A Presentation by:

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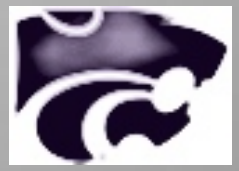
Photopic & Scotopic Light Perception, Related to Outdoor Lighting Design



Overview

- The Human Eye
- Types of Vision
- Current Design Practices
- Case Studies
- Benefits
- Questions

The Human Eye

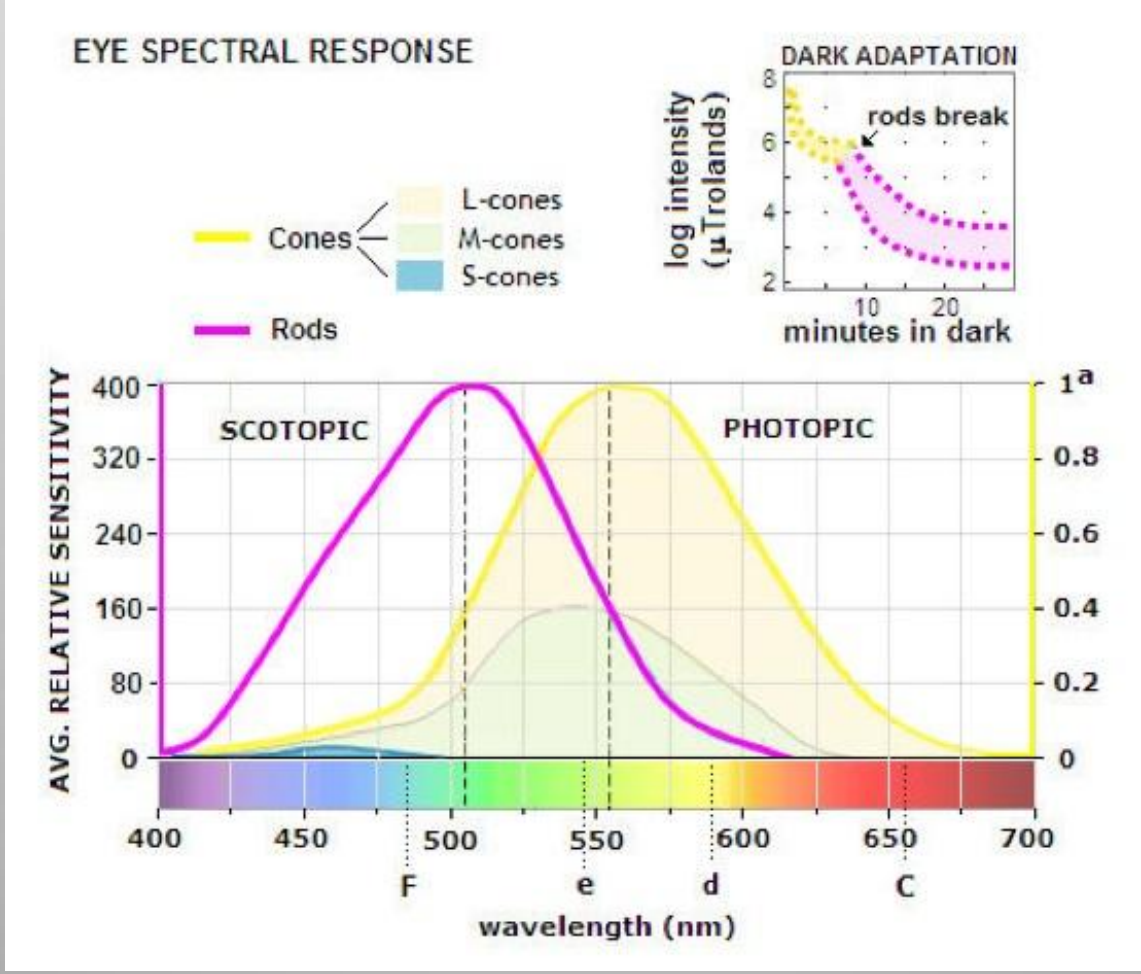
RODS

- Pick up motion
- Peak in the blue-green spectrum (505 nanometers)
- Contribute to vision more in low illumination, night time vision
- Responsible for the opening and closing of the pupil

