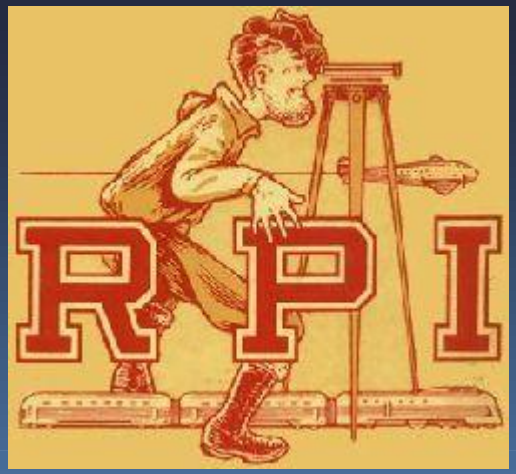

Metrics for the Effectiveness of Flashing Lights

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Lighting Research Center

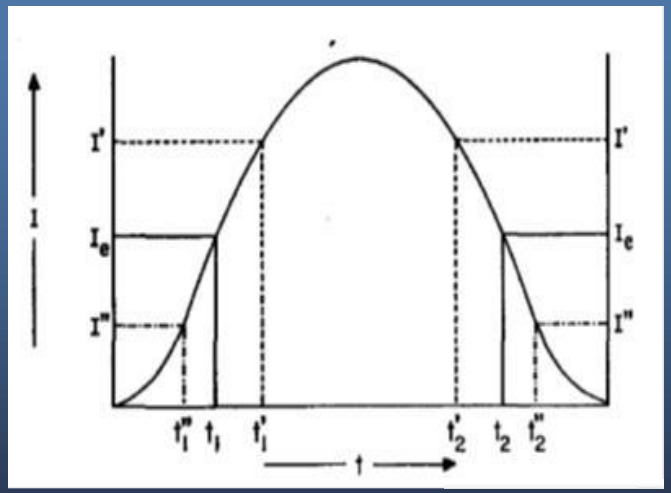
Rensselaer

How Are Flashing Lights Specified?

- Effective intensity (Blondel and Rey 1912)
  - Defined as the luminous intensity of a steady-burning light with the same visual range (at threshold) as the flashing light in question
  - It is a threshold measurement for point sources under dark adaptation conditions

$$I_e = \int_{t1}^{t2} I\,dt/(a + t_2 - t_1)$$

  - t_1/t_2 correspond to start/end times of the individual flash of light
  - I is instantaneous intensity at time t
  - a is a constant defined as 0.2 sec



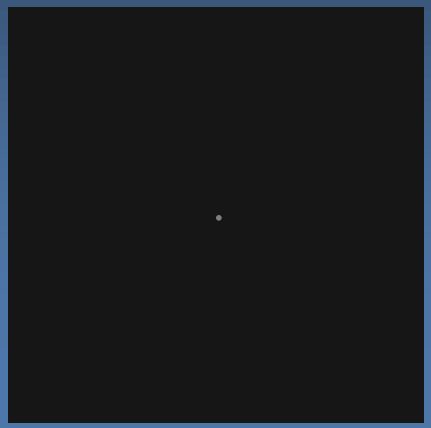
IES (1964)

Threshold versus Suprathreshold

- Many signal lights are designed to be seen and judged well above threshold conditions (i.e., suprathreshold) – Does the effective intensity equation still apply?

