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Investigating the Health Impacts of Outdoor Lighting

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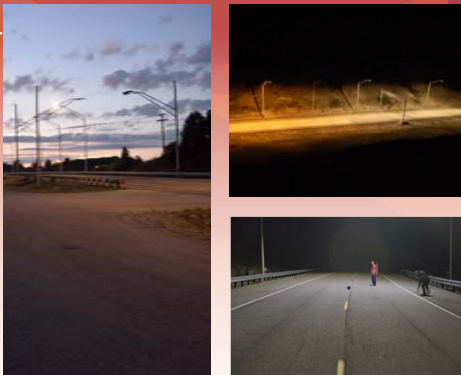
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PROJECT OBJECTIVE

The objective of this project, Investigating the Health Effects of Outdoor Lighting, is to measure the impact of solid-state lighting on the users of an outdoor lighting space. At a minimum, users can be defined as drivers on a roadway, pedestrians, and those living close to a lighted area. This project is measuring the effects of different lighting types on the melatonin levels of different users of lighted spaces at light dosage levels appropriate to that space.

Independent Variable	Luminaires to be tested
Lighting Type	No roadway lighting
	2100K HPS
	2700K LED
	4000K LED
	5000K LED
6500K LED	
Exposure Time	Between 1.5 and 6 hours, depending on the task

Table 1. Experimental Variables

Independent Variables

Luminaires:

Five different light sources with different spectral contents were tested. The luminaires were evaluated in terms of the circadian and neuroendocrine phototransduction of the intrinsically photosensitive retinal ganglion cell (ipRGC) system (melanopic, rhodopic, cyanopic, chloroptic and erythropic as per Lucas et al., 2014) and CCT using custom-developed software.

Activities:

Three different user types/types of light exposure were tested:

- Driver
- Pedestrian
- Person residing near the lighted area (light trespass)

Dependent Variables

Primary Data:

- Melatonin concentration in each user type was measured under each lighting condition over an exposure time determined based on user type (see Table 2).

Secondary Data:

- For drivers, the detection distances of a series of visibility objects were recorded as part of a visibility experiment.
- For pedestrians, the perception of how safe it is to cross the road in front of an opposing vehicle was measured.

Controlled Variables

- Roadway luminance was maintained at 1.0 cd/m².
- The experimental time, start time, duration, and light exposure times were controlled.
- The participant age, sleep cycle, and daily activity were monitored and controlled.
- The on-road and in-experiment activities were controlled while the participants were in the experimental area.
- Light exposure from the beginning to the end of the experimental period was controlled.

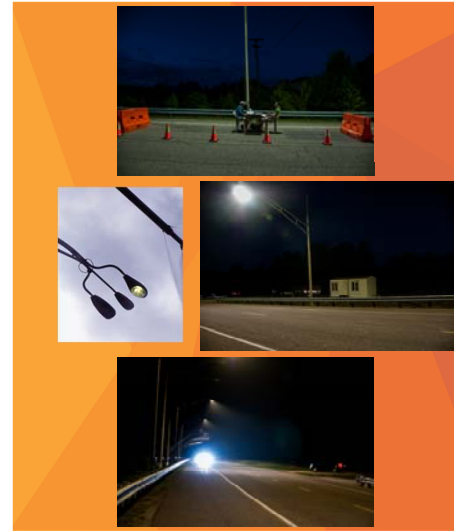
Participants

Ten participants meeting the following criteria were recruited to participate in each of the study's three exposure experiments (for a total of 30 participants):

- Between the ages of 18 and 30 years, gender balanced, non-smokers
- Maintain a normal sleeping schedule monitored using logs and actigraphy
- Avoid substances containing alcohol (24 hours) and caffeine (after midday)
- No napping after 6:00 p.m.
- Use an eyeglass frame-mounted light measurement system to record exposure

Test Facility

The three naturalistic outdoor exposure scenarios were established on the lighted section of the Virginia Smart Roads. The lighting poles are outfitted with height-adjustable triple-tenon arm, allowing the mounting of three luminaires per pole.



Drivers

Time of Exposure	Duration of Exposure	Light Level / Cornea Irradiance	Light Source	Blood/Saliva Sampling	Tasks
11 a.m. to 1 a.m.	2 hours	200 lux	Incandescent	No sampling	
1 a.m. to 3 a.m.	2 hours	1.0 cd/m ²	No roadway lighting 2100K HPS 2700K LED 4000K LED 5000K LED 6500K LED	Saliva at 30-minute intervals	Visibility assessment tasks

Pedestrians

Time of Exposure	Duration of Exposure	Light Level / Cornea Irradiance	Light Source	Blood/Saliva Sampling	Tasks
8 p.m. to 10 p.m.	2 hours	200 lux	Incandescent	No sampling	
10 p.m. to 2 a.m.	4 hours	1.0 cd/m ²	No roadway lighting 2100K HPS 2700K LED 4000K LED 5000K LED 6500K LED	Saliva at 40-minute intervals	Gap acceptance tasks, walking, sitting at a table, etc.

Light Trespass

Time of Exposure	Duration of Exposure	Light Level / Cornea Irradiance	Light Source	Blood/Saliva Sampling	Tasks
10 p.m. to 12 a.m.	2 hours	200 lux	Incandescent	No sampling	
12 a.m. to 2 a.m.	2 hours	3 lux	No roadway lighting 2100K HPS 2700K LED 4000K LED 5000K LED 6500K LED	Saliva at 40-minute intervals	Laying / Sleeping in bedroom located close to the roadway

Table 2. Exposure Criteria

Testing

Each participant completed eight weeks of testing:

- Positive Control (one week)
- Negative Control (one week)
- Six weeks of testing (one week for each lighting condition)

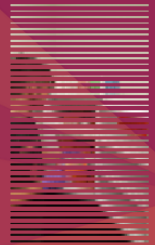
Each test session included a conditioning period and an exposure period

- Conditioning occurred in a controlled indoor environment
- Exposure for the control tests occurred in controlled light space
- Exposure for other tests took place on the Smart Roads

Exposure times and tasks were established based on the test type (see Table 2)

Light exposure was monitored with a dose measurement device.

Samples were centrifuged and stored for shipping for radioimmunoassay.



Analysis

- ANOVA LOGIT and other statistical approaches will be used to evaluate the effects of light source type on the melatonin concentration in blood.
- Analysis will include the melanopic metrics developed as part of the light characterization activity

Project Impact

This project is expected to have a significant and immediate impact on the lighting industry. The results have the potential to determine the best CCT for outdoor lighting and indicate whether a particular CCT can impact user health. Thus, the findings will allow agencies and governments to immediately restart the conversion of outdoor lighting systems to solid state lighting and help them make science based, informed decisions moving forward.

Status

All of the on road activities are complete and data analysis is currently underway. The analysis is scheduled to be completed in April, and final report of the results will be completed by September.

The Team



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