Visual Perception

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CIE Info Day
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Technische Universiteit Eindhoven
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Where innovation starts

Ambition

Improving vision through lighting

- Extend knowledge on human visual perception
- Investigate effect of light characteristics on perception of objects, spaces and quality of light
- Toward task and person-tailored light applications

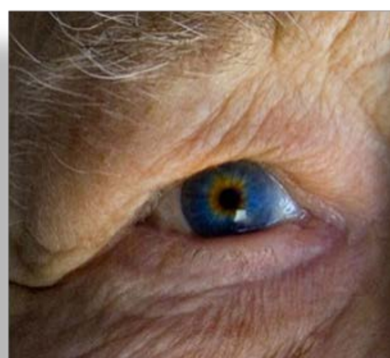
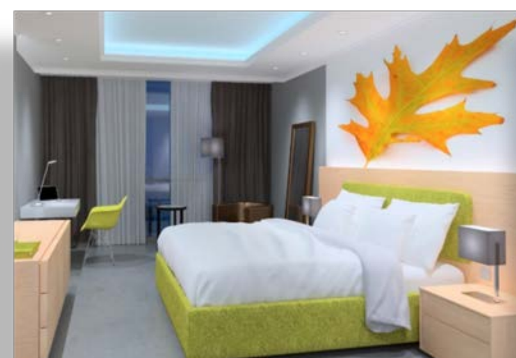



Projects

Simulating aged vision - PostDoc: Y. Ling

Background: Young designers do not take into account the degradation of the eye with age (e.g. visual acuity, contrast sensitivity, color shift)

Aim: Develop a tool to visualise to young designers what elderly people see


Projects

Modeling the temporal behavior of human color vision - PhD: X. Kong

Background: Current models on spatial color vision cannot be used to create smooth dynamic light at predefined speed

Aim:

- Measure chromatic flicker thresholds
- Develop a model that yields uniform flicker thresholds
- Test if model can predict constant speed between colors

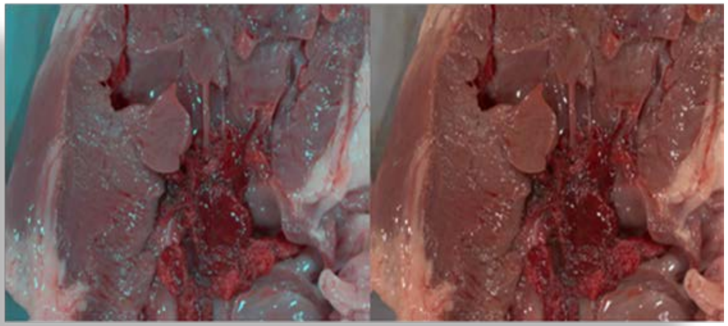
Projects

Optimal illumination for color contrast and texture enhancement - PhD: H. Wang

Background: LED illumination offers new possibilities to optimize the spectral and spatial distribution for improved visibility

Aim:

- Develop a method to determine the SPD for optimal color contrast
- Develop a method to determine the diffuseness and direction of light for optimal texture visibility



Projects

Copying light atmospheres - PhD: M. Stokkermans

Background: Shop chains want to create the same atmosphere at different locations independent of environmental characteristics

Aim:

- Investigate how adaptation affects the perceived atmosphere in a spatially complex environment
- Investigate which lighting characteristics are important for copying the atmosphere from one space to another space

Temporal Quality of Light

Quantifying temporal quality of light - PhD: G. Perz

Background:

- LEDs are everywhere: homes, shops, offices, street
- Advantages
  - low power consumption
  - low heat production
  - long life time
  - no ultra-violet output
  - ecologically friendly
  - near monochromatic light
  - small size (< 2 mm^2)
  - shock resistant
  - fast response

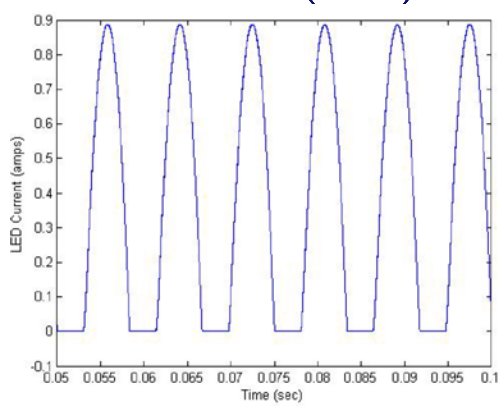
Temporal Quality of Light

Quantifying temporal quality of light - PhD: G. Perz

Background:

