

Abstracts

Lighting Quality Contributions from Biopsychological Processes

Jennifer A. Veitch, Ph.D.

Internal processes, both biological and psychological, are thought to mediate the relationships between luminous conditions and such behavioral outcomes as task performance, mood, social behavior, aesthetic judgments and satisfaction. This review paper summarizes the state of knowledge concerning mediating biopsychological processes: visibility, photobiology and stress and arousal. Visibility is well understood and obviously relevant to lighting practice. Photobiology, however, is a new entrant to the realm of lighting research. Its findings could have important implications for recommended illuminance levels if these were based on more than visibility. Stress and arousal, interrelated concepts, are popular notions, but close examination reveals only weak support for these mechanisms as explanations of lighting effects on behavior. The improved organization of research and increased predictive power that would result from clear exposition of theoretical mechanisms in lighting research holds promise for progress in linking research and application.

Unique Lighting Enables NASA Infrared Camera To Analyze The Star Spangled Banner

Frank A. Florentine and Dr. John J. Hillman

The Smithsonian's National Museum of American History has embarked on a preservation project for the Star Spangled Banner, the Flag that inspired the national anthem. The Flag is approximately 8 x 11 m (26 x 36 ft). To full understand the physical state of this national icon, the National Aeronautics and Space Administration's Goddard Space Flight Center imaged and analyzed the Flag with a camera normally used for ground-based astronomy and future space missions, which was sensitive to the infrared region of the electromagnetic spectrum. The camera, Acoustic-Optic Imaging Spectrometer (AimS), required unique lighting to record its images while not damaging the national treasure. The project's goal was to measure the distribution of moisture and oil stains in the wool fibers of the Flag.

The lighting solution — providing infrared light without causing harm to the fabric — combined experts from many disciplines. In cooperation with the lighting designer, NASA Goddard's camera group took sample lighting luminaires and analyzed the optics. The Goddard group also performed its own transmission curve analysis of various filters to determine the most optimum filter for the AimS system. This paper will present those findings of each analysis phase.

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Implementation of the lighting for the two-weeks of photography included a motorized lighting system to adjust the vertical height of the luminaires and a dimming system that enabled the camera operators to illuminate 1 sq m of the Flag while photographing. Seventy-two separate image cubes were made each containing up to 100 images. This paper will summarize the findings of the project.

A First Look at Visually Aimable and Internationally Harmonized Low-Beam Headlamps

Michael Sivak, Ph.D., Michael J. Flanagan Ph.D. and Toshio Miyokawa

This analytical study evaluated the performance of 40 first-generation low-beam headlamps, which were either visually/optically aimable or which met a proposed internationally harmonized beam pattern, by comparing these low beams to conventional U.S., European and Japanese low beams. The following aspects of headlamp performance were considered: visibility of pedestrians, visibility of pavement delineation, visibility of retroreflective traffic signs, visibility of vehicle rear reflex reflectors, visibility of targets near the road expansion point, glare directed towards oncoming drivers, glare directed towards rearview mirrors of preceding drivers, glare reflected from wet pavement towards oncoming drivers and foreground illumination.

For each performance aspect, typical geometric situations (points in space) were specified in terms of longitudinal, lateral and vertical positions and the corresponding visual angles from each of the two headlamps were calculated. The effects of the novel low beams were quantified by calculating the percent changes in luminous intensity directed from both lamps towards the points in space representing the performance aspects. The results are presented separately for the visually/optically aimable lamps and for the harmonized lamps. The present results could be used by lamp designers to maximize the advantages of the future versions of these novel low beams, while minimizing their disadvantages.

Evaluation of Speech Intelligibility Under Different Lighting Conditions

Yutao Zhou and Peter Boyce

Speech is one of the most important forms of human communication. Background noise and speech distortion make achieving good speech intelligibility difficult. Being able to see the speaker's face clearly can alleviate the effects of background noise and speech distortion. This paper examines the role of lighting in improving speech intelligibility in a video-conference situation.

