

Temporal light modulation: Research progresses, but questions remain

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Temporal light modulation (TLM)

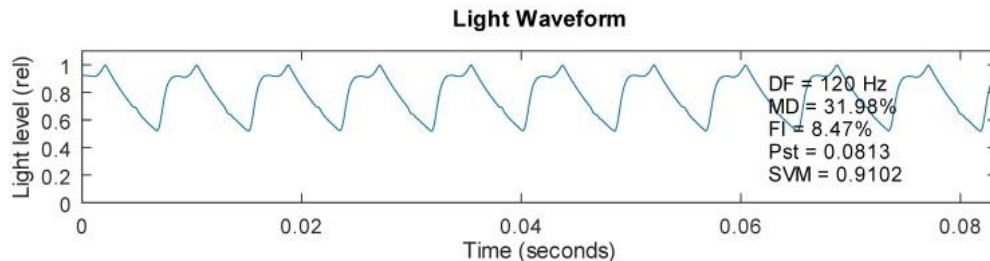
Cyclic variation in light output from a light source or lighting system

Known effects:

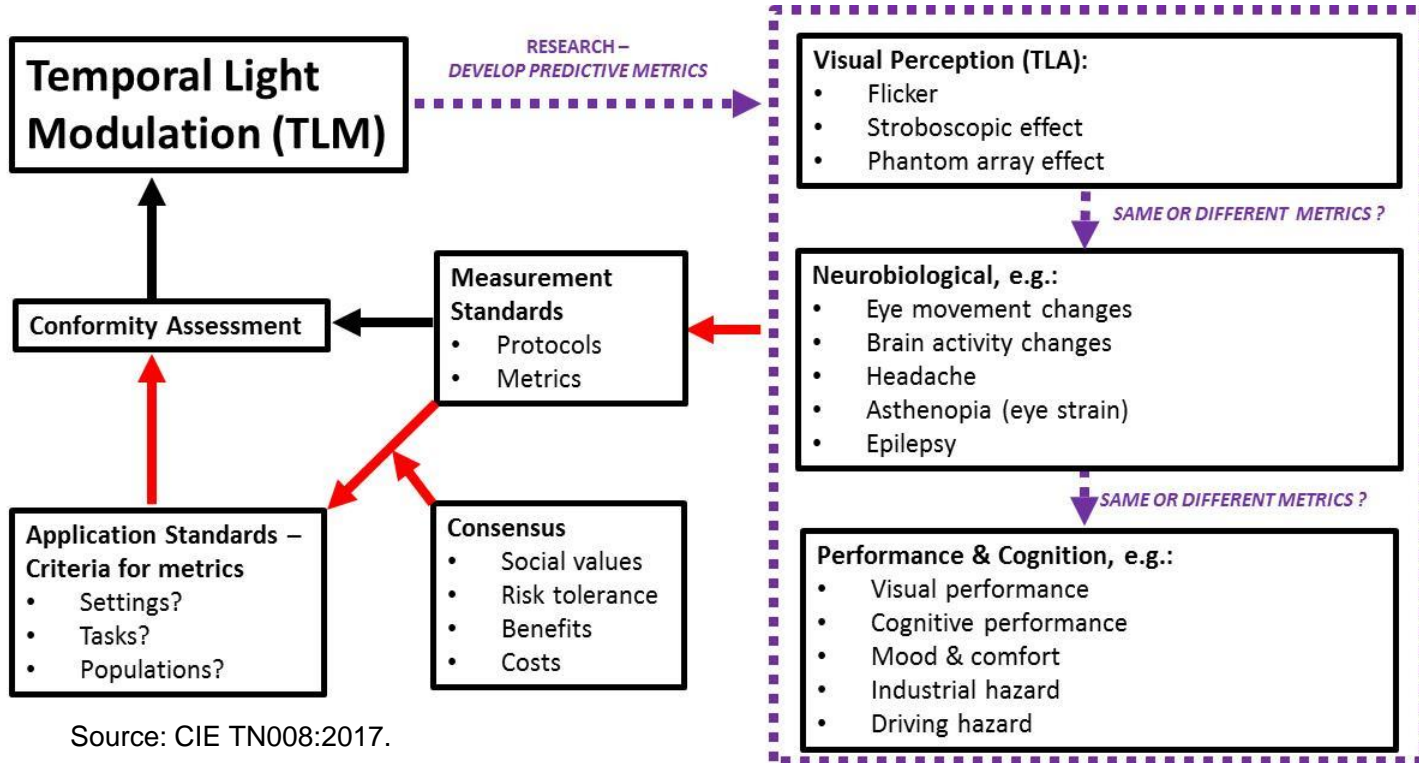
Visual perception: temporal light artefacts (TLA: flicker, stroboscopic effect, phantom array)

