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- Special Projects Team

Evaluation of High Efficiency LED Lighting

2 NOV 2011

US ARMY RDECOM

US ARMY NATICK SOLDIER RD&E CENTER

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Current Lighting System

Jameson Fluorescent Lights

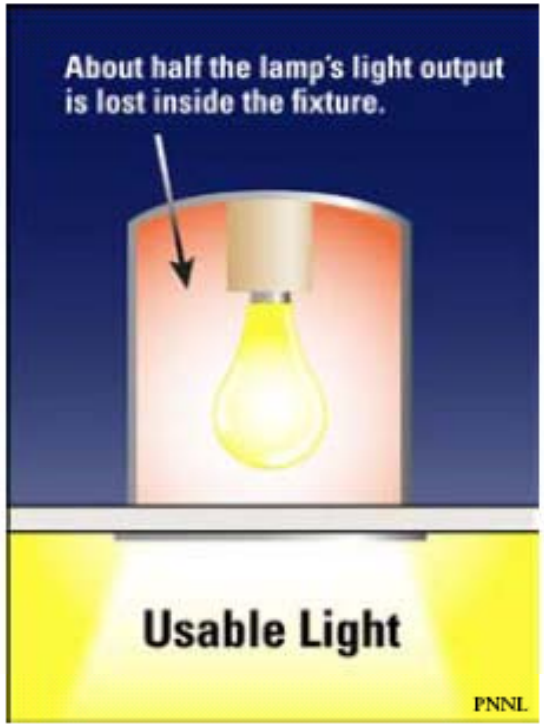
- Electronic Ballast
- Illumination 1598.44 lux
- Length 32.8 inches
- Weight 4.5 lbs each
- 0.35 Amps

- Challenges
  - Heavy and Bulky
  - Expensive
  - Non-Repairable in the Field
  - Ballast Challenges
  - Lower Light Quality and Efficiency
  - Requires HAZMAT cleanup

Current Lighting System

Fluorescent Lighting

- Emits light in all directions
- Light can be lost inside the fixture
- Light can be reabsorbed by the lamp
- Light is not directed to maximize its usefulness.



Source: Dept. of Energy

Military Specifications

- MIL-PRF-44259D
- **Light Set** must:
  - be interconnected with up to 11 other lights
  - provide for the water resistant pass through of fixed external power cords
  - have fixed power cords with a NEMA 5-15 plug at one end and a NEMA 5-15 receptacle at the other
  - have an on/off switch on the NEMA 5-15 plug side
  - have a total length of no less than 113 inches and no more than 120 inches
- **Input voltage** must:
  - operate on a voltage of 120 volts alternating current at 50 to 60 Hertz
- **Input current** must:
  - be a maximum of 0.7 amps
- **Illumination** must:
  - provide a minimum of 1506.95 lux per each light when measured 18 inches from the light

LED Lighting

Shelter Illumination through Light Emitting Diodes (LED's)

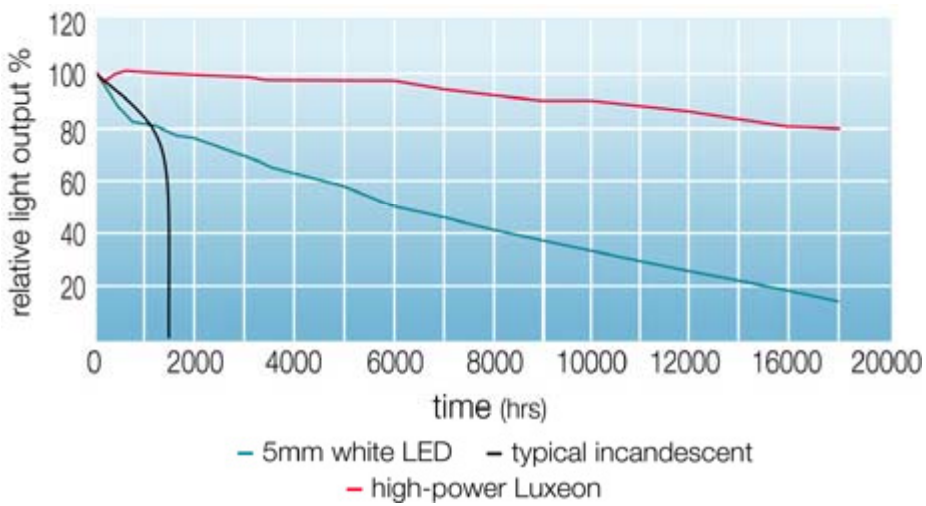
Benefits:

-Produces necessary illumination using less power
-Instant Blackout Capability
- Non hazardous materials
- High quality of light across all wavelengths (CRI)
- Compact, lightweight
- Optimized optomechanics for even, non-dazzling light
- All light is directed to the floor (no dispersed light)
- 10 times longer life than fluorescent light
- Instant on, with no warmup period
--Durability

Extremely Long Life Span

- In ideal condition (~25^{0}C), the life span of LED lights is around 100,000 hours
  - 100,000 hours < 20 years
  - The life span of current LED lights is longer than that of the shelter they will be used in
- Life span compared to other lighting systems:

	Incandescent	Fluorescent	Solid-State
Average Life Expectancy	1000 – 1500 hours	10,000 – 12,000 hours	**50,000 – 100,000 hours**



Design Goal

The development of a solid state LED lighting system that is 1) equal to or greater than fluorescent lighting in efficiency (economy), while 2) producing an equivalent or better light output suitable for deployed military lighting needs

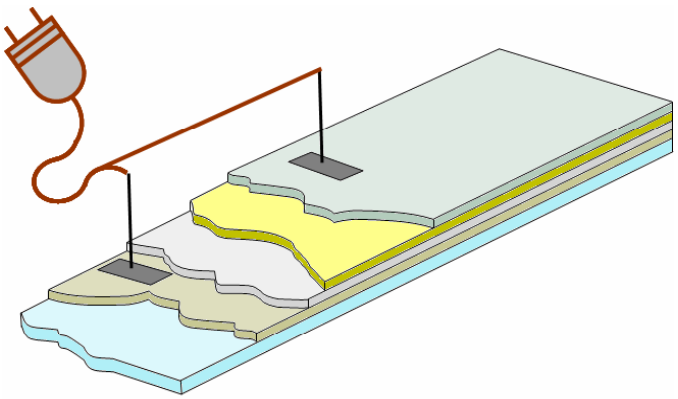
SBIR Design Challenges

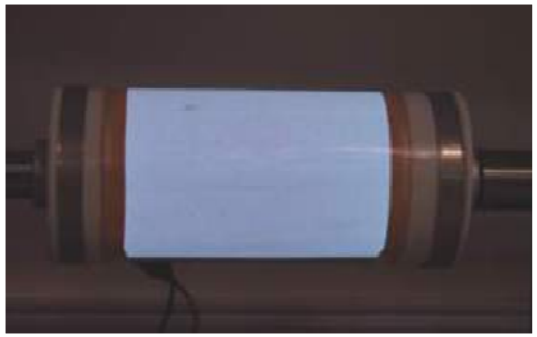
1. In Fy2004, large, high output LEDs were inefficient ~ only 50-60 lumens/watt
2. High output LEDs clustered in a quantity equal to fluorescent generated significant heat.
3. Requirement for small housing + high heat required on-board cooling system
4. High output LED's were very expensive
5. Complex power management system
6. And many more…

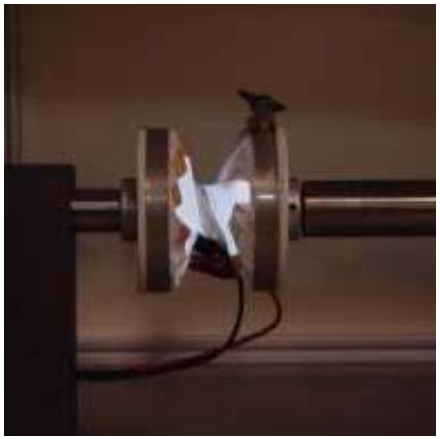
Electroluminescent Lighting

Flexible, Electroluminescent (EL) Lighting Surfaces:

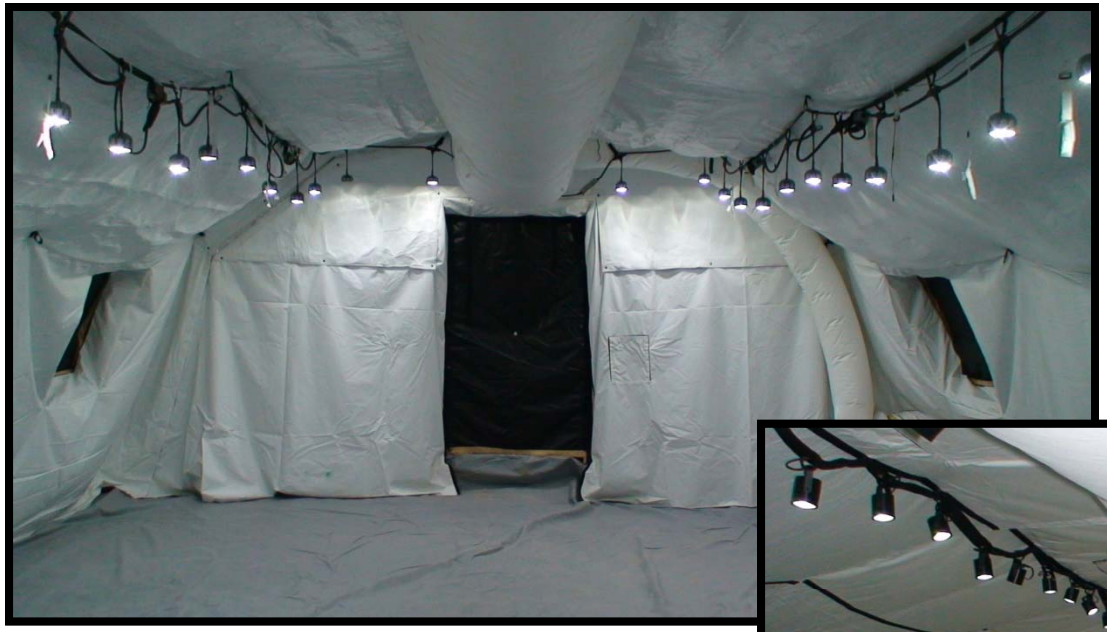
- Provide general illumination for shelters
- Decreases deployment time, weight, and cube
- Polymer-based lighting surfaces are flexible, durable and safe
- Can be printed on multiple substrates (including fabric)
- Puncture of EL lamp does not cause failure







SBIR Deliverables



Techshot

Physical Optics Corp.

