ROD-CONE INTERACTION IN TEMPORAL PROCESSING

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WHY IS THIS IMPORTANT?

- **Scientifically**, it helps to understand how rod and cone signals are combined to contribute to our vision.
- **Practically**, it helps to design optimal lighting environments.
- **Clinically**, it provides a framework for development of new techniques for the early detection and monitoring of progression of retinal eye diseases such as rod-cone dystrophies, retinitis pigmentosa, and age-related macular degeneration.

UNIQUE RESEARCH APPROACH

A 2-channel 4-primary colorimetric system allows independent control of stimulation of the rod and 3 cone (L, M, and S) types.

Two studies:
1. How dark adapted rods alter critical fusion frequency
2. How rods alter cone impulse response functions

Rod effects are evaluated by comparing the difference between two adaptation conditions:
- following dark-adaptation for 30 min (DA, rods are fully sensitive)
- during the cone plateau (4-5 min) (LA, rods are not sensitive).

STUDY 1:
Rod Suppression of Cone Critical Fusion Frequency (CFF)

Stimulus Pattern

<table>
<thead>
<tr>
<th>Receptoral</th>
<th>Post-receptoral</th>
</tr>
</thead>
<tbody>
<tr>
<td>[L], Modulate L-cones alone</td>
<td>[L+M+S], Modulate luminance without rods</td>
</tr>
<tr>
<td>[M], Modulate M-cones alone</td>
<td>[L+M+S+R], Modulate luminance with rods</td>
</tr>
<tr>
<td>[S], Modulate S-cones alone</td>
<td>[L/(L+M)], Modulate PC- chromatic signal</td>
</tr>
</tbody>
</table>
Results:

![Graph showing CFF difference for different modulations under dark- and light-adapted conditions.]

**Summary**

*Rod suppression of cone flicker detection*
- Occurred at low surround illuminances (≤ 0.5 Td)
- Specific to luminance-containing modulations: [L]-cone, [M]-cone, [L+M+S], and [L+M+S+R].
- Inferred: strong interaction in the Magnocellular pathway.

**STUDY 2:**

**Rod Suppression of Cone Temporal Impulse Response Functions**

**Stimulus Conditions**

DA  |  LA
---|---

Measurements
- temporal contrast sensitivity functions (periodic stimuli)
- 2-pulse summation data (aperiodic stimuli).

Cone Impulse response functions were derived from periodic data or directly from 2-pulse summation data.

**Why do we want to measure the Impulse Response Function?**

The Impulse Response Function (IRF) completely describes the temporal response of a linear system to any arbitrary waveform.

If the Impulse Response Function is known, it can be used to predict visual function (e.g. temporal contrast sensitivity) and performance (e.g. reaction time) in other conditions.
Impulse Response Functions

Following dark adaptation, the cone IRF amplitude is reduced and the time to peak is slower.

Summary

- Dark-adapted rods in the surround area reduce cone IRF amplitudes, derived from either periodic and pulsed luminance stimuli.
- Rod suppression of cone function is due to a change in IRF, not a result of temporal modulation per se.

WHY IS THIS IMPORTANT?

- **Scientific implication:** Rod-cone interactions in temporal processing are primarily mediated by the Magnocellular pathway.
- **Practical implication:** In real world situations, objects or persons viewed in dim surrounding light may be less visible. Dark adaptation may not be the optimal strategy for object detection under light levels where rods and cones are simultaneously active.
- **Clinical implication:** People with retinal eye diseases may have abnormal rod-cone interaction. Tests could be developed for the early detection and monitoring of disease.

THANK YOU!

Anatomy: Rod Pathways

- Thresholds estimated using a double random alternating staircase with a Yes/No paradigm that included 10% blank trials.
- Periodic temporal contrast sensitivity functions: 1-sec raised cosine envelope.
- 2-pulse summation data: 4 ms rectangular pulses.
- Three conditions: 2°, 80 Photopic Td field positioned at 7° temporal eccentricity with:
  - 80 Td 13° surround
  - dark-surround following 30 min of dark adaptation
  - dark-surround during the cone-plateau after recovery from a rod bleach (~52%).
- Center and surround chromaticities were metameric to the equal-energy spectrum $L/(L+M) = 0.667$; $S/(L+M) = 1.0$.
- Cone IRFs were derived from TCSFs using the Stork & Falk method or directly from 2-pulse data using the Burr & Marrone method.

FROM GANGLION CELLS TO LGN

Shared rod-cone pathways provide the basis for rod-cone interactions in color vision, spatial vision and temporal vision.
Results:

- CFF approximately constant at surround illuminances ≤ 0.5 Td
- CFF increased monotonically with increasing surround illuminances ≥ 5 Td
- Higher CFF at low surround illuminances following light adaptation compared to dark-adapted condition.

Results:

Magnitude of suppressive rod-cone interaction

- No differences for the [S]-cone modulation at all surround illuminances.
- CFF differences for the [L/(L+M)] modulation increased with surround illuminance reaching a maximum at 5-20 Td. Rod suppression was small.
Temporal Contrast Sensitivity

- Temporal contrast sensitivity is highest for the 80 Td surround (red symbols) and lowest with the zero surround under dark adaptation (green symbols).
- The magnitude of the suppressive rod-cone interaction is ~0.3 log units for frequencies >10Hz.

2 Pulse Summation Data

- Contrast sensitivity is comparable for dark adapted 80c-80s and light adapted 80c-0s conditions.
- Contrast sensitivity is reduced in the presence of the dark surround.

Impulse Response Functions

- In the absence of rod activity, cone IRFs amplitude is largest.
- Following dark adaptation, the cone IRF amplitude is reduced and the timing is slower.