What is Dimming?

Project Update

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Alliance for Solid-State Illumination Systems and Technologies

Lighting Research Center

Please Note…

- The information contained in this presentation is preliminary and still under investigation. Please do not circulate.
- Once the research is finalized, we will submit reports or documents and provide an electronic copy to you.

Introduction

- No formal definition of dimming
  - Universally understood as the ability of a light source to change in light output between fully on and a minimum value
    - Incandescent lamps: dim to zero
    - Linear fluorescent lamps: could dim to 1%
  - Dimming modes: continuous or step
    - Purpose of dimming: ambiance, energy savings
- Objective: Identify parameters that create a precise definition of dimming

Background

- LRC research focused on
  - Evaluating dimmers/lamps under NEMA SSL-6
    - Electrical characteristics
    - Dimming profile
    - Flicker
  - Conducting human factors research to understand consumer requirements

Literature review

- IES Lighting Handbook (2000) identifies the following issues with dimming
  - Dimming is contextual: absolute light levels, color shift
    - Conference room: reading vs. audiovisual presentation
    - Color shift may be desirable in hospitality applications
      - May be desirable and expected from incandescent lamps
      - Not desirable from fluorescent lamps
  - No flicker
  - No audible sound

Literature Review

Dimming Characteristics Identified in NEMA SSL-6

Human Factors

- Dimming profile
- Dead travel
- Monotonic dimming
- Audible noise

Photometric

- Maximum light output
- Minimum light output
- Color shift
- Light level turn on compared to set light level
- Flicker

Electrical

- Inrush current
- RMS current
- Voltage ring up
- Current ring up
- Pop on phase angle
- Turn on time
- Turn off voltage
- Current crest factor
- Efficiency

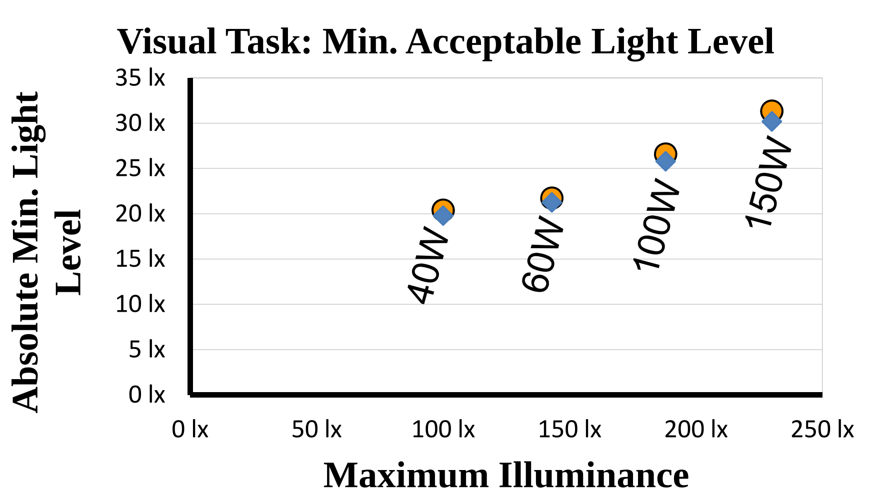
Study Focus
Selected Parameters to Define Dimming

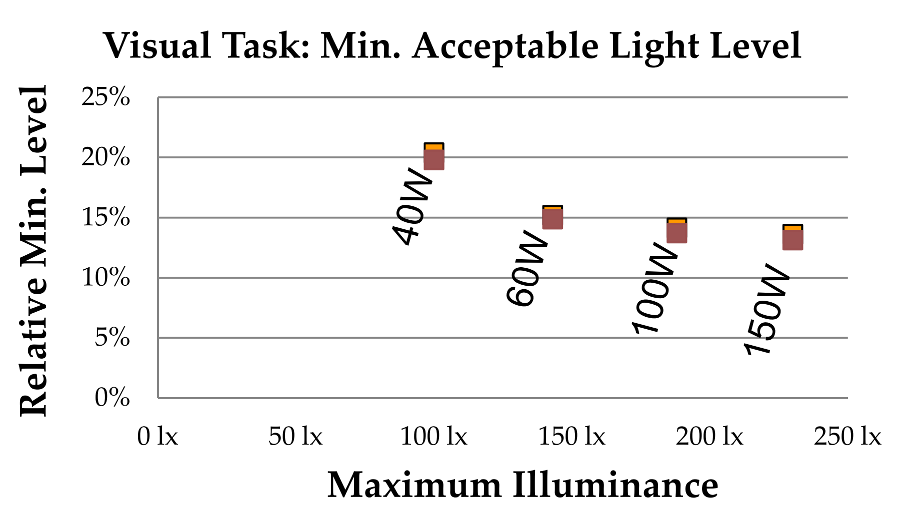
1. Minimum light level
2. Dimming profile
   - 2.1. Dimming curve
   - 2.2 Dead travel
   - 2.3 Monotonic dimming
3. Flicker
4. Audible noise
5. Maximum light level

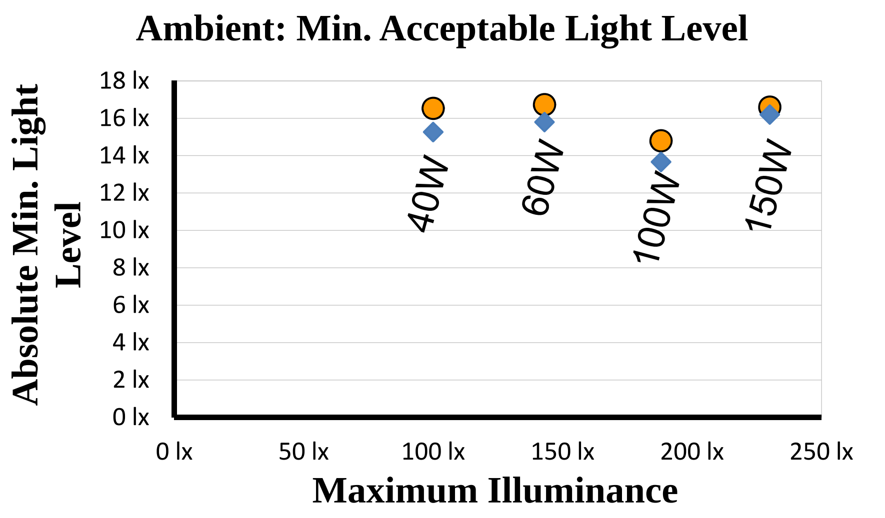
1. Minimum Light Level
Experimental Design

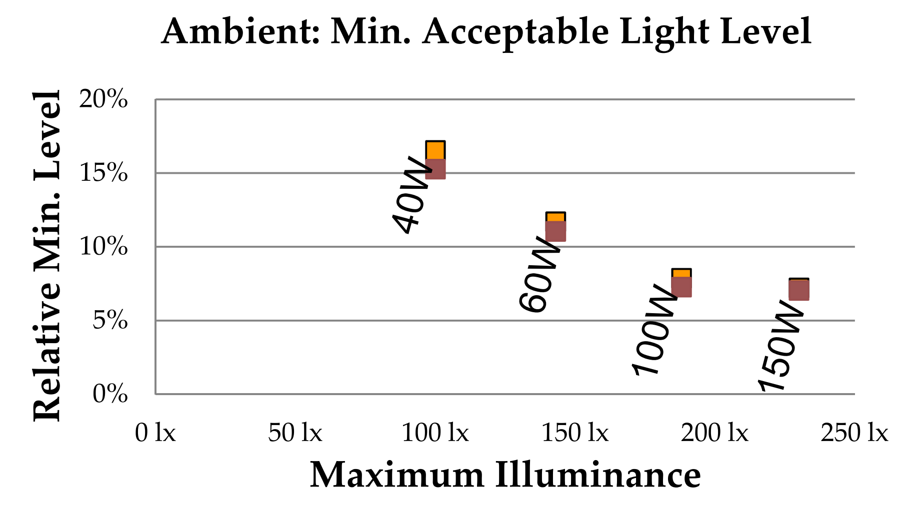
- Reading task
  - "Please let me know when the light level reaches the minimum acceptable level where you can still search for names and numbers in the white pages."
- Ambiance setting task
  - "Please let me know when the light level reaches the minimum acceptable level that you would dim to make the room relaxing and comfortable."