Eighteen subjects listened to lists of mono-syllabic and bi-syllabic words, while viewing the speaker on a television screen, and wrote down all the words they could identify. Speech intelligibility was measured as the percentage of

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words correctly recorded. The video tapes viewed by the subjects were recorded under six different lighting installations, ranging from no lighting at all, through strongly directional lighting to indirect lighting. These video tapes were viewed and listened to in the presence and absence of noise. The subjects consisted of two groups, one having English as their first language, the other not.

The percentage of words correctly recognized is higher when the speaker's mouth is lighted, is higher when the listeners' first language is English and is higher when the words are bi-syllabic. When there is louder ambient noise, the impact of the lighting is greater.

Effects of Simulated Dawn Lighting on Awakening *Hiroki Noguchi, Toshihiko Sakaguchi, Shuichiro Shirakawa and Yoko Komada*

The effects of simulated dawn lighting, gradually increasing in illuminance from 0 lx to 100 lx during 30 minutes, just before the hour of rising, on quality of awakening was investigated. Eight healthy men, aged 24-27 years old, were performed with polysomnography, alpha attenuation tests, measuring blood pressure and awakening feelings in the climatic chamber controlled to a temperature of 25 degrees C and a relative humidity of 50 percent.

Awakening mood in the simulated dawn lighting condition was significantly better than that in no lighting condition ($p < 0.05$; Wilcoxon test). Appearance time of sleep stage w during 30 minutes just before the hour of rising in the simulated dawn lighting condition decreased significantly ($p < 0.05$), and appearance time of stage W had tendency to increase ($p = 0.0796$). There are no significant differences in alpha attenuation coefficient and blood pressure after awakening between two conditions.

These results suggest that simulated dawn lighting enhances the awakening process and causes light sleep as a preparation of rising. Consequently, light sleep in the morning prevents sudden awakening from sleep, and produces good sleep awakening mood. In addition, it seems there is no side effect to light sleep just before awakening, due to the decline of cerebral cortex activity and sympathetic nervous activity after awakening.

What is Useful Life for White Light LEDs? *N. Narendran, J. D. Bullough, N. Maliyagoda, and A. Bierman*

The goal of this paper is to initiate a discussion within the lighting community regarding standardized measurement procedures and a definition for useful life for light emitting diode (LED) technology. In general, LEDs do not fail catastrophically, but instead their light output slowly decreases over their operating period. Presently, some manufacturers use a 50 percent light output level as the criterion for LED life. Although 50 percent light loss might be acceptable for non-critical signage applica-

tions using monochromatic LEDs, it might not be acceptable for general lighting applications. It is important to develop a method for rating lamp life and a definition of "useful life" for LEDs so, when reported by manufacturers, the lighting community can compare LEDs to traditional light sources.

The "useful life" definition for LEDs should consider light loss and color shift. Therefore, an experimental study was conducted to investigate light loss and color shift patterns of white LEDs as a function of operating time. The 5 mm type white InGaN +YAG LEDs evaluated in this experiment, representing technology commercially available in 1999, exhibited high light output degradation rates and color shifts as a function of operating time. It is further shown, using a simple mathematical fit to the data gathered during a short life-test study, and extrapolating it to predict the life of white LEDs, depends on the initial data collection period. Therefore, an alternate method for projecting LED life is investigated by overdriving the LEDs at different currents. Using their degradation patterns at higher drive currents, the life of these LEDs was predicted at normal drive current values. The results show excellent correlations between predicted light loss and actual measured losses at 20 and 30 mA drive currents for the LEDs tested. The authors believe this technique is applicable for accurately predicting life of any type of LED and hope to verify this using future configurations. This study adds information to the knowledge needed for the lighting community to develop standardized measurement procedures and a definition for useful life for LED technology.