- Disadvantages:
  - LED light is temporally modulated
  - LED light can result in visible temporal artefacts

AC LED (50Hz)



PWM (>50 Hz)

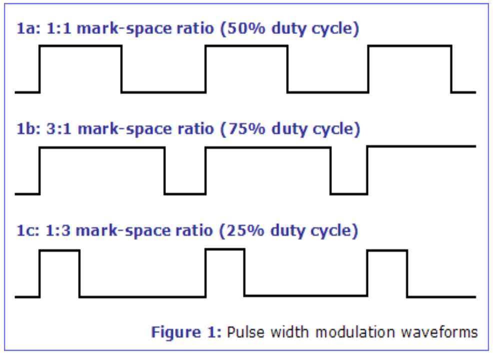
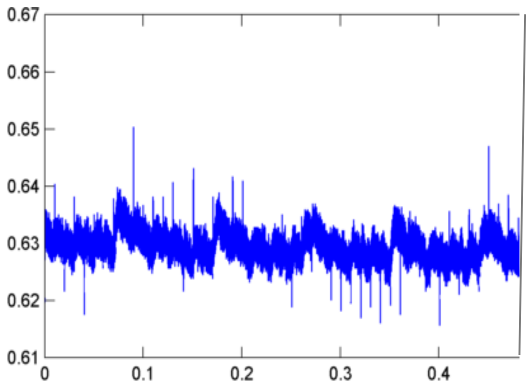


Figure 1: Pulse width modulation waveforms

Interaction dimmer (< 50 Hz)



Temporal Quality of Light

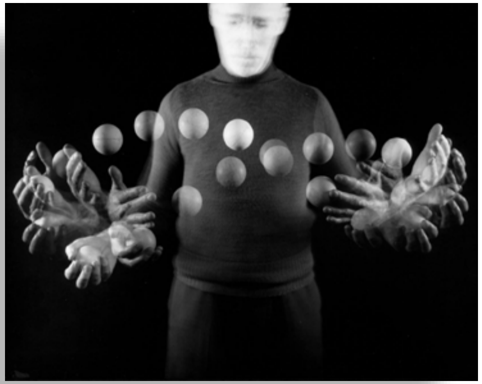
Quantifying temporal quality of light - PhD: G. Perz

Aim: Develop measures to quantify the visibility of temporal artefacts

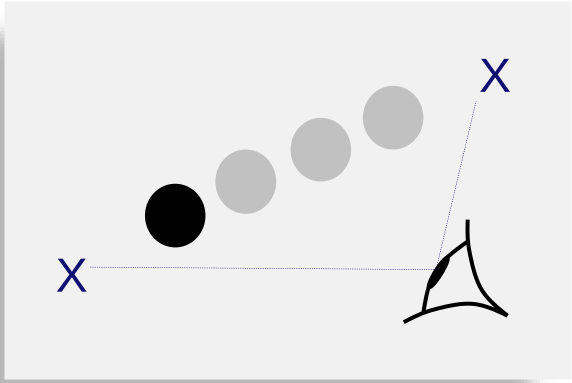
- Flicker: FVM (periodic) and FVM_t (transient)
- Stroboscopic effect: SVM
- Phantom array: in progress

Flicker

Stroboscopic effect



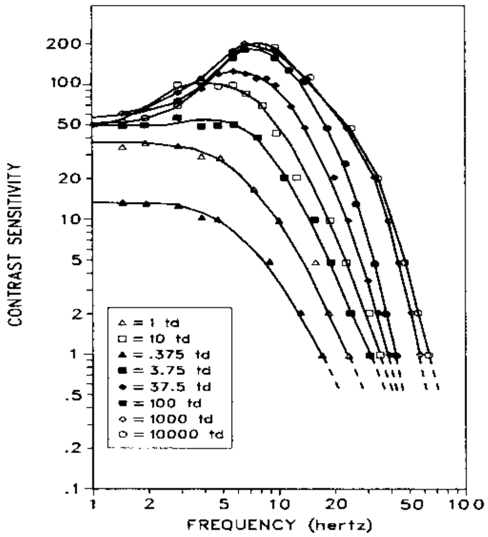
Phantom array



Temporal Quality of Light

Flicker

- Flicker visibility depends on many factors (< 80 Hz)
- Existing measures to predict flicker visibility:
  – Flicker Index (IESNA)
  – Flicker Percent (Modulation Depth)
  – Pst (aperiodic flicker)



