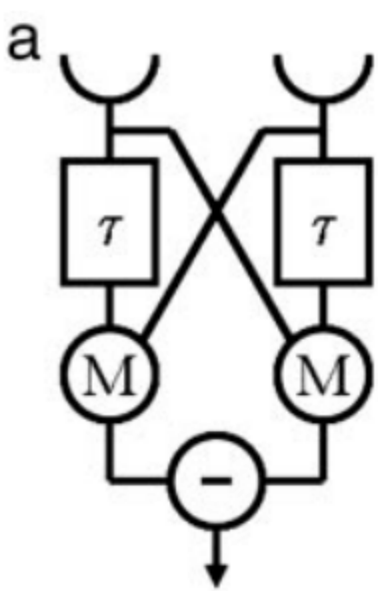
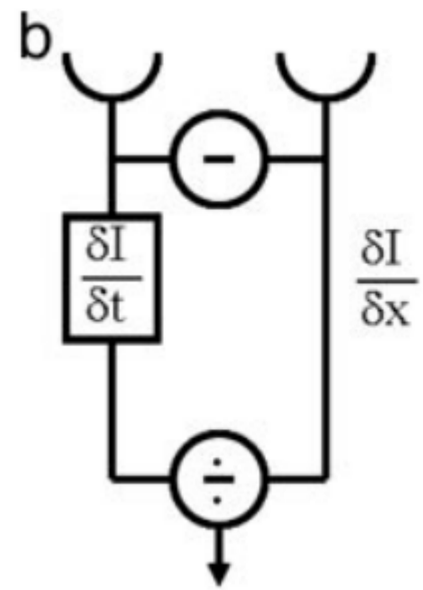
Noise independence of Reichardt detection

Haag, Denk & Borst (2004)

