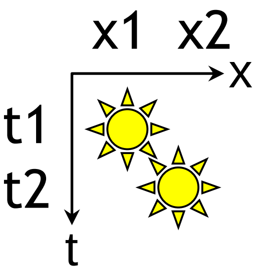
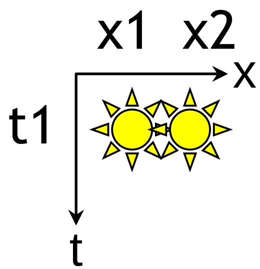
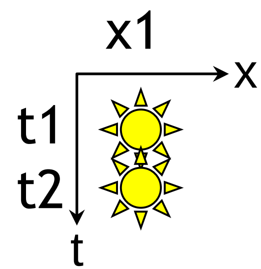
MOTION PERCEPTION. II

BASIC OBSERVATIONS AND THEIR INTERPRETATION

These are facts of motion. They all involve *distinct* high-level processes. But before accessing that processing stage the system must code the *elementary, local motion signal*.

So here is how all this has started and how it proceeded.

Apparent motion: Exner’s experiments (1875)

<table>
<tr><td rowspan="2">Apparent motion

</td><td>Inseparable in position

</td><td>Inseparable in time

</td></tr>
<tr><td>Test with flashes at different positions</td><td>Test with flashes at different times</td></tr>
</table>

Motion is *primary*, not a matter of comparing a spatial and temporal interval.

Apparent motion (Exner 1875; Wertheimer, 1912)

Jump size

Shape & size

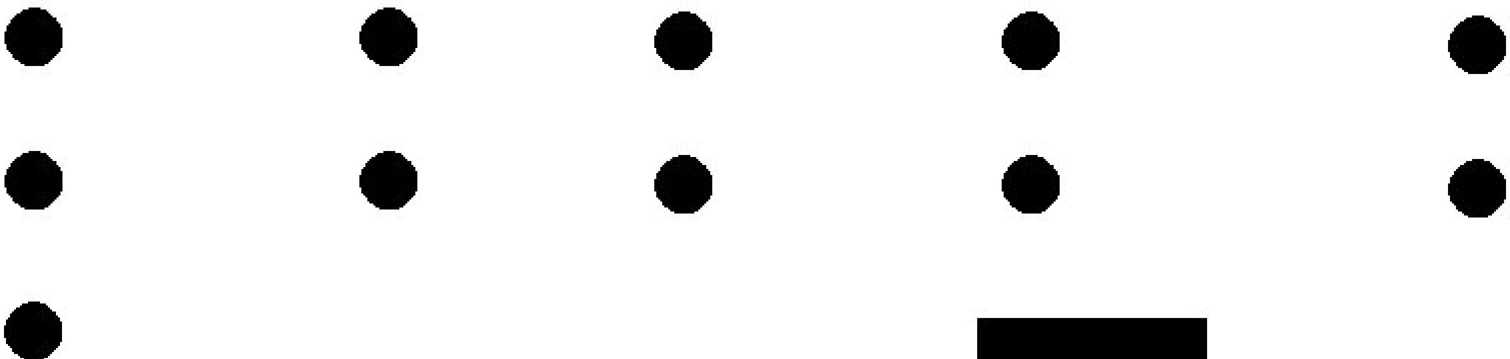
Color & size

Shape, color & size

1 i/s

6 i/s

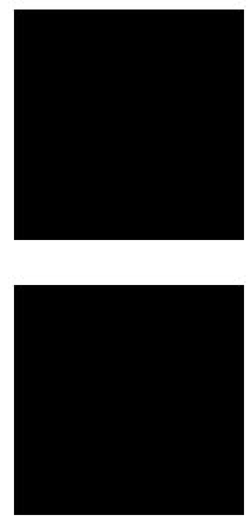
29 i/s

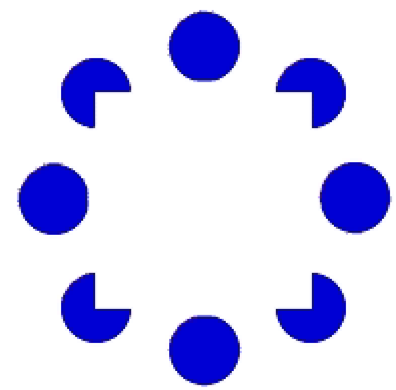


1 i/s

Morphing

6 i/s





3D Kaniza from motion

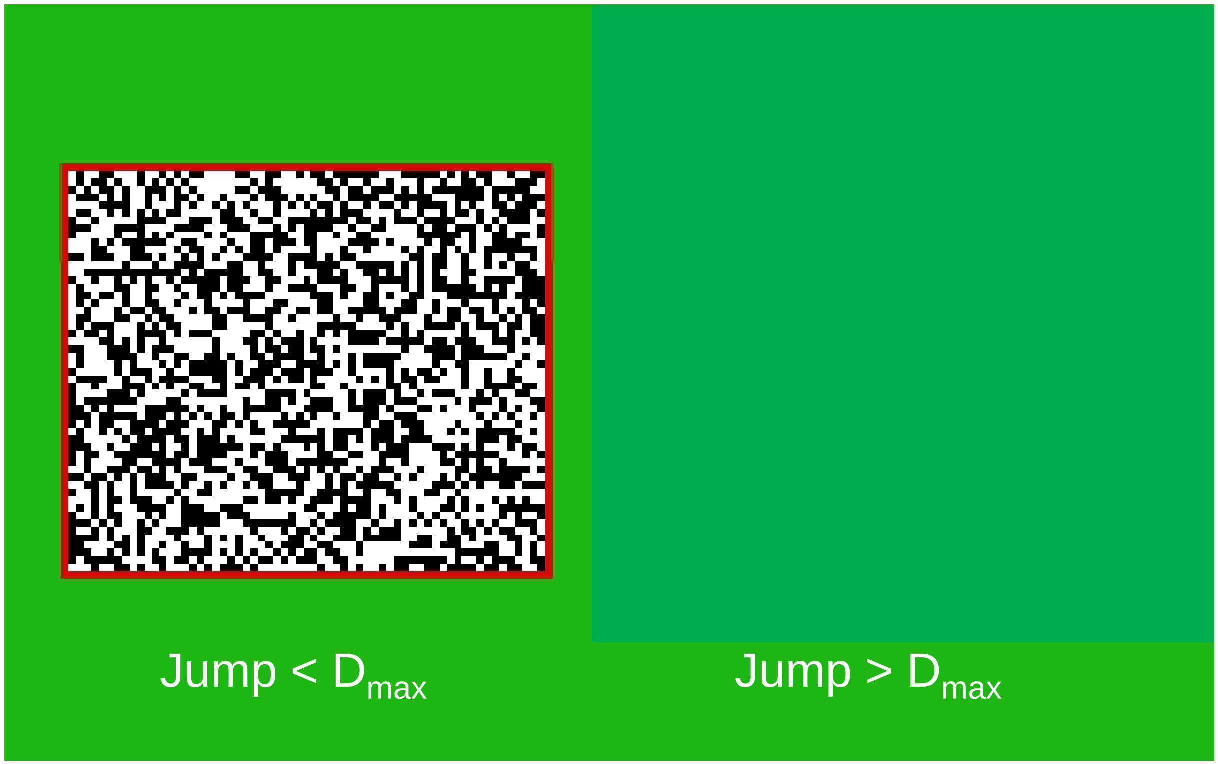
http://www.settheory.com/Glass_paper/wave_movie.dcr

http://www.settheory.com/Glass_paper/Naka_psi_from_rects.gif

http://www.settheory.com/Glass_paper/Naka_bar_psi.gif

The whole (motion) is more than the sum of its parts (Wertheimer).

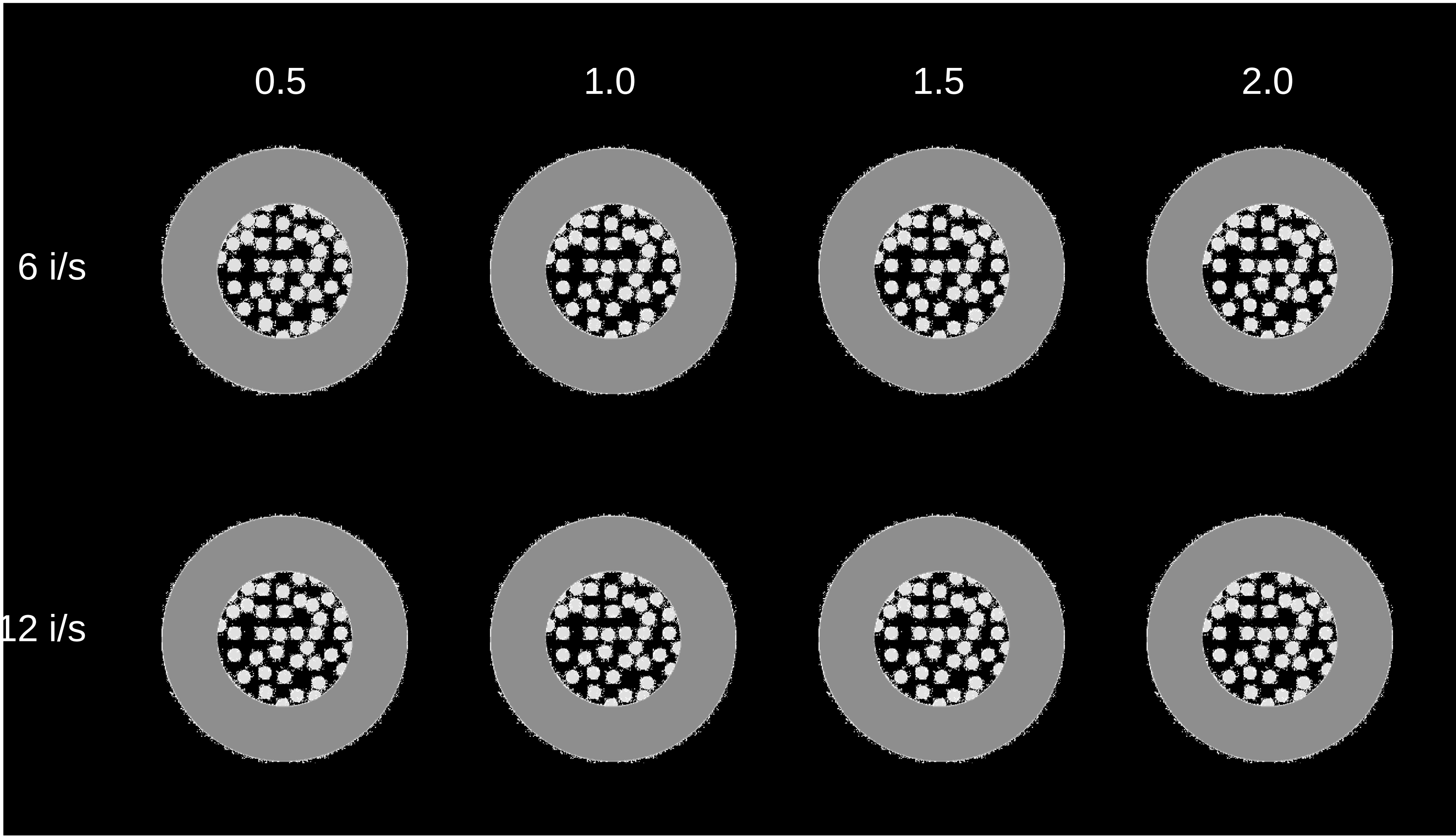
Dmax with random dots



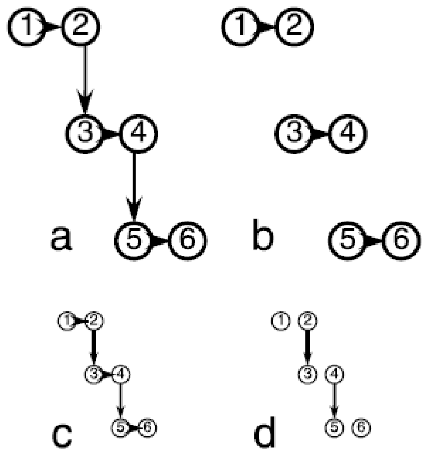
D_{max}: Braddick (1974)

Time & Space; Dmax (& Tmax)

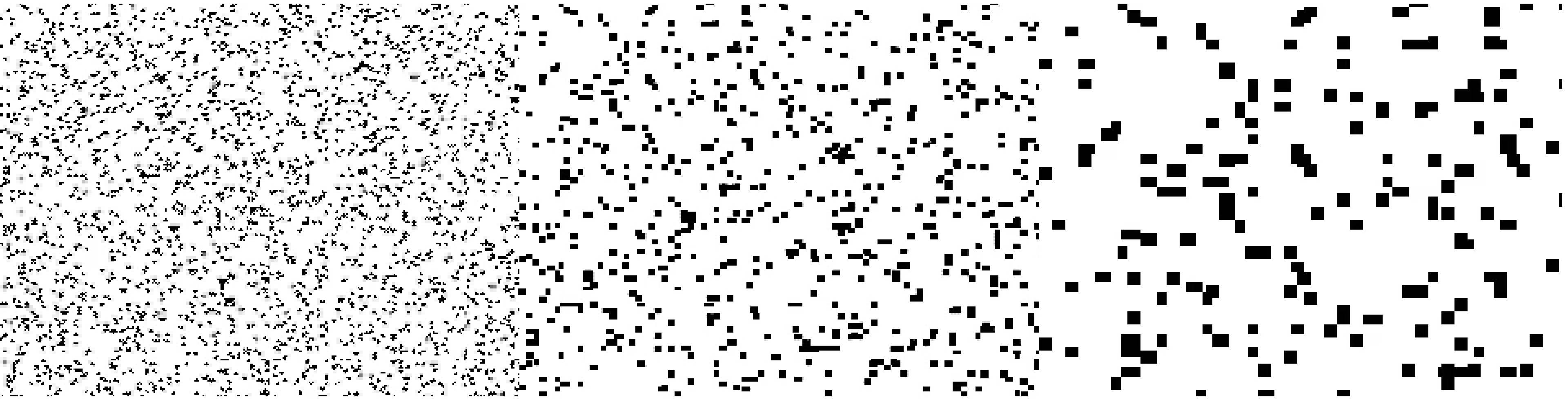
(steps are in element size units)



Dmax Anstis' (2009) demos



(a) Trajectory of a rigid random-dot field that makes alternate long jumps downward and short jumps to the right. Each arrow is one movie frame. (b) If the long jumps exceed Dmax, then the dots appear to drift to the right. (c) Identical display at a smaller spatial scale appears (d) to be drifting downward.