- But:
  – do not (fully) account for effect of frequency and wave shape
  – based on 2 degree visual field at low light level
  – difficult to implement in electronic systems

Temporal Quality of Light

Flicker Visibility Measure – periodic (FVM)

The visibility measure corresponds to the summation of all Fourier components (C_m), divided by the flicker visibility threshold of a sine wave at the corresponding frequency (T_m)

$$FVM = \left(\sum_{m=1}^{\infty} \left| \frac{C_m}{T_m} \right|^{n} \right)^{1/n} \begin{cases} > 1 & \textit{visible} \\ = 1 & \textit{just visible} \\ < 1 & \textit{not visible} \end{cases}$$

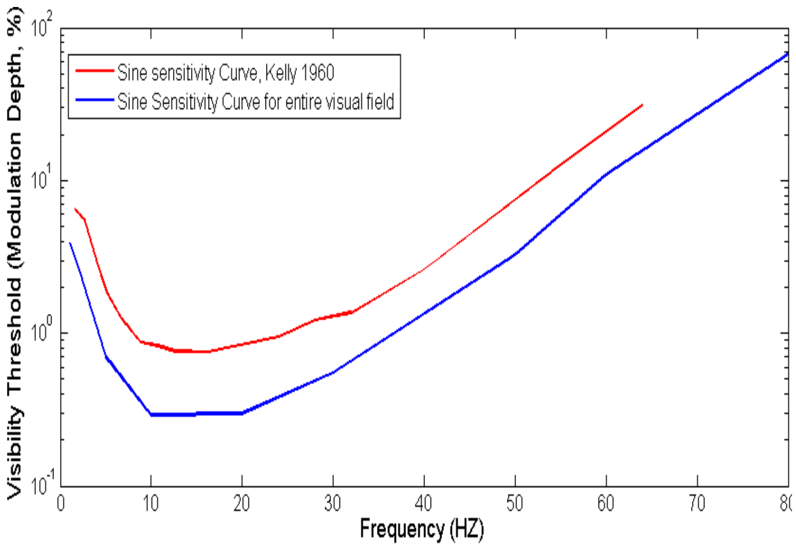
Temporal Quality of Light

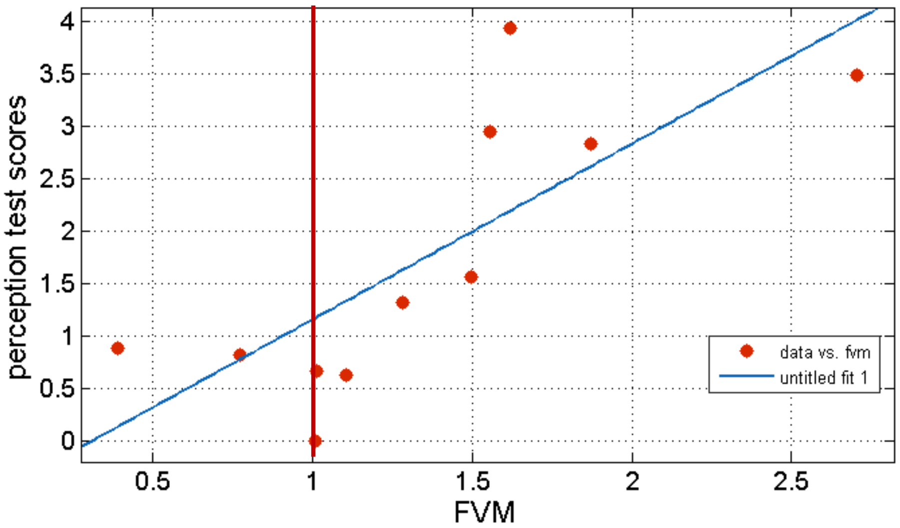
Flicker Visibility Measure – periodic (FVM)

Approach:

1. Measure visibility thresholds for sine waves as function of frequency
2. Measure visibility threshold for complex waves → n = 2.05
3. Validate measure for realistic wave forms → r = 0.77

$$FVM = \left(\sum_{m=1}^{\infty} \left| \frac{C_m}{T_m} \right|^n \right)^{1/n}$$