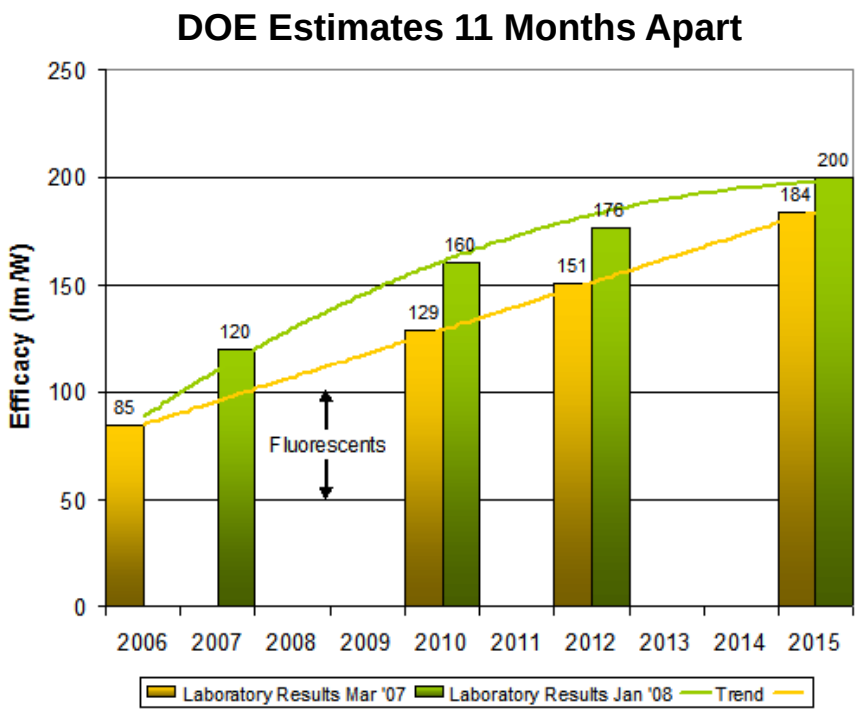
Market Need – Filling the Gap

Comparison of General Lighting Types Available Today

Deployed Shelter Lighting Needs	Incandescent	Fluorescent	Solid State
Light Output	504 lm (40 watt bulb)	3060 lm (36 watt T-8)	4320 lm (36 watt input)
Efficiency (lm/w)	12.6 lm/w	ave~ 85 lm/w	120+ lm/w
Standard Color Temperature	2700-3000 K	2700-6000 K	2500 - 6000 K
Ave Life Expectancy	1000-1500 hrs	10-12,000 hrs	50-100,000 hrs
Dimmer Capability	YES	NO	YES
Adjustable Color	NO	NO	YES
Perform in wide thermal range	YES	NO	YES
Robustness of Design	NO	NO	YES
Drop Shock/Concussion Tolerant	NO	NO	YES
Integrate into structure	NO	NO	YES
Immediate Blackout Capability	NO	NO	YES
Logistical Support	HI	HI	MED

➢*231 lm/w LED recently demonstrated (driven at 350mA and color temperature of 4500K)*

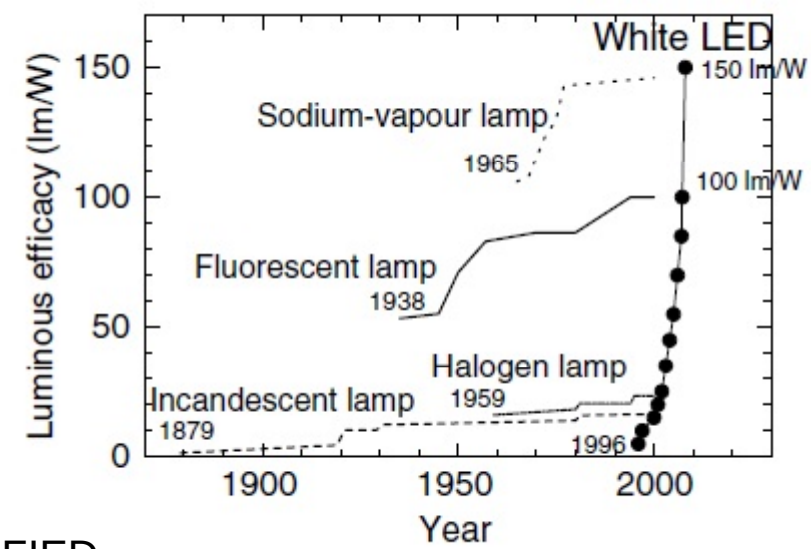
LED Efficiency Improvements



The Luminous efficiency of white LED technology has been increasing at an unprecedented pace, with **231 lm/w** recently being demonstrated.

- Testing of systems with an efficiency of 120+ lm/W underway, representing a 40% reduction in energy use without accounting for the more efficient distribution of light by LEDs.

- Assuming a 170 watt LED system vs. fluorescent, a single shelter would save 125 gallons of fuel if run continuous for a year off of a 60kW TQG.