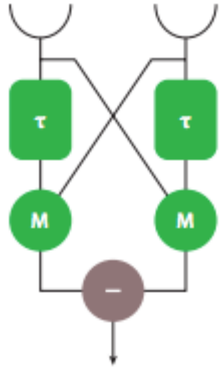


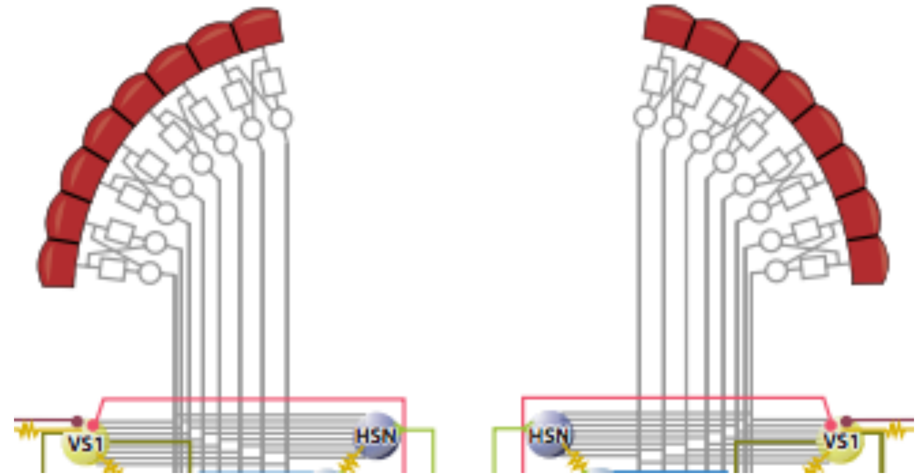
vs

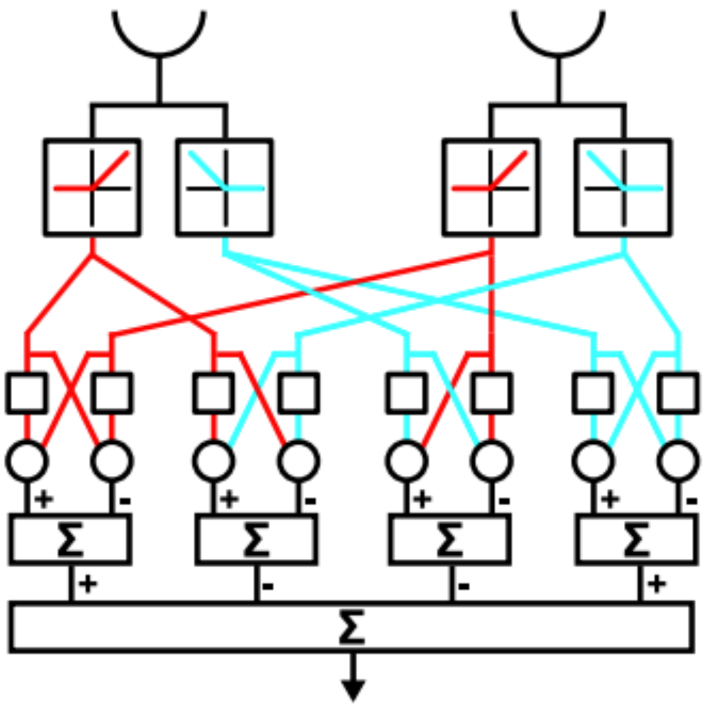


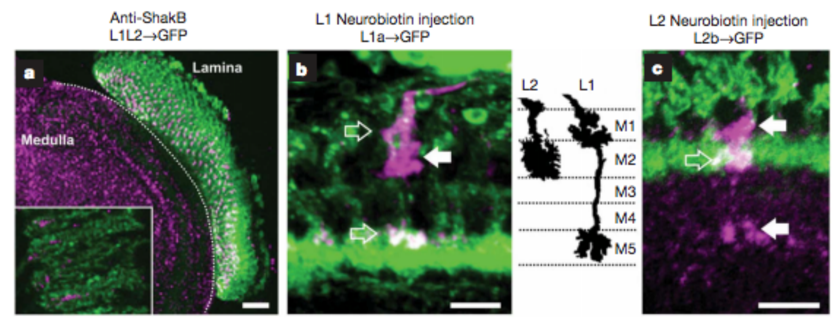
Do flies have gradient detectors?

- Potters & Bialek (1994): statistics are promising in high signal-to-noise regimes
- No experimental evidence. But most experiments have low contrast or high noise
- **Hyp**: gradient detection happens at high S2N.
- Test 1: Look for smoothing out of oscillation in local signals
- Test 2: Look for dependence of optimal velocity on pattern size
- Noise should decrease proportional to C, $\sqrt{I}$









Reichardt + Hassenstein: correlation-type detectors

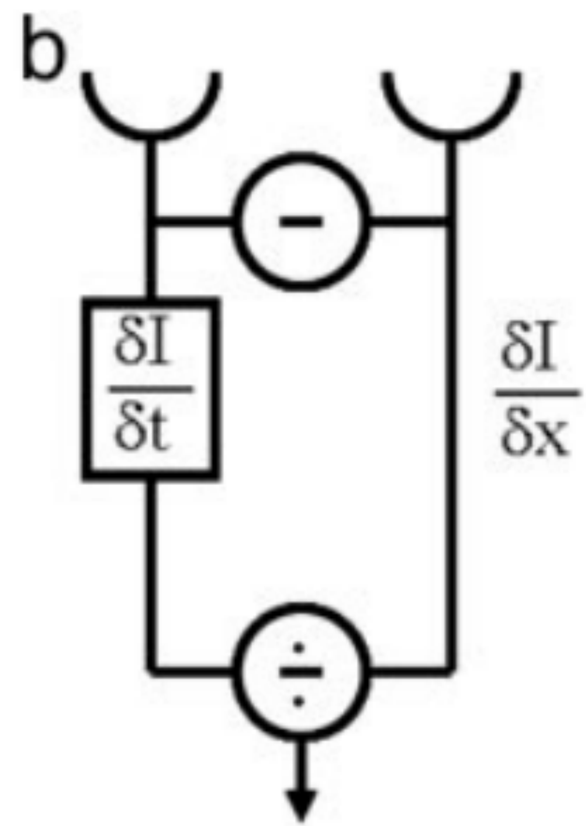
Average DC output + AC local modulation.