CONES

- Sees fine detail and color
- Peak in the yellow-green spectrum (555 nanometers)
- Contribute to vision more in higher illumination, day time vision
- Types
  - L (long wavelength)
  - M (mid wavelength)
  - S (short wavelength)

The Human Eye



Eye Spectral and Intensity Response. (n.d.). Retrieved February 19, 2010, from http://www.telescope-optics.net/eye_spectral_response.htm

Types of Vision

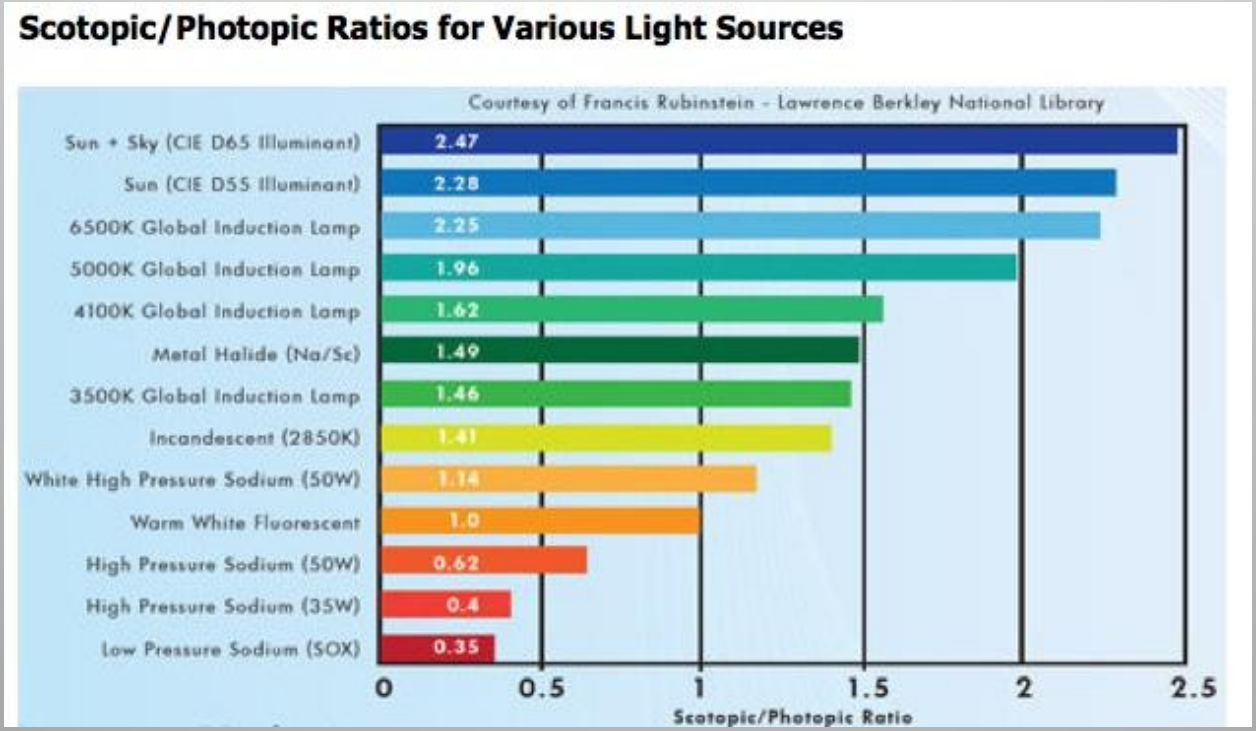
- Photopic
  - Cones are activated
  - Occurs during the day & in high illumination areas
- Scotopic
  - Rods are activated
  - Controls pupil size
  - Occurs during the night & in low illumination areas
- Mesopic
  - In-between vision
  - Rods and cones are utilized

Current Lighting Design

- Light levels are measured based on photopic lumens emitted by the source. (This is not conducive to all settings and does not reflect the way the eye operates.)
- Scotopic and rod response has been assumed to be irrelevant. (Not true as the rods control pupil size.)
- Pupil size is reduced by increasing luminance levels, this is inefficient and does not take advantage of the rods' effect on pupil size; this theory in addition adds glare.