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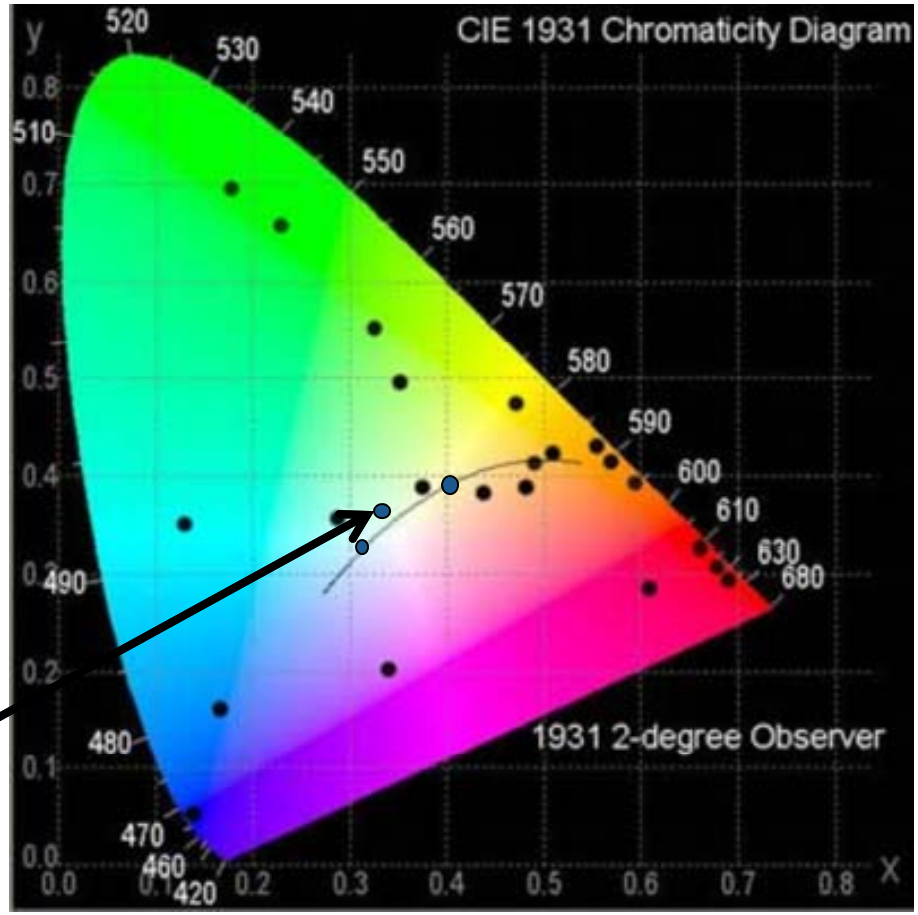
The Science Behind LEDs

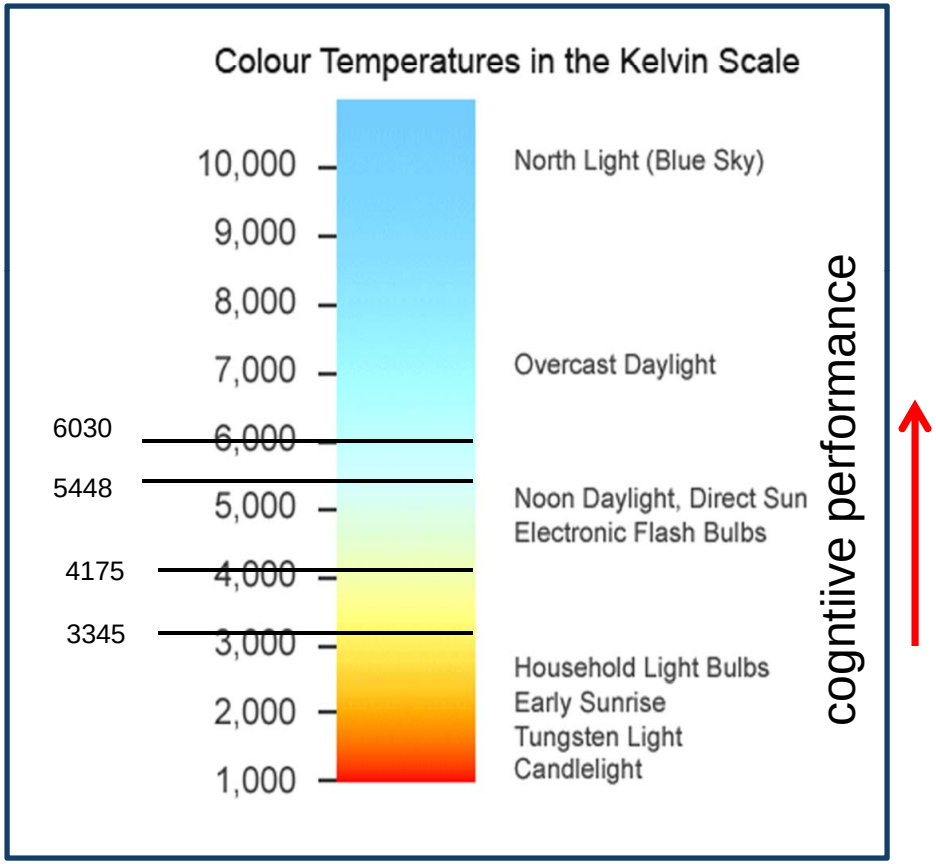
- Conducted Evaluations to prove the benefits of LEDs
  - Tests include:
    - Efficiency
    - Energy and light output
    - Current
    - Temperature of light output
    - Color of light (shown right)
    - Durability

