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Light and Lighting

# Correspondence: Flicker: The sneaky perception that ranges from invisible to debilitating

When I'm in a group discussing the issues of temporal light modulation (TLM), colloquially known as flicker, the responses range from eye-rolling, to *...that's just a few hypersensitive people...* to *...prove to me with double-blind studies in a prestigious neurology journal that seeing flicker leads to physiological symptoms...*, to *...OMG: that's why I get sick looking at my cell phone screen, driving in my car at night, walk out of half the restaurants in my neighborhood, and have learned to despise Christmas because of the annoying LED holiday string lights.*

I am writing this paper in response to all the manufacturers and retailers, automotive companies and property owners/managers whose automatic response is, *...that's just anecdotal.* Although there are peer-reviewed papers addressing the cognitive, behavioural and physiological responses to TLM,<sup>1–10</sup> reports of headaches, seizures, nausea, disorientation, etc. are still considered anecdotal because the neurological evidence is slow to arrive. But when consistent complaints flow into my in-box, unsolicited, with individuals begging for help to fix the flicker in their homes/cars/workplaces and their kids' schools, it is hard to discount them as fanciful or the product of hypochondriacs.

This is an paper about anecdotes. Here are a few of dozens of credible reports:

- A fellow who calls me every holiday season because all the LED light strings are adorning houses and businesses, and he feels not joy, but nausea. It is the phantom array effect he is disturbed by because he also has trouble crossing streets safely at night due to the automotive LED taillights, daytime running lights, marker lights, etc. that modulate from full on to full off 200 times a second, creating a repeating retinal pattern that produces a deceptive impression of where the vehicle is and what direction it is moving. It makes him disoriented, and he fears for his safety.
- A woman in New York City who wears welder's glasses in grocery stores, shops, post offices and even in some areas of schools where she teaches. She must limit the places she can safely visit because even LED lighting in the apartment buildings of her friends can cause her pain. She has given up using the subway because of LED tube replacements in subway light fixtures, and because of display screens that announce arrivals and departures of trains. She gets traumatic brain injury-type symptoms that can trigger debilitating head pain and extreme fatigue that can be sustained for weeks. She rues the day in 2016 when her own apartment building agreed to let the local utility upgrade the building lighting from fluorescent to LED.
- A woman whose neurologist suggested calling me because she gets seizures from LED lighting. When asked to describe the kinds of lights, she responded, 'bus tail-lights, airplane cabin interior lights, dashboard and instrument lights inside my car', and more. I knew this was a genuine flicker complaint because I, too, have been distracted by 100% flicker from these same products and places. Having measured them, I know the frequency can

range from 120 Hz up to over 840 Hz, and they use pulse-width modulation (PWM) to control LED output. Seizures are not supposed to happen from those high frequencies. I used to discount these incidents. I do not anymore, although I still think they are rare.

- A woman who has dealt with albinism all her life is bothered by flicker, as are many of the students in her special education classes. She and her engineer husband have tried dozens of big-box store LED light bulbs, developing a list of those producing the least flicker. This list is now posted online, and she shares that list with families in her school.
- Multiple people who are struggling with sensitivity to cell phones and other display screens. They complain of fatigue, brainfog, headaches and migraine, and eyestrain. OLED screens are identified as being especially troublesome. PWM control of pixels is one explanation offered on websites such as LEDstrain.org, as is temporal dithering of color pixels. There are multiple online lists of cell phones and laptop computers that produce less TLM and fewer symptoms.
- A fellow in the United Kingdom looking for help from a TLM researcher. He describes his symptoms: *...For over a year I have experienced a range of medical problems related to my exposure to all new light bulbs. My symptoms include strong headaches/migraines and severe eye pain with sensations akin to cutting or strong pressure.* He goes on to report that this exposure has made him sensitized even to flicker from older light sources such as halogen and CFL, plus almost all cell phone and computer display screens. *...The overhead lights in most shops*

*cause me to experience some of the above symptoms within seconds.*

- An imaging scientist commented, *...Try as I might I just can't get across to some folks how noxious flicker is, but I suppose it's like a migraine – if you've never had one it's very difficult to understand how much it can make you ill. Seeing phantom arrays impressed across my field of vision while turning my head is completely debilitating.*
- An executive in the financial industry wrote, *...Now that LEDs are prevalent in most stores, offices, train stations, airports, etc., my lifestyle has changed dramatically, but I am keeping a positive attitude and my family is helping me adapt to what is mostly a daytime-, outdoor- and incandescent-based lifestyle. The company I work for has been very flexible for three years allowing me to work at home three days a week, but after being exposed to LEDs every Monday and Thursday, I am concerned about any potential longer-term damage from the continuous 24-h recovery period I need from vertigo and debilitating pain two days every week.*
- Two friends have identified colour-changing products as causing migraines. Preliminary observations and measurements point to sequential color changes (e.g. red followed sequentially by green to produce a perception of yellow) as a possible trigger.

Anecdotes are accumulating from individuals who have sustained a head injury or concussion in recent years, and now describe seeing and experiencing symptoms from TLM that they never noticed before. Several people getting headaches they associate with flicker have purchased flicker meters to document the offending

light source's performance, or they have used slow-motion video on their phones to demonstrate the TLM. They have shared these with me.

What could be causing this neurological response? My initial thought was glare, the spectrum or TLM. Is it glare from poor LED luminaire optics? Is it the spectrum from a blue-pump LED which exhibits a local blue peak in the spectral power distribution? Or, is it TLM, because regular, high-modulation oscillation in luminance rarely occurs in the natural world in which humans evolved? If the latter, is it the stroboscopic effect or the phantom array effect or something else altogether that is the culprit? All of these possibilities are testable, given careful experimental studies with neurology collaboration and reliable, sensitive subjects willing to help solve the problem.

Recent TLM visibility work at PNNL has pointed to a difference in sensitivity between migraineurs and non-migraineurs, as well as a greater incidence of headaches among migraineurs following the experiment. The significance of this is perhaps *average* response of a population is an inadequate target for establishing a flicker metric. Perhaps we should address the 15% of the population that gets migraines instead. Or, should we focus on the very sensitive few that are almost completely debilitated by this issue?

We need to know what populations experience these discomforting or disabling responses, how many people this represents, what characteristics of the TLM waveform are responsible for the problematic symptoms, and the mechanism by which the eye/brain system is affected. We need it soon if we are to avoid imposing limits on the manufacturing of products which are cost-effective, efficient, useful, fun and even inspiring. In the meantime, the responsible action is to reduce TLM in electric light sources to ensure fewer people are affected by them.

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