S/P

- Ratio of scotopic to photopic lumens
- Visually effective lumens=$P(S/P)^{0.78}$



Visually Effective Light. (2010). Retrieved February 19, 2010, from http://www.globalinductionlighting.com/visuallyeffectivelighting.php?osCsid=d859be17e3de288a4b5f8574bef52487.

Case Studies

ANN ARBOR, MICHIGAN

- 1,000 LED street lights will be installed over 2 years.
- Payback period is 3.8 years
- 50% energy savings is expected

AUSTIN, TEXAS

- LED retrofit began in 2008
- City officials believe $500,00 per year can be saved by retrofitting 5,000 streetlights with LEDs

Raleigh, North Carolina Parking Garage

- 400 residents were surveyed before and after
- Residents felt the garage was safer, cleaner, and had better light-quality after the change-out.
- Overall preference was for the LED fixtures.
- Energy efficiency increased with the LED change-out, resulting in a 40% energy savings.

Raleigh, NC Parking Garage **before** with HPS lamps

Raleigh, NC Parking Garage **after** with LEDs

Survey Shows Public Feels Safer in City Spaces Lit by LEDs. (n.d.). Retrieved February 19, 2010, from http://www.cree.com/press/press_detail.asp?i=1175179209372.

Better Days BP
Racine, Wisconsin

- All LED exterior lighting
- Enhanced appearance
- 62% energy savings

Better Day BP – Racine, WI. (n.d.). Retrieved March 10, 2011, from http://www.betaled.com/us-en/LEDApplications/entire-site/better-day-bp.aspx.

Cub Foods
St. Paul, Minnesota

- Area and security parking lot lighting
- Full cut-off complying with Dark Sky
- Improved visibility and security for customers
- 0.085 w/sf, 57% below LEED required 0.15 w/sf
- 5.46 average footcandle rating with today's luminance meters

Cub Foods – St. Paul, Minnesota. (n.d.). Retrieved March 10, 2011, from http://www.betaled.com/us-en/LEDApplications/entire-site/cub-foods.aspx.

Universities

- Kansas State University
- Notre Dame
- California State University
- University of Colorado
- University of Alaska

Site and Area, Project Gallery. (n.d.). Retrieved March 10, 2011, from http://www.betaled.com/us-en/LEDApplications/ProjectGallery/Entire-Site.aspx.

Poyntz Avenue

- Background
- Topics Surveyed
- Results
- Conclusions

Background – Poyntz Ave.

- Poyntz Avenue from the Mall to Juliette
- Existing fixtures are 150 W High Pressure Sodium
- Replacement fixtures will be 51WLED
- Each pole has 2 two lamps in acorn style housings
- Mounting height: 11’

Background – Poyntz Ave.