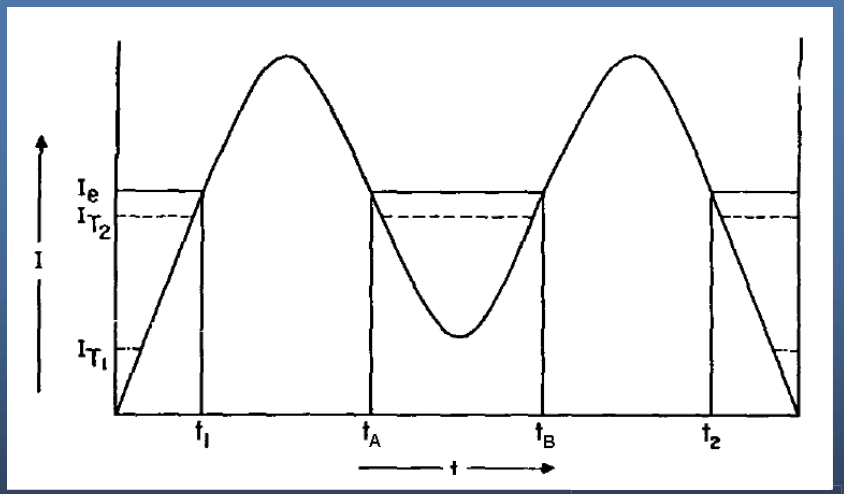
  $I_e = \int_{t1}^{t2} I dt/(a + t_2 - t_1)$

- Adjustments to the effective intensity equation (generally, adjsutment to the value of a) have been investigated for:
  - Higher background light levels (a is usually smaller)
  - Higher signal intensities (a sometimes higher, sometimes smaller)
  - Larger signal sizes (a is usually smaller)
- Inertia probably keeps a at 0.2 sec



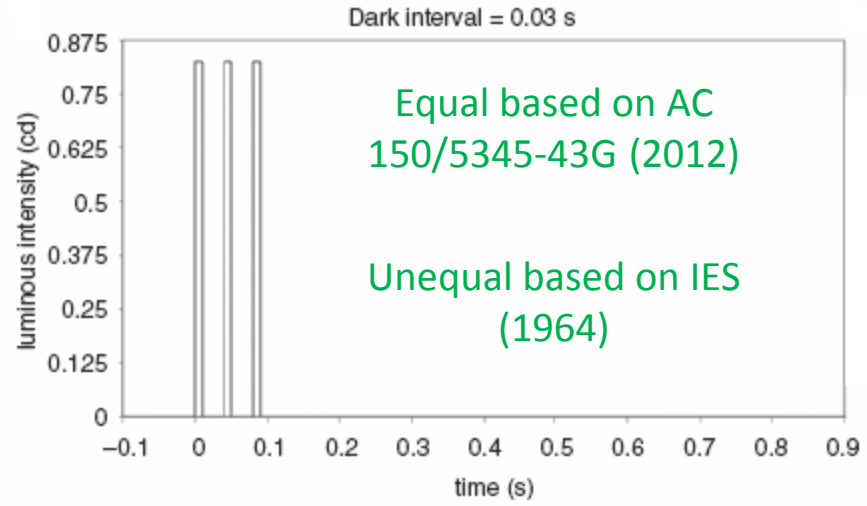
What About Flash Characteristics?

- Some flashing lights consist of a train of pulses that may "blend" into a single flash of light
- For multiple-pulse flashes, from AC 150/5345-43G (FAA, 2012):
  - $I_e = \int_{t_A}^{t1} I dt/(a + t_A - t_1) + \int_{t_2}^{t_B} I dt/(a + t_2 - t_B)$
  - If $t_B - t_1 \leq 0.02$ s (dark period ≤ ~0.01 s)
- For multiple-pulse flashes, from IES (1964):
  - $I_e = \int_{t2}^{t1} I dt/(a + t_2 - t_1)$



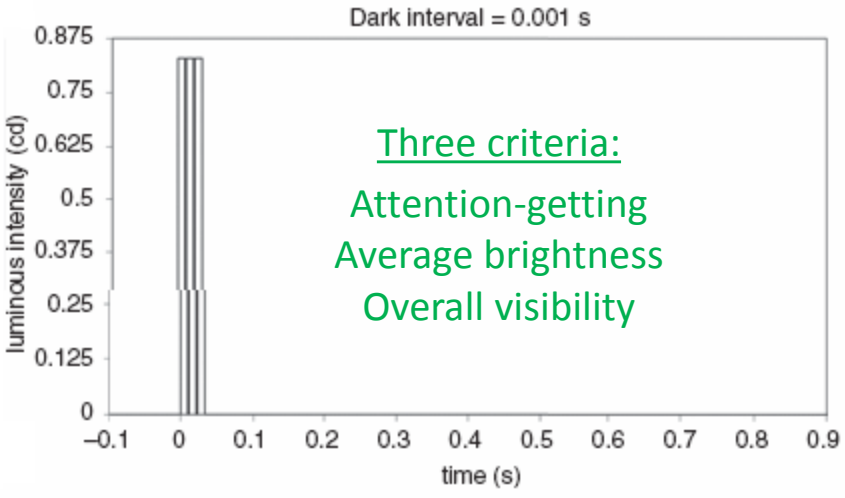
IES (1964)