An Efficacy Analysis of HID Lamps *Gregory J. Nelson, Ray G. Gibson and Andrew D. Jackson*

HID lamps have a wide variety of chromaticity, color rendering and luminous efficacy values. It will be shown that these three parameters are closely related to one another. This relationship is demonstrated by analyzing the luminous efficacy in terms of three efficiency factors: 1) visual efficiency, 2) maximum spectral efficiency and 3) spectral efficiency. It has been observed, in spite of the many differences between high pressure sodium, metal halide, coated mercury and even microwave-driven sulfur lamps, a remarkably linear relationship for these lamp types has been found between the spectral efficiency and CRI. The results presented give, in perspective, the limits of existing HID technologies with respect to color point, CRI and efficacy.

Non-Hazardous Fluorescent 'TL' Lamps *David C. Nesting, Manuel Oomen and Paul Walitsky*

Linear fluorescent (TL) lamps are widely used in businesses and homes because of their high energy efficien-



cy and long life. However, growing awareness and concern over the environmental hazards associated with mercury and fluorescent lamp disposal have prompted the development of low mercury non-hazardous fluorescent lamps. The mercury content in these lamps has been dramatically reduced so that they pass the U.S. EPA's stringent Toxicity Characteristic Leaching Procedure (TCLP) and other waste-characterizing tests at any point in the product life cycle. Thus, they are not considered hazardous waste. The benefits of such lamps include a lower cost-of-ownership through reduced disposal cost and less mercury in the environment due to fluorescent lighting. The background issues associated with fluorescent lamp disposal including TCLP and State of California requirements will be compared. In addition, the methodology, design criteria and testing protocol involved in the development of TCLP-compliant lamps is described.

A New Visibility Criteria for Roadway Lighting

Merle E. Keck, FIES

The ratio of the nighttime accident rate to the daytime accident rate per million miles is the best non-subjective measure of the effectiveness of fixed roadway lighting. Small Target Visibility (STV) has been adopted as a criteria for design in the most recent IESNA Recommended Practice for Roadway Lighting, but does not correlate with the night/day accident rates at speeds below 45 MPH. STV is currently calculated using a visibility model and the influence of only the fixed lighting system. When the effect of the vehicle headlights on pavement luminance, target luminance and glare are added to the calculation of target visibility, the criteria is named STV-H and correlation with the night/day accident rate is achieved at all vehicle speeds.

In order to include the effect of headlights on target visibility it has been necessary to develop and validate algorithms for calculating pavement luminance at angles other than the conventional one degree viewing angle (alpha angle) from both headlights and fixed lighting luminaries. Correlation results using all currently recommended lighting criteria and STV-H are compared using night/day accident data from FHWA Report 92-R-00016.

Additivity Constraints and Visual Task Considerations in Mesopic Photometry

Sam Berman and Robert Clear

It has been recently suggested that a mesopic photometry based on off-axis reaction times would be superior to one based on large-field brightness matching because the former exhibits Abney's law of additivity and the latter does not. We show that additivity is not a requirement for mesopic photometry and that no mesopic luminance function that transitions between

scotopic and photopic sensitivity can satisfy the requirements for additivity. A comparison of the proposed reaction time and mesopic brightness matching functions shows that they can be surprisingly similar. This suggests that a broadly based mesopic photometry may be possible. We provide a closed-form expression for off-axis mesopic luminance efficacies that depends only on the photopic luminance and the scotopic/photopic ratio.

