Parameters for Indirect Viewing of Visual Signals Used in Emergency Notification: Part I. Study Results

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SUPDET 2014 – March 4-7, 2014
Orlando, FL

How are flashing visual signals detected?

◆ Direct detection

   › When the light source is well within the field of view and is seen through its flashing characteristics

◆ Indirect detection

   › When the light source is outside the field of view and only the effect of increased room surface illuminance is seen
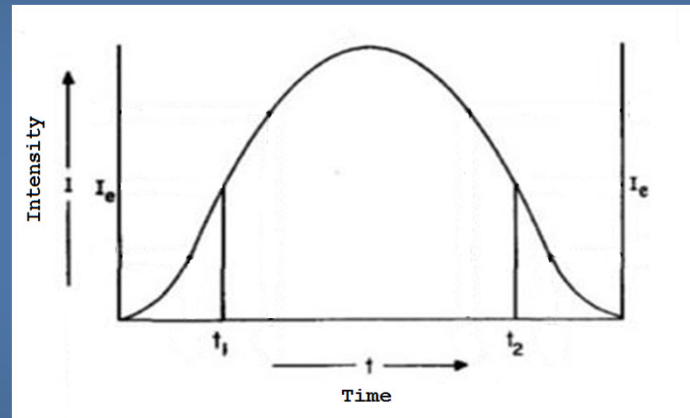
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How are flashing visual signals specified?

◆ Effective intensity (Blondel and Rey 1912; IES 1964):

› Defined as the intensity of a steady-burning light with *the same threshold visibility as a particular flashing light*

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

where:

t_1, t_2 correspond to start, end times of flash (in s)

I is instantaneous intensity (in cd) at time t

a is a constant defined as 0.2 s, which is related to the integration time of the human visual system under dark conditions (i.e., conditions under which navigation signals are viewed on ships at night)

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Does effective intensity "work"?

- Yes, for **direct detection**
- Effective intensity properly rank-orders different flashing signal lights in terms of multiple criteria:
  - Attention-getting characteristics (conspicuity)
  - Apparent brightness
  - Overall ratings of visibility

(Bullough et al. 2013)

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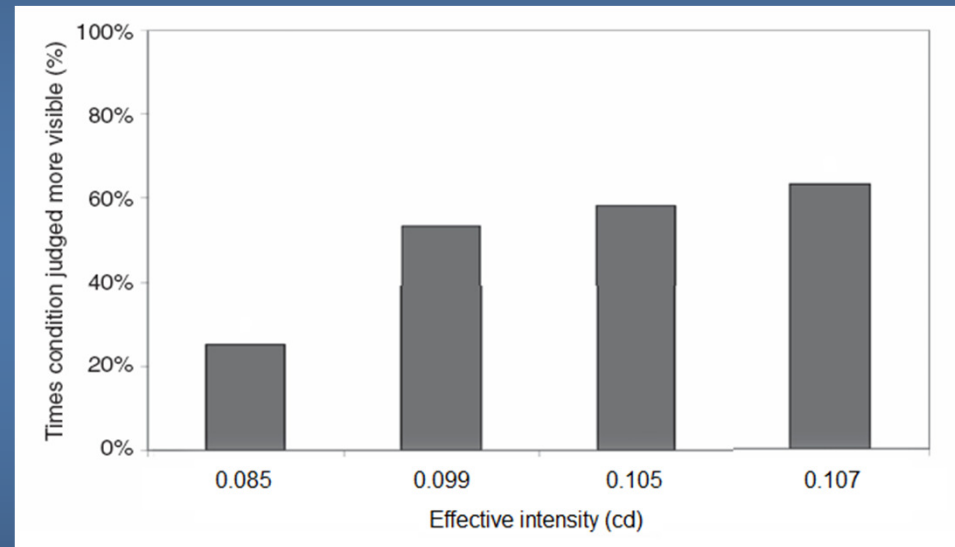
Does effective intensity "work"?

- Apparently not, for **indirect detection**

- Effective intensity of <u>15 cd</u> for xenon strobes (<<1 ms flash duration) based on UL research (DeVoss 1991) for awake people, indirect detection

  - › Effective intensity of <u>260 cd</u> needed for incandescent signals

- Savage (2011) compared lights with effective intensity of <u>15 cd</u>: xenon strobe (flash duration << 1 ms), and LEDs with pulse durations of 25, 50, 100 ms

  - › Peripheral/indirect detection was inversely proportional to pulse duration

- What does work for indirect detection?

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How did we investigate what "works"?

