the decreased brightness. This accounts for some of the advantage of yellow glasses for the eyes.

11. C. E. Ferree and G. Rand, The Effect of Mixing Artificial Light with Daylight on Important Functions of the Eye, Trans. Illum. Eng. Soc. 21, 588 (1926). The undesirable results of mixing incandescent-lamp light with diminishing daylight in the late afternoon are not due to the color of the mixture, but to a lag in adapting to the lower brightness.

12. F. E. Carlson, Relative Value of Daylight, Tungsten Filament, and Mercury Arc Light, and Mixtures as Measured by Visual Acuity, Trans. Illum. Eng. Soc. 21, 613 (1926). The acuity differences are not great, but daylight is generally the best.

13. I. G. Priest, Note on the Relative Comfort in Reading by Artificial Daylight and Unmodified Gas-Filled Tungsten Lamps, J. Opt. Soc. Am. and Rev. Sci. Instr. 15 , 131 (1927). For one observer artificial daylight proved highly satisfactory and incandescent-lamp light of the same intensity unacceptable.

14. M. Luckiesh and F. K. Moss, Visual Acuity under the Mercury Arc and Tungsten Filament Lamp, J. Franklin Inst. 205, 565 (1928). For a range of illumination from 5 to 125 foot-candles, there is no significant difference in visual acuity.

15. W. L[illegible]ffer, Uber die Beeinflussung menschlicher Leistungen durch farbiges Licht, Ind. Psychtechn. 5, 161 (1928). For general illumination little relation exists between color and performance. Local illumination at the work place showed best performance for yellow and green, poorer for blue and daylight; red, variable.

16. K. Y. Tang, Visual Performance under Daylight, Incandescent, Mercury Vapor, and Their Mixtures, Trans. Illum. Eng. Soc. 26, 258 (1931). Daylight is definitely best, mercury-vapor light second, and incandescent-lamp light a good third.

17. C. E. Ferree and G. Rand, Visibility of Objects as Affected by Color and Composition of Light. I. With Lights of Equal Luminosity or Brightness, II. With Lights Equalized in Both Brightness and Saturation, Personnel J. 9, 475; 10, 108 (1931). More careful and complete tests of the functions reported by the authors in 1922 (see reference 7) are described and the previous conclusions are corroborated.

18. M. Luckiesh and F. K. Moss, Visual Acuity and Sodium-Vapor Light. J. Franklin Inst. 215, 401 (1933). Sodium-vapor light is superior to incandescent-lamp light for revealing detail of small achromatic objects at low brightness.

19. M. Luckiesh and F. K. Moss, Seeing in Sodium-Vapor Light, J. Opt. Soc. Am. 24, 5 (1934). Sodium-vapor light has some advantage over incandescent-lamp light in accentuating in general the lightness contrasts between objects surfaces, but it has the disadvantage of obliterating contrasts in chromaticity. It gives a higher recognition speed for small achromatic objects than incandescent-lamp light gives.

20. J. E. Ives, Effect on the Eye of the Yellow Light of the Sodium Vapor Lamp, Public Health Reports, 49, 931 (1934). No permanent effect on the eye was found, nor any significant difference in the amount of work performed under sodium-vapor light compared with that under incandescent-lamp light.

21. M. Luckiesh and F. K. Moss, Seeing in Tungsten, Mercury and Sodium Lights, Trans. Illum. Eng. Soc. 31, 655 (1936). Mercury light makes objects appear to be more distinct than the incandescent-lamp light at the same illumination, but actual measurements of visibility, visual acuity from 0.1 to 125 foot-candles, and speed of performing visual work failed to show a significant difference. Sodium light was found to give a larger pupil diameter than incandescent-lamp light and is therefore used more efficiently, but it is more glaring when the light source is near to the line of vision. These two lights yield about the same recognition speed for large objects but sodium light is better for small objects, and also yields superior visual acuity.

22. C. S. Woodside and W. Reinhardt, Comparison of the Light from the High-Intensity Mercury Vapor Lamps and Incandescent Filament Lamps for Visual Tasks, Trans. Illum. Eng. Soc. 32, 365 (1937). No significant differences were found except at the lowest illuminations (5 to 10 foot-candles) where the mercury-vapor lamp appeared to have a slight advantage.

23. American Recommended Practice of School Lighting (ASA-A23-1938), obtainable at 25¢ a copy from the Secretary of the American Standards Association, 29 W. 39th St., New York, N. Y. For most visual tasks, with the common light sources found in schools, it appears that with equal foot-candles of illumination, variations in color quality have little effect upon clearness and quickness of seeing.

24. Recommended Practice of Industrial Lighting, Trans. Illum. Eng. Soc. 34, 382 (1939). For most visual tasks, it appears that with equal foot-candles of illumination, variations in color quality have little or no effect upon clearness and quickness of seeing.