Potters & Bialek (1994)

Gradient detector has some nice properties:

- Detects actual v, w/o spatial averaging
- Works over a wide range

- Two detectors: change in I over time (at one detector) and diff b/t neighbors. (δI/δt / δx/δt) estimates v.
- Amplifies noise for high N.



Borst
2006

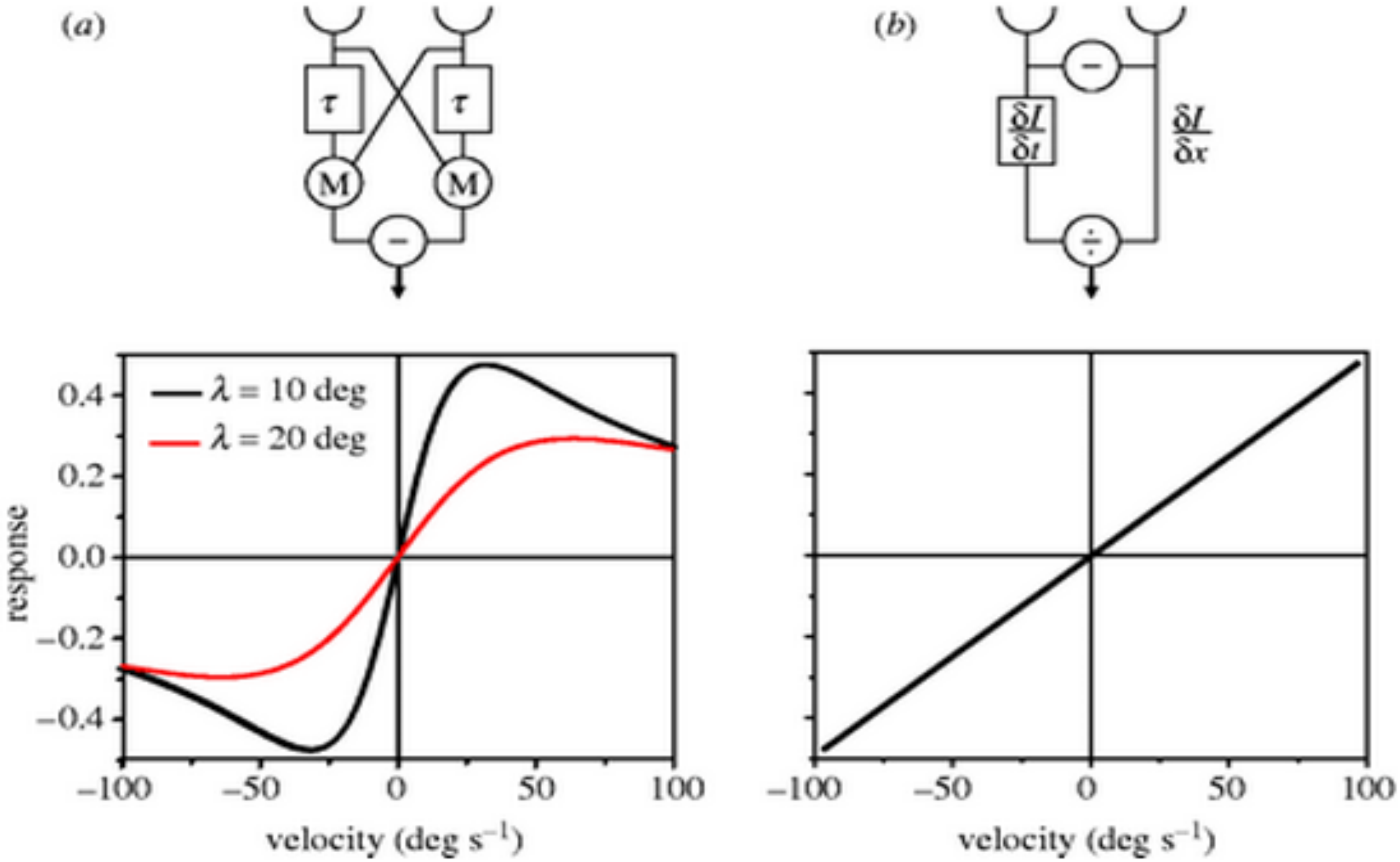


Figure 2

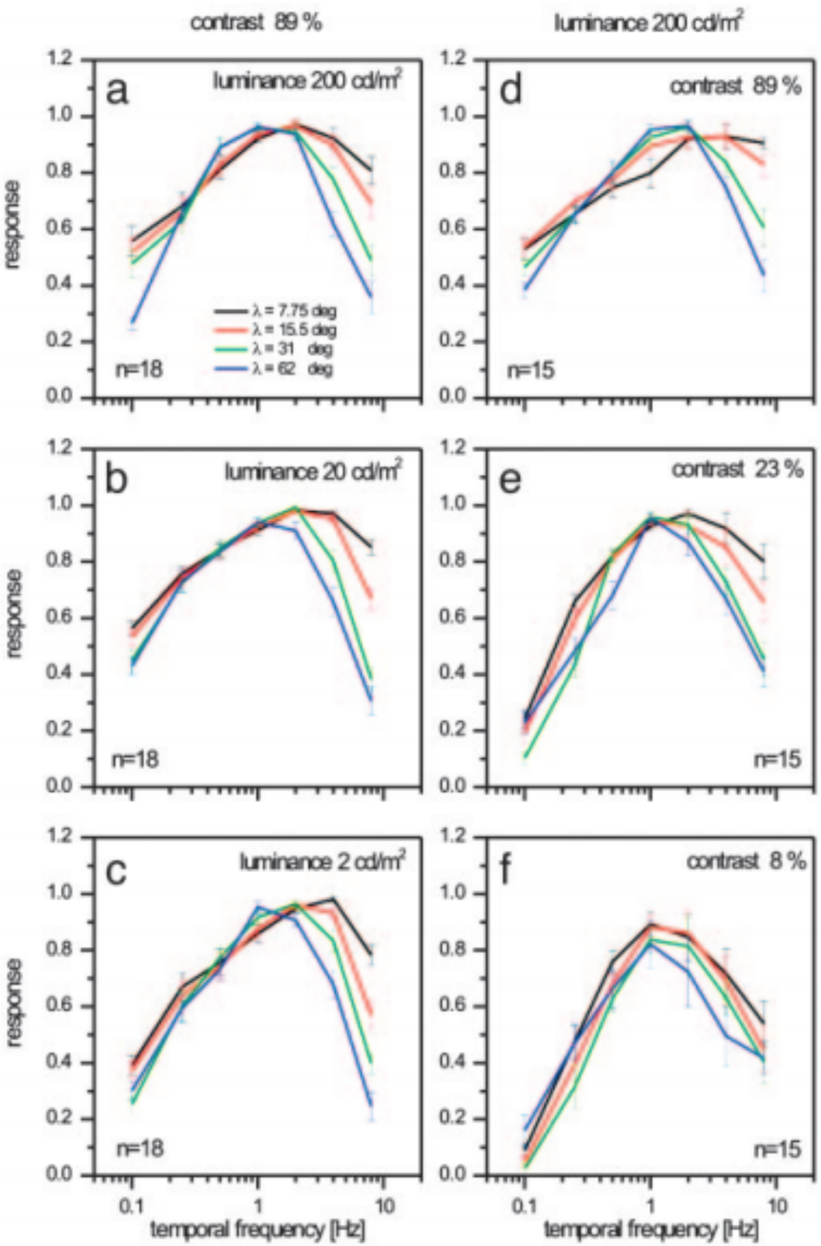
Steady-state velocity dependence of (*a*) Reichardt and (*b*) gradient detectors in response to moving sine gratings (spatial wavelength *λ* as indicated). The Reichardt detector shows a peaked velocity dependence. For velocities higher than the optimal velocity, the response gradually returns to 0. Furthermore, the optimal velocity is different for different pattern wavelengths. In contrast, the response of the gradient detector follows the pattern velocity in a linear way and is independent of the pattern wavelength.