Investigation of Multiple-Pulse Flashes of Light



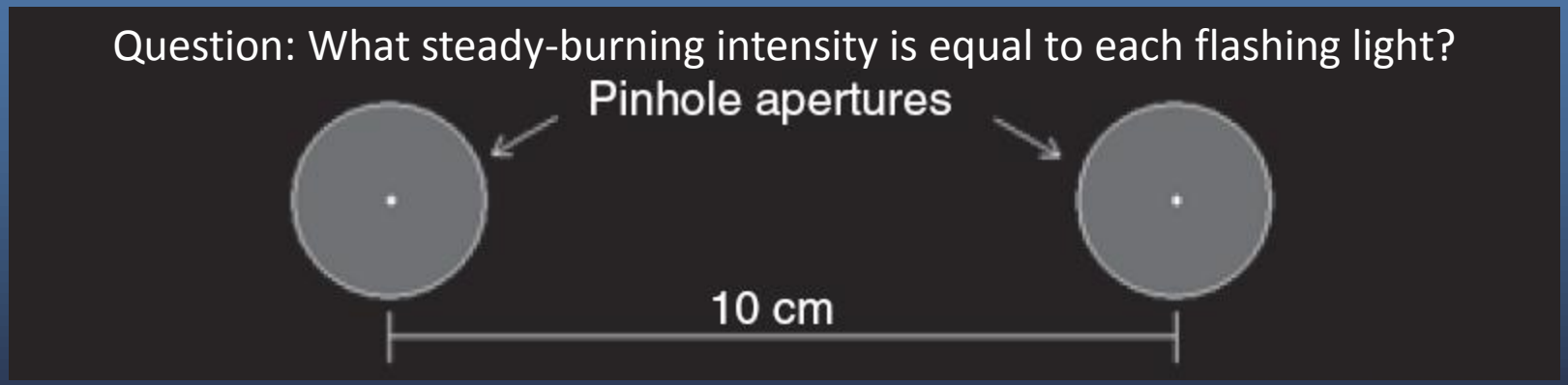
Equal based on AC 150/5345-43G (2012)

Unequal based on IES (1964)



Three criteria:

Attention-getting
Average brightness
Overall visibility

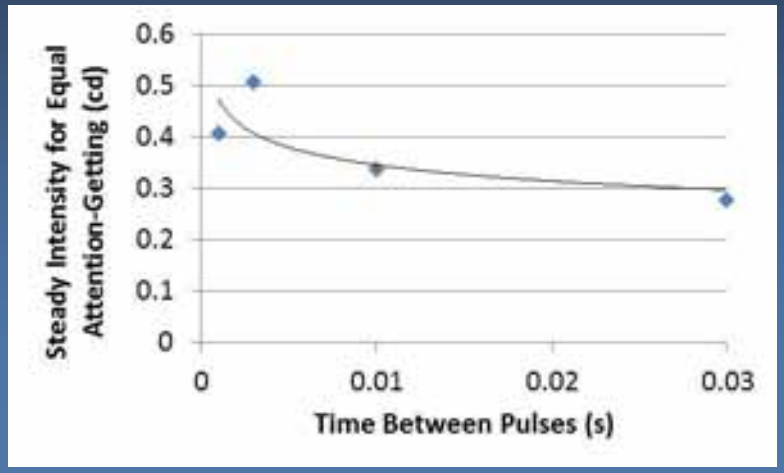


Bullough et al. (2013)

