Metrics for the Effectiveness of Flashing Lights

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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.

\[ I_e = \int_{t_1}^{t_2} I dt / (a + t_2 - t_1) \]

- \( t_1/t_2 \) 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?

\[ I_e = \int_{t_1}^{t_2} \frac{ldt}{a + t_2 - t_1} \]

- Adjustments to the effective intensity equation (generally, adjustment 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):
  \[ I_e = \int_{t_A}^{t_1} \frac{Idt}{(a + t_A - t_1)} + \int_{t_2}^{t_B} \frac{Idt}{(a + t_2 - t_B)} \]
  
  - If \( t_B - t_1 \leq 0.02 \text{ s} \)
    (dark period \( \leq \sim 0.01 \text{ s} \))

- For multiple-pulse flashes, from IES (1964):
  \[ I_e = \int_{t_2}^{t_1} \frac{Idt}{(a + t_2 - t_1)} \]
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

Question: What steady-burning intensity is equal to each flashing light?

Pinhole apertures

10 cm

Bullough et al. (2013)
Results

Longer durations between pulses tend to reduce effectiveness

\[ \text{IES (1964) is a more appropriate characterization than AC 150-5345-43G (2012)} \]

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?

<table>
<thead>
<tr>
<th>Duration</th>
<th>Flash Intensity 1</th>
<th>Flash Intensity 2</th>
<th>Flash Intensity 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ms</td>
<td>0.003 cd</td>
<td>0.015 cd·ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.015 cd</td>
<td>0.075 cd·ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.075 cd·ms</td>
<td>0.375 cd·ms</td>
<td></td>
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<tr>
<td>25 ms</td>
<td>0.003 cd</td>
<td>0.015 cd·ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.015 cd</td>
<td>0.075 cd·ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.075 cd·ms</td>
<td>0.375 cd·ms</td>
<td></td>
</tr>
<tr>
<td>125 ms</td>
<td>0.003 cd</td>
<td>0.015 cd·ms</td>
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<tr>
<td></td>
<td>0.015 cd</td>
<td>0.075 cd·ms</td>
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<tr>
<td></td>
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<td>0.375 cd·ms</td>
<td></td>
</tr>
</tbody>
</table>

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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