Test 1: H1 response to pattern size

Prep blowflies (-trachea, airsacs), normalize each to its own max response.

- Extracellular measure: 1 H1 cell
- Run sets of 10 sweeps of a pattern, for 3 contrasts (8%-90%) and 3 luminosities (2-200 cd/m2).
- 4 patterns: sinusoids, 8-60 degrees of v.a.
- A gradient detector should start seeing a change in optimal pattern-frequency

H1 response to pattern size



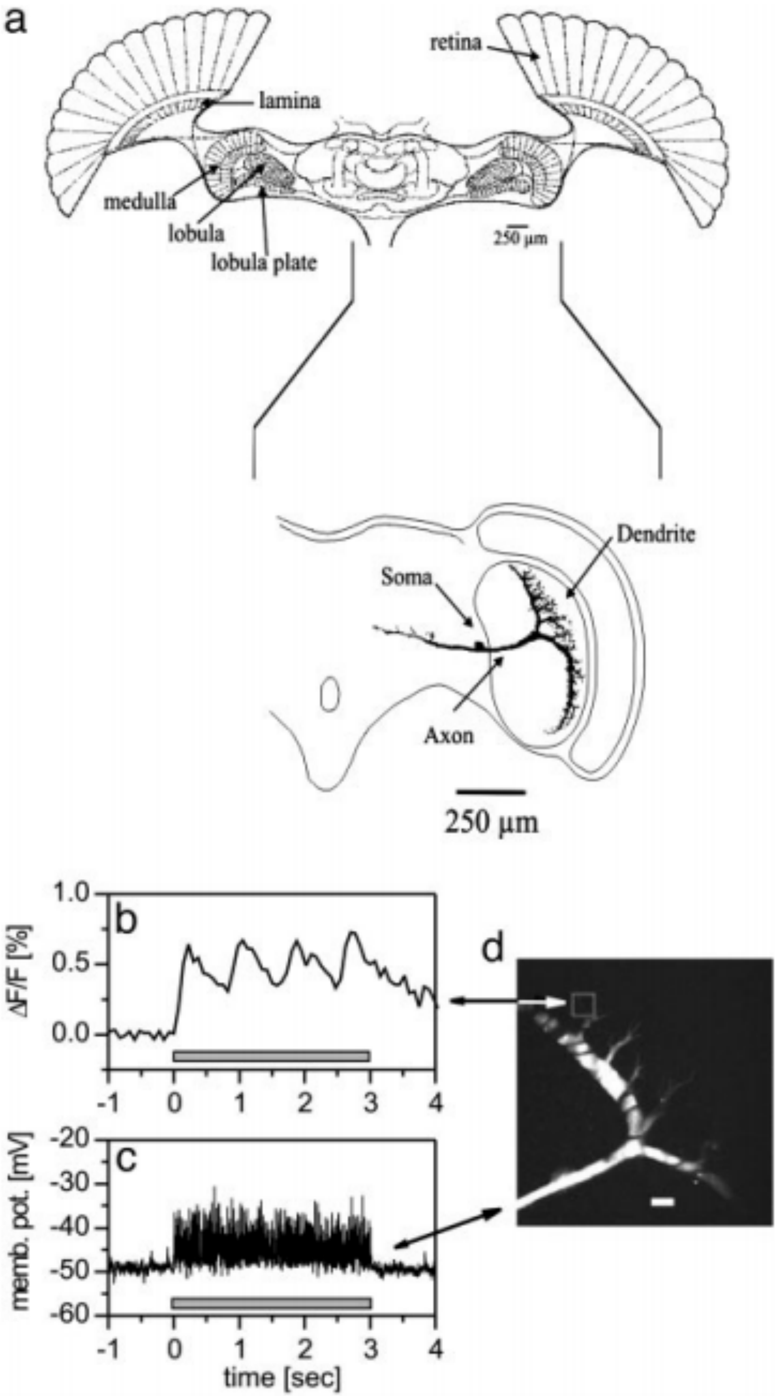
Great match w R theory at low contrast.