1. Minimum Light Level
Results









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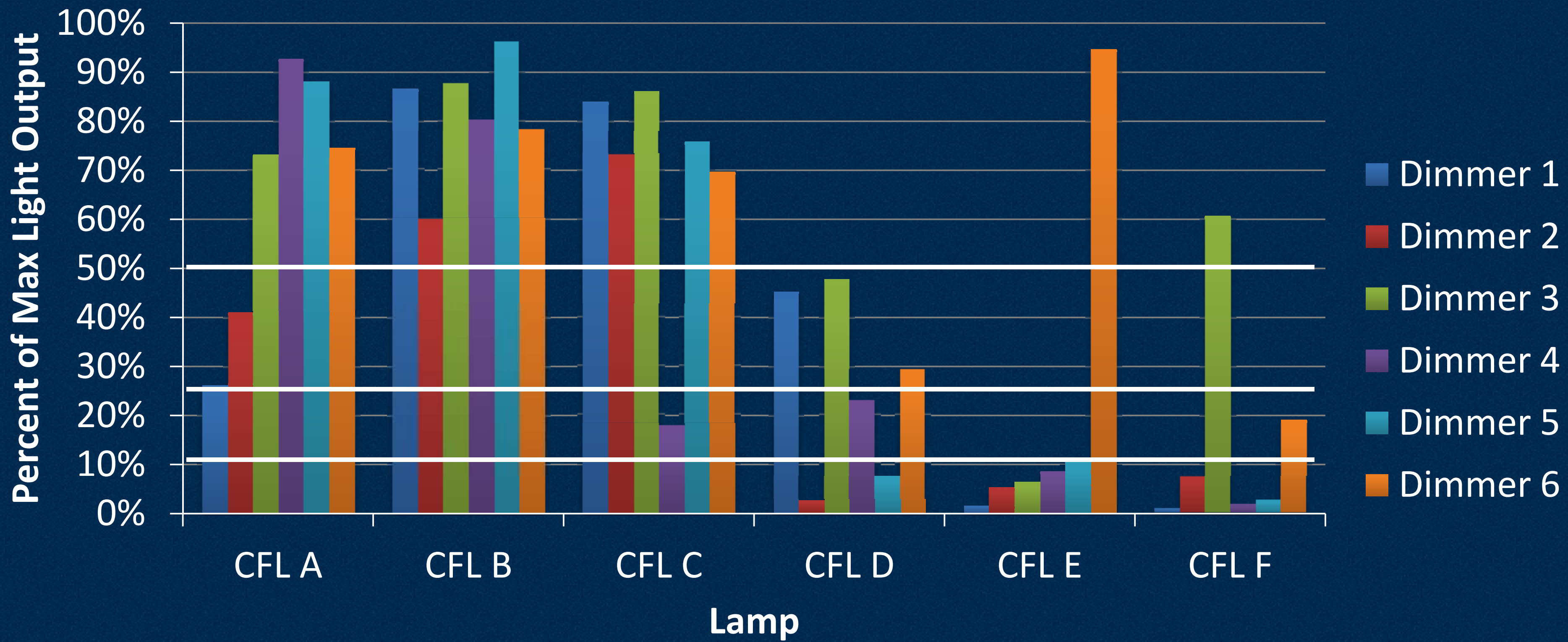
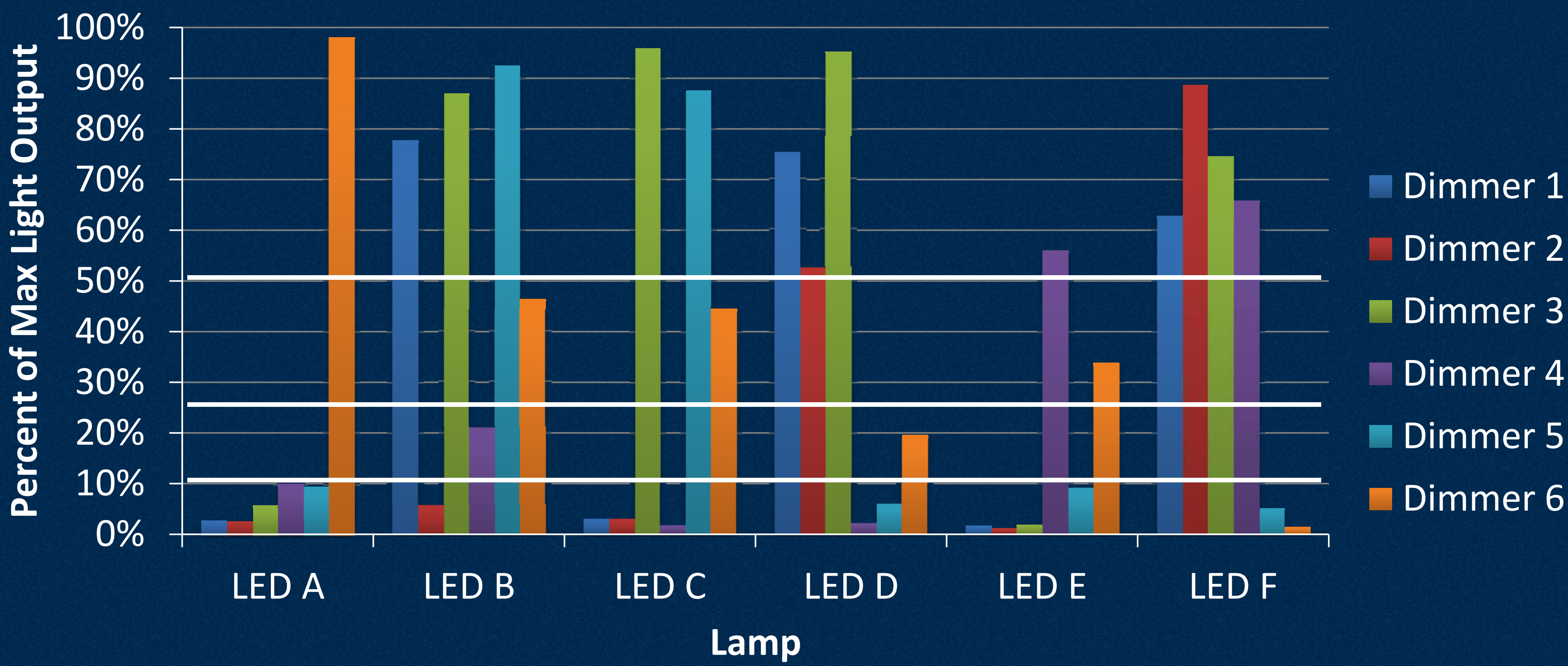
1. Minimum Light Level
CFL samples



19 (53%) combinations dim below 50%
13 (36%) combinations dim below 25%
10 (28%) combinations dim below 10%

1. Minimum Light Level

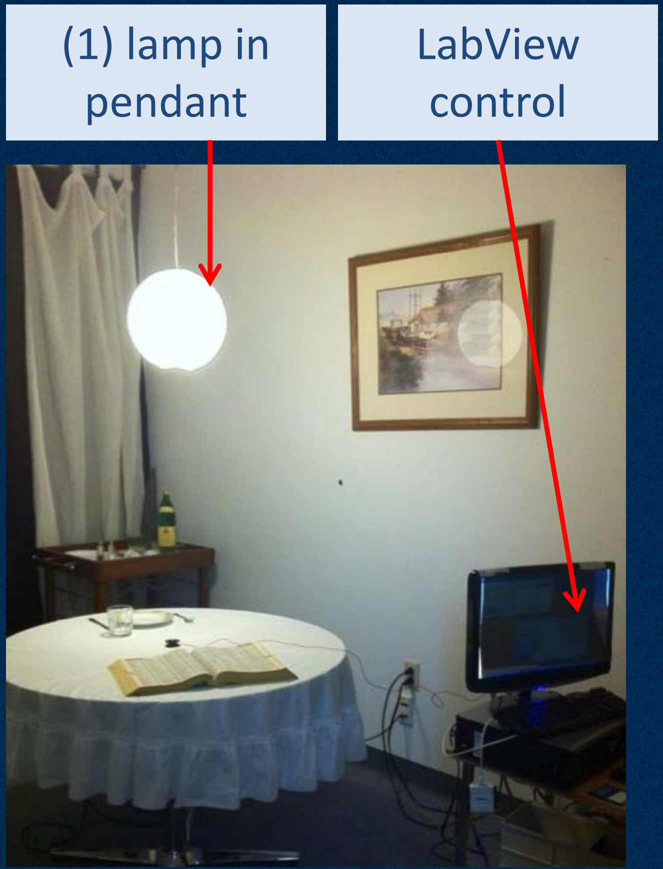
LED samples



22 (61%) combinations dim below 50%
19 (53%) combinations dim below 25%
17 (47%) combinations dim below 10%

2.1. Dimming Curve
Experimental Design

- Subjects were asked if the light level of each presentation matched their expectations of the light level (in percent) as stated by the experimenter.