Results

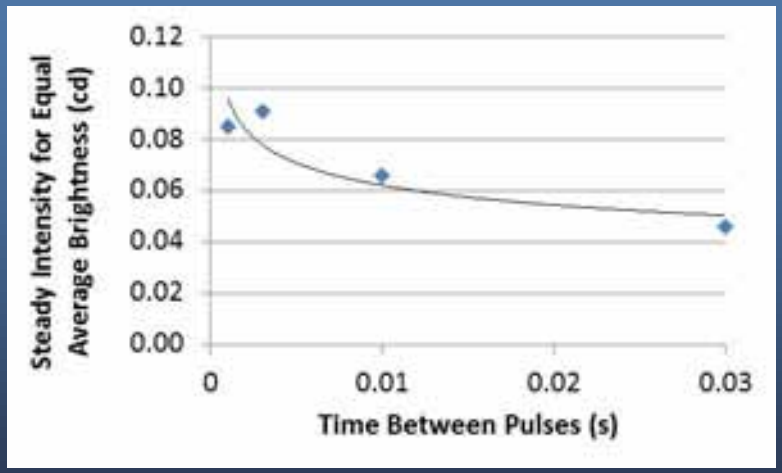
Longer durations between pulses tend to reduce effectiveness

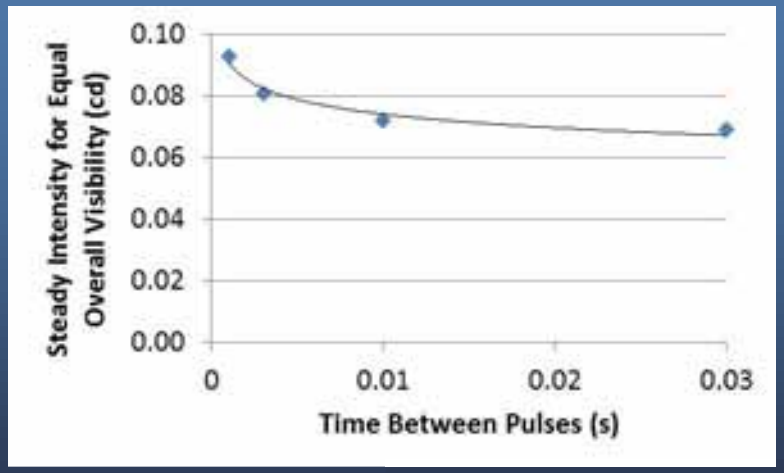
∴ IES (1964) is a more appropriate characterization than AC 150-5345-43G (2012)



Different responses have different equivalencies to a steady light

For attention getting, steady intensity has to be higher than for brightness/visibility



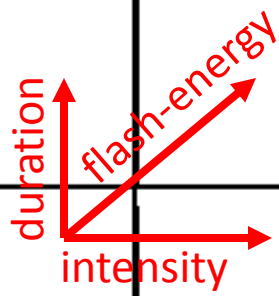


Bullough et al. (2013)

Systematic Comparison of Flash Intensity and Duration on Perception

Questions: Which light appeared to be faster? Which light appeared to be brighter?

