From Optics to Actions

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A flowing optic array

<u>General theme</u>**: The <u>dynamics</u> of an observer's actions — their timing, direction, and force — are effectively controlled by the continuously changing optical produced by the observer's movements.**

- Why is this interesting? important?
- What is the optical information?
- What are the visual mechanisms?

<u>Reading</u>:

- Warren, W.H. (2004). Optic flow. In J.S. Werner & L.M. Chalupa (Eds.), *The visual neurosciences* (Ch. 84, pp. 1247-1259). Cambridge, MA: MIT Press.
- Also relevant: Duffy, C.J. (2004). The cortical analysis of optic flow. (Ch. 85 in the same book).

Examples:

- **Walking, running, skiing, skating, etc.**

  (Demand accuracies of ~ 1-3 deg.)

- **Driving cars, riding bikes, flying planes**

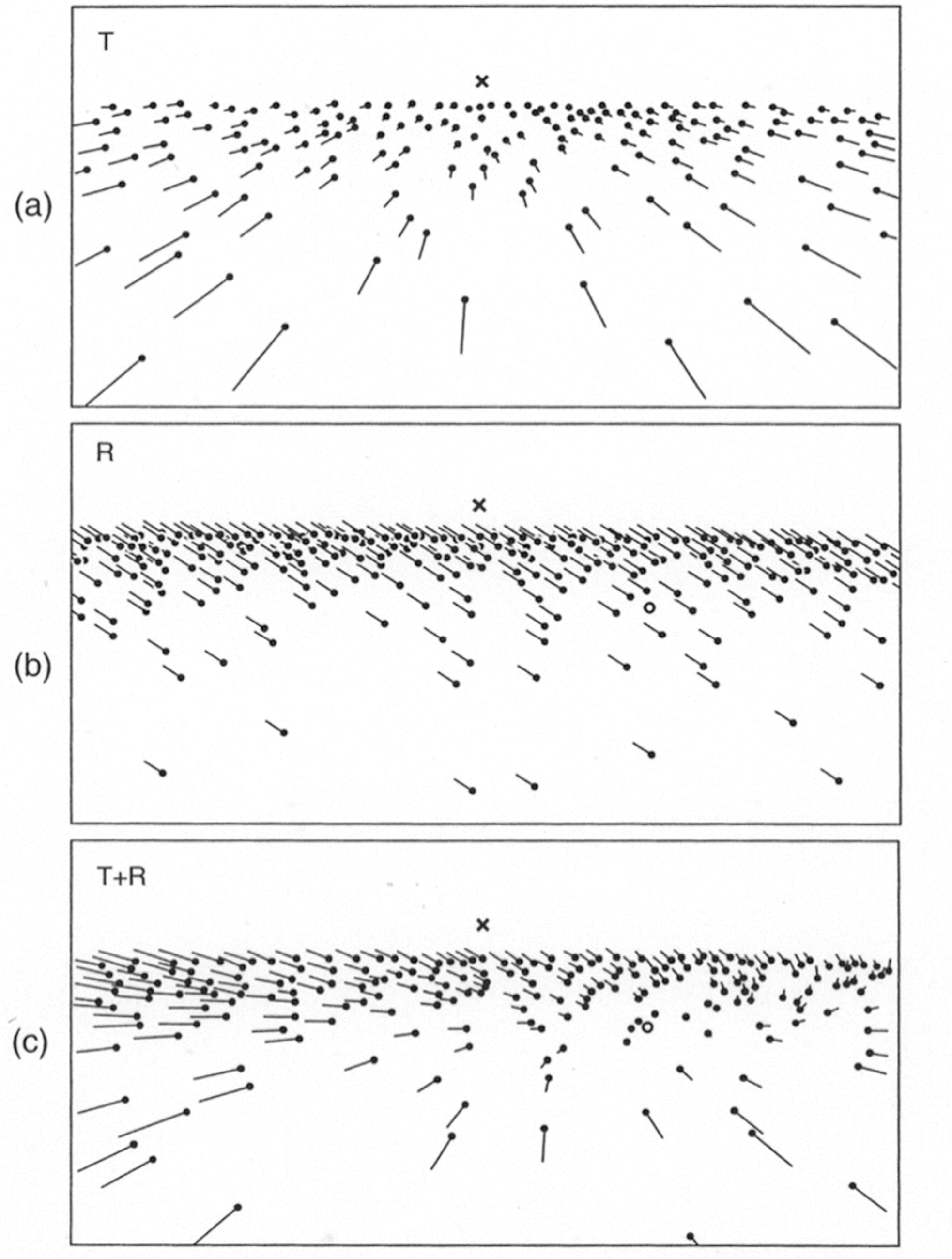
- **Games with fast-moving balls**

  (Regan et al., 1995, calculate that bat-ball intersections in cricket & baseball must occur within a space-time window of about 10 cm x 2.5 msec!)

