Addressing flicker in lighting to improve comfort and wellbeing

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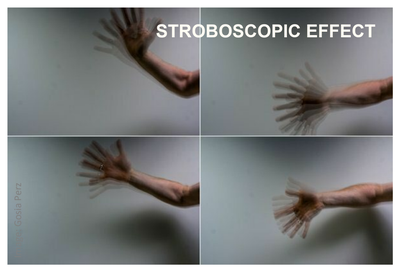
Peer Review
Wednesday 10:00 AM
Wilson/Harrison Room

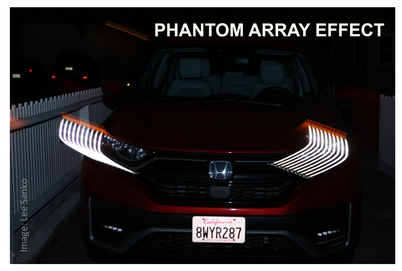
More info:

Flicker can cause or exacerbate cognitive, behavioral, physiological, and psychological problems including headaches, migraines, nausea, seizures, distraction, disorientation, and more.

Ameliorating flicker, which affects different people in different ways (or not at all) will lead to fewer negative health consequences, increased customer acceptance and use of LEDs, and energy savings.

This project will produce a new metric to quantify the phantom array effect and develop standards, recommendations, and performance criteria to limit problem products.





"If I am crossing a street at night…the "flickering" daytime running lights and taillights superimpose phantom arrays on my field of view, making it very difficult to gauge speed and distance of the oncoming cars…I am unable to interpret the series of phantom array afterimages that do not correlate to the motion of the cars. This is very distracting and disorienting, causing a slight loss of balance, sense of nausea, and real danger."

- Lee Sonko, Flickering Light Project

FLICKER PERCEPTION EXPERIMENT

Miller NJ, Rodriguez-Feo Bermudez E, Irvin L, Tan J. Phantom Array and Stroboscopic Effect Visibility under Combinations of TLM Parameters. Lighting Research & Technology. In Press.

Concern:
While the stroboscopic effect (SE) is better characterized, the phantom array effect (PAE) remains largely unstudied despite there being evidence of visibility at higher frequencies.

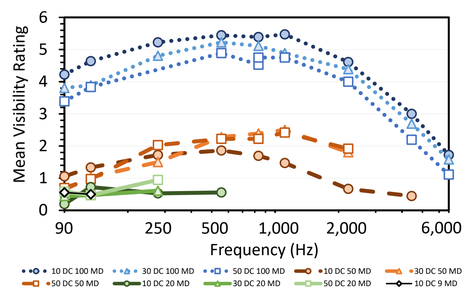
Goal:
Investigate and compare visibility of the stroboscopic and phantom array effects with intention to assess SVM (stroboscopic visibility measure) applicability and potentially create a new metric to describe phantom array effect visibility.

Impact:
Two significantly different sensitivity populations were found, and it is better understood how waveform properties affect PAE visibility. This work will ultimately lead to the creation of a metric to describe PAE perception and the increased comfort and wellbeing of sensitive populations.

Phantom array **average** visibility:

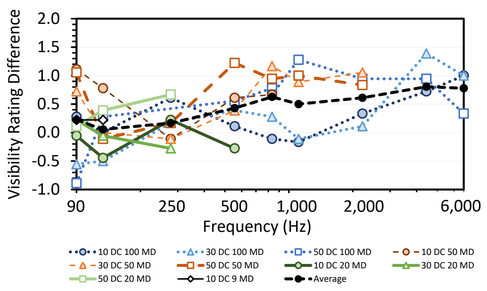
- Peaks between 500 Hz and 1000 Hz
- Increases with higher modulation depths
- Increases at lower duty cycles
- Is higher for rectangular waveforms than sine waveforms if all else is equal

The phantom array effect was visible *on average* at 6,000 Hz at 100% modulation depth, 10% duty cycle.



The Leiden visual sensitivity scale (Perenboom et al., 2018) was used to differentiate between higher and lower sensitivity subjects.

Differences were greatest when the effects were "harder to see" (lower modulation depths, higher duty cycles, higher frequencies).



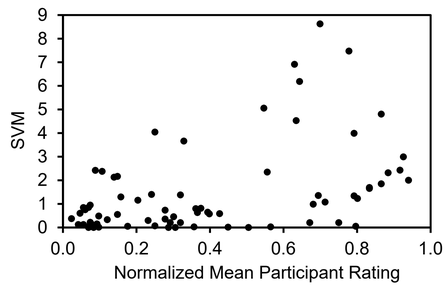
PHANTOM ARRAY VISIBILITY MEASURE (PAVM)

Tan J, Miller N, Irvin L, Royer M. A Metric for Phantom Array Effect Visibility. Lighting Research & Technology. Pending Submission.

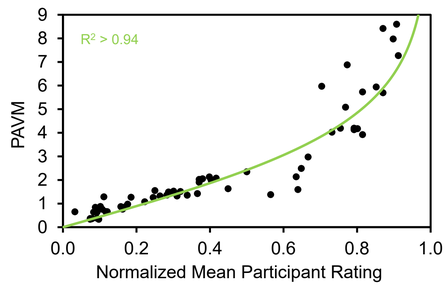
Concern:
There is no well-established metric for quantifying phantom array effect visibility, but there is growing awareness of the need for one among design professionals and sensitive populations. The phantom array visibility data collected from the flicker perception experiment do not correlate well to the stroboscopic visibility measure (SVM).