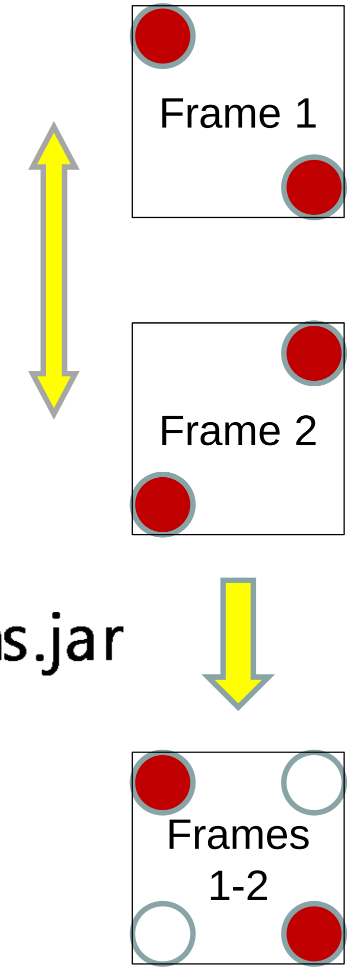
These movies are identical, at respective magnifications of 1, 2, 4. Yet #1 seems to move downward, #3 to the right, and #2 in between. View them in Loop mode from different distances. Also, fixate a point and adapt, then notice that they all give motion aftereffects (MAE) to the left.

Anstis, S. (2009). 'Zigzag motion' goes in unexpected directions. *Journal of Vision, 9(4):*17, 1–13.

http://michaelbach.de/ot/mot-sam/index.html

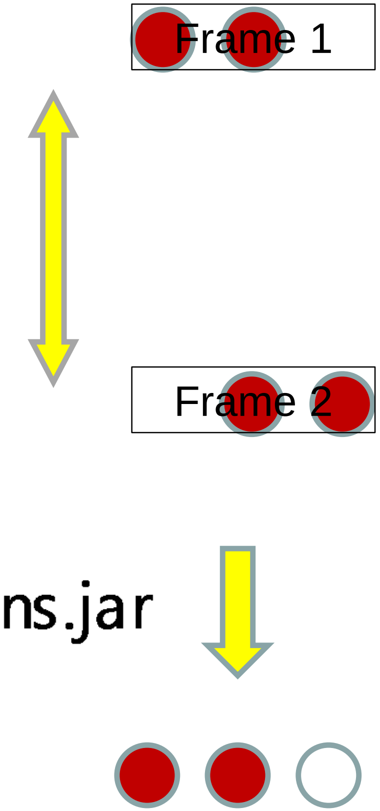
Apparent Motion Manipulations.jar

Bistable Motion



http://en.wikipedia.org/wiki/File:**Group_motion**_in_a_Ternus_display.gif

http://en.wikipedia.org/wiki/File:**Element_motion**_in_a_Ternus_display.gif



Apparent Motion Manipulations.jar

Bistable Motion: Ternus

Direction selectivity & Motion opponency

- Motion after-effect (MAE)
  - ❖ Adapt to a drifting pattern
  - ❖ Test on a static pattern
    - ➢ Motion is perceived in the opposite direction

- Direction selective threshold elevation
  - ❖ Adapt to a moving pattern (same/opposite direction)
  - ❖ Test sensitivity and appearance
    - ➢ Sensitivity and apparent contrast are reduced for same
    - ➢ Perceived direction of a physically similar direction to the adaptor is shifted away (Levinson & Sekuler, 1975)

Levinson & Sekuler (1975) The independence of channels in human vision selective for direction of movement. *J Physiol. 250*(2): 347–366.

ADAPTATION
and
OPPONENCY

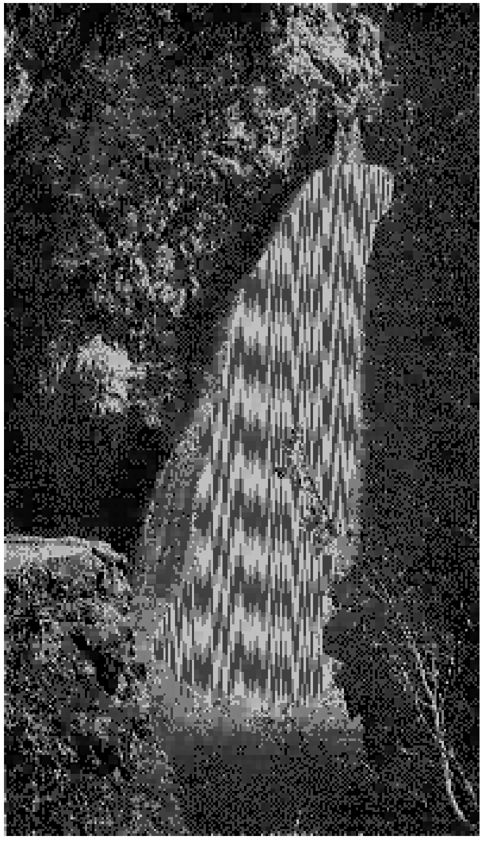
Direction selectivity & Motion opponency

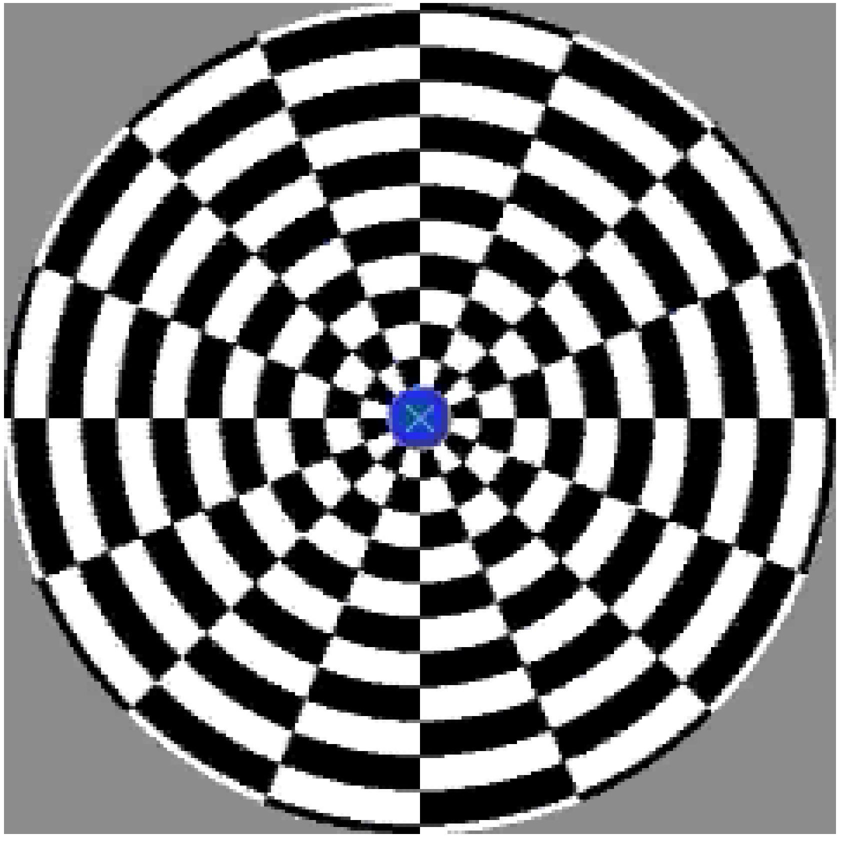
Motion After Effect (Addams, 1834; Wohlgemuth, 1911)

View from Train Window: Train stops

Direction selectivity & Motion opponency

Motion After Effect (Addams, 1834; Wohlgemuth, 1911)



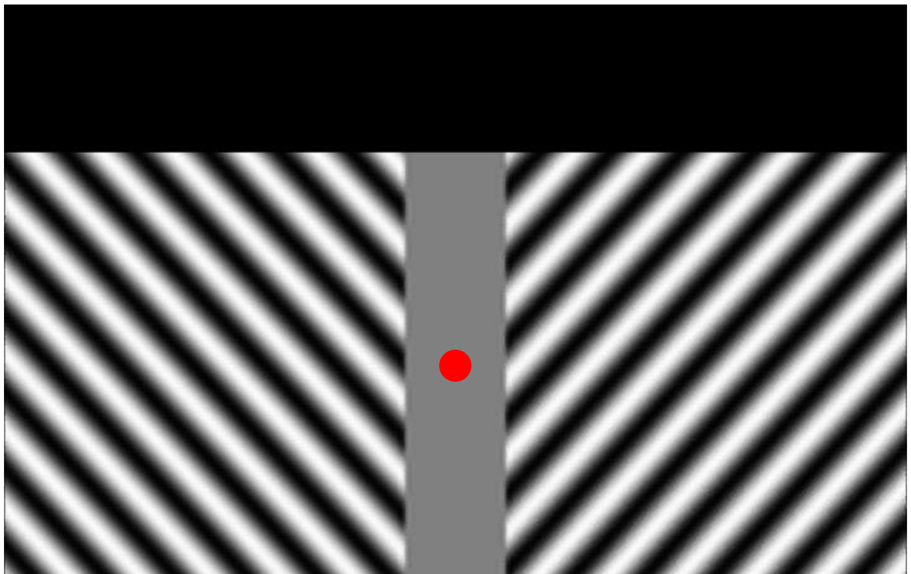


MAE-Waterfall

MAE-Boudha

Direction selectivity & Motion opponency

Direction specific adaptation (Pantle, 1974; Levinson and Sekuler, 1975)



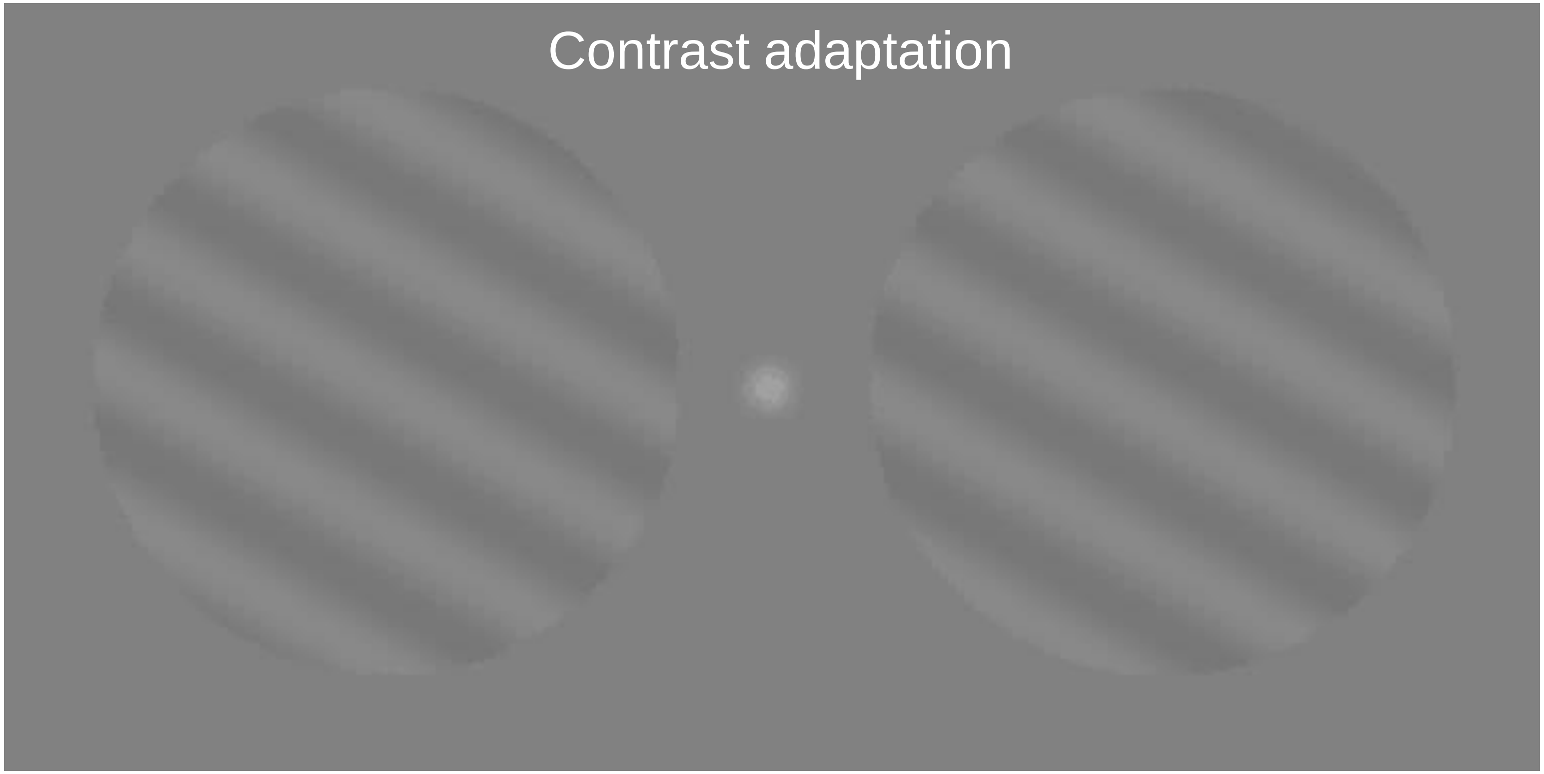
Direction specific adaptation

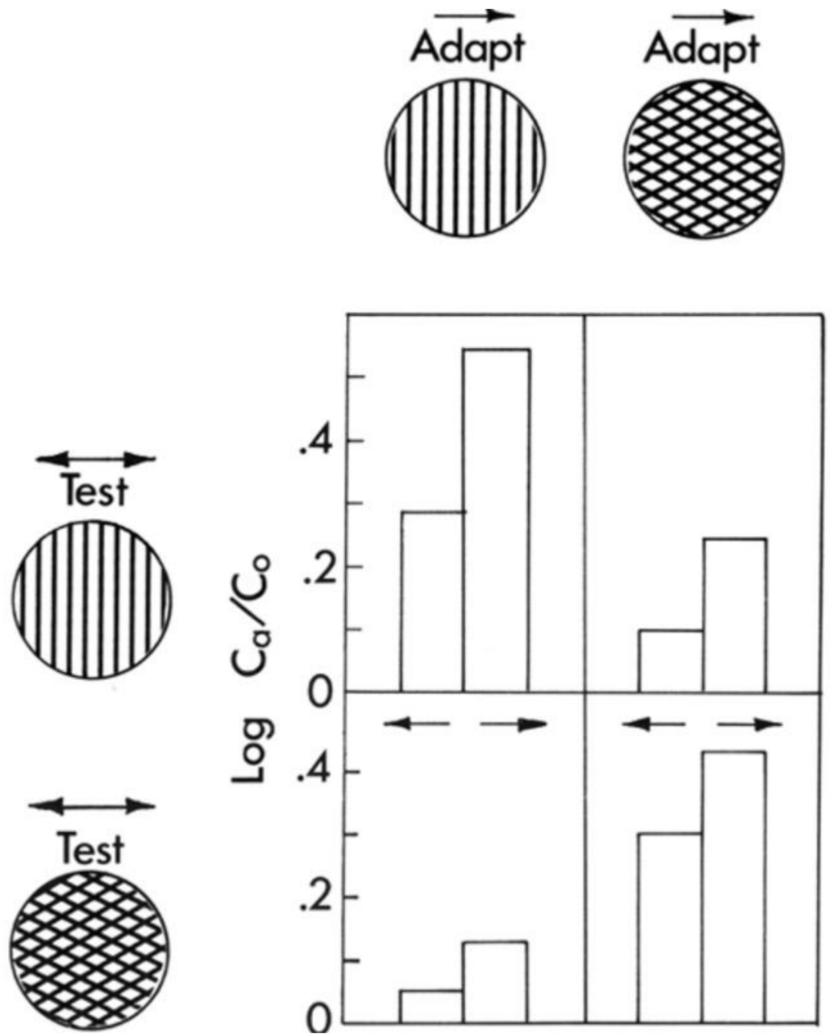
Direction selective neuron

Separate ‘channels’ for opposite directions of motion

Direction selectivity & Motion opponency

- Direction selective threshold elevation
  - Adapt to a moving pattern (same/opposite direction)
  - Test sensitivity and appearance
    - ➢ Sensitivity and apparent contrast are reduced for same