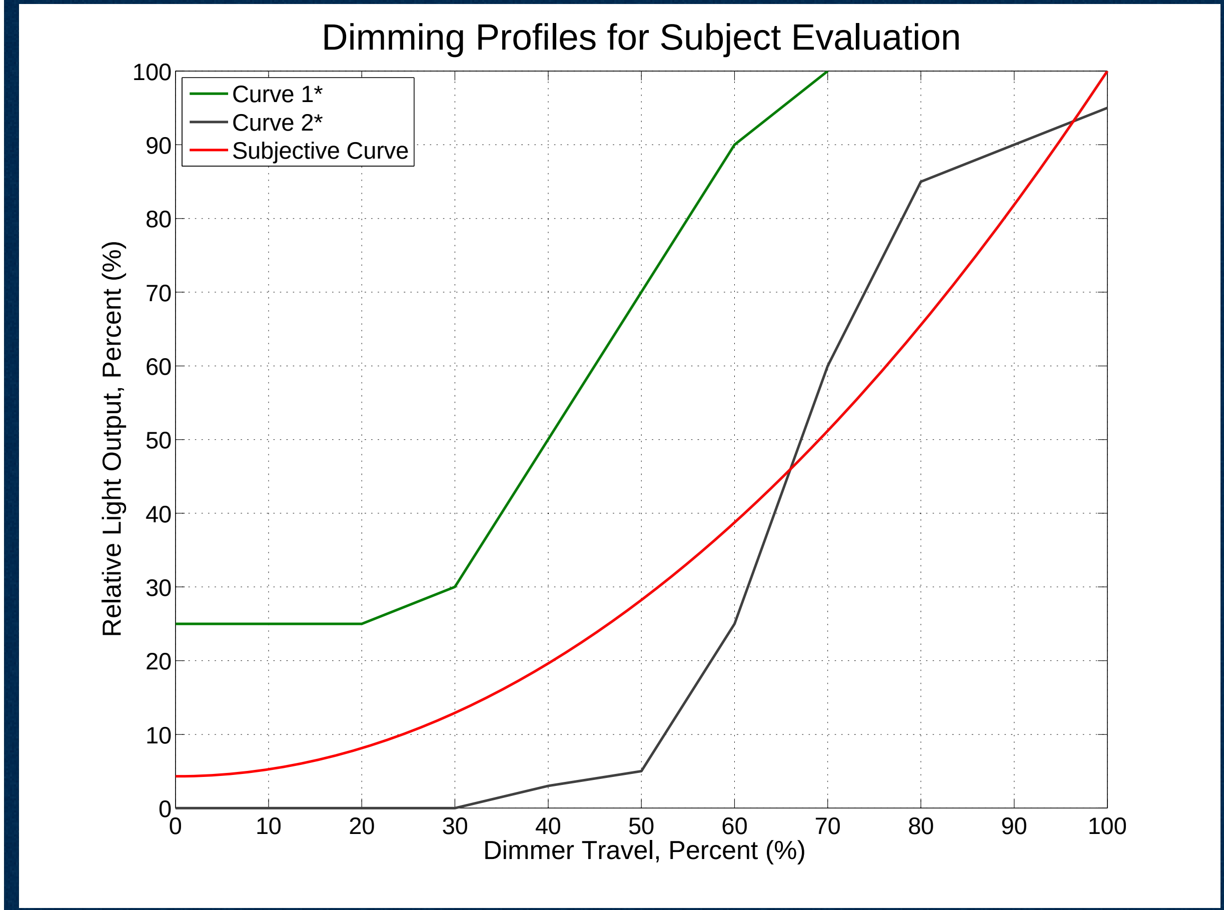
2.1. Dimming Curve
Results

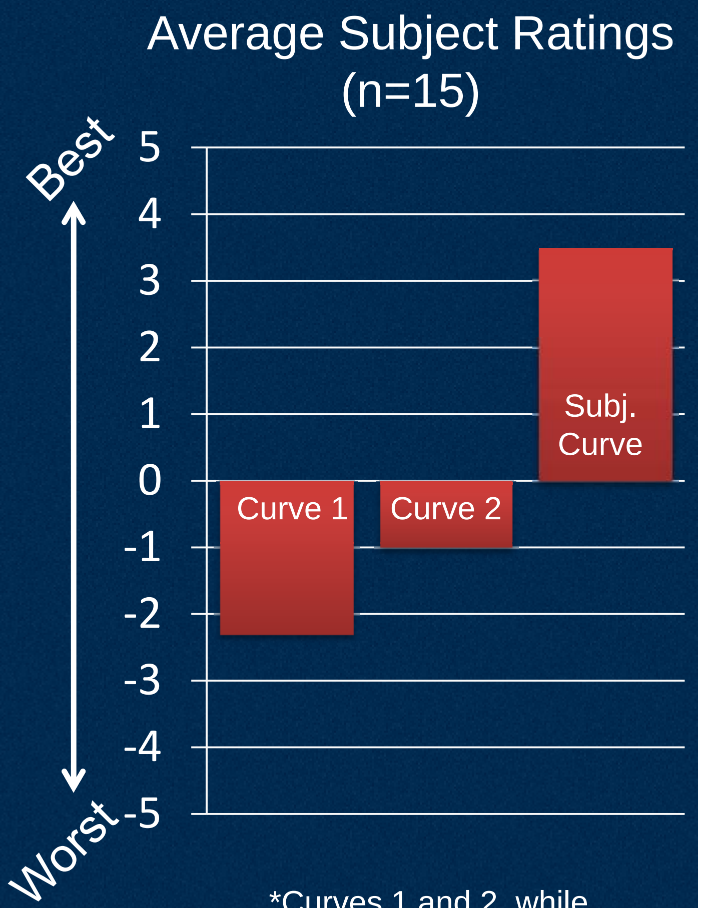
Relative Perceived Light Output (%)

Experiments verified the square law curve for brightness perception (n=15)