Task performance: reading, typing, eye movements

Neurobiological effects: headache, eyestrain, migraine, epilepsy, etc.



CIE Stakeholder workshop on TLM standards



Source: CIE TN008:2017.



Canada-France stroboscopic effect experiment

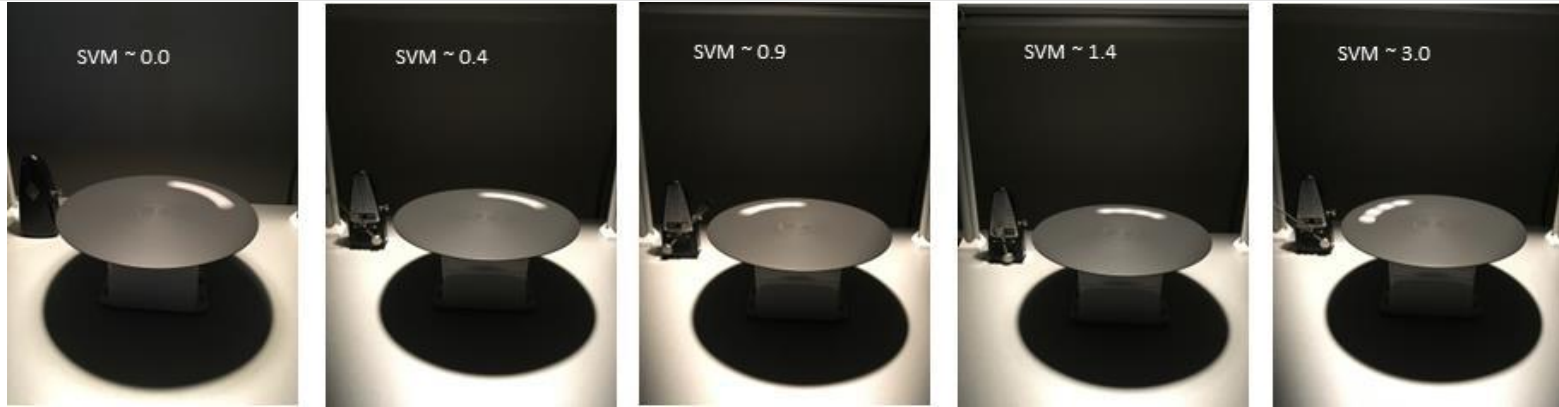
Same protocol in Canada and in France

5 commercially-available LED replacement lamps, chosen to meet SVM criteria

3 tasks: horizontal stroboscopic detection (rotating disc); vertical stroboscopic detection (metronome); acceptability & annoyingness ratings



Canada-France experiment - Hypotheses



H1: Participants will detect the stroboscopic effect on 50% of trials for SVM=1.