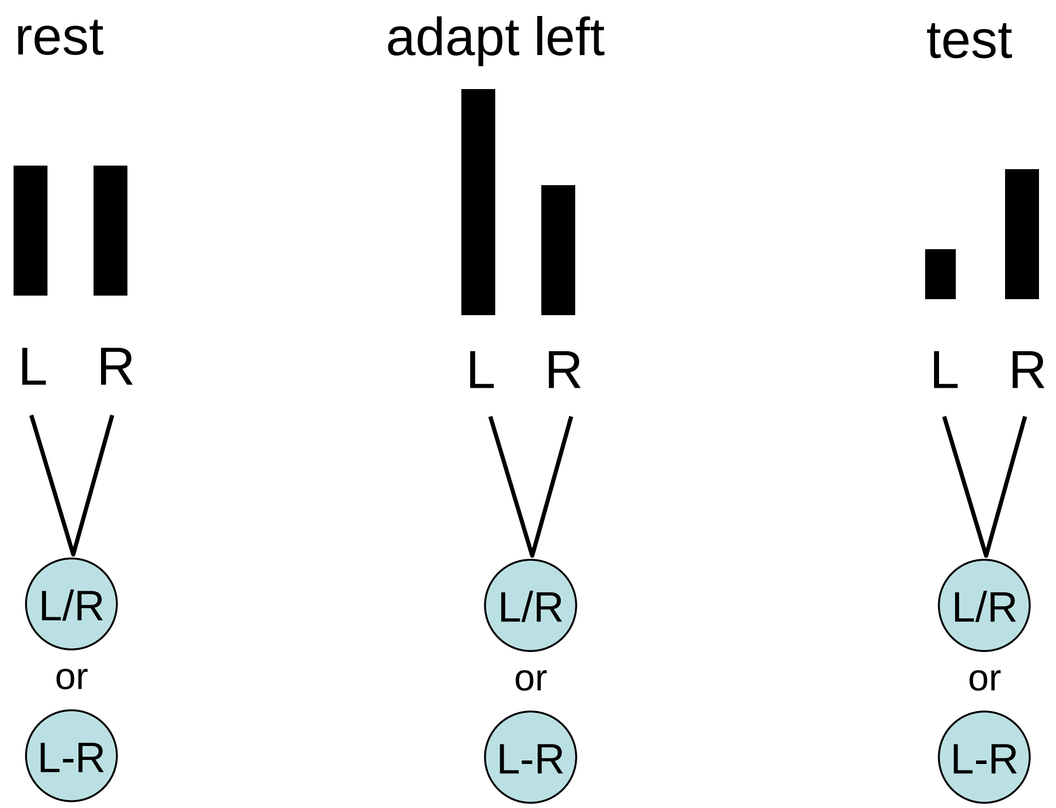




Movshon, Adelson, Gizzi & Newsome (1985).

Direction selectivity & Motion opponency

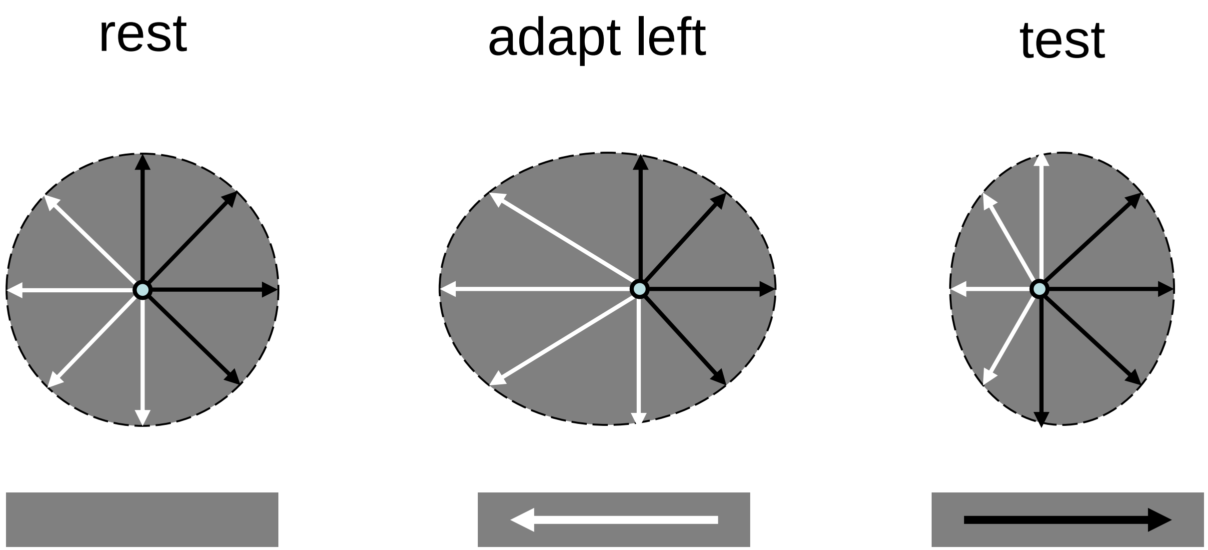
Motion Aftereffect – *Ratio model* (Sutherland, 1961)



Direction selectivity & Motion opponency

Motion Aftereffect – *Distribution shift model* (Mather, 1980)

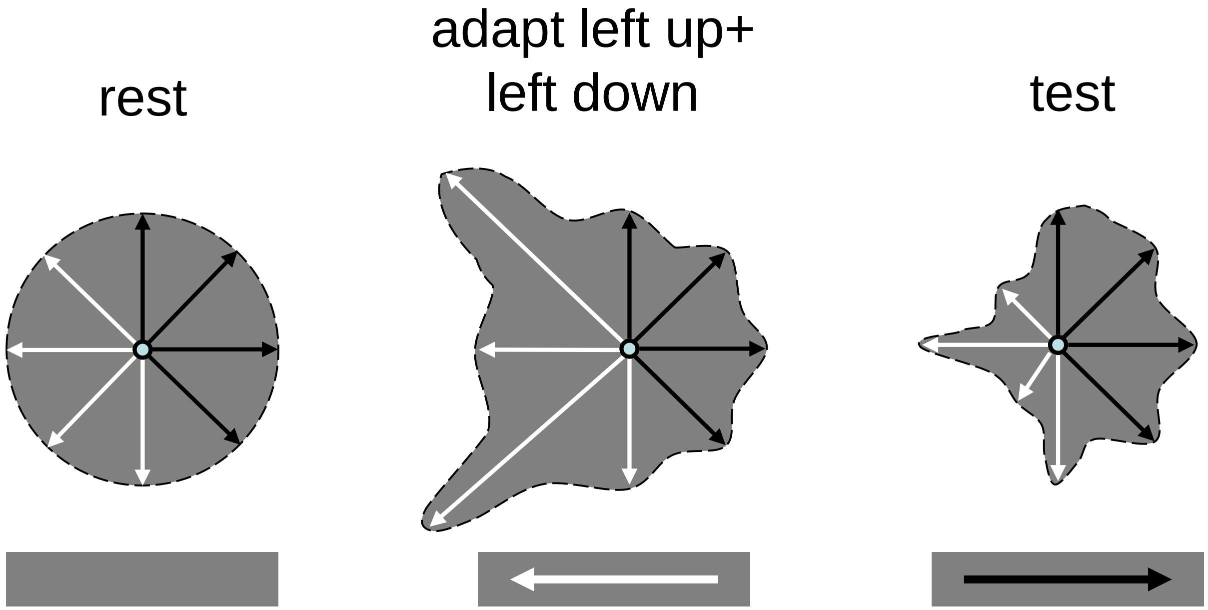
Adapt to one direction, test all directions



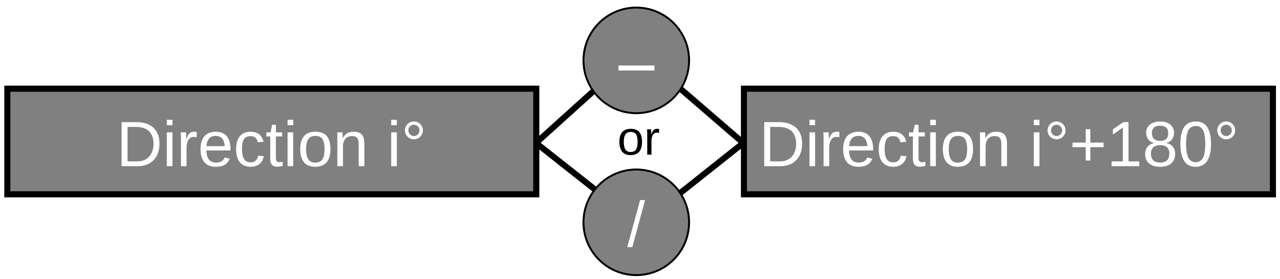
Direction selectivity & Motion opponency

Motion Aftereffect – *Distribution shift model* (Mather, 1980)

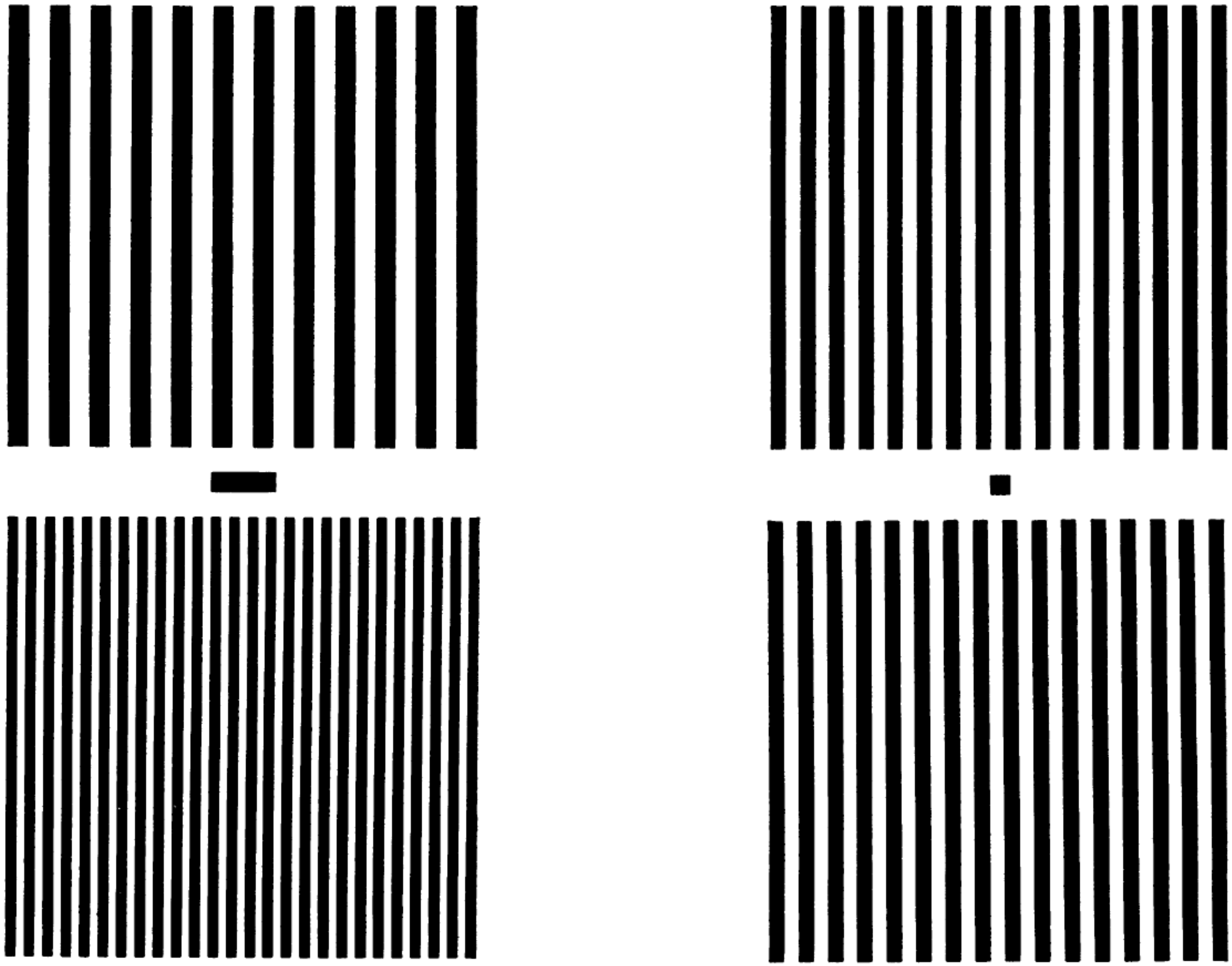
Adapt to two directions, test all directions



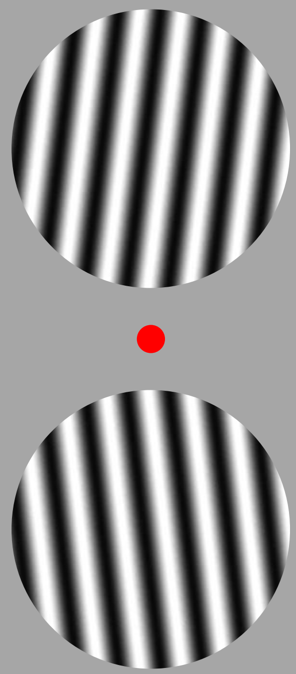
Direction selectivity & Motion opponency



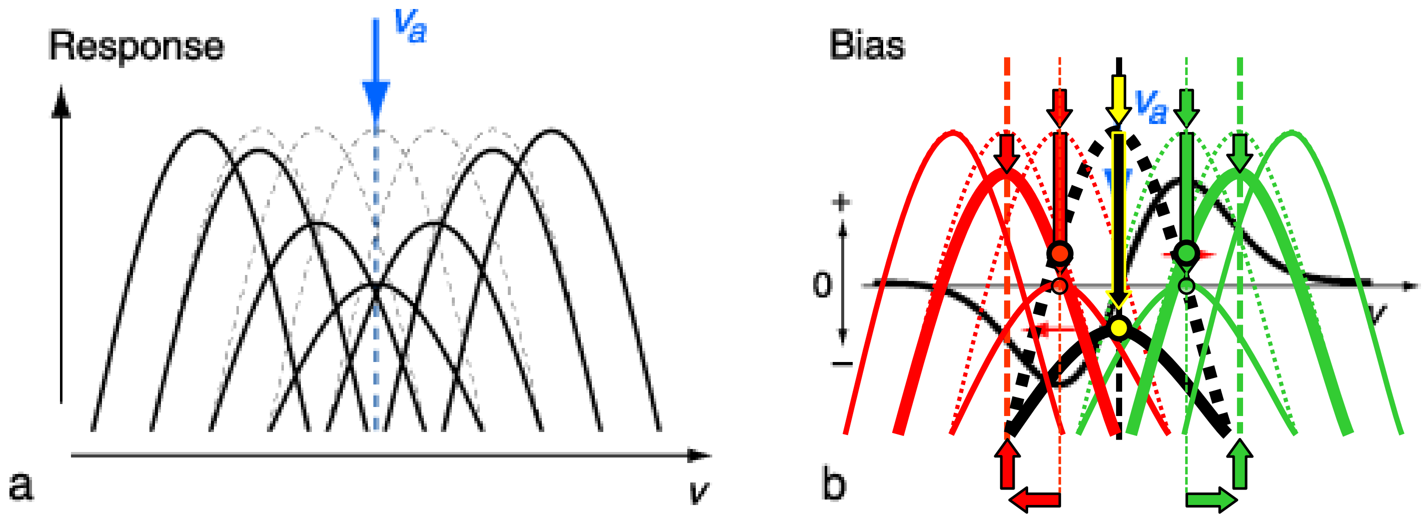
- Pairing “opposite” detectors can eliminate spurious activity;
- Opponency enhances direction specificity.