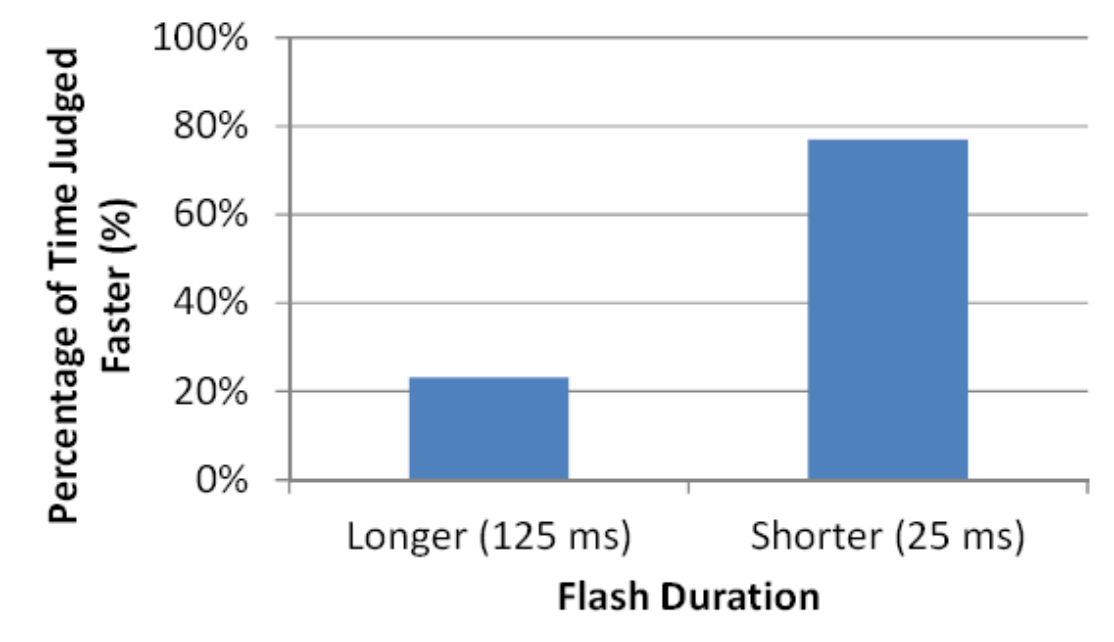
5 ms 0.003 cd 0.015 cd·ms	25 ms 0.003 cd 0.075 cd·ms	125 ms 0.003 cd 0.375 cd·ms
5 ms 0.015 cd 0.075 cd·ms	25 ms 0.015 cd 0.375 cd·ms	125 ms 0.015 cd 1.875 cd·ms
5 ms 0.075 cd 0.375 cd·ms	25 ms 0.075 cd 1.875 cd·ms	125 ms 0.075 cd 9.375 cd·ms



Bullough and Skinner (2013)

Results: Equal-Intensity Flashes

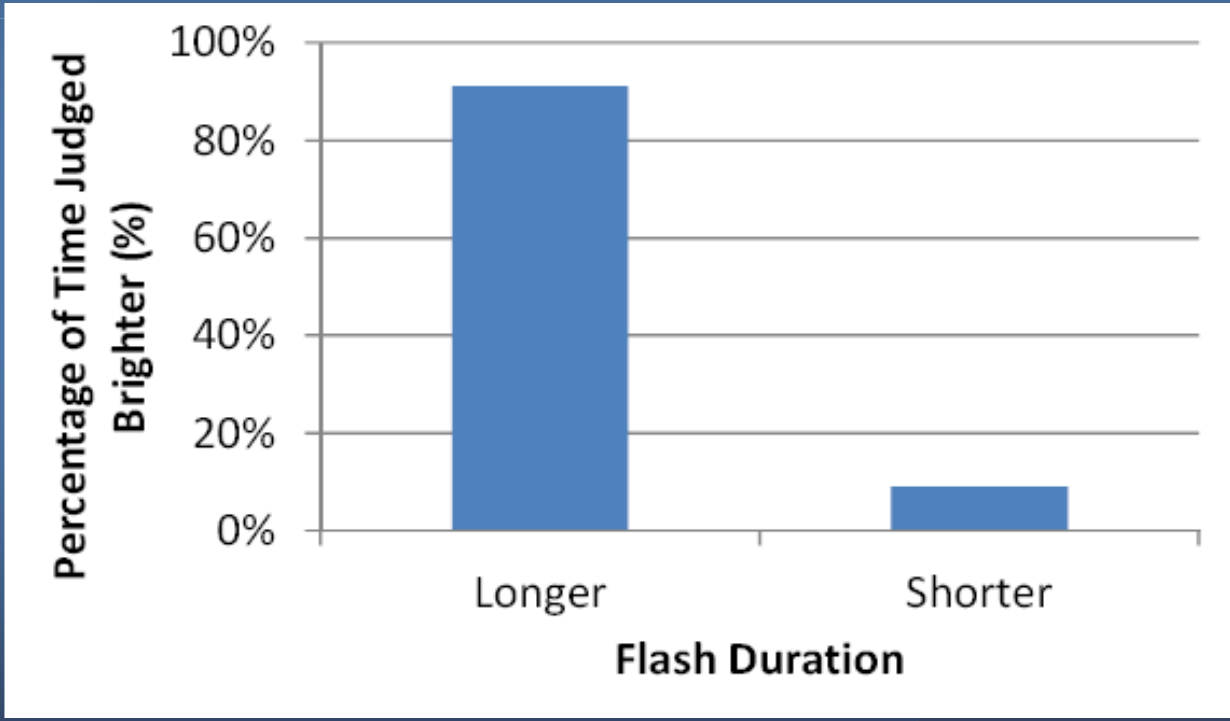
- For 5-25 ms durations, equal-intensity flashes were judged as equally fast
- For 25-125 ms durations, shorter durations were reliably ($p<0.05$) judged as faster