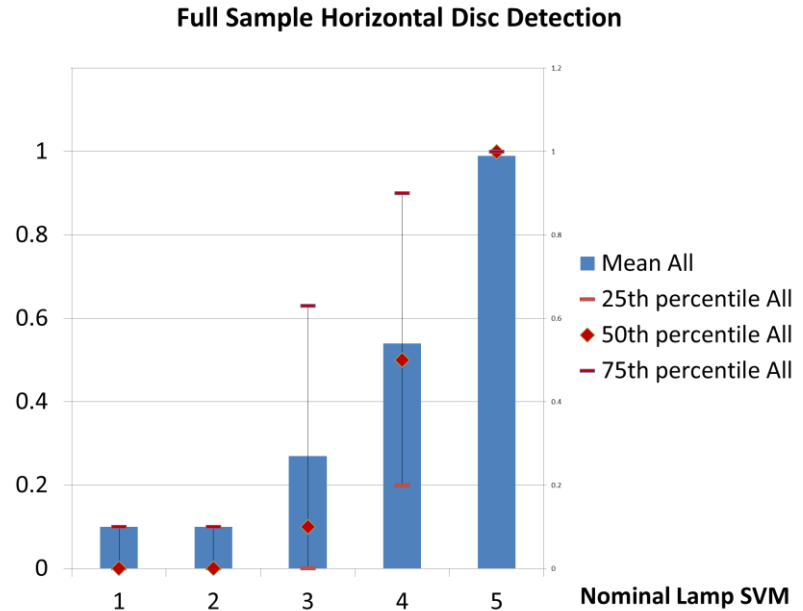
H2: Participants will detect the stroboscopic effect on an increasing percentage of trials with increasing SVM.

H3: Comfort and pleasantness drop with increasing SVM, and annoyingness increases with increasing SVM.

Canada – France experiment: Results

Preliminary results were presented at CIE 2019 – paper available in the online proceedings:
<https://doi.org/10.25039/x46.2019.PP04>

Results based on larger sample currently under journal review, including analyses that focus on possible individual differences in sensitivity.



Cognitive performance, eye movement & phantom array experiment (TLM ex 2)

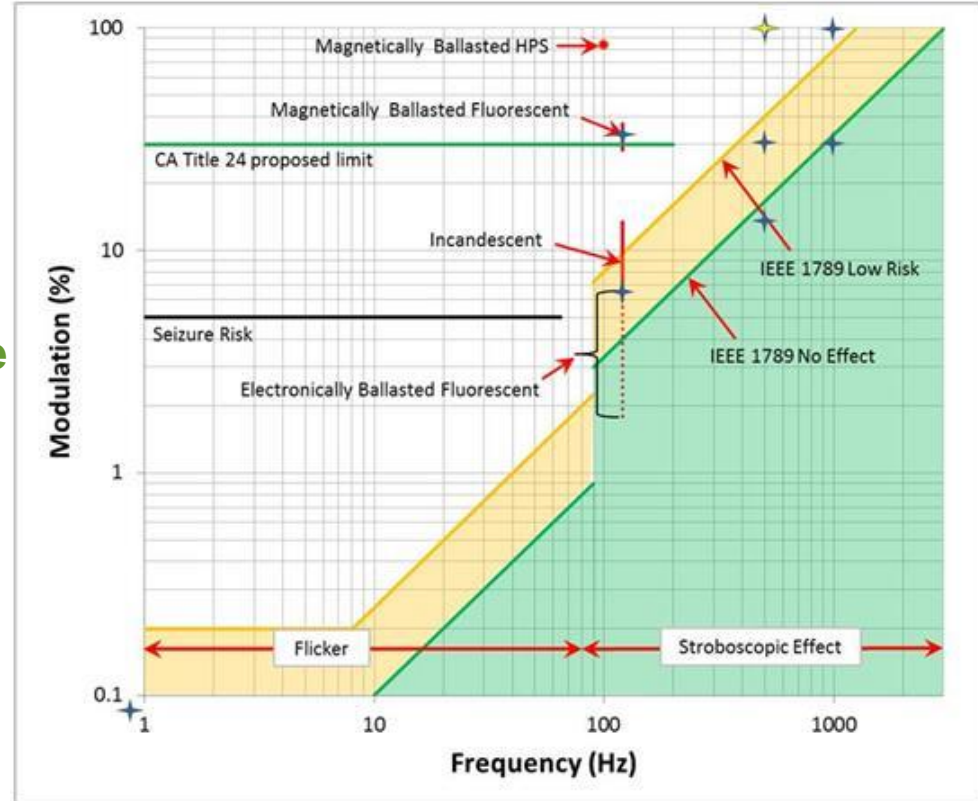
Compared 9 conditions defined as no, low, or high-risk according to IEEE 1789-2015