Blakemore & Sutton (1969). *Science, 166*, 245-247..



Adaptation, Bias & Labelled channels

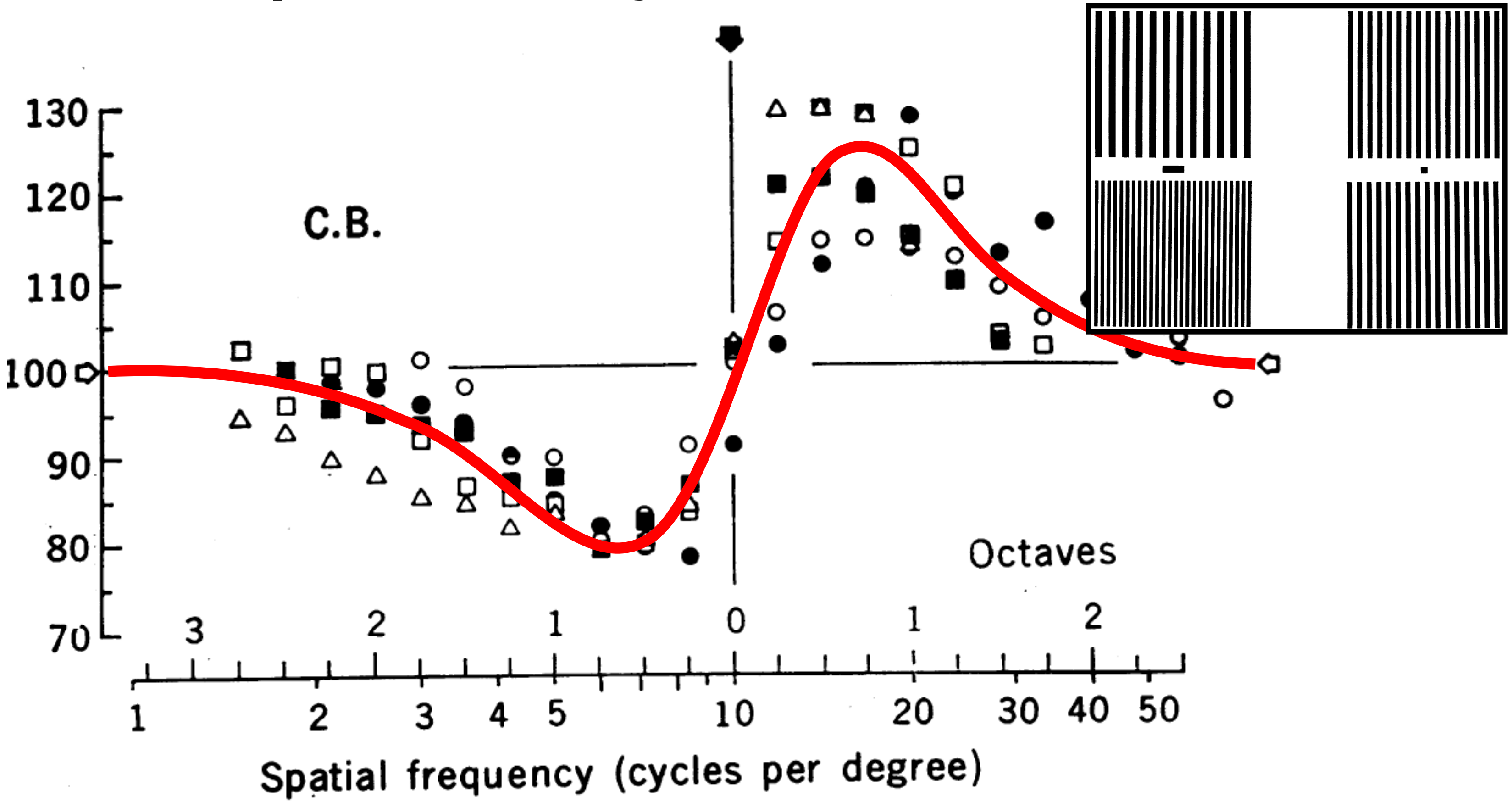


Signature of adaptation*. (a) A generic mechanism for sensory adaptation: the response gain of channels that are selectively activated by the adaptor is reduced. The reduction is largest for channels that respond most. (b) Decoding such channel activity by taking the population average leads to a stereotypical *signature* in subsequent perception: the perceived values of stimuli *v- and v+* are repulsively biased away from the value of the adaptor, V_a. We define bias as the difference between the mean of perceived stimulus value *V*, before and after adaptation.

* Levinson & Sekuler (1975) The independence of channels in human vision selective for direction of movement. *J Physiol. 250*(2): 347–366.

Stocker & Simoncelli (2009). *Journal of Vision*, *9*(9):9, 1-14.

Adaptation & Symmetrical Bias



The magnitude of the aftereffect. The abscissa is spatial frequency in cycles of the grating per degree of visual angle, on a logarithmic scale. Octaves are equal increments on this scale. The ordinate is the matched spatial frequency expressed as a percentage of a correct match; 100 is a perfect setting. Results of adapting at five different frequencies for subject C.B. The data points are normalized on the abscissa in the bottom graph, with all the adapting frequencies superimposed at 10 cycles per degree.

Blakemore & Sutton (1969). *Science, 166*, 245-247..

…BUT Velocity adaptation effects are NOT symmetric about the adapting velocity!

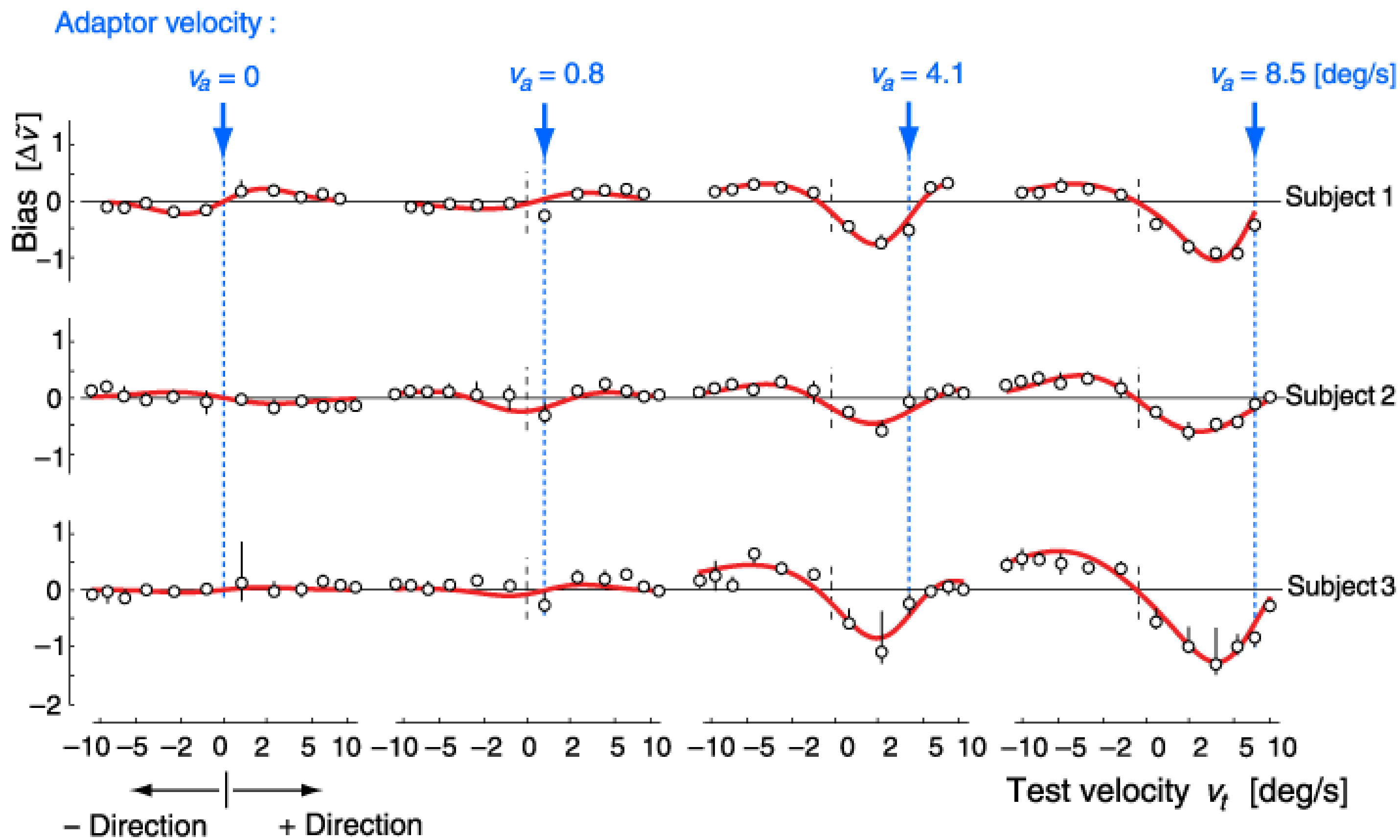


Fig. 3. Perceptual estimation bias due to adaptation. Each row shows the perceptual biases of one subject, for each of four adaptation conditions, with adaptor velocities indicated by arrows and dashed vertical lines. Hollow points represent measured ***shifts in the point of subjective equality with respect to the control condition***. Red bold lines indicate the bias of the two-mechanism model, fitted separately for each subject, using a total of 9 free parameters (see also Figure 4). Both axes represent nonlinearly transformed velocities with horizontal and vertical distances scaled identically. Note that ***bias is a signed velocity difference***; thus ***positive bias*** *for negative test velocities indicates reduced perceived speed, while* ***positive bias*** *for positive test velocities indicates increased perceived speed*. All subjects show similar behavior, with adaptation affecting subsequent perception over the whole range of test velocities, including test stimuli moving in the opposite direction.

Stocker & Simoncelli (2009). *Journal of Vision*, *9*(9):9, 1-14.

A 2-mechanisms velocity perception model: *Non-Directional* + *Directional*

Stocker & Simoncelli (2009) *Journal of Vision*, *9*(9):9, 1-14.

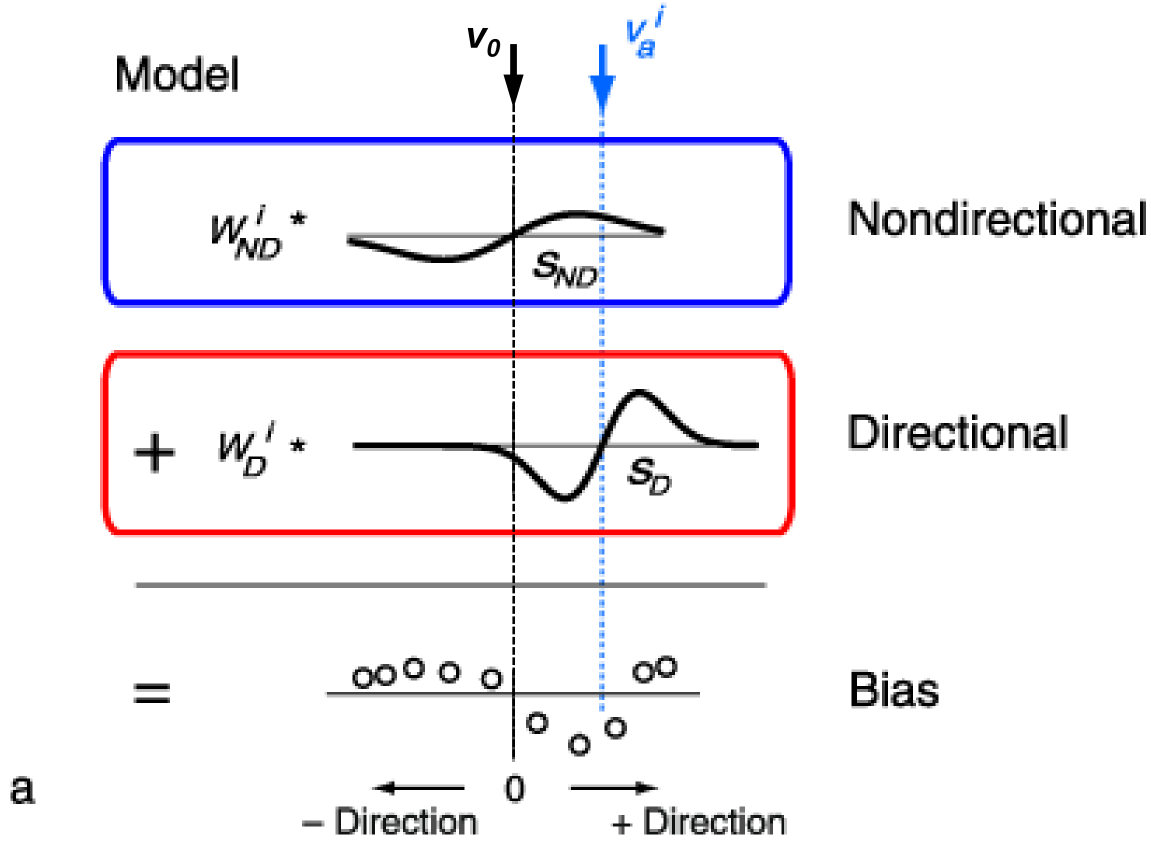


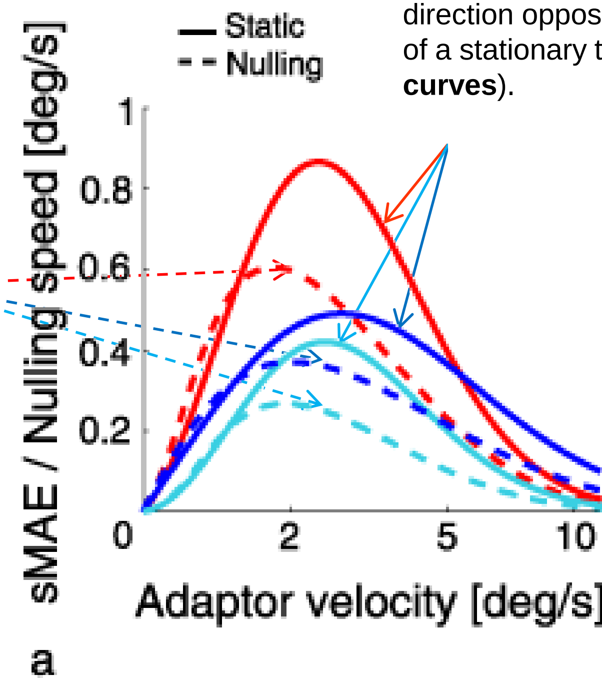
Fig. 4. Superposition of a directional and a nondirectional signature. (a) Perceptual bias is modeled as a weighted sum of two signatures (Figure 2b): a nondirectional signature centered at zero motion and a directional signature centered at the adaptor. For the nondirectional signature, the fitted weights were predominantly *negative*, which flips the polarity of the signature.