    - Tested prototypes of various color temperatures across the white LED range.



The many different LEDs and their respective color output

Impact of Color Temperature on Cognitive Performance



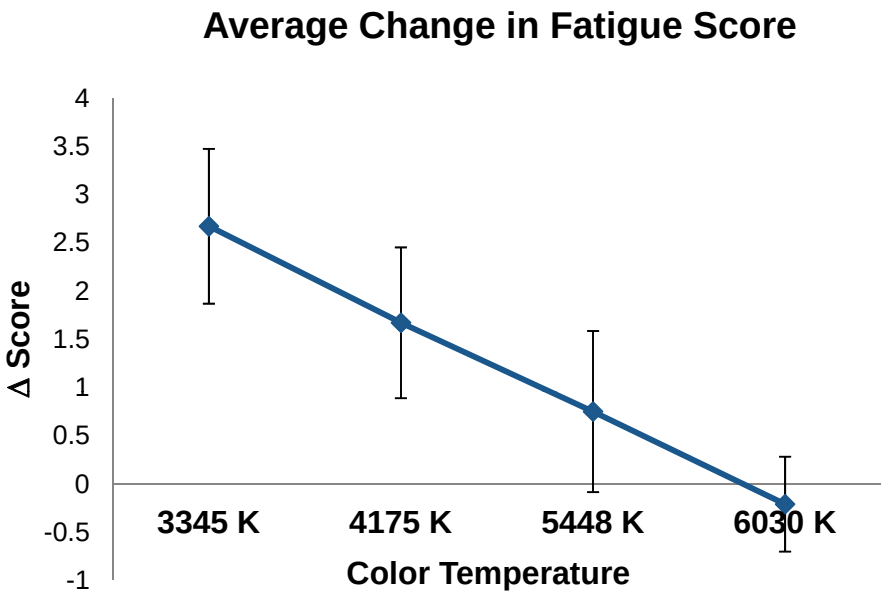
Cognitive Performance Analysis

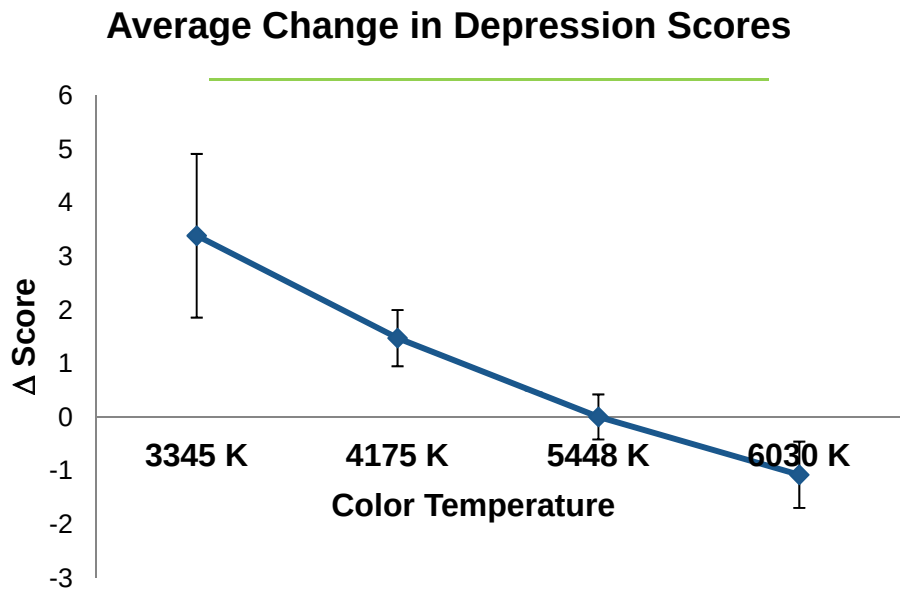
Recently, testing of the cognitive performance of Soldiers at Natick while subjected to various LED systems which feature different color temperatures took place in an attempt to find a correlation between color temperature and Soldier performance.