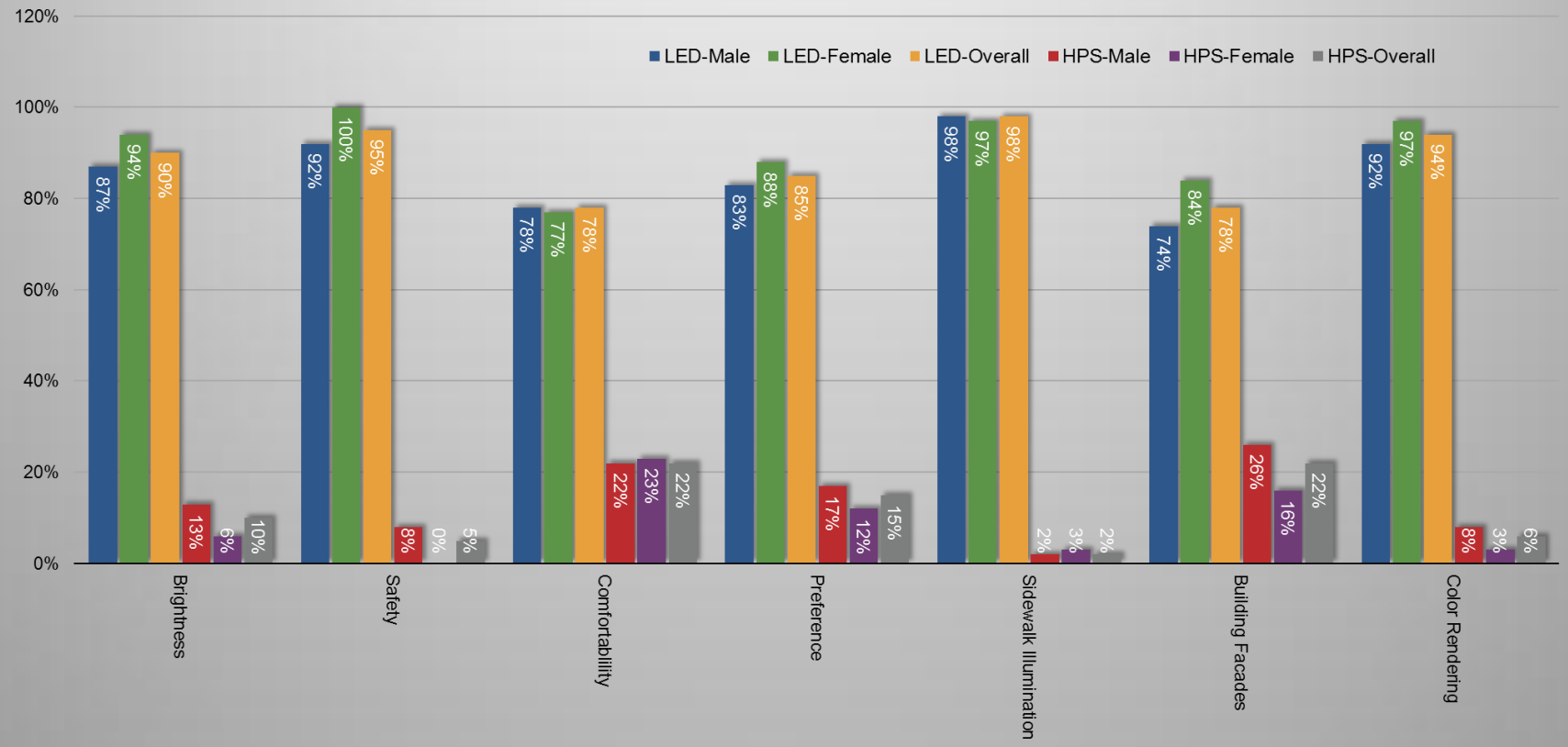
- Survey took place: May 2, 4, & 5 2010 from 9-10:40pm and September 14 & 15 from 8:15-10pm
- 89 individuals participated
- Majority of participants were college-aged

Survey Topics – Poyntz Ave.

- Gender
- Brightness
- Feeling of Safety
- Feeling of Comfort
- Overall Preference
- Sidewalk Illumination
- Building Façade Illumination
- Color Rendering
- Uniformity of Distribution
- Ease of Reading
- Seeing & Distinguishing Objects
- Comments