Perceived MAE speed

Predicted perceived speed (in the direction opposite to the adaptor) of a stationary test stimulus (**solid curves**).

Nulling

Predicted speed of a test stimulus moving in the same direction as the adaptor that "nulls" the aftereffect (**dashed curves**).



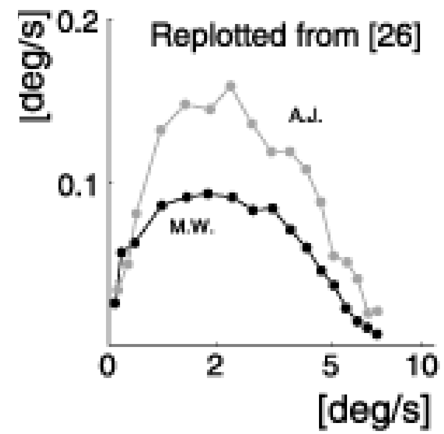
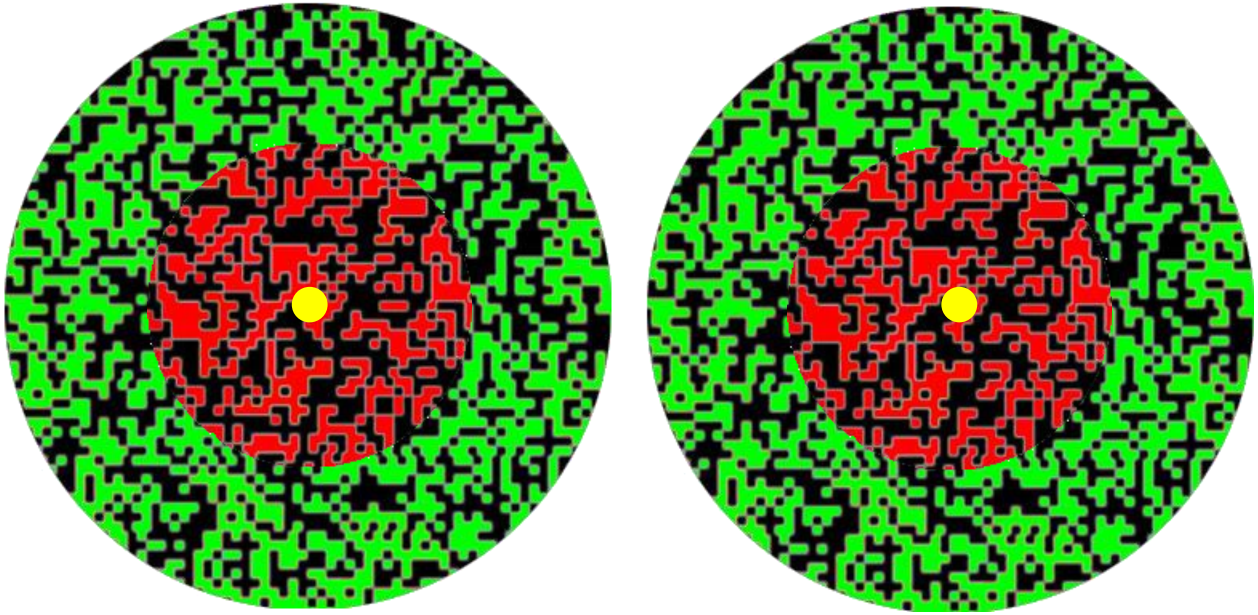


Fig. 7. Predictions derived from estimated model parameters of individual subjects. (a) Classical motion aftereffects as a function of the adaptor speed. Solid lines indicate predicted perceived speed of a stationary test stimulus (in the direction opposite to the adaptor), as a function of adaptor speed. Dashed lines indicate the speed of a test stimulus (moving in the same direction as the adaptor) that "nulls" the aftereffect (i.e., makes the test stimulus appear to have no net motion). Inset shows measured nulling speeds for two subjects as reported by Wright and Johnston (1985).

Direction selectivity & Motion relativity

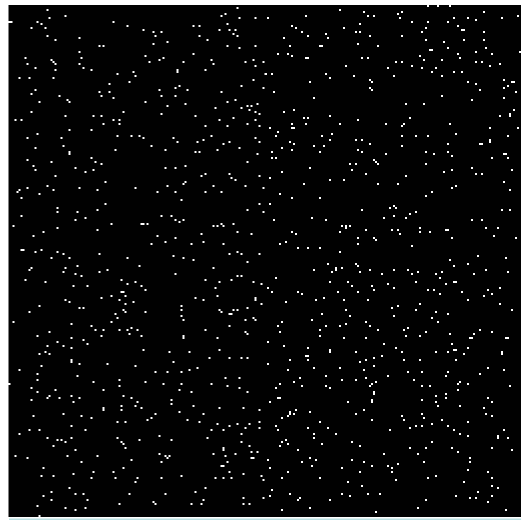
Inhibition / Excitation within motion detectors



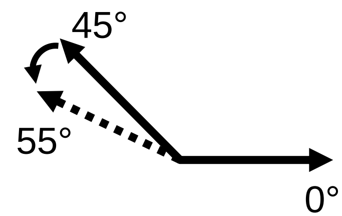
Direction selectivity & Motion opponency

Motion repulsion (Levinson & Sekuler, 1975)

Mutual inhibition between motion detectors



Motion repulsion



Although one set of dots is moving 45 degrees clockwise from vertical while the other set moves horizontally, this difference appears to be enlarged.

SEGREGATION vs.TRANSPARENCY
and
MOTION INTERACTIONS

Direction selectivity & Motion opponency

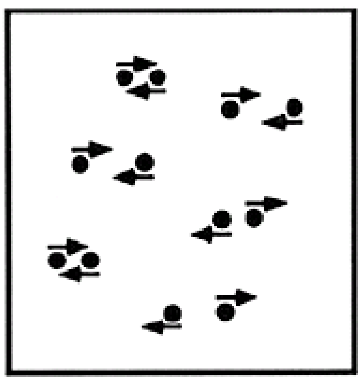
Segregation vs. Transparency

van Doorn & Koenderink, (1982)

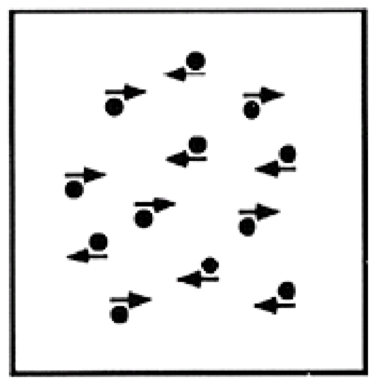
To obtain transparency, the different motion vectors should be neither too close (they cancel), nor too far apart (they yield disparate motion patches).

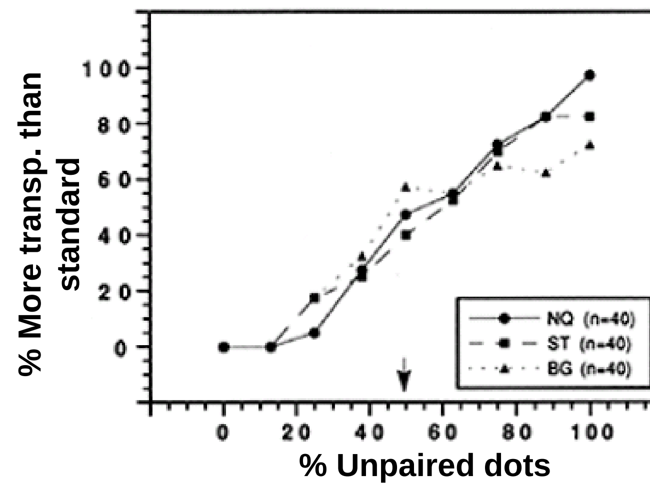
Qian et al. (1994)

Paired dot pattern: Not transparent



Unpaired dot pattern: Transparent





Whenever a display has *finely balanced opposing motion signals* in all local regions, it is perceptually *non*-transparent. The displays that appear transparent always contain ***locally unbalanced motion signals***, with some local regions having net motion signals in one direction and some other regions in the opposite direction.

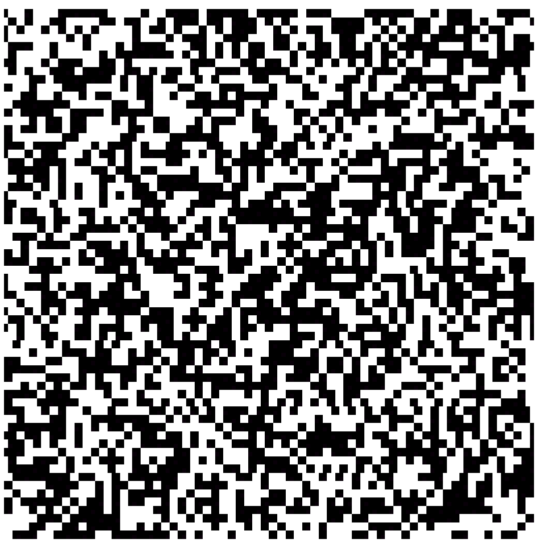
Direction selectivity & Motion opponency

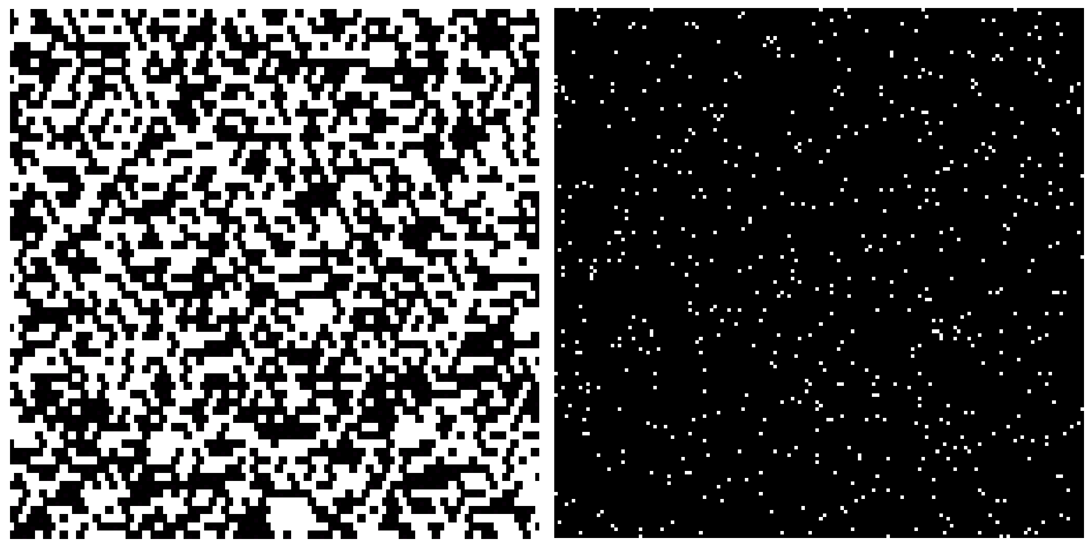
Segregation vs. Transparency

Local interactions between motion detectors

Segregation
(streaming)

Transparency

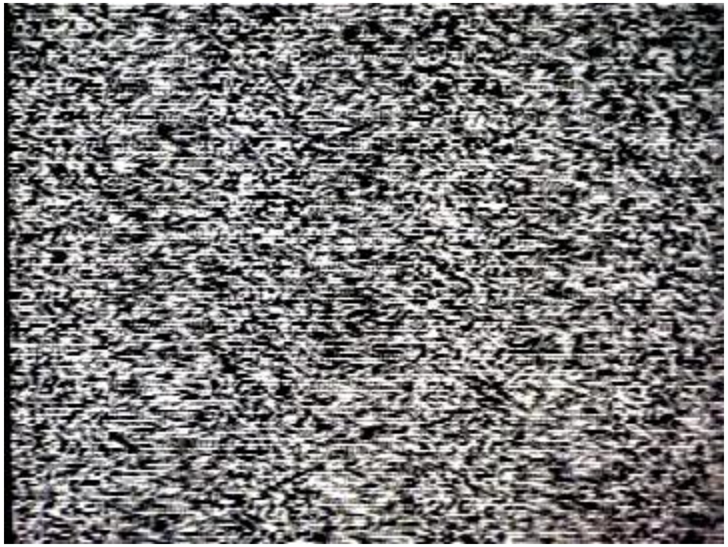




van Doorn & Koenderink (1982); Qian et al. (1994)