- ◆ Light-emitting diode (LED) source mounted at ceiling above/behind subjects to illuminate the facing wall 20 ft away

  - › Adjustable intensities and flash durations of 1, 10, 25, 50, 100 ms

  - › Could create various effective intensity values from ~0.5-200 cd

  - › Also sometimes included a xenon strobe with a very short flash duration (<<1 ms)

- ◆ Ambient room illumination adjustable from 250-500 lux

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# Indirect detection vs. effective intensity
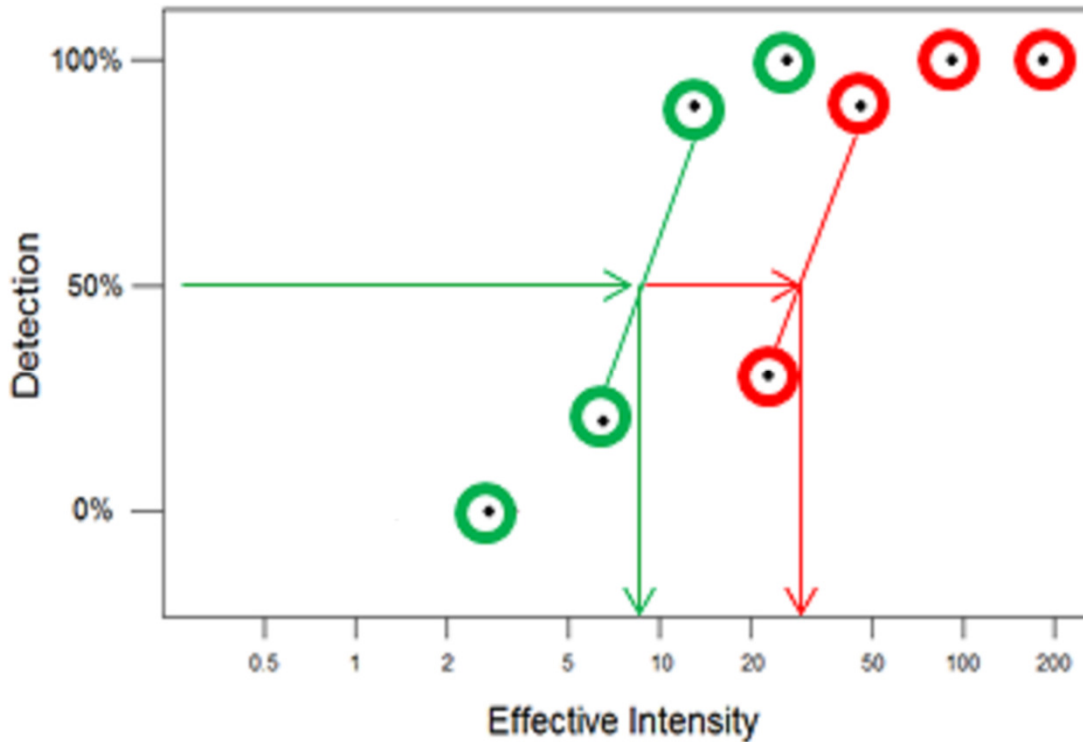
Red: 100 ms
Green: 10 ms

- For these results, observers were looking at the wall ahead under an illuminance of 500 lux, waiting to see if they detected the indirect flashing
- What if they were looking down at their desk, or performing a demanding visual task? What if the ambient light level was different?

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Experimental conditions tested

| Experiment	Illuminance Increment (%) on wall	Duration (ms)	Frequency (Hz)	Beam Spread (°)	Ambient Illuminance (lx)	Visual Task?	Subjects Aware of Purpose?
1	1%, 2%, 4%, 8%	1, 10, 100	1	40	500	N	Y
2	1%, 2%, 4%, 8%	10, 25, 50, 100	2	40	500	N	Y
3	2%, 4% 8%, 16%	10, 25, 50, 100	1	40	250	N	Y
4*	1%, 2%, 4%, 8%	10, 25, 50, 100	1	40	500	Y	Y
5*	2%, 4% 8%, 16%	10, 25, 50, 100	1	40	250	Y	Y
6	2%, 4% 8%, 16%	10, 25, 50, 100	1	6	250	Y	Y
7	4%, 16%	50	1	40	250	Y	N

*Xenon strobe signal included.