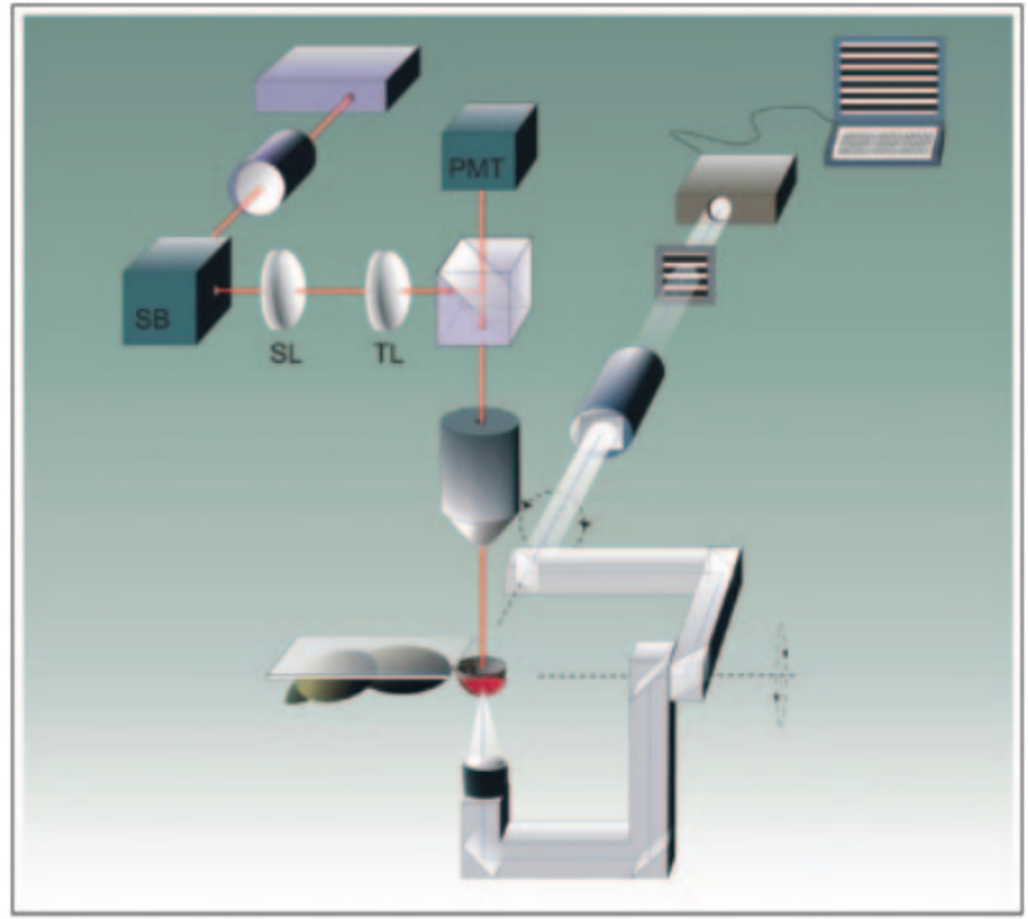
"Almost no" change at higher S2N. Similar spread for low and high Intensities.