Direction selectivity & Motion opponency*

Segregation vs. Transparency



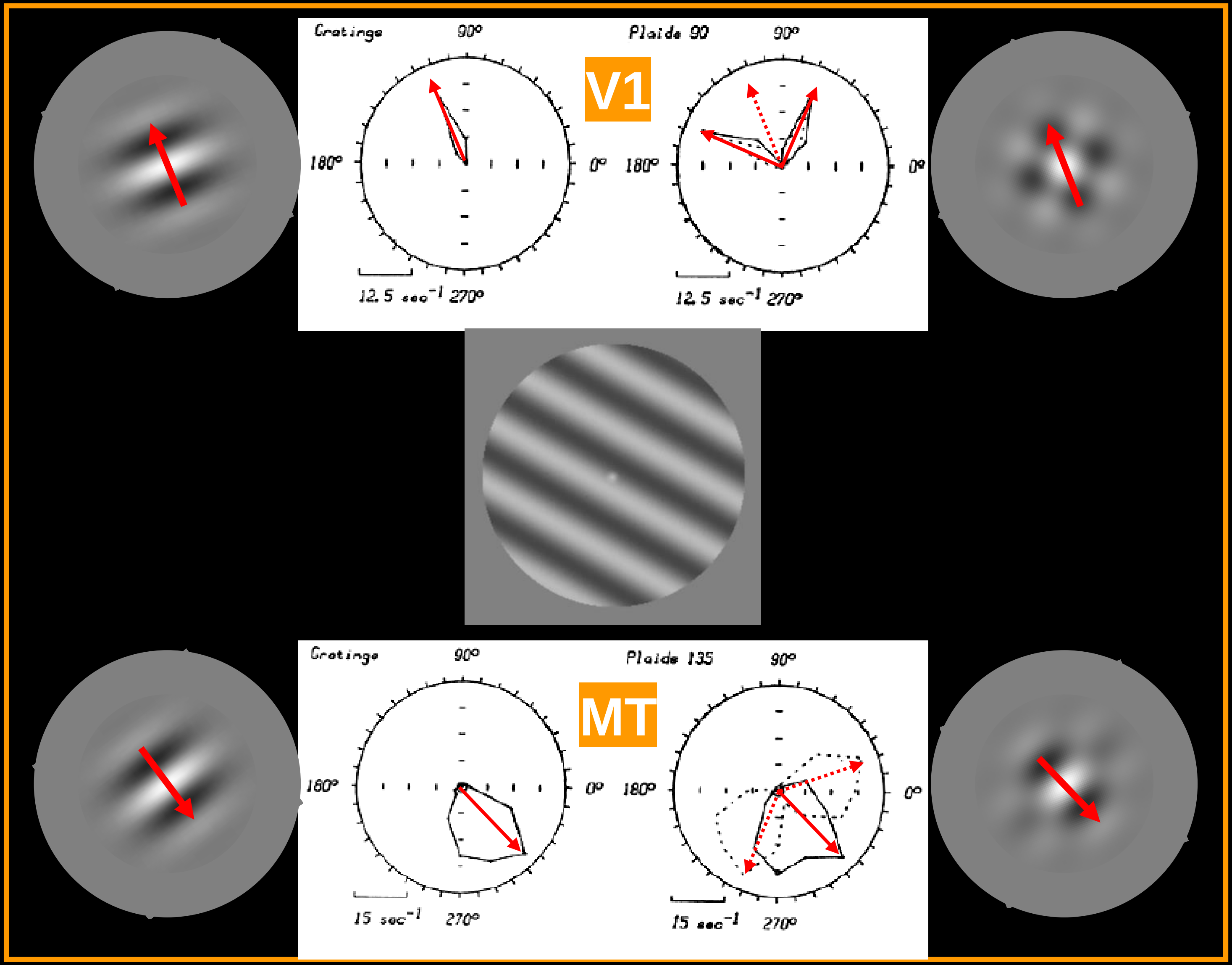
*Second order motion

SECOND ORDER STIMULI
&
THE NEED OF NONLINEARITIES

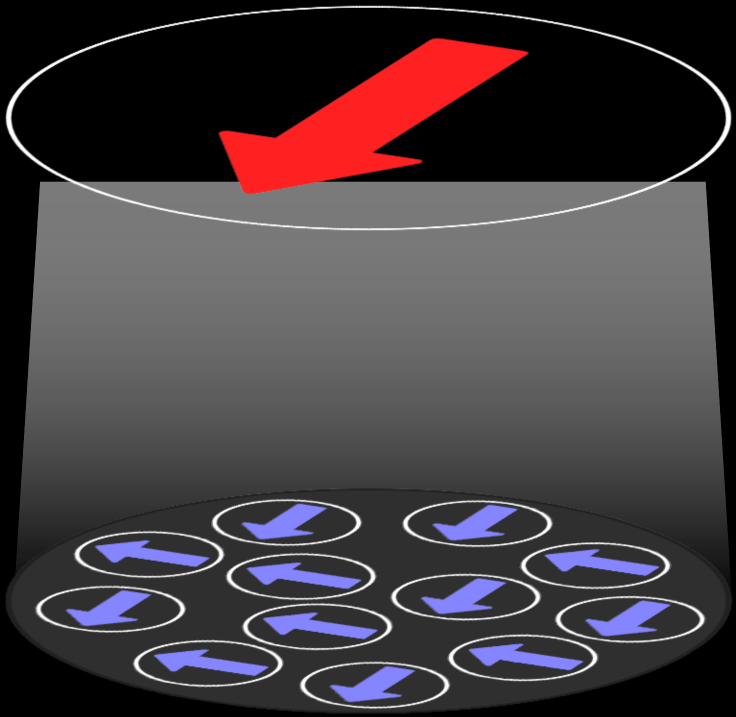
LOCAL vs. GLOBAL MOTION

Coding locality in space-time and frequency

V1 & MT responses (Movshon et al., 1983)



Hierarchical Motion Processing



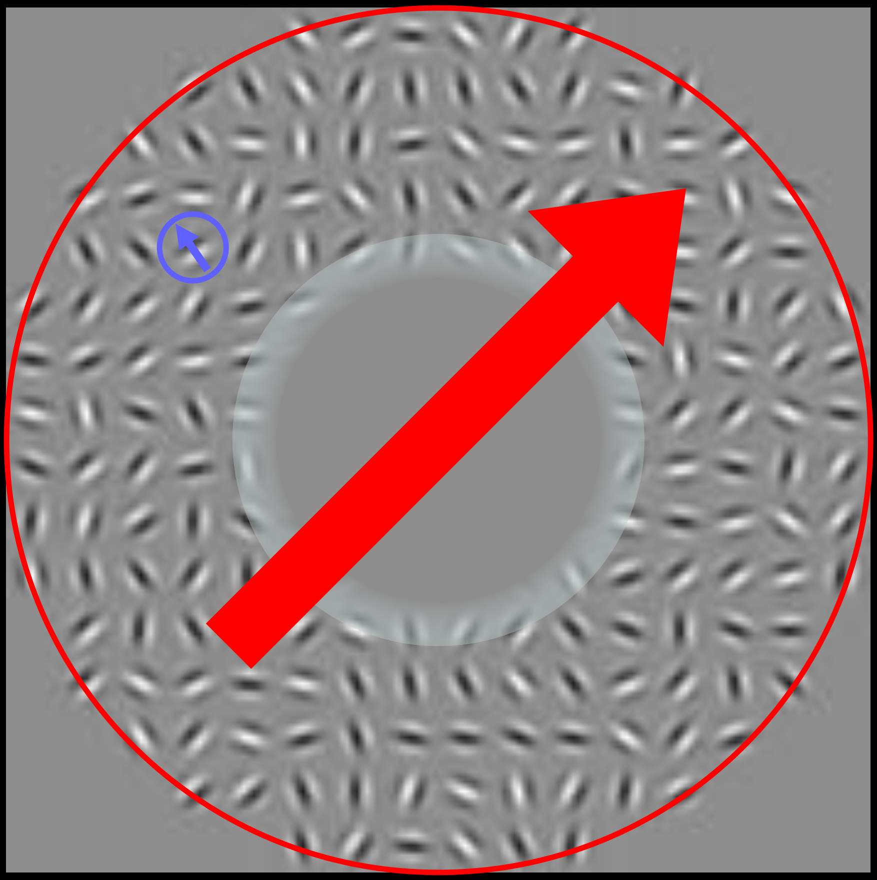
Global motion detectors
- found in later areas (e.g., MT)
- integrate signals to produce a **global percept**

Local motion detectors
- located in early visual areas (e.g., V1)
- extract ambiguous **local motion signals**

Courtesy of Alan Lee

The Multiple-aperture Stimulus

Independently manipulate **local** and **global** motion

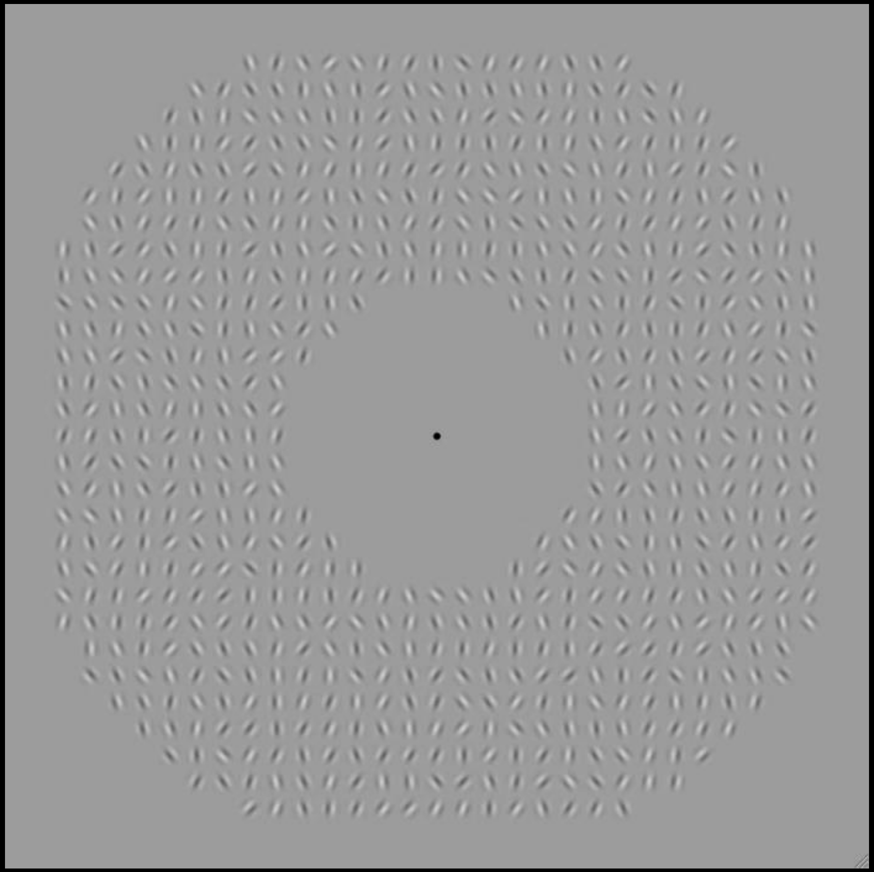


Courtesy of Alan Lee

Amano et al. (2009). *J. Vision, 9*(3), 1-25.

The Multiple-aperture Stimulus

Independently manipulate local and global motion



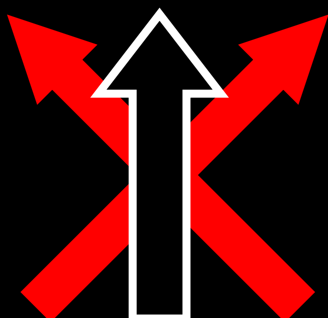
±45° oriented Gabors with speeds assigned to be consistent with a single 2D object moving to the right

A. Johnston, http://www.psychol.ucl.ac.uk/vision/Lab_Site/Demos.html.

Adapting to Transparent Motion

- Motion AfterEffect (MAE) is **integrated**

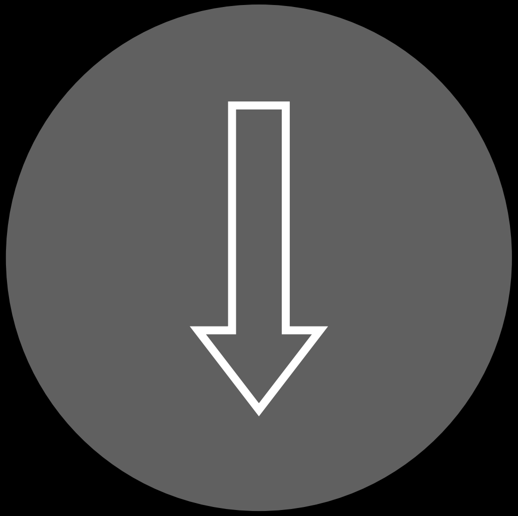
Transparent



Adapt

Test

Integrated

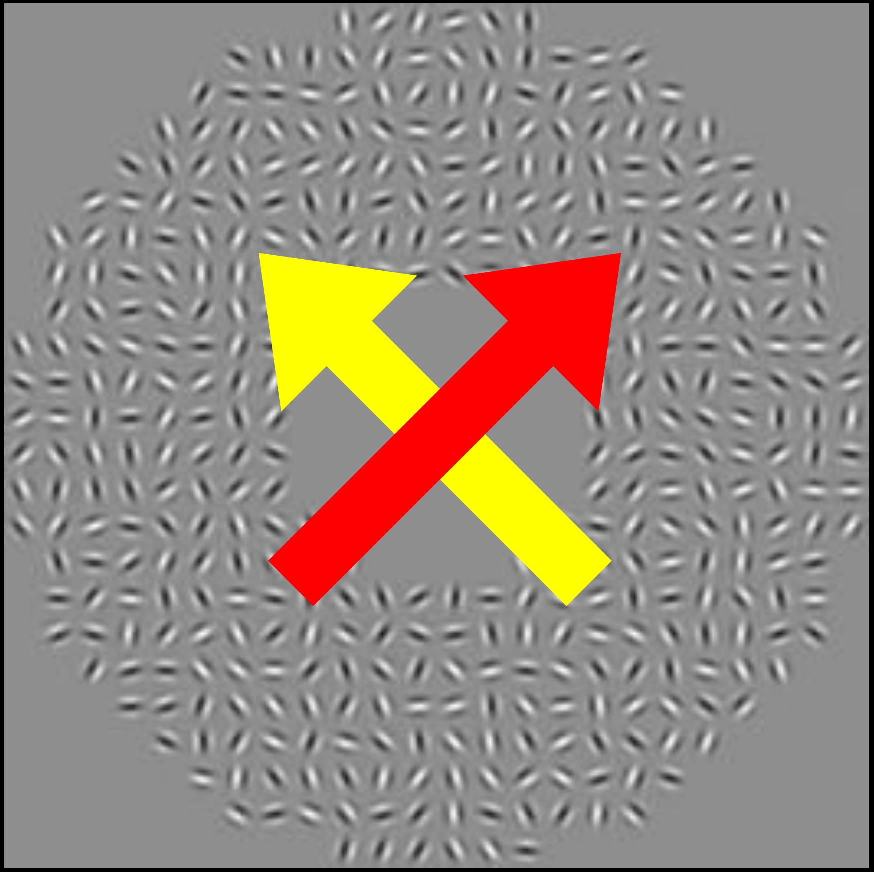


MAE

Courtesy of Alan Lee

Mather, G. (1980). *Perception, 9*, 379-392.
Verstraten, F. et al. (1994). *Perception, 23*, 1181-1188.