2.1. Dimming Curve

Results

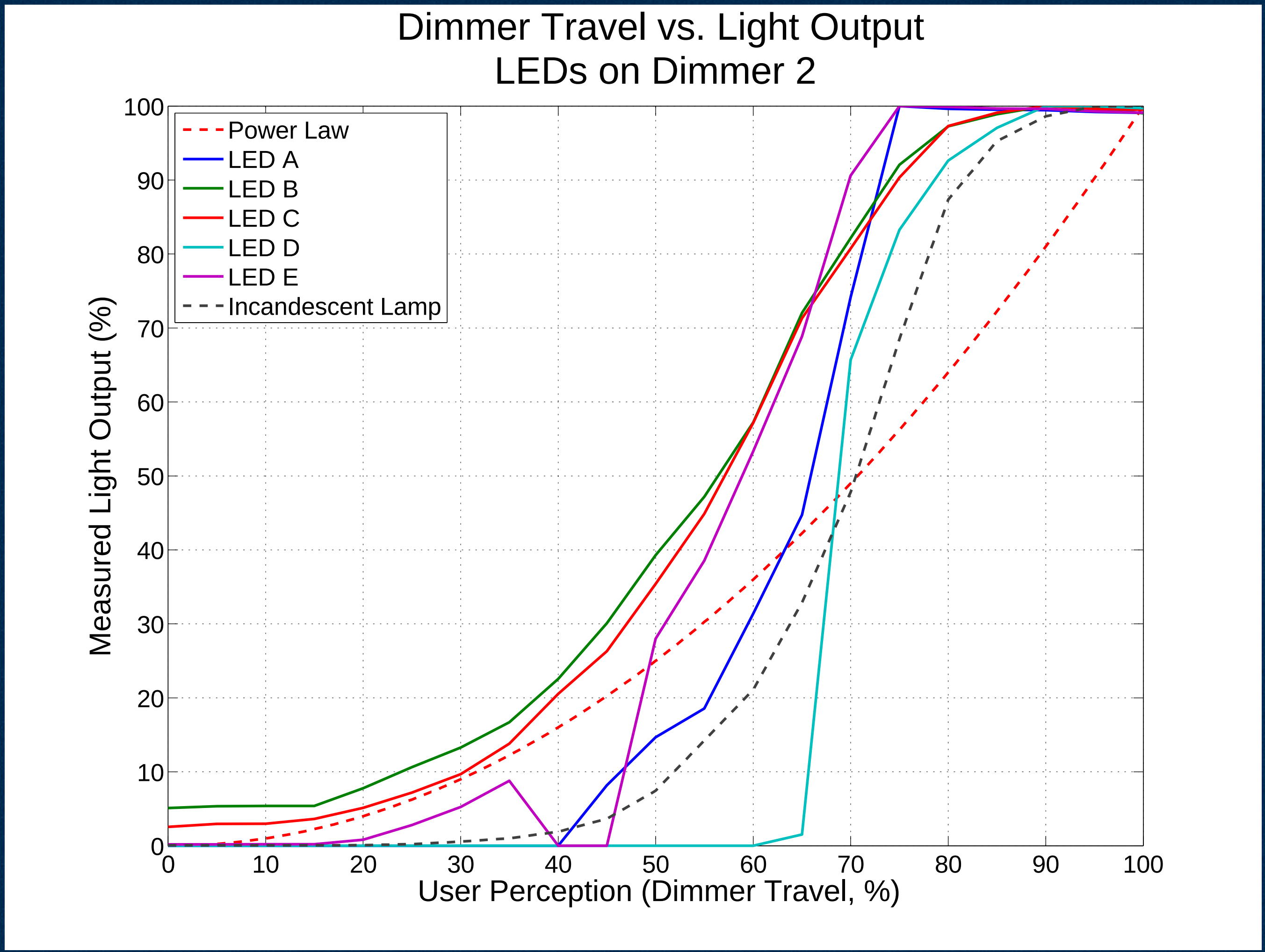




*Curves 1 and 2, while based upon the NEMA boundary curves, are *not* actually the NEMA curves