DVs: eye movements; pupil size; reading performance; Stroop cognitive interference; phantom array detection

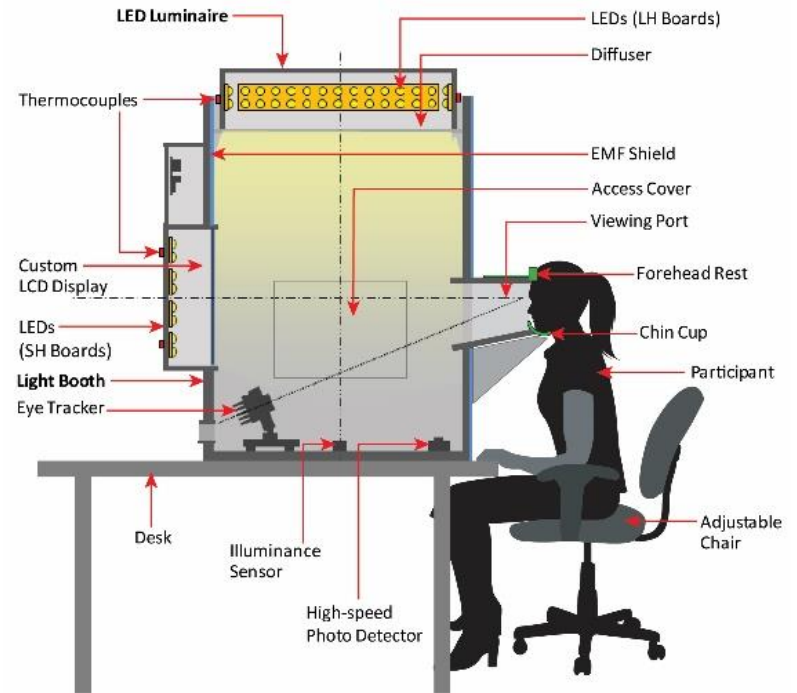
Individual differences:
Pattern Glare Sensitivity

N=25 men, 25 women, 18-65 years

~15-20 min per exposure



TLM apparatus



TLM ex 2: Dependent measures & controls

Wilkins Rate of Reading test

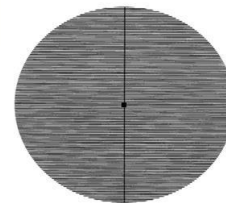
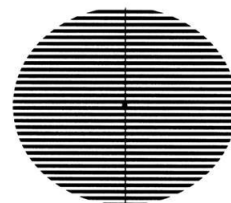
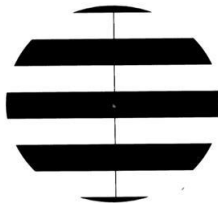
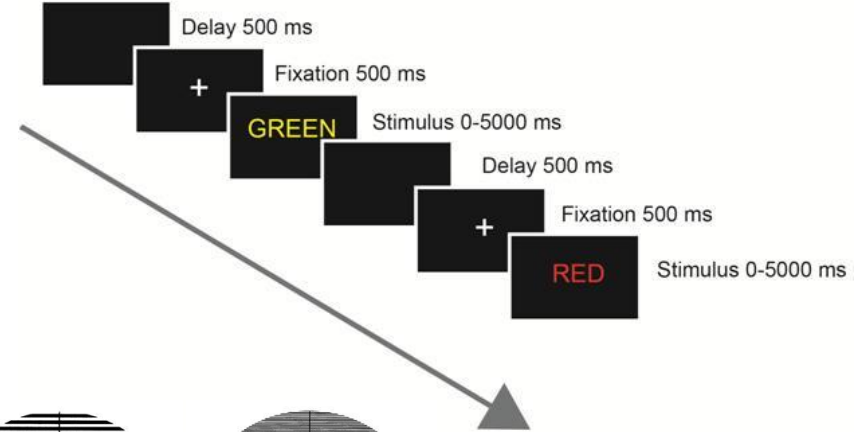
Stroop cognitive interference task