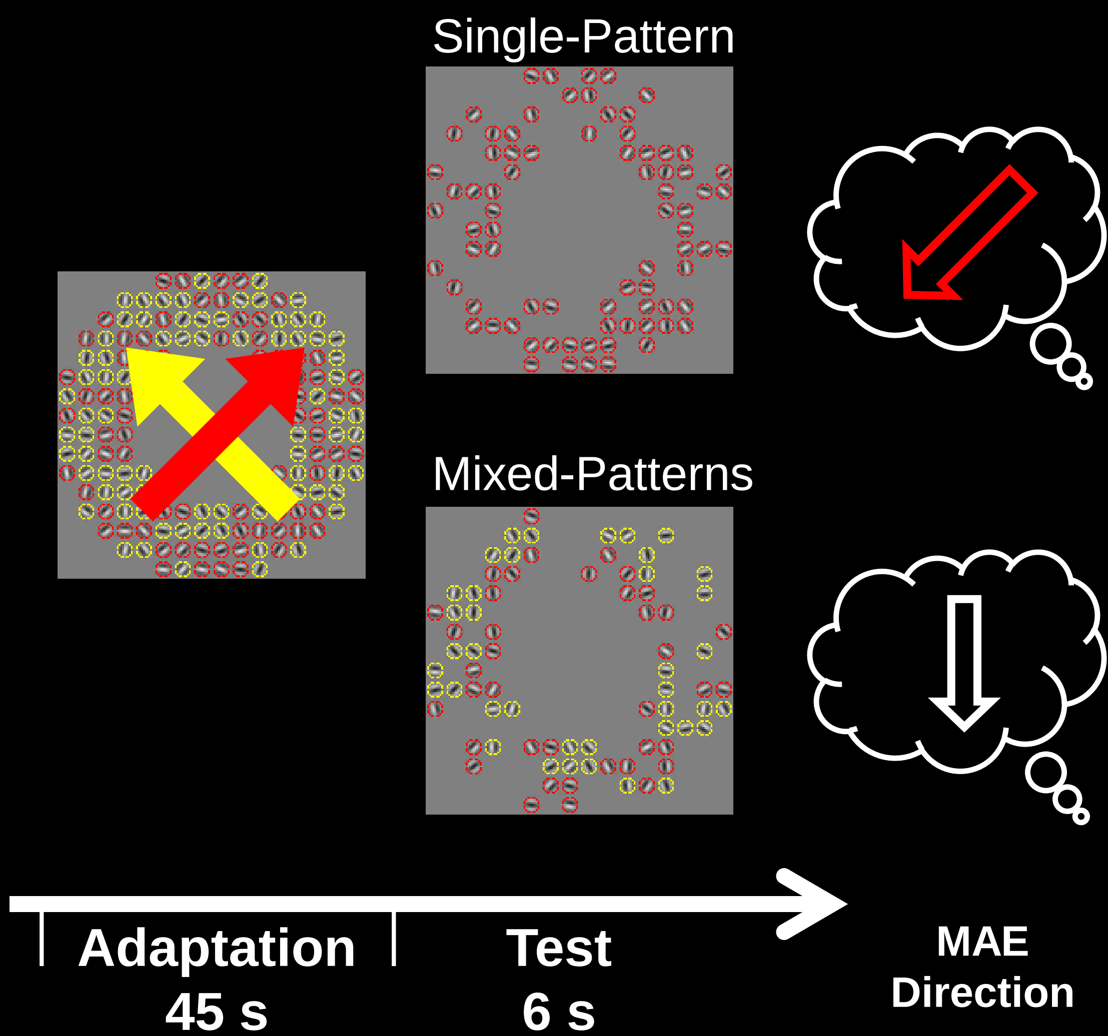
Multiple-aperture Transparent Motion

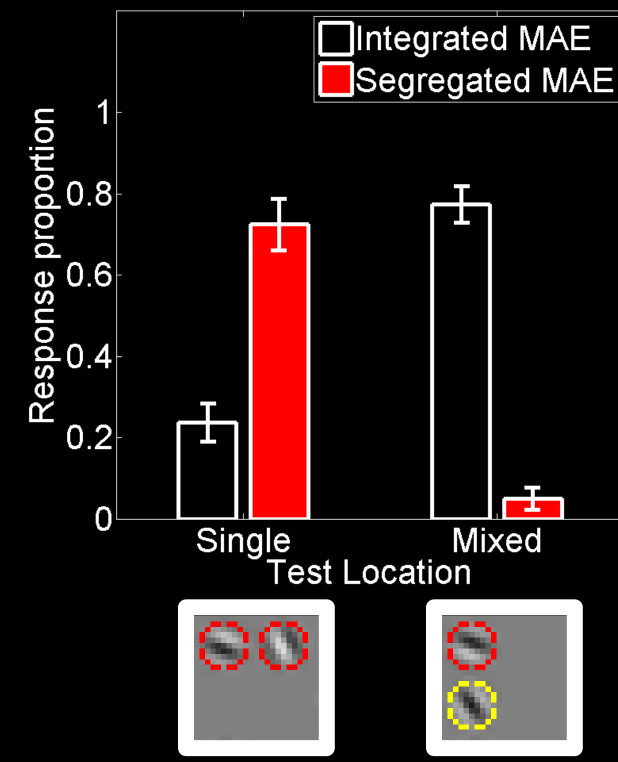


Courtesy of Alan Lee

Amano et al. (2009)

Aftereffect depends on Test Locations

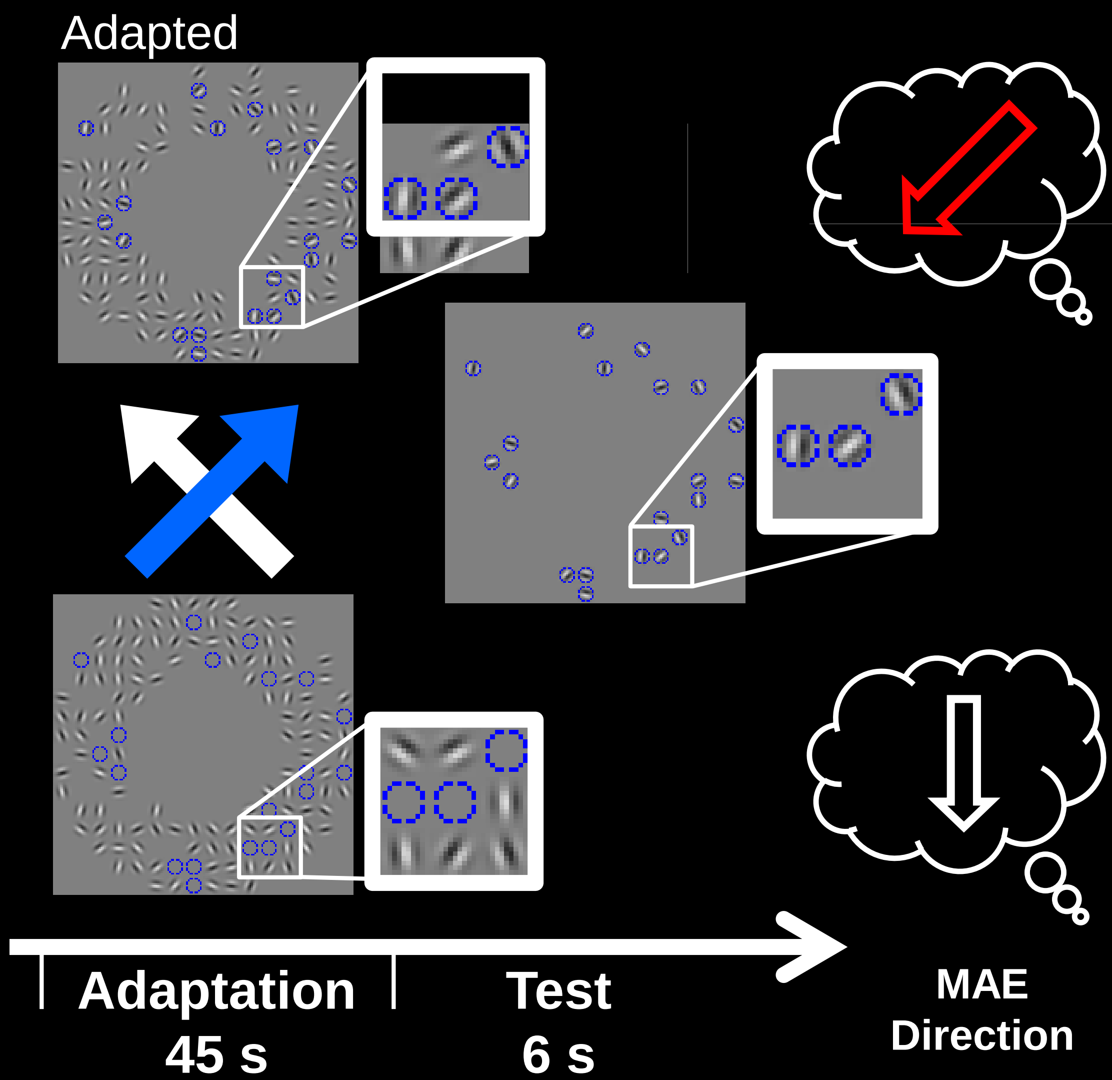


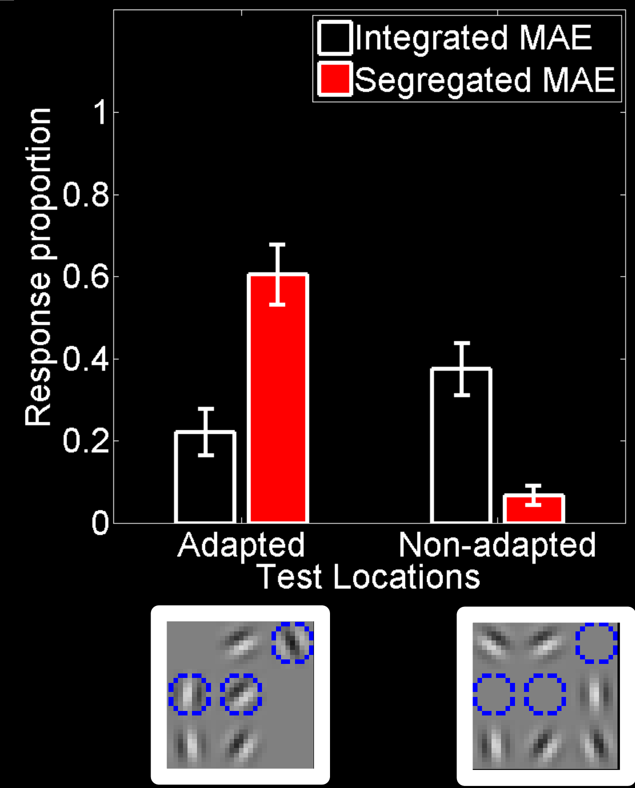


Courtesy of Alan Lee

Lee & Lu (2012) *JoV*

Toggling Local Adaptation ON/OFF

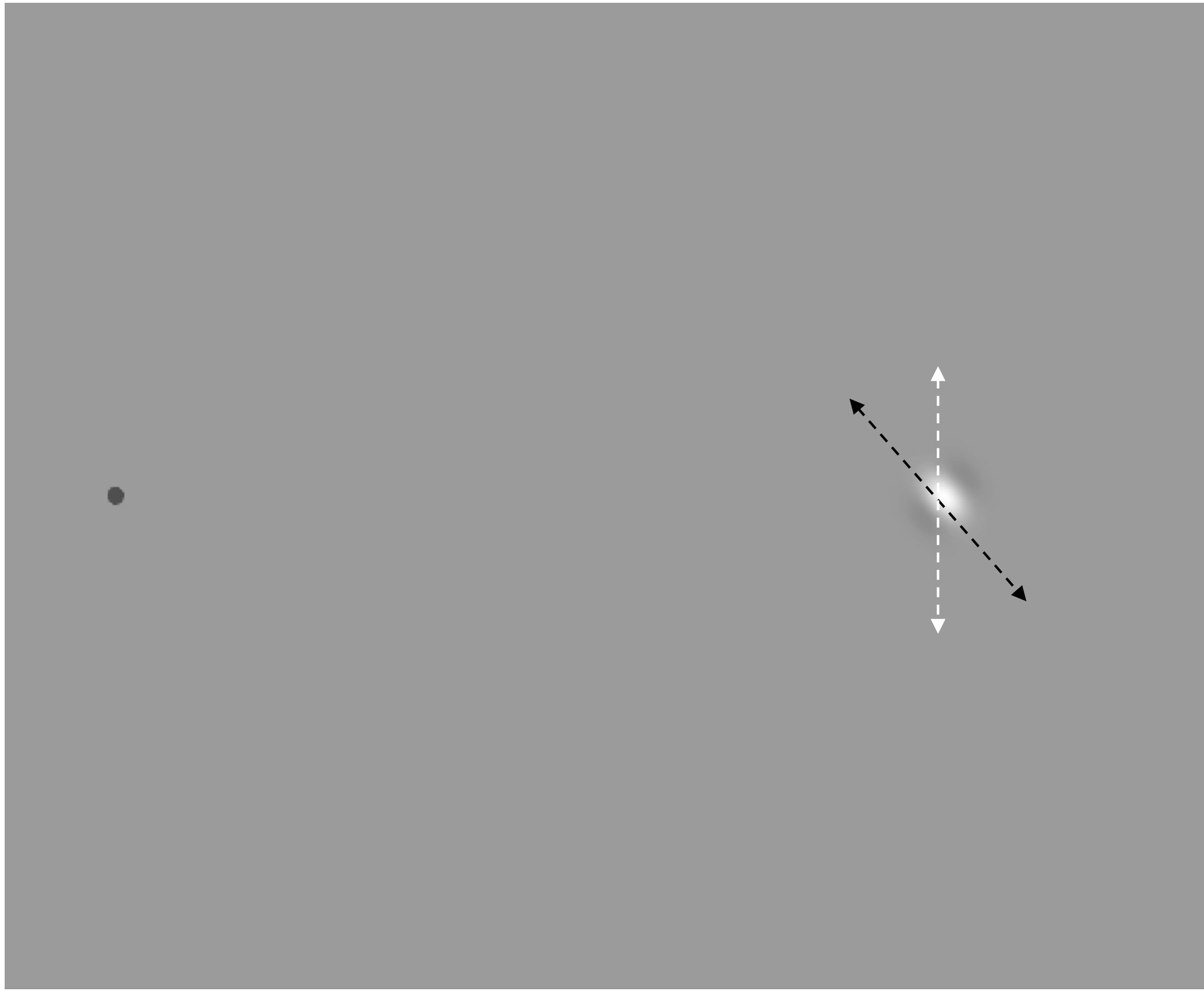




Courtesy of Alan Lee

Lee & Lu (2012) *JoV*

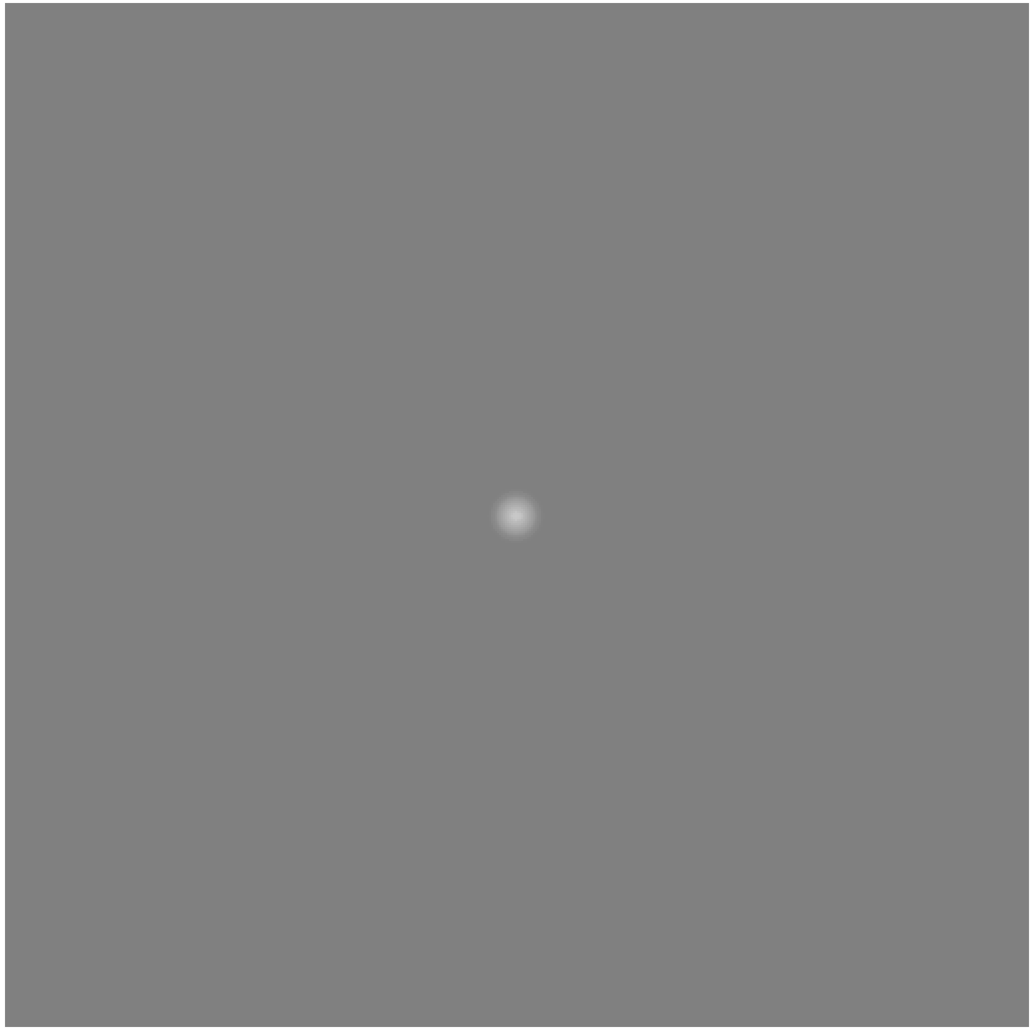
Local-Local
orthogonal
directions



Tse & Hsieh (2006). The infinite regress illusion reveals faulty integration of local and global motion signals. *Vision Res. 46,* 3881–3885.
Lisi & Cavanagh (2015). Dissociation between the perceptual and saccadic localization of moving objects. *Curr. Biol., 25*, 1-6.