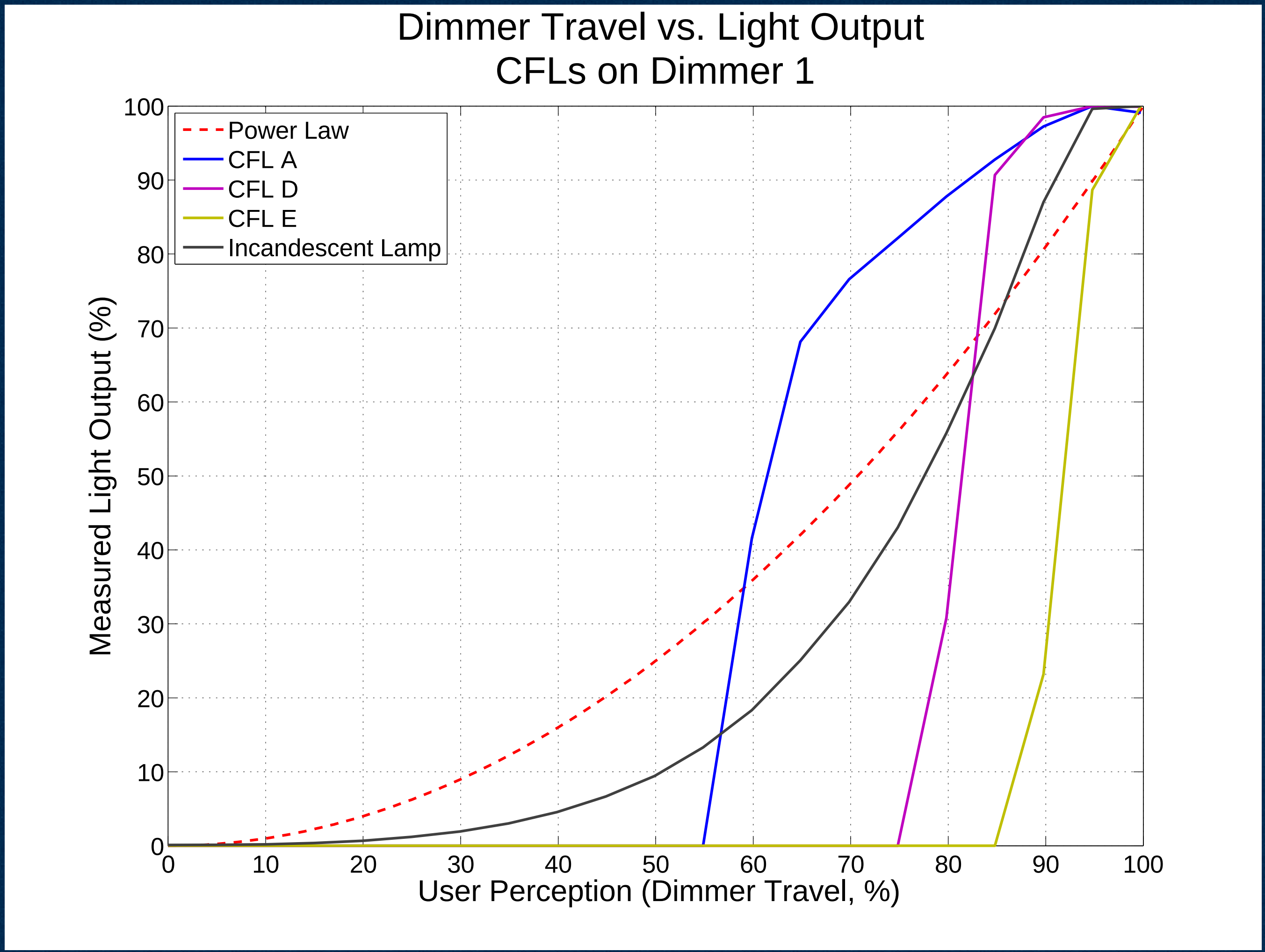
2.1. Dimming Curve

Measured dimming curves of 5 LED/dimmer combinations



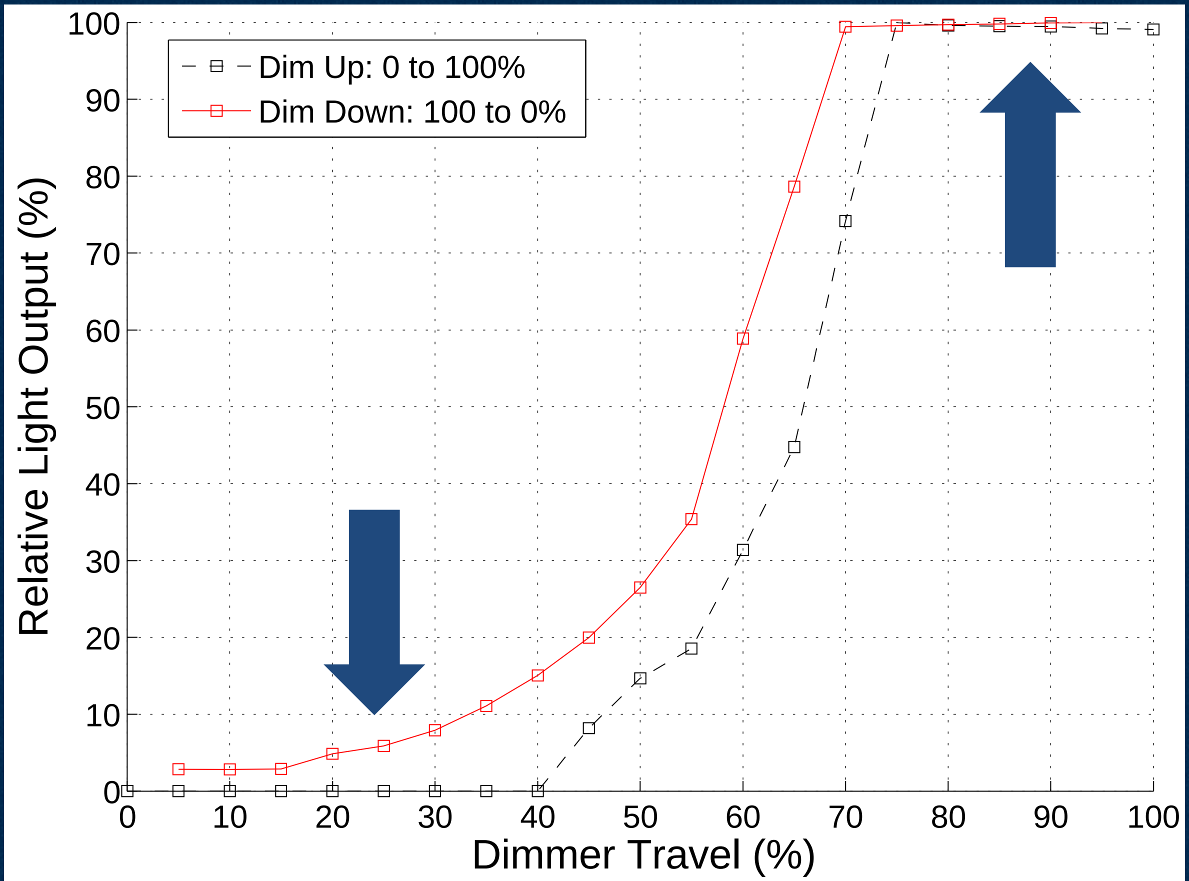
2.1. Dimming Curve

Measured dimming curves of 3 CFL/dimmer combinations



2.1 Dead Travel

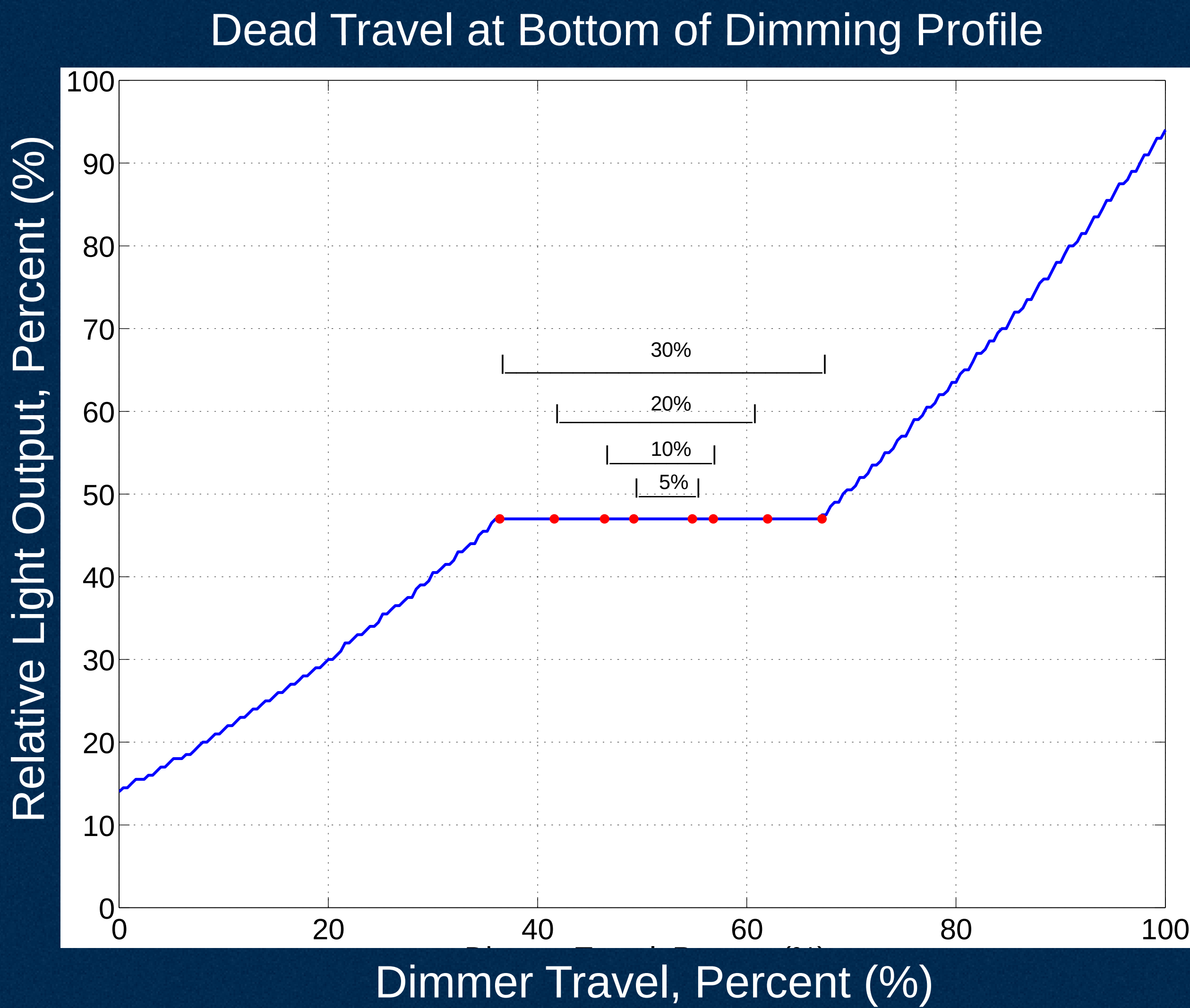
Dead travel occurs when the actuator of the dimmer changes value while the light output does not.



2.1 Dead Travel

- Dimming profiles with various levels of dead travel were assessed by subjects.

- None
- Top of Profile
  - 5%, 10%, 20%, 30%
- Middle of Profile
  - 5%, 10%, 20%, 30%
- Bottom of Profile
  - 10%, 20%, 30%



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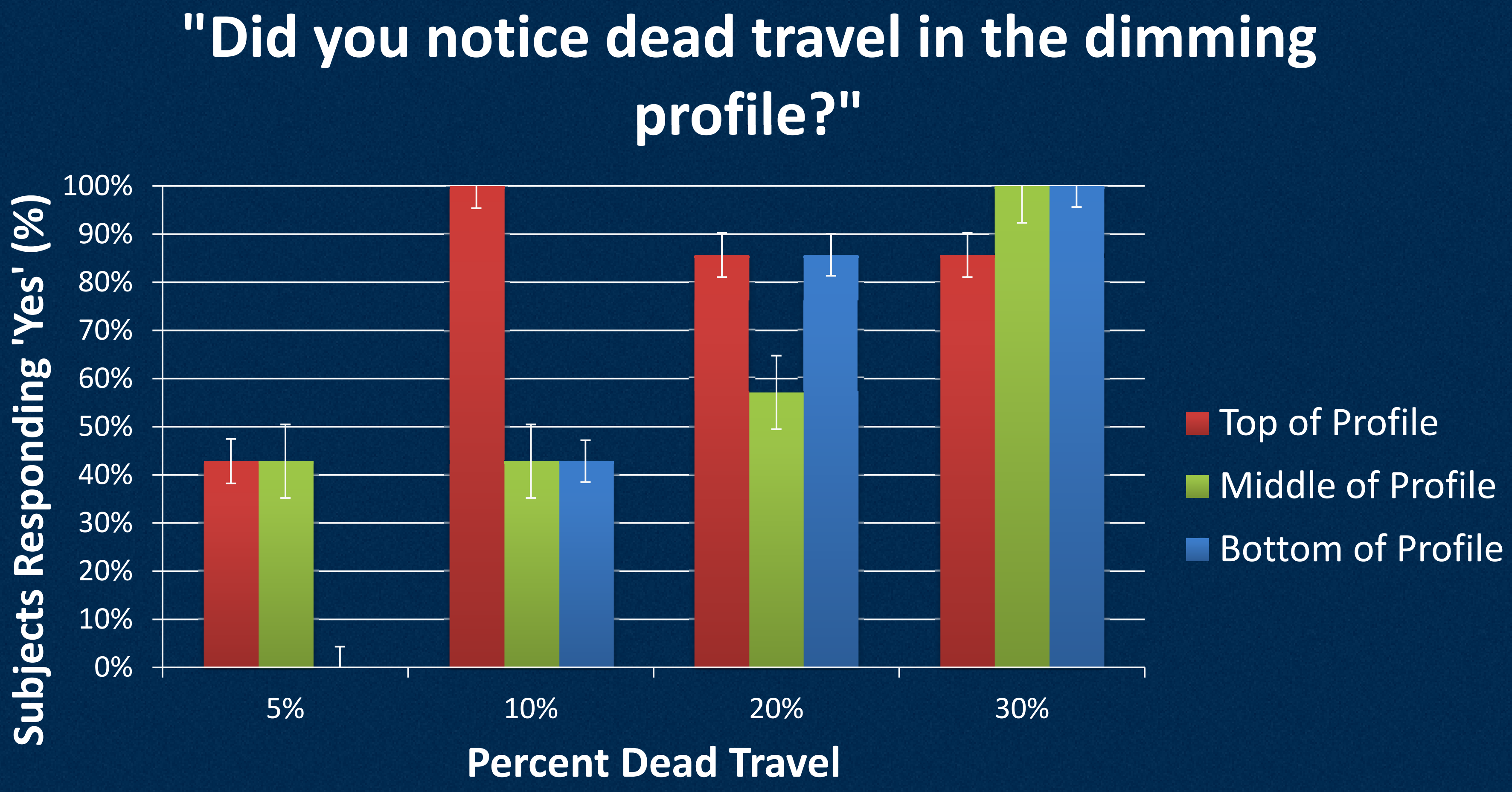
2.1 Dead Travel Results