Test 2: H & V response to high S2N

Prep blowflies (-prob., gut), fix in 2-photon microscope

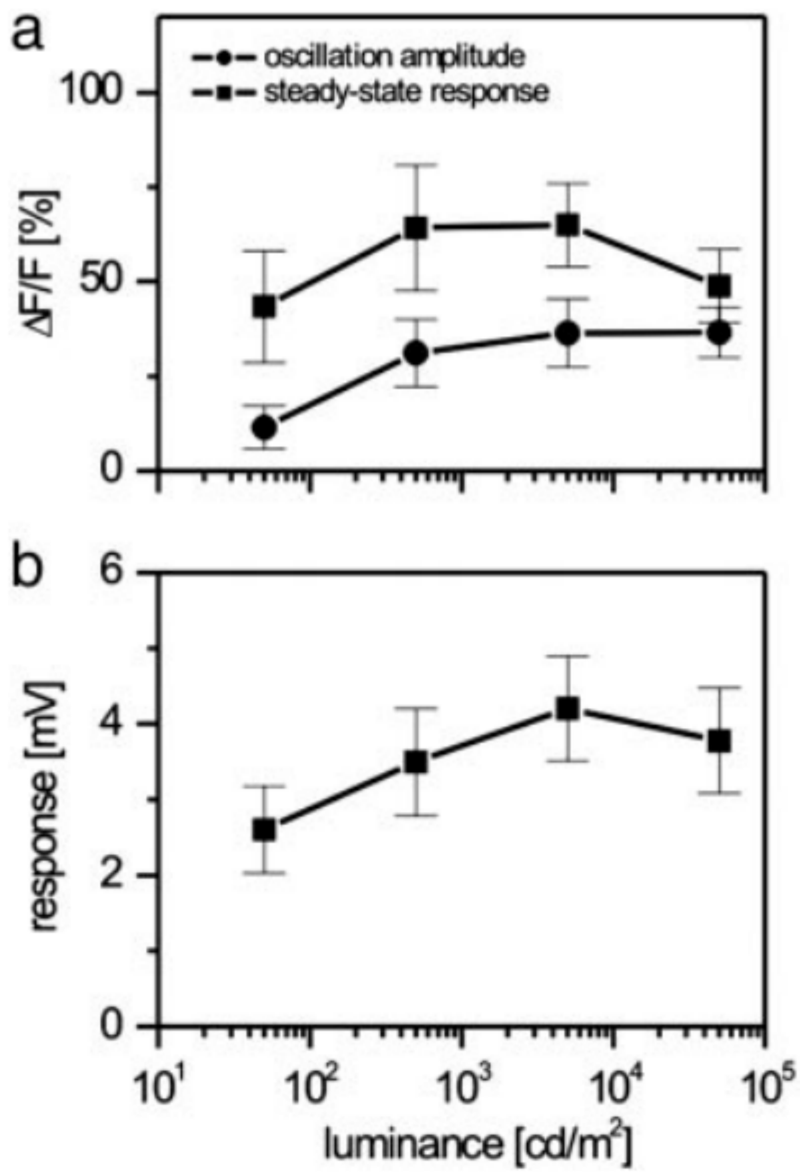
- Intracellular measure: HS & VS axon potential. + Fluorescence to measure local electrical activity in dendrites
- Minimize noise: this is the focus of most of the experimental work
- Vary C (10-90%) and I (50-50K cd/m2)
- A gradient detector should start to smooth out oscillations in local activity.





Filters: 450nm
2ph Fluorescence: 850nm
Focus: Eye's c. of curvature
Imaging: 8Hz.   Lifespan: 1hr