Integrating Sphere Simulation on Spatial Non-uniformity Errors in Luminous Flux Measurement

Yoshi Ohno and Ronald O. Daubach

To obtain general knowledge on the spatial nonuniformity errors of an integrating sphere photometer associated with the spatial intensity distributions of test lamps, a series of computer simulations have been conducted for various designs of an integrating sphere measuring different types of lamps. An integrating sphere simulation program, previously developed for the realization of the luminous flux unit at NIST, has been utilized for this analysis. The program simulates interreflections in an integrating sphere and calculates the final luminance distributions on the sphere wall, as well as the detector output. Using this program, simulations have been conducted on a 2 m integrating sphere having a 30 cm circular baffle, with varied sphere wall reflectance ($\rho = 80$ to 98 percent) and baffle reflectances, the size and location of the baffle, and the angular response of the detector. Measurement errors (with respect to an isotropic point source) were calculated for actual intensity distribution data of eight different types of incandescent and discharge lamps. The results show, with a well-designed integrating sphere photometer with no contamination of coating, measurement uncertainties ($k=2$) on the order of one percent ($\rho = 80$ percent) to 0.1 percent ($\rho = 98$ percent) can be expected for typical general service lamps with no reflectors, measured against a calibration source of uniform intensity distribution. Larger errors are shown with integrating sphere photometers not properly designed.

Effects of Light Exposure on The Appearance of Meat Displays

Christopher "Kit" Cuttle, Andrew Bierman and Mary Beth Gotti

The visible degradation of refrigerated displays of meat products was examined in a three-phase experimental program. Experimental variables included:

- Fluorescent lamps with and without plastic sleeves
- Metal halide lamps with and without glass covers on the luminaires
- Three types of meat products: ground beef, lean steak and bologna sausage
- Wrapped and unwrapped meat samples



An 8 ft long refrigerated merchandiser was divided into three compartments. Different types of lighting were installed over the end compartments, and the central compartment was shielded from light and served as a control. Meat samples were prepared in plastic Petri dishes and wrapped samples were covered with the type of clear plastic film used for meat displays. They were exposed in the merchandiser continuously for up to five days. Surface temperatures of the samples were monitored periodically using an infrared thermometer and illuminances were recorded. The samples were removed briefly at intervals for their spectral reflection characteristics to be measured and CIELAB color metrics were calculated from these data.

It was found during initial testing that unwrapped samples discolored rapidly, and they were not examined further. Color changes of the wrapped samples were almost entirely due to loss of chroma or graying of the samples. Samples in all three sections of the merchandiser underwent losses of chroma over time and small but significant differences between the control and the unsleeved fluorescent lamp conditions were found, whereby the effect of exposure was to reduce the rate of chroma change. The change of chroma for Bologna sausage was more gradual than for the raw meat samples, and showed some small differences for the metal halide lighting compared with the control. The practical implications of these findings are discussed.

Psychological Processes Influencing Lighting Quality
Jennifer A. Veitch, Ph.D.

Veitch and Newsham proposed a behaviorally-based model for lighting quality research, in which individually-based processes mediate the relationships between luminous conditions and such behavioral outcomes as task performance, mood, social behavior, aesthetic judgements and satisfaction. This review paper summarizes the state of knowledge concerning mediating psychological processes: perceived control, attention, environmental appraisal and affect. These processes were selected because of their relevance to the explanations often given for lighting design choices. More explicit use of theoretically-driven predictions to guide lighting research would result in greater precision in our comprehension of lighting-behavior relationships to form the foundation of empirically-based lighting recommended practice.

Analysis and Synthesis of Lighting Atmospheres
Martin Moeck

This paper defines lighting atmospheres by referring to luminance patterns as seen from representative points in the setting that capture the mood of a particular indoor or outdoor scene. It analyzes those maps, filters

out specific pixels and averages others to form a new luminance map with regions of varying sizes and constant luminance that approximates the original map. This analysis singles out three basic light source types, which, when applied together, repeat the lighting effects on objects in the setting, i.e., a small sphere or face, so that those typical objects will look the same and see a simplified luminance map that resembles what they saw before. Lighting effects are highlights, body shadow and cast shadow properties for objects at strategic locations in the scene. The general properties of those light sources are analyzed. The verification uses spherical illuminance values derived from spherical luminance maps to prove the validity of the basic light sources as lighting atmosphere descriptors.