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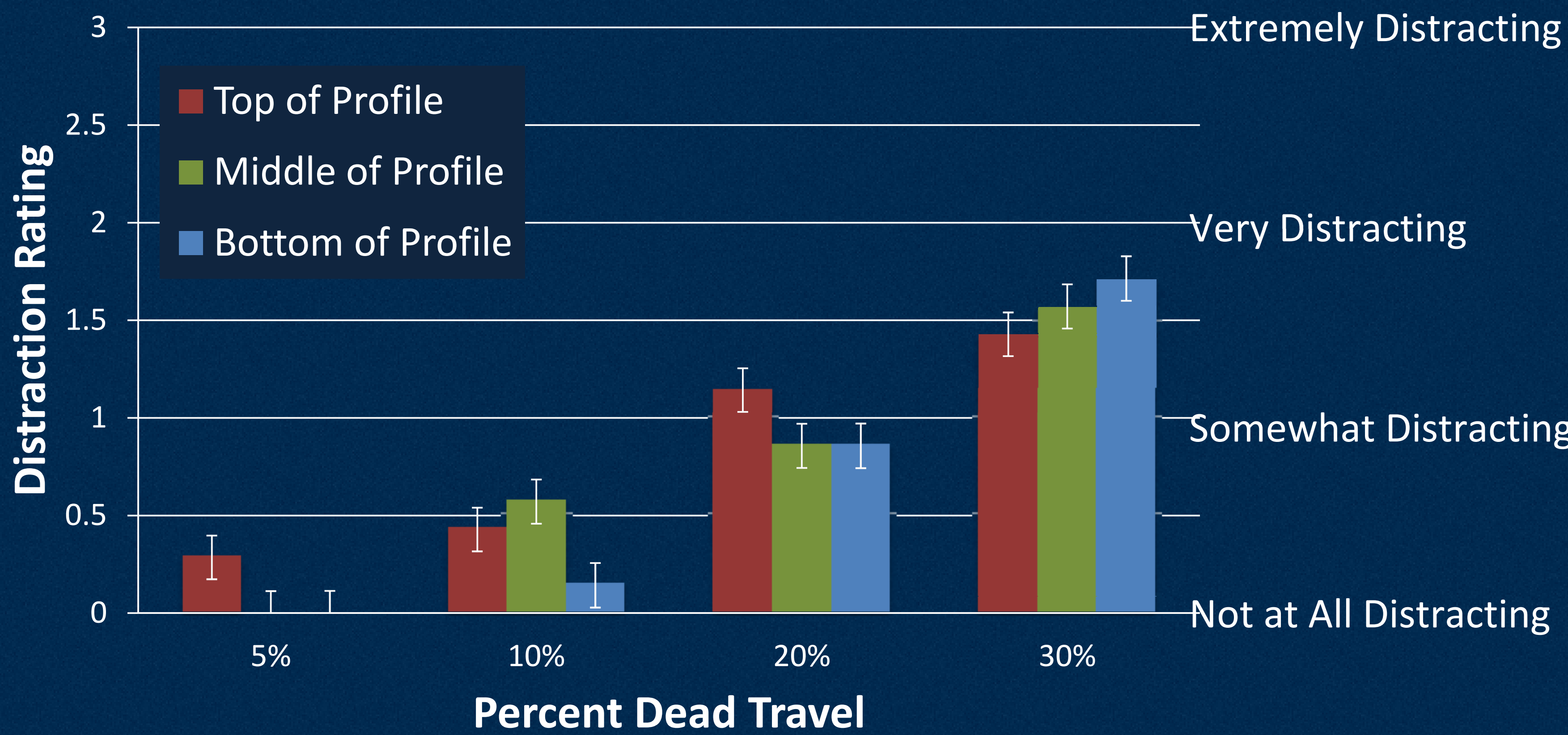
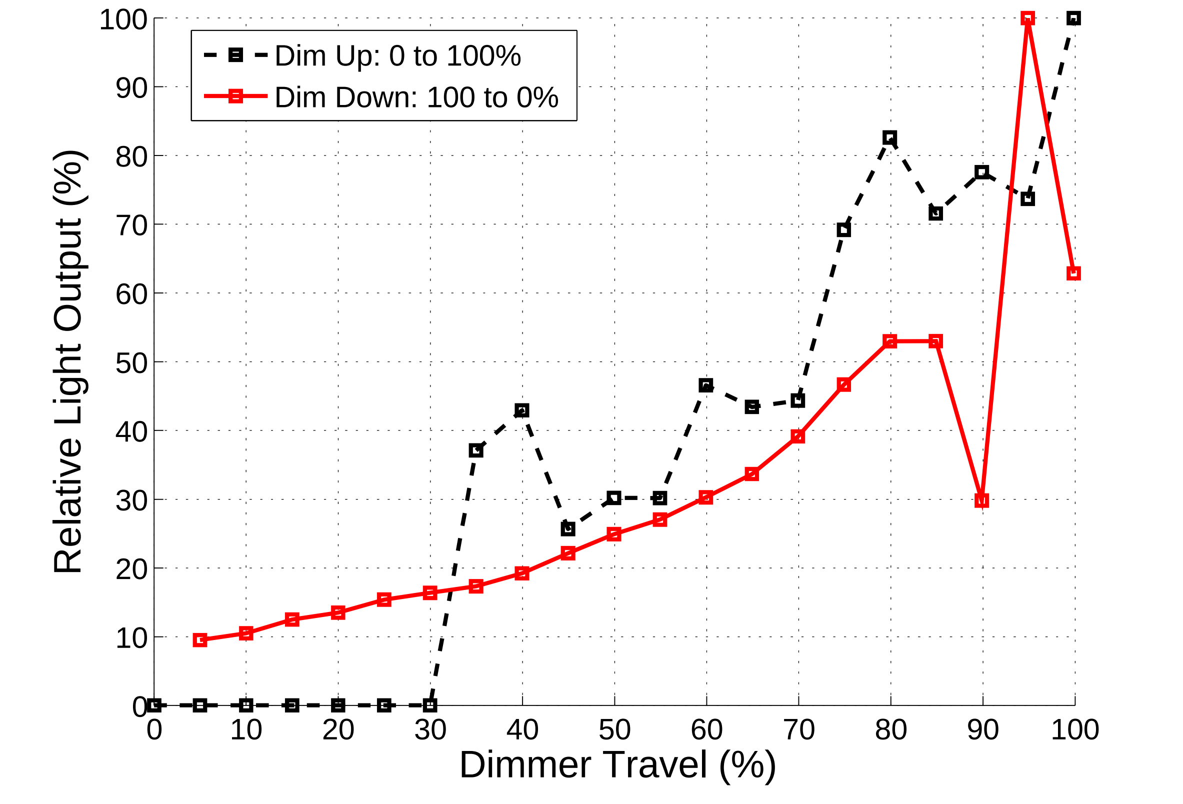
2.1 Dead Travel Results

"How distracting was the dead travel?"