- **Anticipating & controlling collisions, time-to-contact:** $\tau = \theta / d\theta/dt$. (David Lee's research with long-jumpers and diving birds — indirect evidence of optical control of timing. Yilmaz & Warren (1995) provided more direct evidence in experiments on braking in response to computer-generated displays.)

Brief review of some principal ideas:

- Gibson (1950) coined the term "optic flow" to refer to the changing structure of optical images produced by observers' movements through 3D environments.
  - visual importance of changing rather than static images
  - visual importance of the active observer
  - Locomotion (e.g., of pilots in planes) must be controlled by the changing structure of optical patterns.
  - focus of outflow (of expansion, FOE) specifies heading direction
- Gibson (1979): "ecological approach" — perception, environment, & action as inseparable
- David Lee (e.g., 1980, *Proc. Royal Society*) develops theory and evidence to show that the rate of optical expansion, tau, $\tau = a/a^*$, provides visible information about time-to-contact.
- Differential geometry of optic flow (Koenderink & van Doorn, 1970s, 1986): 1st-order differential components: div [divergence, expansion], curl [rotation in image plane], def [deformation, slant]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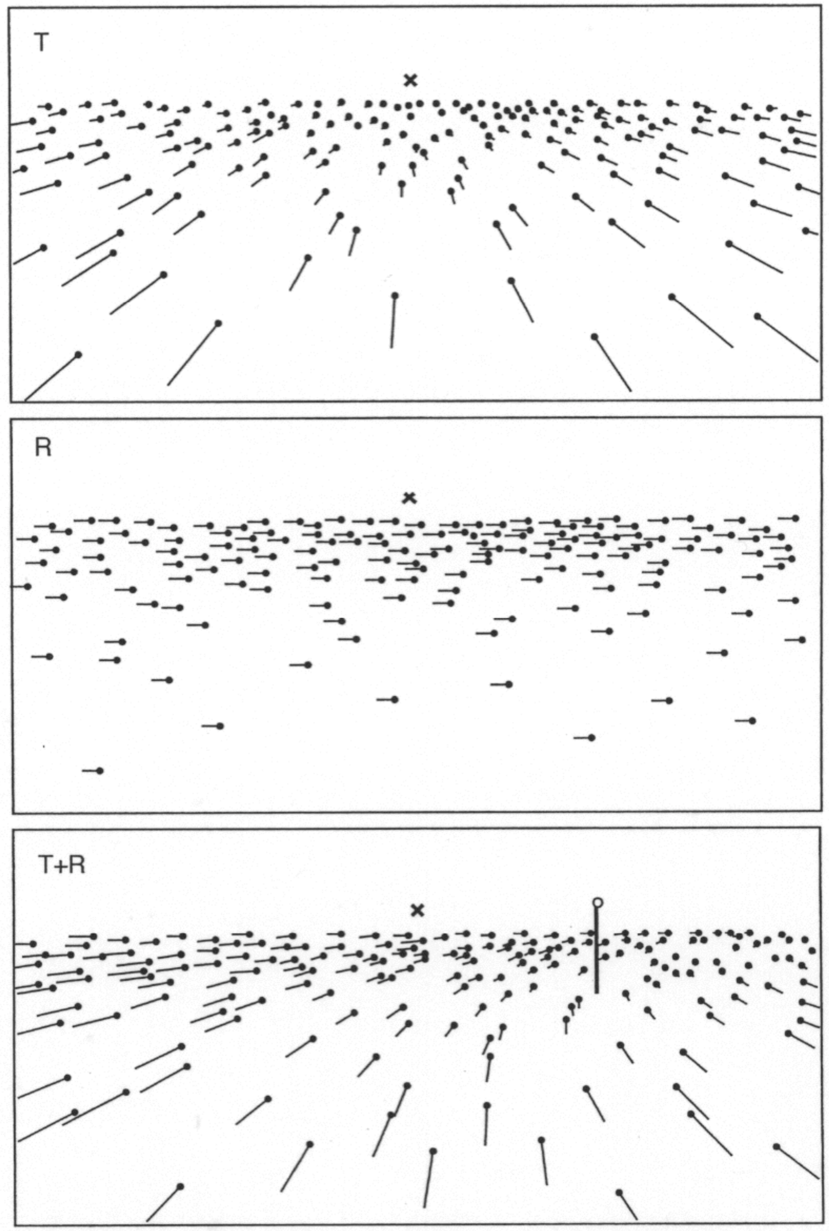