Bullough and Skinner (2013)

Results: Equal-Intensity Flashes (cont'd.)

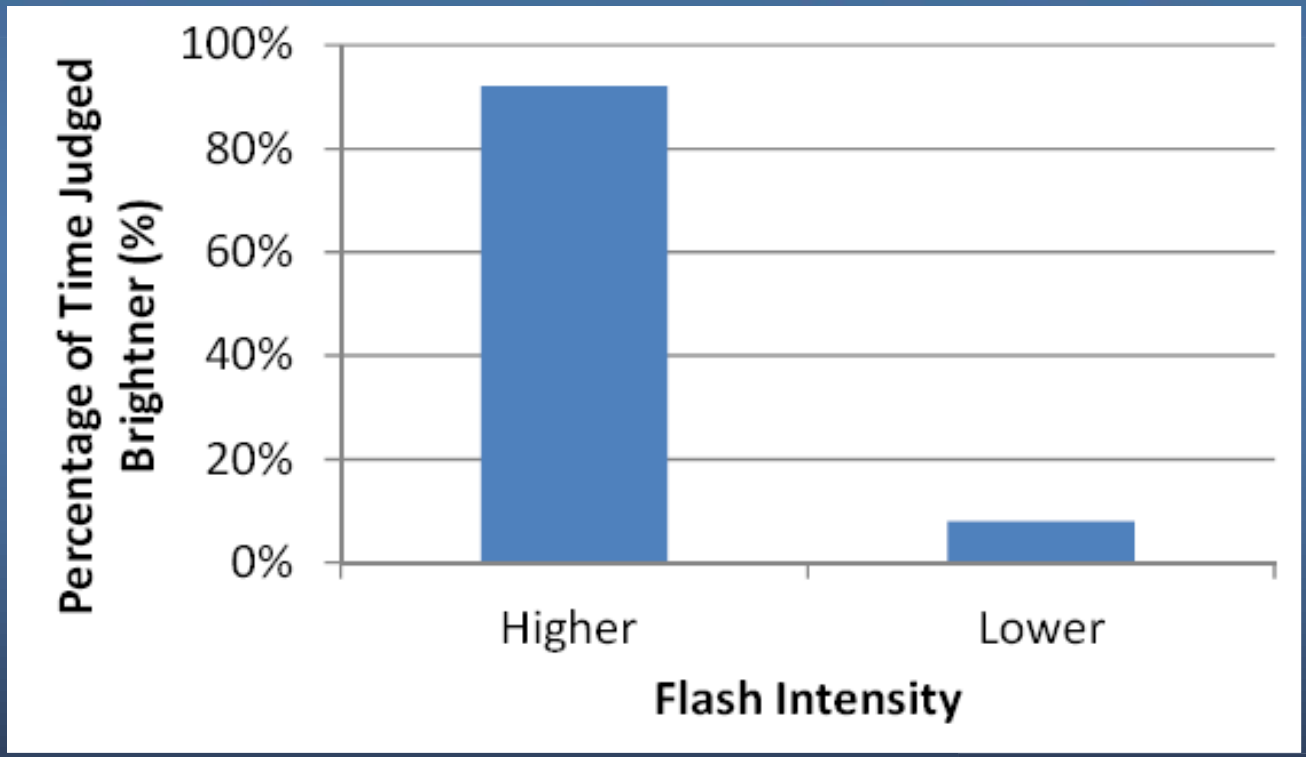
- The flash with the longer duration was reliably ($p<0.05$) judged as brighter