Phantom array detection

Eye movements

Visual discomfort

Individual difference:
Pattern Glare Sensitivity



TLM ex 2: Results – Modulation depth

Small effects, not on all outcome measures

Phantom array eye movements:

At 500 Hz, smaller pupil size for 30% modulation compared to 100%

Reading:

At 1000 Hz, fewer reading errors at 30% modulation than 100%:

TLM8 (1000 Hz, 100% mod depth) M = 2,58 (SD = 2,19)

TLM9 (1000 Hz, 30% mod depth) M = 2,15 (SD = 1,73)

Visual discomfort:

At 500 Hz, unexpectedly lower discomfort for 100% modulation than for 30%
...but both were very low (0,47 and 0,56 on a scale from 0 [low] to 4 [high])

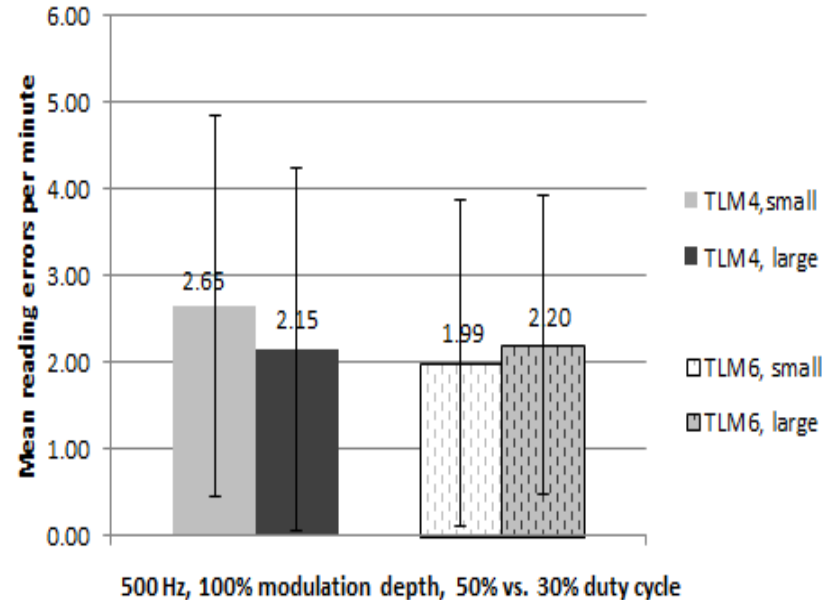
TLM ex 2: Results – Duty cycle

Interaction of duty cycle and print size for reading error rate – all small effects

For 50% duty cycle, print size mattered; errors were higher for small print

For 30% duty cycle, errors were the same for both print sizes

Overall, errors were higher for 50% duty cycle than 30%



TLM ex 2: Conclusions

Small effects with these short exposures – typical of TLM literature

Few studies have examined effects of duty cycle – more data needed!

This is critical because of the widespread use of PWM dimming

Didn't replicate Stroop effect, but did see fewer reading errors at 500 Hz 30% duty cycle than 500 Hz 50% duty cycle (interaction with task difficulty)

Possible link to literature on stochastic facilitation

Phantom array was detected in these photopic conditions – also worthy of further study, with less restrictive viewing

Deeper analyses of data from sensitive individuals still to come

Conclusions and next steps

Verbal reports of visual detection are not required for behavioural and brain activity effects to occur

Visual perception effects happen fast; other effects require a longer time course

Visual perception effects might or might not predict other behavioural or health effects

Some people seem to be more sensitive to such effects

How might we identify these individuals? What are the effects on these people, how severe are they, and when do they arise?

Metrology: measurement in a lab is comparatively easy (CIE TC 2-89)

Field measurement is a harder challenge – instruments are inconsistent & multiple luminaires in the space add complexity

THANK YOU

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