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Additional results

500 lx, 2 Hz
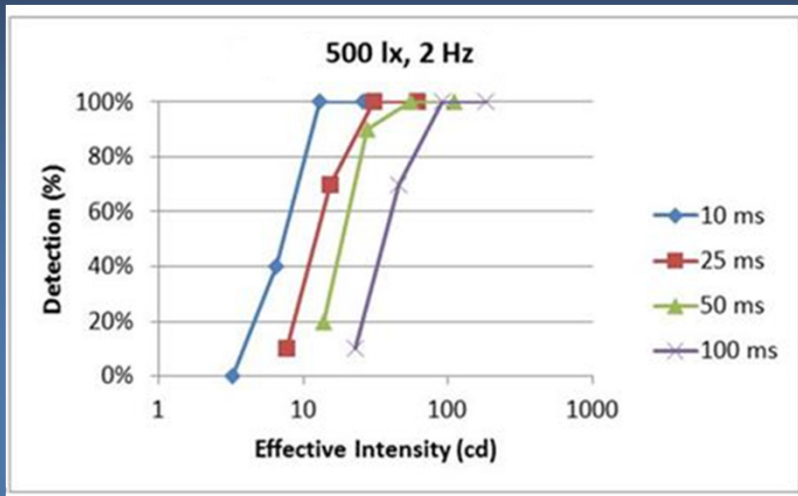
For all conditions tested, there were systematic differences between sources with the same effective intensity but different flash durations

- The conditions with <u>shorter</u> flash durations were consistently easier to detect

500 lx, 1 Hz (visual task)

250 lx, 1 Hz (visual task)
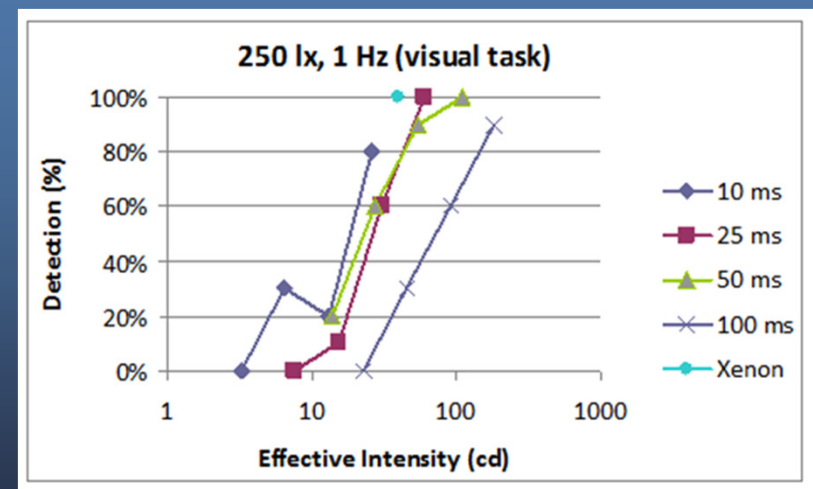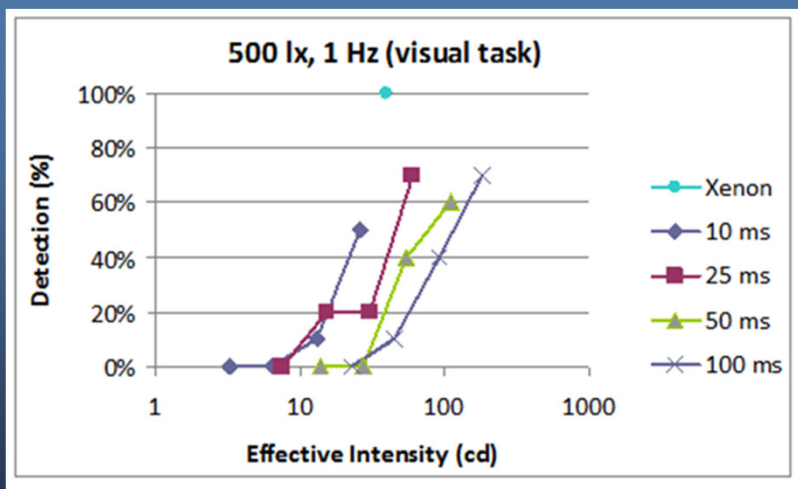
So, effective intensity does not "work" for indirect detection – what does?

- Recall that effective intensity (Blondel and Rey 1912) was developed for direct detection under dark viewing conditions

- Visual integration times (approximated by $a = 0.2$ s in the effective intensity equation) are shorter at high (interior) light levels than at low (nighttime) light levels

  - Battersby and Schuckman (1970) reported temporal integration times for the human visual system of ~0.01 s at high light levels

  - A preliminary **indirect effectiveness quantity (IEQ)** based on the Blondel-Rey (1912) formulation but using $a = 0.01$ s was evaluated