Bullough and Skinner (2013)

Results: Equal-Duration Flashes

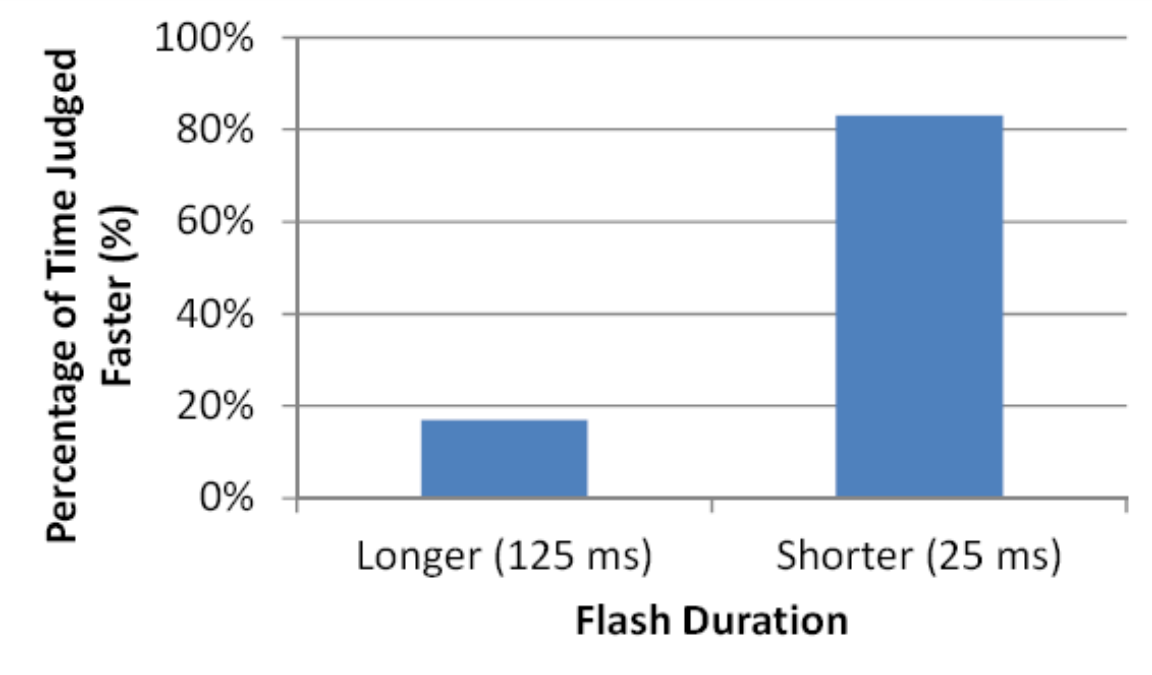
- No differences in apparent speed for equal duration flashes
- Higher intensity flashes were reliably ($p<0.05$) judged as brighter



Bullough and Skinner (2013)