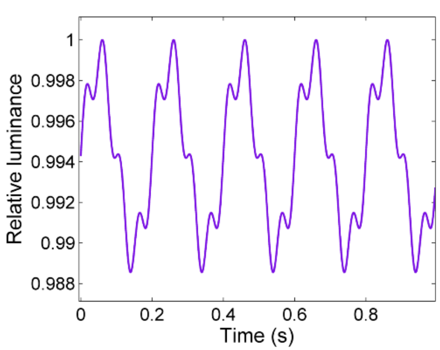




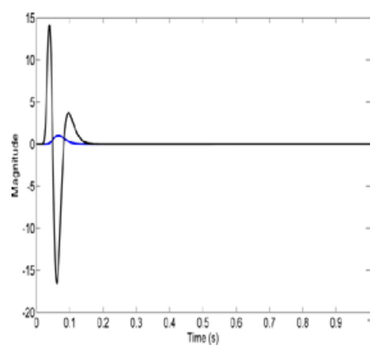
Temporal Quality of Light

Flicker Visibility Measure – transient (FVM_t)

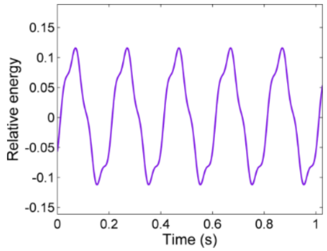
1. The response of the human visual system is equal to the convolution of the input signal f(t) and the impulse response h(t)
2. The impulse response can be described by a combination of two temporal filters ($h_1(t)$: low-pass and $h_2(t)$: band-pass)
3. The measure corresponds to the summation of $R_1(t)$ and $R_2(t)$



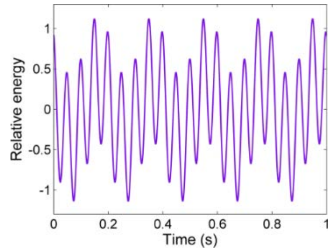
$h_1(t)$ and $h_2(t)$



Convolution



$R_1(t)$



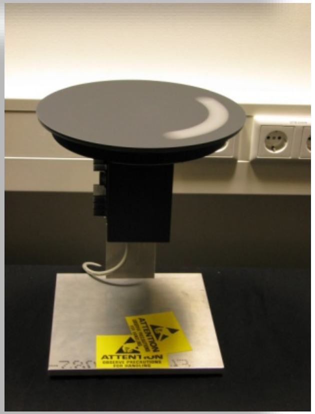
$R_2(t)$

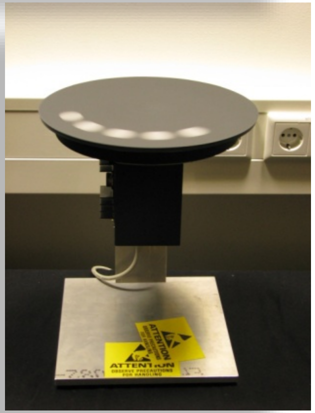
$$FVMt = A * \sqrt[n]{R_1^{\,n} + R_2^{\,n}}$$

Temporal Quality of Light

Stroboscopic effect

- No existing measures
- Bullough et al. (2012): detection equation for square waves at a duty cycle of 50%, a frequency between 300Hz and 10KHz and modulation depths from 5% to 100%.
- Perz et al. (2014): visibility depends on many factors
  - frequency (> 80 Hz)
  - duty cycle
  - light level
  - luminance contrast
  - speed rotating dot
  - test stimulus (rotating dot vs. pen movements)





Temporal Quality of Light

Stroboscopic Visibility Measure (SVM)

The visibility measure corresponds to the summation of all Fourier components (C_m), divided by the flicker visibility threshold of a sine wave at the corresponding frequency (T_m)

$$SVM = \left(\sum_{m=1}^{\infty} \left| \frac{C_m}{T_m} \right|^{n} \right)^{1/n} \begin{cases} < 1 & \textit{not visible} \\ = 1 & \textit{just visible} \\ > 1 & \textit{visible} \end{cases}$$