Goal:
Create a phantom array metric using a process similar to the accepted SVM that can accommodate people of different sensitivities.

Impact:
For the first time, there will be a metric specifically designed for measuring PAE from a flickering light, allowing perception of high frequency TLM to be reliably characterized. The metric will take into account sensitive populations who can see the PAE at higher frequencies than previously described. A PAVM metric makes it possible to create recommendations for lighting systems in the built environment to protect those affected by TLM.



SVM versus participant rating of phantom array visibility in the flicker perception experiment. Mean PAE visibility ratings show little correlation to SVM. Therefore, a new metric, PAVM, was developed.



PAVM versus participant rating of phantom array visibility. When compared to the same visibility ratings, in-progress metric PAVM shows higher correlation to the perception experiment data than SVM.

DATA PROCESSING AND METRIC CALCULATIONS

Tan J, Leon F. Temporal Light Modulation: Data Processing and Metric Calculations. Lighting Research & Technology. In Press.

Concern:
Existing flicker metrics are not straightforward to calculate, and the values sometimes vary according to sampling rates. This work addresses the vagaries in processing TLM waveform data and calculating the metrics.

Goal:
Determine consistency of existing temporal light modulation (TLM) metrics by investigating sensitivities to waveform sampling rate.

Impact:
With the recommendations from this paper, TLM will be measured more accurately and consistently. With more consistent measurements, consumers can have a better idea of what they are buying, and technology can improve at a faster rate.

Situations where large variations were observed. SVM was relatively stable (i.e., produced the same value regardless of sampling rate), while P_{st}^{LM} and M_P values exhibited greater variability based on sampling rate. Metric values from sinusoidal waveforms were generally more stable than those from rectangular waveforms, although P_{st}^{LM} showed inconsistency even with sinusoidal TLM.

	Sinusoidal TLM	Rectangular TLM
PF, FI and PPF	When $F_S/f \leq 4$	When $F_S/f < 10$
SVM	When $f = 2000\ Hz$, but variation is of little significance	When $f = 1000\ or\ 2000\ Hz$, but variation is of little significance
P_{st}^{LM}	When $F_S \geq 40\ kS/s$, and $f = 20\ and\ 30\ Hz$	When $F_S \geq 40\ kS/s$, and $f = 20, 25\ and\ 30\ Hz$
M_P	-	At frequency of 40 – 65 Hz
JA10	Fundamental frequencies near the JA10 cut-off frequencies	Fundamental frequencies near the JA10 cut-off frequencies

PF: Percent flicker
FI: Flicker index
PPF: Physiological percent flicker
SVM: Stroboscopic visibility measure
P_{st}^{LM}: Short-term flicker indicator
M_P: Perceived modulation
JA10: Test method from California Title 24

Future Work: Higher Sensitivity Perception and Response

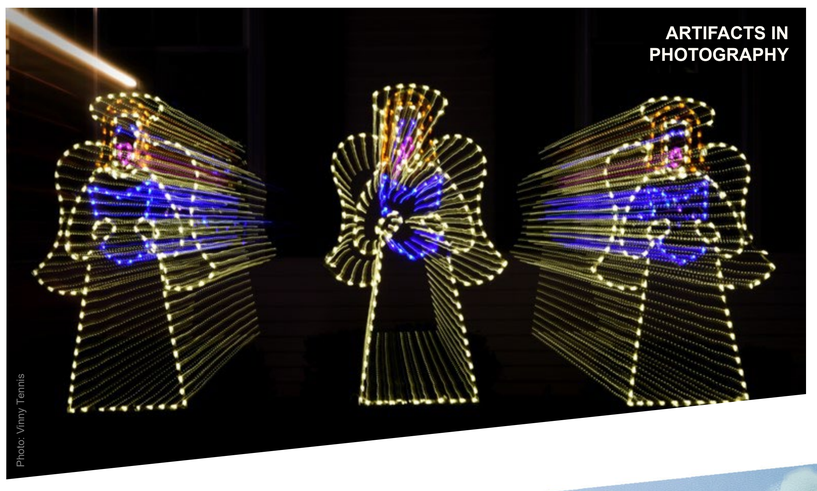
Concern:
Because migraineurs had to be excluded from the flicker perception experiment, the resulting data is biased toward a less sensitive population than is represented in the real world. Consequences of exposure to flicker can be severe for highly sensitive individuals, so it is important to characterize their responses to make sure the built environment is accommodating for their needs.

Potential:
Collaborate with neuroscientists to investigate flicker perception and response in migraineurs, then adjust PAVM as necessary.

Future Work: Automotive Lighting

Concern:
Newer cars with LED daytime running lights, taillights, interior lights, and dashboard displays utilizing pulse width modulation (PWM) have introduced the phantom array effect to roadways. At night the contrast is high, increasing the visibility of the phantom array effect. Any distraction caused by flicker is dangerous for the driver, and potentially unhealthy or hazardous for pedestrians.

Potential:
Characterize flicker perception of automotive-typical TLM waveforms under road-like conditions. Recommend guidelines for the vehicular industry.



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