(a)

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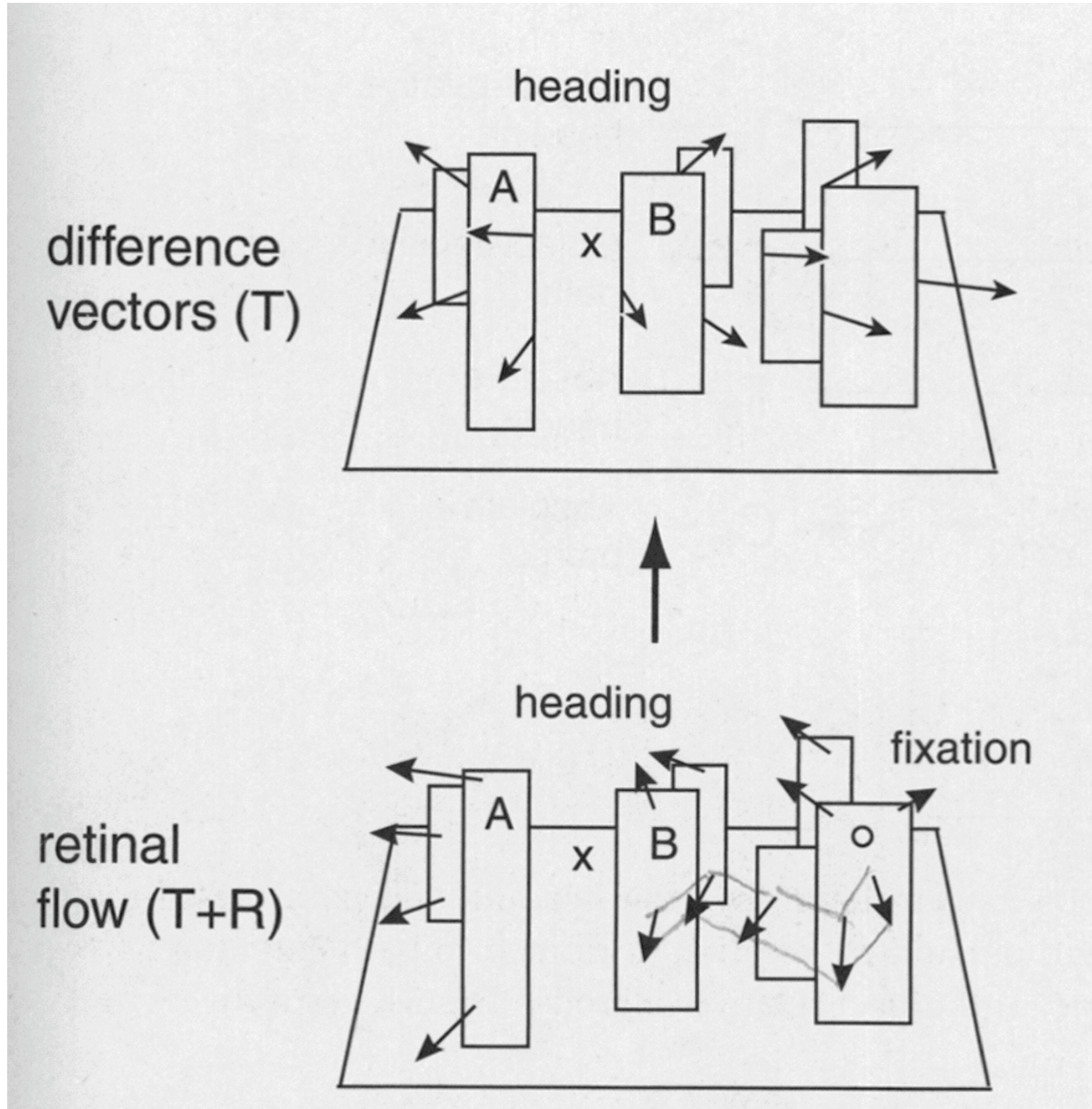
<u>**Issue**</u>: Optic flow or retinal flow?