H & V response to high luminance

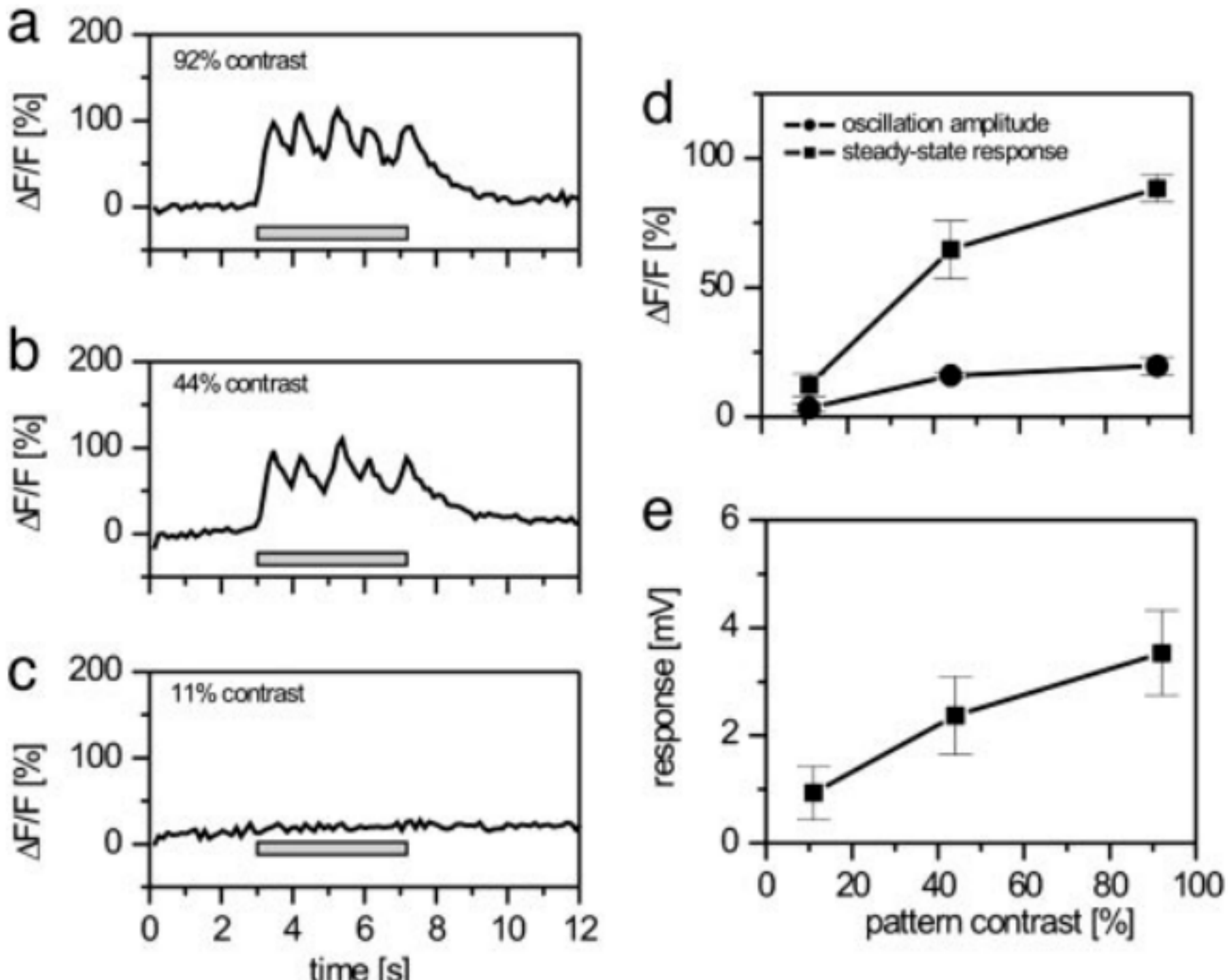


Increasing oscillation of ouput with L

Slight drop in membrane potential for highest L

As with high contrast, no evidence of a shift to a gradient regime.

H & V response to high contrast



Conclusions

- No evidence of gradient detection, for a range covering most of the normal daylight Luminance/Contrast range.

- High-S2N data continues to match Reichardt detection: in particular, both local and global signals reaching the lobula plate are pattern dependent (not just v-dependent).

Remaining questions

- Does this cover highest-S2N regimes?
- Does this work with flies in natural state?

Negative experimental evidence:

- Amplitude becomes contrast-independent at high contrast. (saturation? adaptation?)
- Free-flight of honeybees can depends on absolute velocity (Srinivassa, 1989-91)