Results: Equal-Energy Flashes

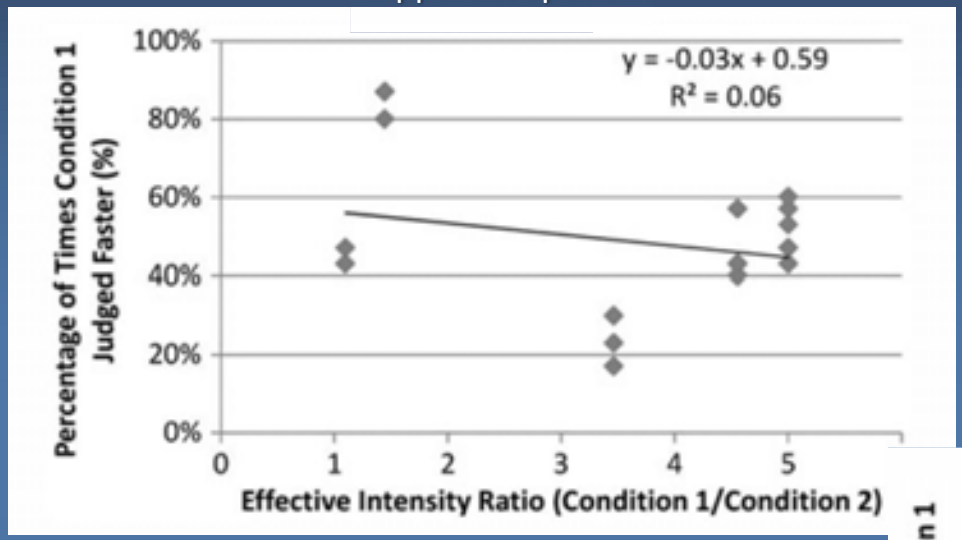
- Between 25-125 ms, shorter flashes were reliably ($p<0.05$) judged as faster, but not between 5-25 ms
- Equal-energy flashes were judged equally bright



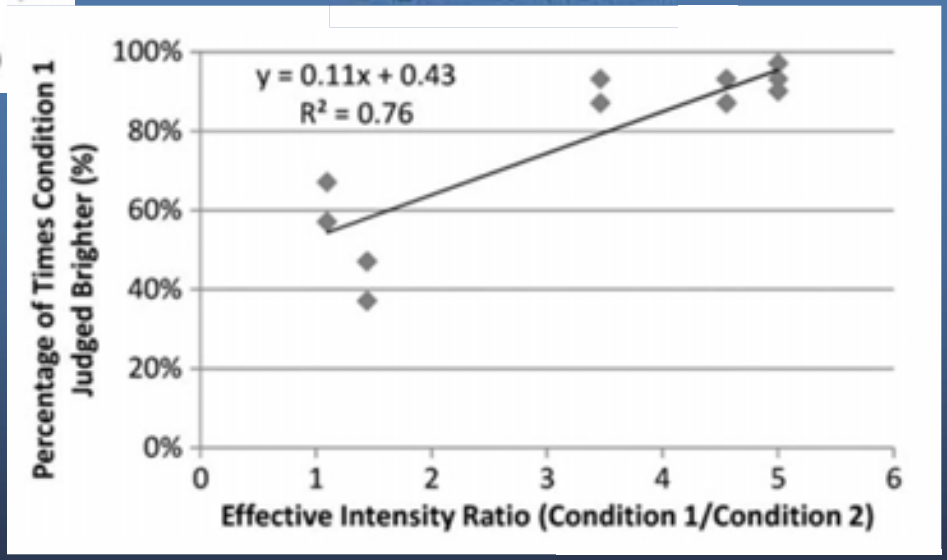
Bullough and Skinner (2013)

Flashing Lights and Effective Intensity

Apparent Speed



Brightness Appearance



Bullough and Skinner (2013)

Summary

- Effective intensity (Blondel and Rey 1912) can rank-order suprathreshold light sources based on visual responses such as attention-getting, brightness appearance, and overall visibility
  - But not apparent speed
- Flashing lights with similar flash-energy (or effective intensity) and with durations ≤ 25 ms were judged equally fast and equally bright
- Absolute value of the steady-burning intensity for equivalence differs for different responses
  - A much higher steady intensity is needed to match attention-getting properties, and lower for brightness and visibility responses
- Visual characterization of signal lights producing multiple-pulse flashes of light should be based on IES (1964) calculation procedure and not on the procedure outlined in AC 150/5345-43G (2012)

Thank You!

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