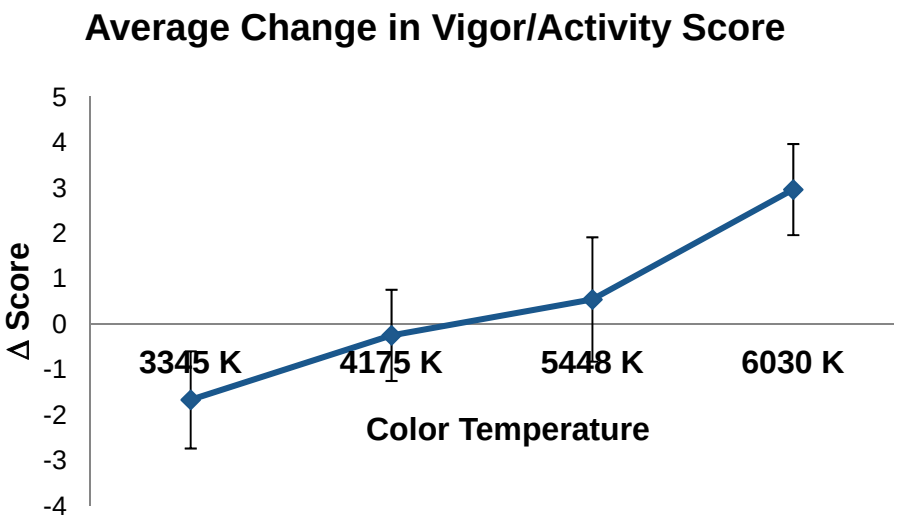
Tasks

- Color recognition
- Visual acuity
- Cognitive tasks
- Mood assessment

Results: Mood Measures

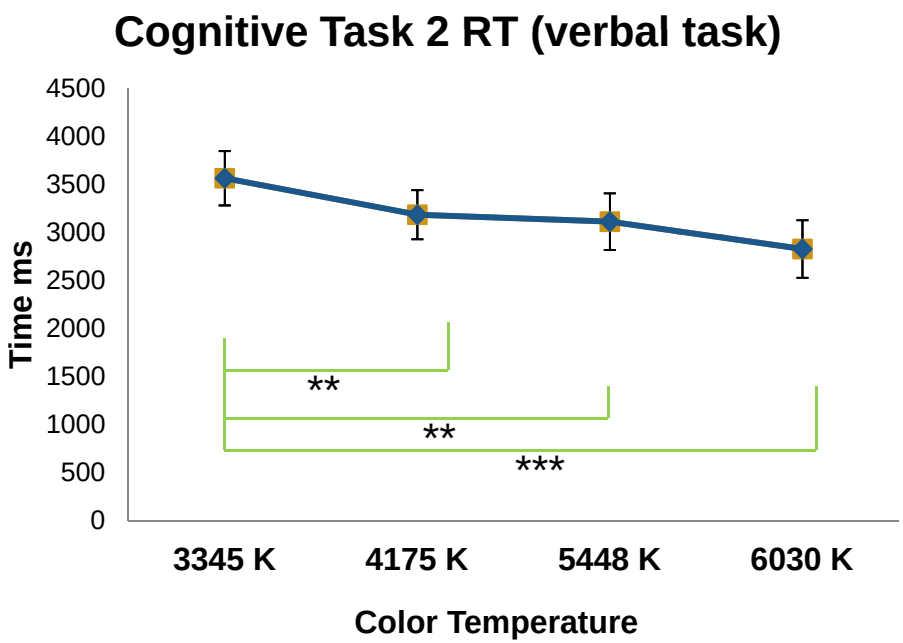


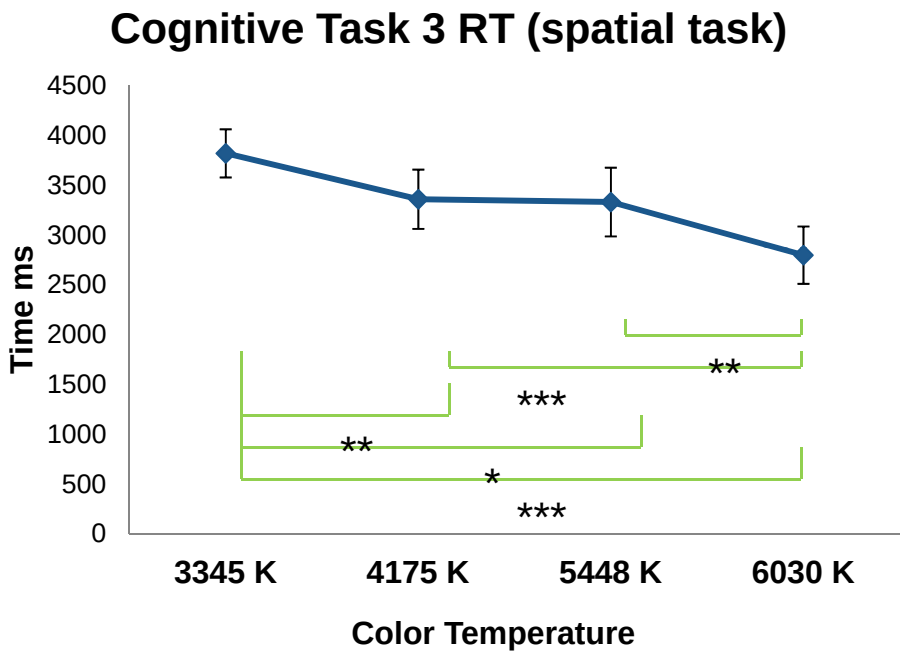




Results: Cognitive

Cognitive Tasks





Not significant:

- CT1 (auditory sequence monitoring) Accuracy
- CT2 (verbal event planning) Accuracy
- CT3 (spatial memory) Accuracy

*** = p < .01
** = p < .05
* = p < .10

Cognitive Study Conclusions

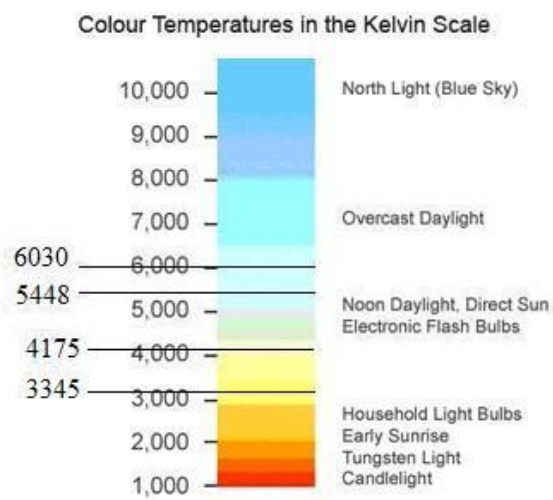
Impact of higher color temperature

- Faster color recognition visual perception tasks
- Higher arousal states and lower depression ratings
- Faster reaction times on cognitive tasks
- Increased comfort level and willingness to spend time in lighting area

Lighting → mood → task performance

LED

Fluorescent



LED Technology Status

Technical Readiness Level 8

- Systems available that are fieldable and can save 30+% energy compared with fluorescents
- Price is still a limiting factor despite ROI's that make them justifiable
- Working with PM-FSS to field test larger quantities for potential transition

Future Developments

- More testing of color temperature affects on cognitive performance

- Currently selecting Phase I SBIR proposals for a hybrid day lighting solution that'll utilize both concentrated daylight and supplemental LED lighting to significantly reduce energy use.

- Begin larger scale LED testing at Fort Devens SIL

- Completion of NSRDEC lighting test lab
  - Multiple switched circuits to compare systems
  - Integrated illumination, color temperature, and current sensors connected to a central data acquisition system

Questions

POC:

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