2.2 Monotonic Dimming

Clear tolerance levels are needed for 'non-monotonic dimming'



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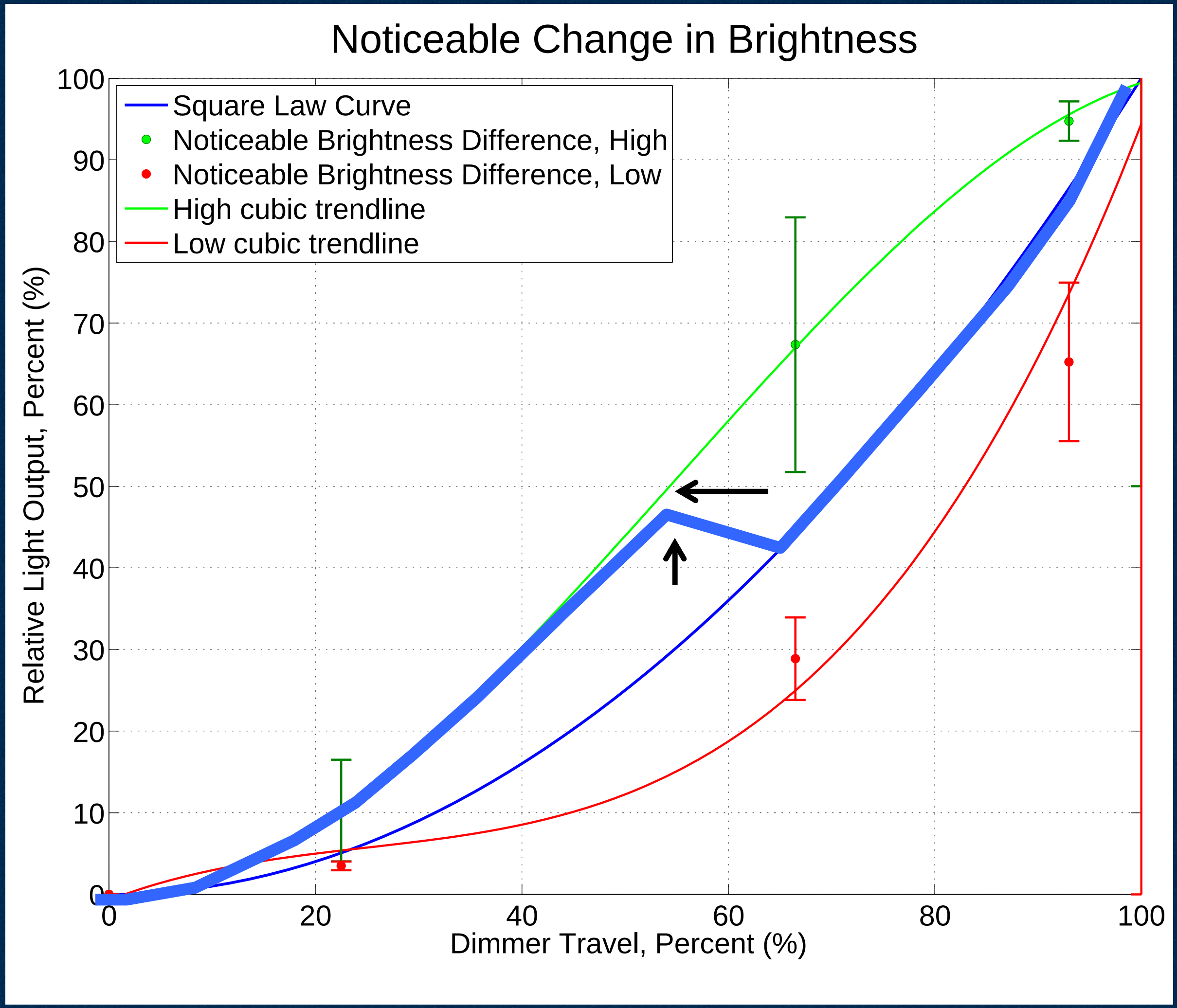
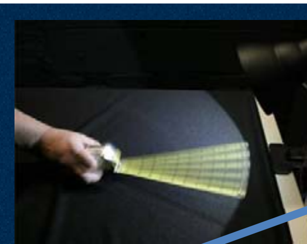
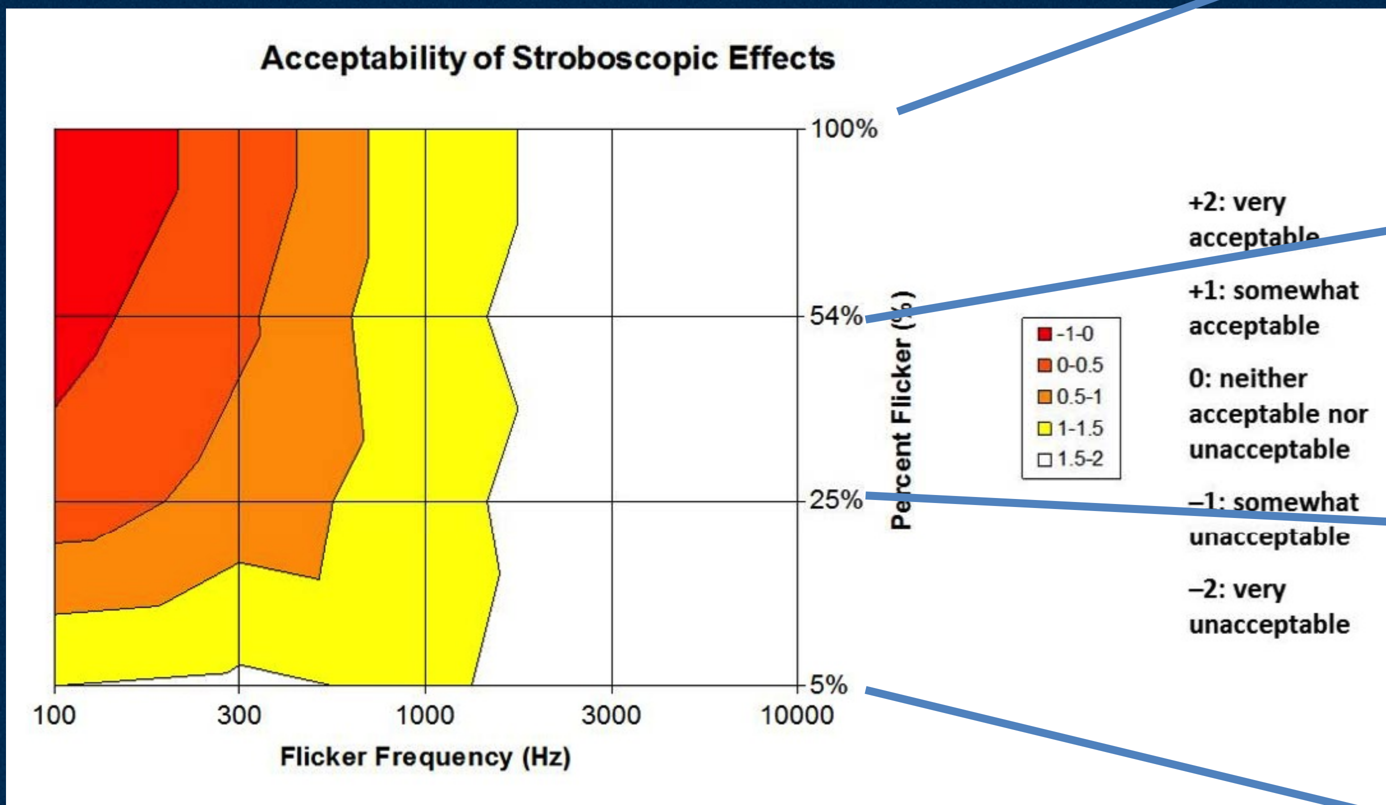


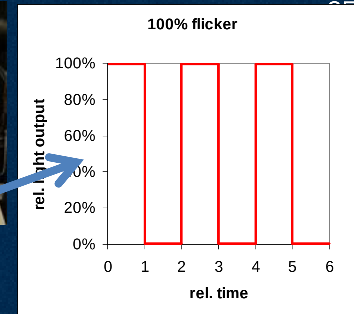
3. Flicker

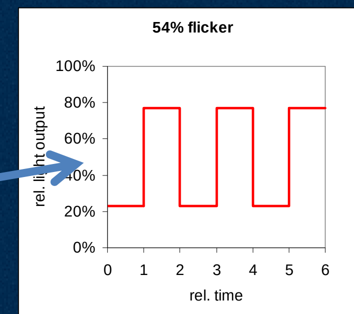
- Detection and acceptability of stroboscopic effects (above 100 Hz) can now be modeled (Bullough et al. 2012)
- What's needed:
  – A method to distinguish between high frequency and low frequency light output signals
  – A model to evaluate frequencies below 100 Hz
  – Limits on 'acceptable' perceivable flicker

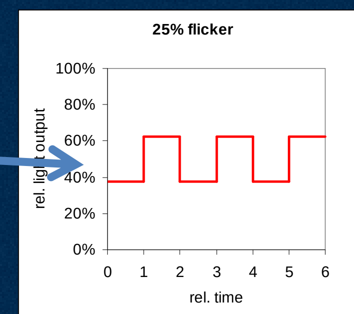
Rated Acceptability of Stroboscopic Effects: Was it acceptable?