1

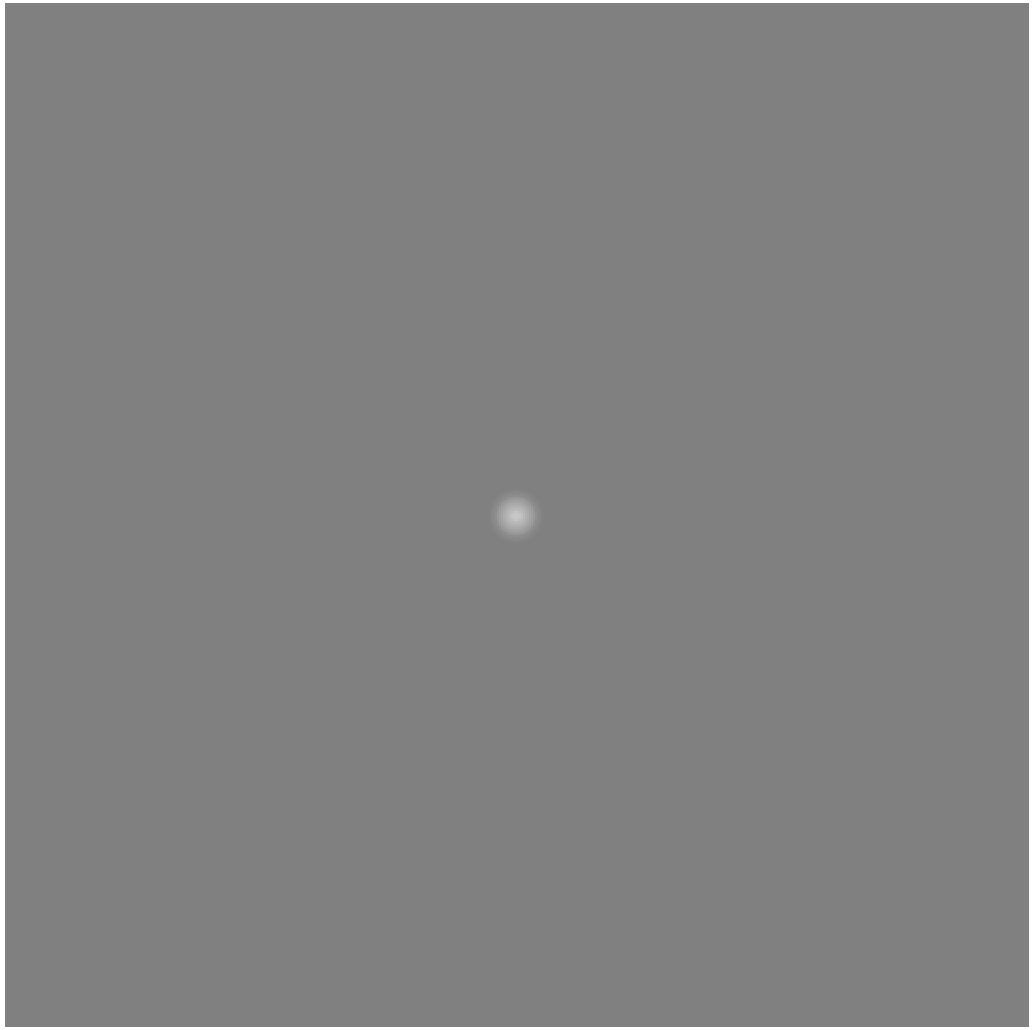
Local-Local
opposite
directions



Hedges, Gartshteyn, Kohn, Rust, Shadlen, Newsome & Movshon (2011). Dissociation of Neuronal and Psychophysical Responses to Local and Global Motion, *Curr. Biol., 21*(23), 2023-28.

2

Local-Global
same direction

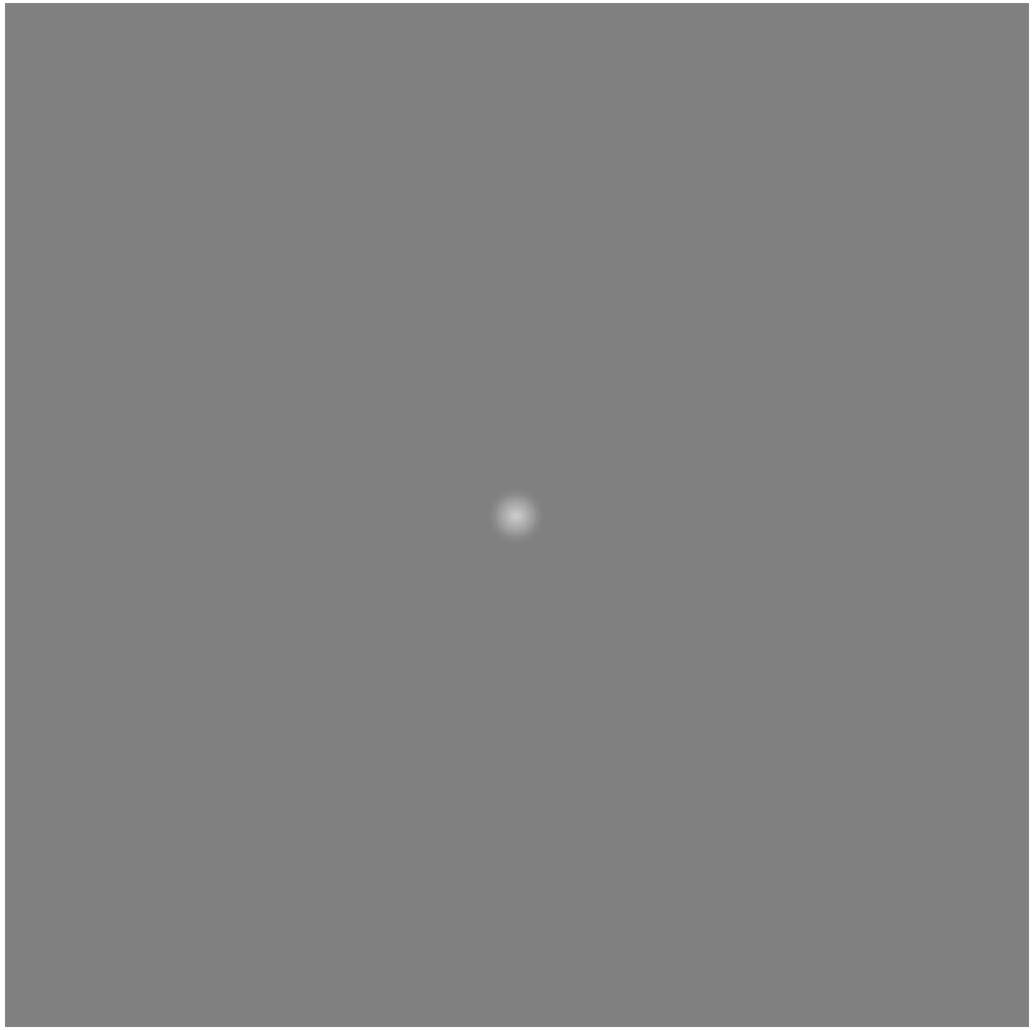


Hedges, Gartshteyn, Kohn, Rust, Shadlen, Newsome & Movshon (2011). Dissociation of Neuronal and Psychophysical Responses to Local and Global Motion, *Curr. Biol., 21*(23), 2023-28.

3

Local-Global
same direction

Local-Global
opposite
directions



MT neurons perceive only local motion (despite their very large RFs).

In contradiction to the common view that the activity of neurons in MT is closely associated with our experience of motion

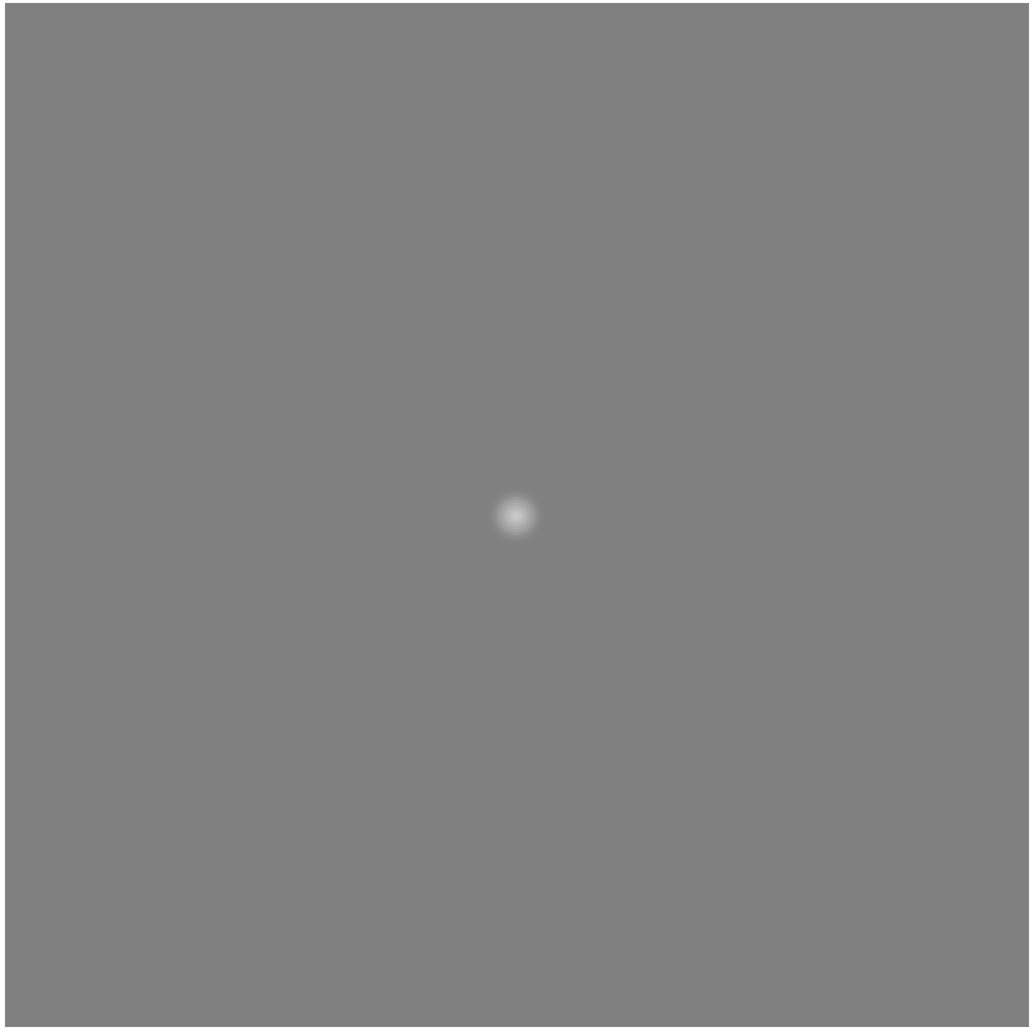
Hedges, Gartshteyn, Kohn, Rust, Shadlen, Newsome & Movshon (2011). Dissociation of Neuronal and Psychophysical Responses to Local and Global Motion, *Curr. Biol., 21*(23), 2023-28.

4

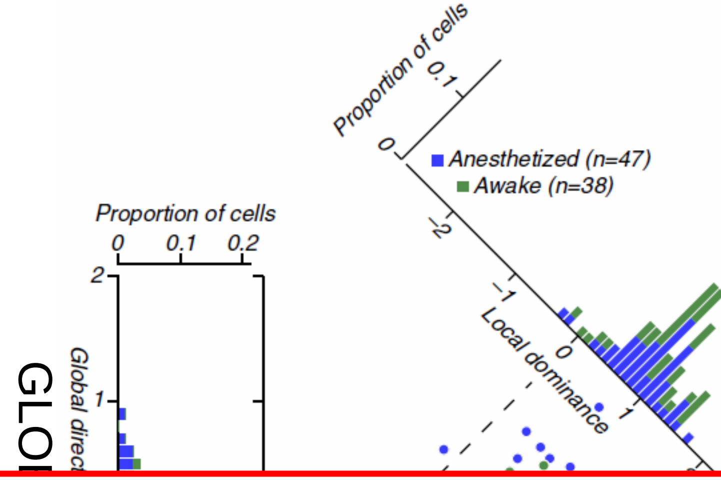
Local-Global
same direction

Slowed down
x10

Local-Global
opposite
directions



Hedges, Gartshteyn, Kohn, Rust, Shadlen, Newsome & Movshon (2011). Dissociation of Neuronal and Psychophysical Responses to Local and Global Motion, *Curr. Biol., 21(*23), 2023-28.



Although local motion perception might depend on MT signals, global motion perception depends on mechanisms qualitatively different from those in MT. Motion perception therefore does not depend on a single cortical area but reflects the action and interaction of multiple brain systems.

MT neurons *do* compute ‘global’ motion *at a given spatial location* (i.e. when different motions are spatially superimposed), but they do *not* compute global motion *across space*.

A Comparison of Directional Selectivity for Local and Global Components of Motion in MT.

Local DI values are plotted against global DI values for 85 MT neurons. Data from anesthetized monkeys is in blue; data from awake monkeys is in green. The marginal distributions on the ordinate and abscissa capture the directional selectivity for the global and local motions, respectively. The oblique marginal distribution is of the difference between local and global DI, which we term local dominance.

Hedges, Gartshteyn, Kohn, Rust, Shadlen, Newsome & Movshon (2011). Dissociation of Neuronal and Psychophysical Responses to Local and Global Motion, *Curr. Biol., 21*(23), 2023-28.