- Can the expansion component and heading direction be extracted from retinal images produced by both observer translation and eye movements?

- Retinal coordinates or relative motions & image deformations?

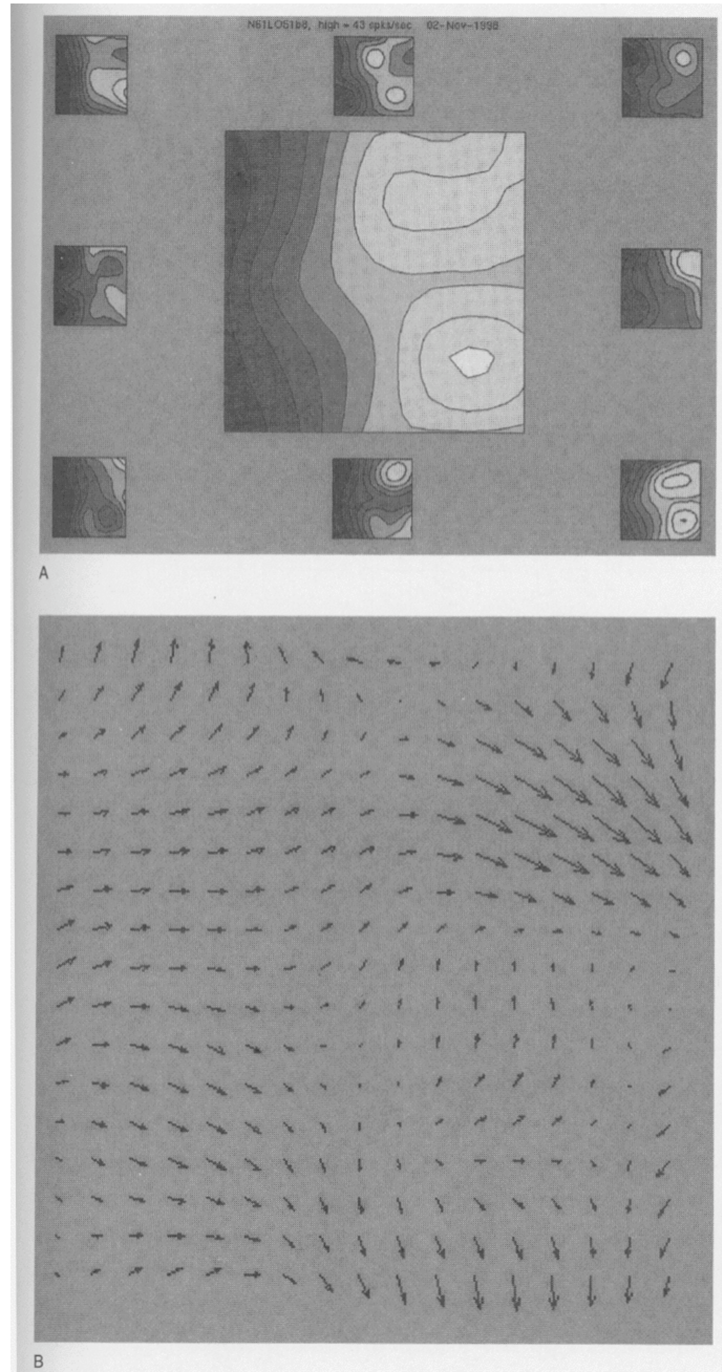
- RFs of some MSTd cells change with active eye movements.



MST neurons have very large RFs, often > 40° diameter. Thus, they will integrate large areas of optic flow.

Differentiation (via center-surround antagonism) also occurs in both area MT and MST.

The images at the right show the complex RF of a neuron in MSTd. (from Duffy, 2004)



Thank you for your attention!