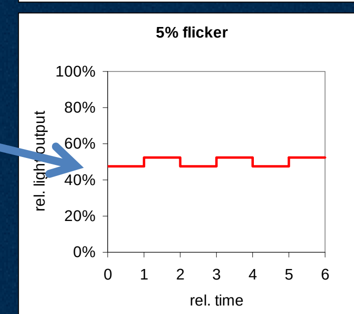












Bullough et al. (2012 in press)

http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/flicker.asp

4. Audible Noise

- Specific methodology required
  - NEMA SSL-6 uses dBA with no test procedure requirements
- Methodology standards (examples):
  - ISO 532:1975
  - ISO 9296:1998
  - ISO 7779:2010

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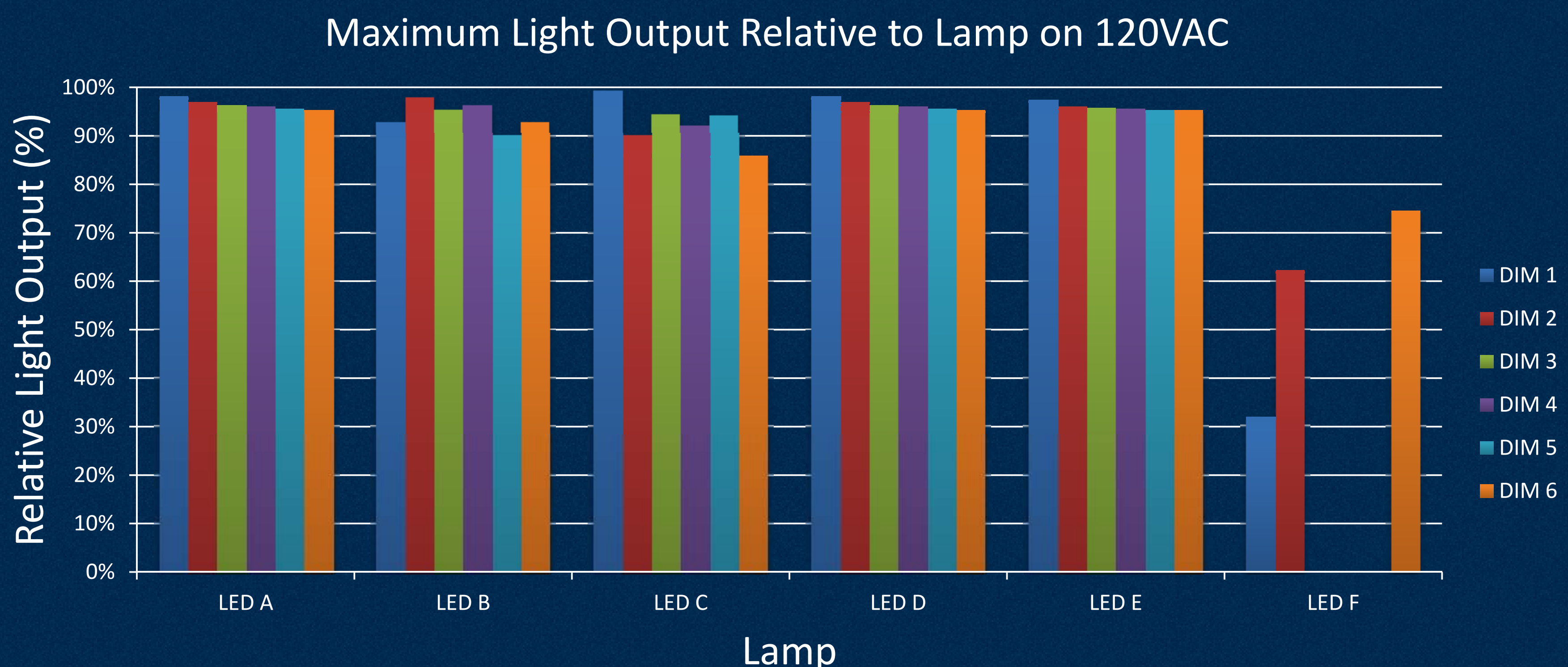
5. Maximum Light Level

- A dimmer/lamp combination should have a light output within X% of the lamp's output when operated without a dimmer.

$$\max(\%) = \frac{\phi \dim(\max)}{\phi AC}$$



ASSIST Recommends Draft Definition of Dimming

1. Minimum light level
   – 10% of maximum light level
2. Dimming profile
   – Within a defined tolerance of initial profile (Figure 1)
   – No more than 10% dead *dimmer* travel anywhere in dimming profile
   – Monotonic dimming, within a defined tolerance of inverse change in intensity over a *dimmer* travel period < 10% of dimming profile (Figure 2)

Figure 1

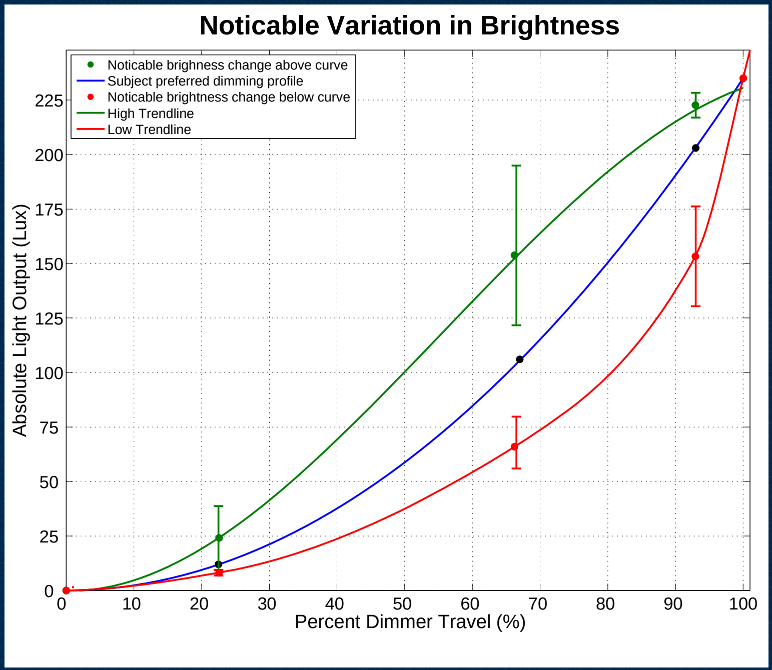
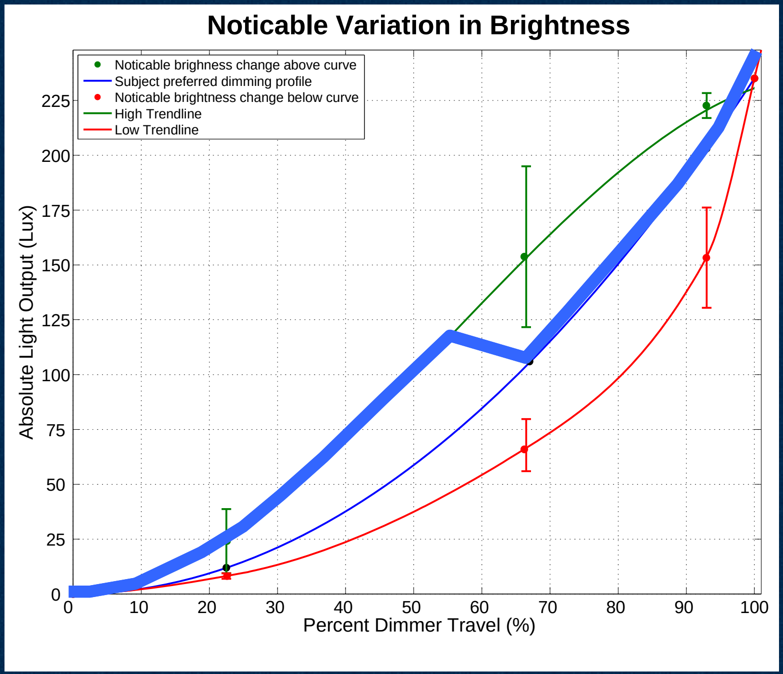


Figure 2



ASSIST Recommends Draft Definition of Dimming

3. Flicker
   – No flicker below 100 Hz; < 25% flicker above 100 Hz.
4. Audible Noise
   – Maximum limit to be determined for audible noise; update methodology.
5. Maximum light level
   – No less than 90% of maximum when operated on constant AC voltage

Acknowledgments

3M
Acuity Brands Lighting
amerlux
BRIDGELUX
CIRRUS LOGIC
COOPER
CREE
DOW CORNING
FAA
GE Lighting Solutions
ITRI Industrial Technology Research Institute
INTEMATIX
LG Electronics
LG Innotek
LightingScience
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Questions/Discussion

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