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Indirect detection vs. IEQ
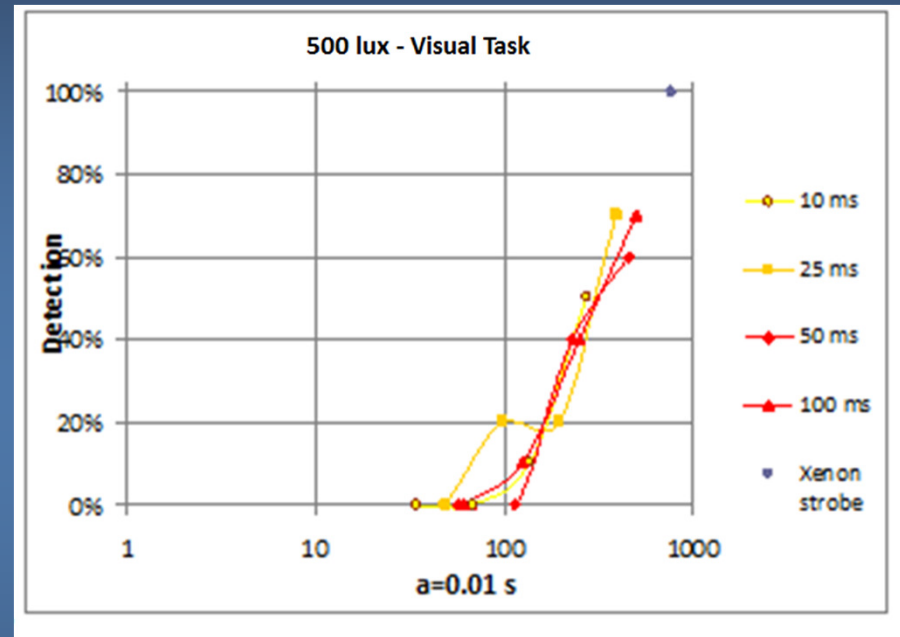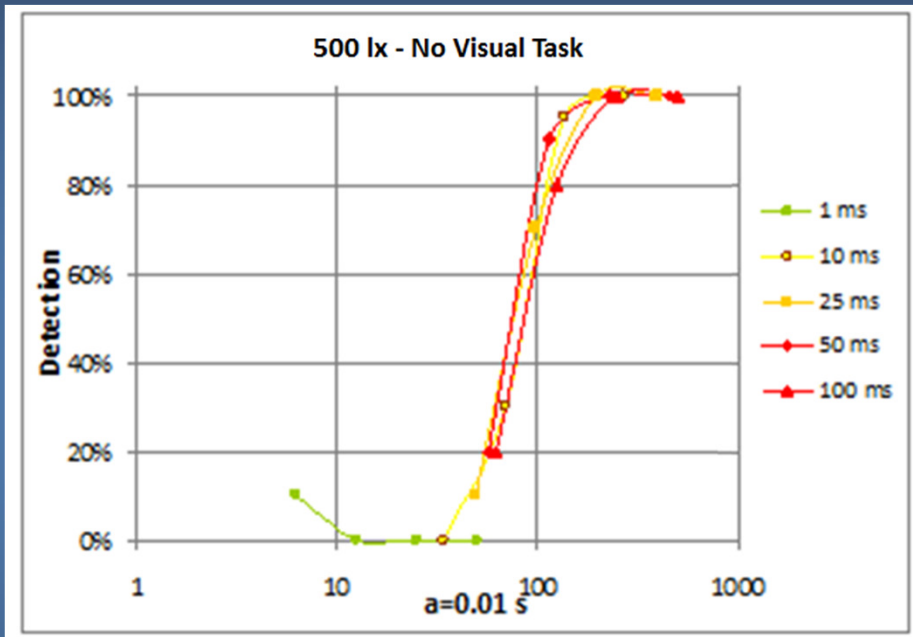
The **indirect effectiveness quantity (IEQ)** using <u>**a = 0.01 s**</u> provided a much better rectifying variable for indirect detection, regardless of the flash duration (<u>including xenon strobes</u>)

Caveats and constraints

- The IEQ value necessary for a particular level of detection changes with the ambient light level in the space
  - To achieve an indirect detection rate of 90%, the IEQ value must be 375 cd under a room illuminance of 250 lux, but 750 cd under 500 lux (seems to be proportional)
- The IEQ value necessary for a particular level of detection changes with the distance between the light source and the surface it is illuminating
  - All conditions tested used a distance of 20 ft; at 30 ft the IEQ values would have to increase by 2.25 ($30^2/20^2$) to provide the same effectiveness
- The area of the surface being illuminated by the visual signal cannot be a small visual angle
  - Detection was much worse for a 6° cone of light than for a 40° cone from the signal

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Acknowledgments

- Study supported by the Fire Protection Research Foundation with sponsorship from:
  - Honeywell/System Sensor, NEMA, Siemens, SimplexGrinnell, Bosch, Gentex
- Amanda Kimball, project manager
- Technical panel and sponsor representatives:
  - Robert Elliot, Dan Finnegan, Bruce Fraser, Larry Grodsky, Jack McNamara, Dave Newhouse, Warren Olsen, Isaac Papier, Mark Pavlica, Rodger Reiswig, Lee Richardson, Robert Schifiliti, Andrew Trotta

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Final Report

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