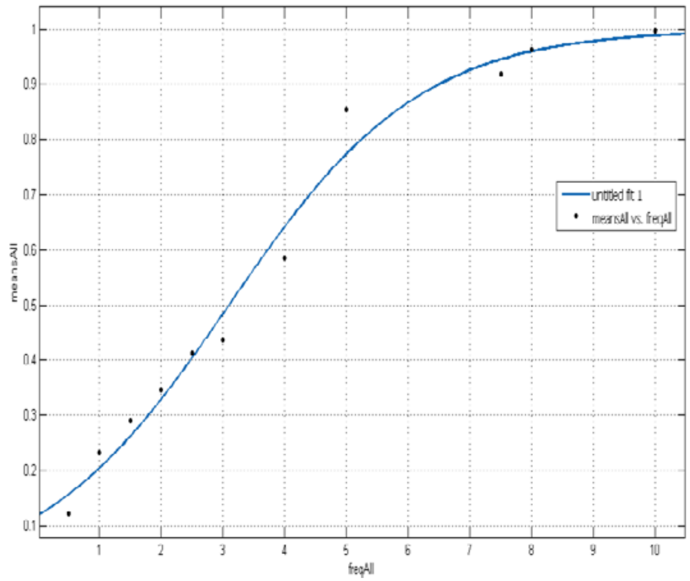
Temporal Quality of Light

Stroboscopic Visibility Measure (SVM)

$$SVM = \left(\sum_{m=1}^{\infty} \left| \frac{C_m}{T_m} \right|^{n} \right)^{1/n}$$

Approach:

1. Measure visibility thresholds for sine waves as function of frequency
2. Measure visibility threshold for complex waves → n = 3.7
3. Correlation between perceived level of the effect and SVM → r = 0.96

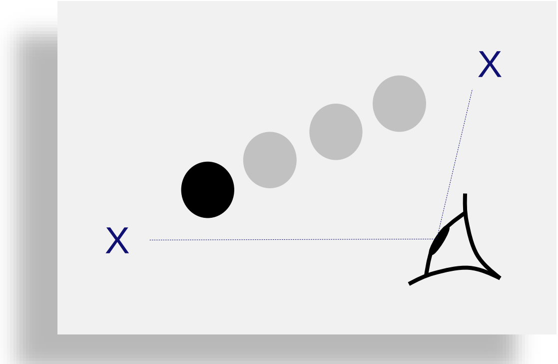


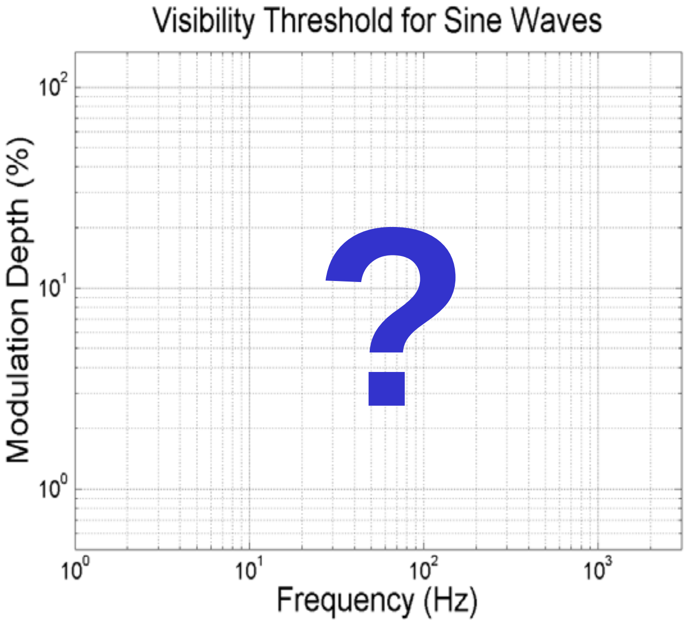
Temporal Quality of Light

Phantom Array

- Hershberger and Jordan (1998):
  - 97% people perceive phantom array
  - visible at 500 Hz (2º, 50 cd/m²)
- Wilkins (2012)
  - visibility depends on modulation depth
  - visible at 2 kHz (150 cd/m²)
- Vogels and Hernando (2012):
  - visibility depends on: beam size, light level,
  - visible at 3 kHz (2º, 64 cd/m²)

→ **a more complicated model is needed**





Conclusion

Based on visual perception reseach we can:

- Optimise light for target groups/individuals
- Optimise light to enhance visibility of local structure
- Create appealing static or dynamic light effects
- Create high (temporal) quality of light




Questions?

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