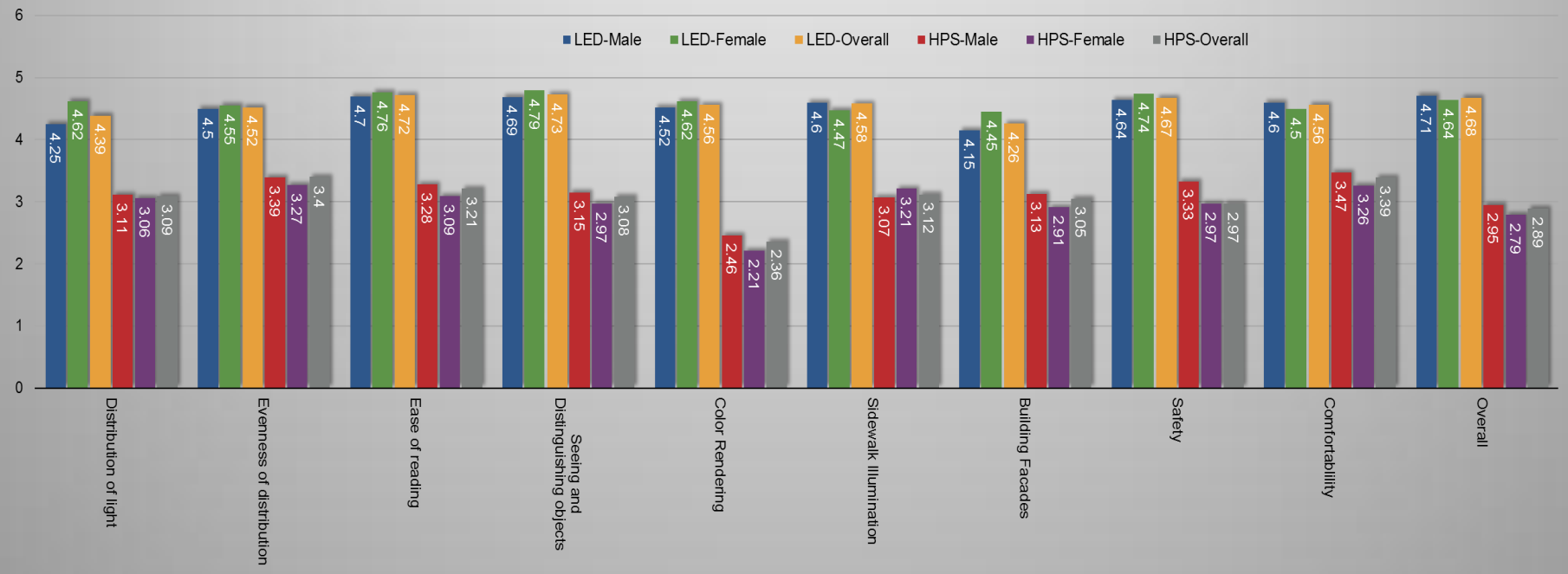
Survey Results – Poyntz Ave.

Percentage Results of Participant Preference



Survey Results – Poyntz Ave.

Average Results of Ratings
(5=most favorable, 1=least favorable)



Survey Conclusions – Poyntz Ave.

- Large preference towards LED
- Readings reinforced the idea that LEDs appear brighter than HPS

Lamp	Luminance Meter, Avg. (fc)	S/P Ratio	Pupil Reading (fc)
LED	2.23	2.00	3.83
HPS	2.02	0.62	1.39

- 66% energy savings for the city ~ $4,150/yr
- Decreased required maintenance
- Results correlated with results from other surveys and studies.

Benefits of LED Outdoor Lighting

- Many uses: area, sign, pedestrian, security, landscape, architectural, and decorative lighting applications
- Many colors available and color temperatures
- Dynamic control capability
  - can be dimmed and flashed
  - increases efficiency and security & safety
  - broadens installations opportunities
- Uniform distribution
- Low light pollution

Benefits of LED Outdoor Lighting

- LED diodes do not get hot
  - greatly reducing the risk of burning patrons
  - greatly reduces risk of fire
- No risk of lamp explosion or breakage
- Zero toxic or harmful materials
- Efficient
  - low energy cost
- Long lamp life
  - low maintenance
  - reduced risk to maintenance personnel (can be difficult and dangerous to reach)
  - failure is less likely

Benefits of Incorporating Scotopic Vision

- Increased energy efficiency
- More adequate luminous levels for the given space and tasks
- Increased visual accuity
- Owner and occupant satisfaction, as individuals prefer scotopically enhanced lighting

"I predict within the next 10 years you're going to see street lights all over Toronto either converted or in the process of being converted to LED lighting, because LED lights will reduce the energy consumption by 50% or more. It's a no brainer really to do this. It will save tax payers' money and save the environment."

- Joe Pantalone, Deputy Mayor of Toronto