Motion Aftereffects Without Motion:
Engaging the Human Motion Perception System With Still Photographs

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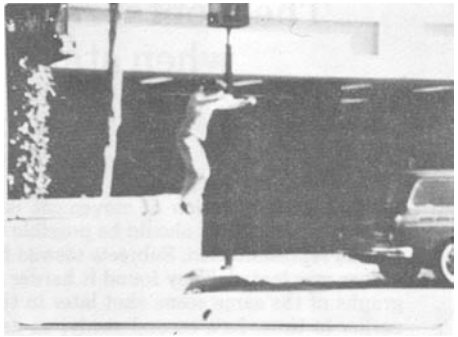
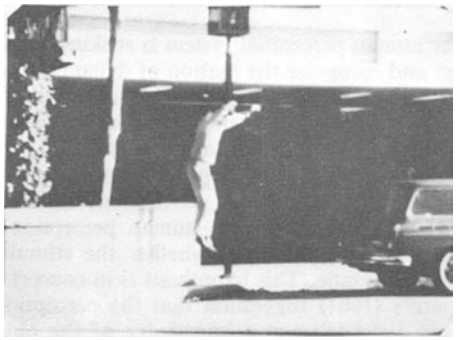
None of these images contain motion

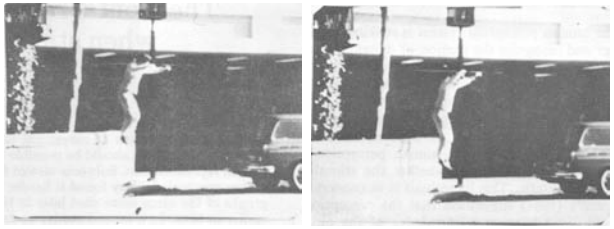
Yet, some images have more motion than others





Were the two images the same?

A B

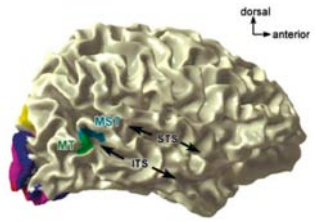


Jennifer Freyd, 1983

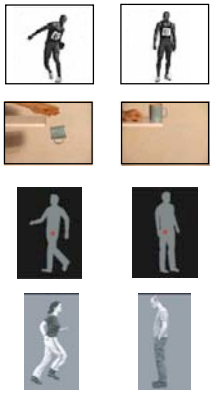
Over a 250 ms delay, we tend to think that we saw B instead of A

• Motion selective areas in human cortex also activated by implied motion in static photos

– people, animals, scenes, and objects



- Kourtzi & Kanwisher (2000)
- Senior et al. (2000)
- Peuskens et al. (2005)
- Lorteije et al. (2006) [EEG]

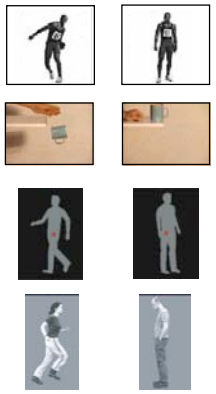


• Motion selective areas in human cortex also activated by implied motion in static photos

– people, animals, scenes, and objects

– BUT, there are between a kagillion and a gazillion neurons even in one voxel
  - Are the same neurons used?
  - Are the same direction-selective mechanisms used?
– "The psychologist's microelectrode": The motion aftereffect

- Kourtzi & Kanwisher (2000)
- Senior et al. (2000)
- Peuskens et al. (2005)
- Lorteije et al. (2006) [EEG]



Motion Aftereffect (MAE)

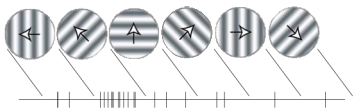
- Aristotle 330 BC
  - streams
- Lucretius 57 AD
  - streams
- Purkinje 1820
  - parade
- Plateau, 1849
  - spiraled umbrellas
- Addams 1834
  - waterfall
- Wohlgemuth 1911
  - motorized gratings

Fall of Foyers

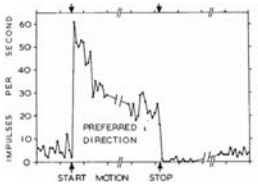
Motion Aftereffect

Theory

Neurons have personalities



Excitement is short-lived



Direction-selective reduction in response

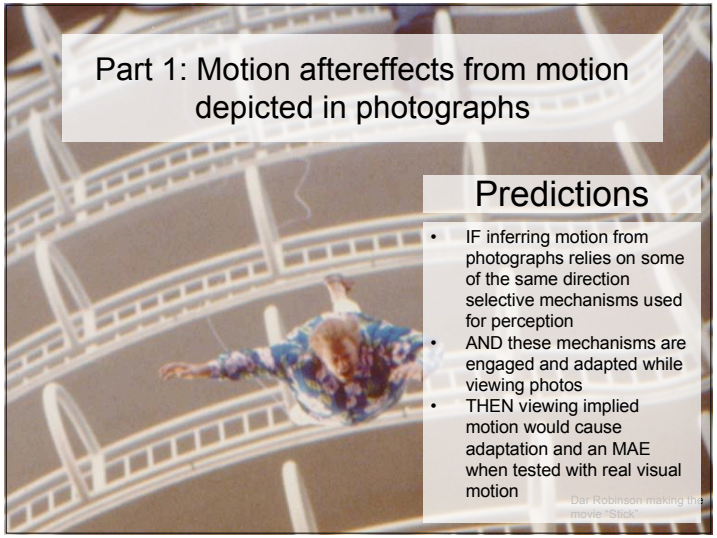
Single Unit:

Rabbit retina
Barlow and Hill 1963

Cat Primary Visual Cortex
von der Heydt et al 1978

Monkey MT
Petersen et al 1985
van Wezel & Britten, 2002
Kohn & Movshon, 2003

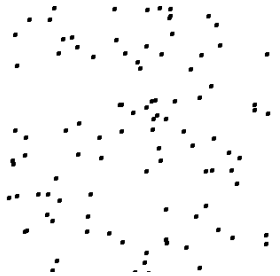
fMRI:
Human MT/MST
Huk et al, 2001



Winawer, Huk, Boroditsky, Psychological Science, 2008

Test Stimulus

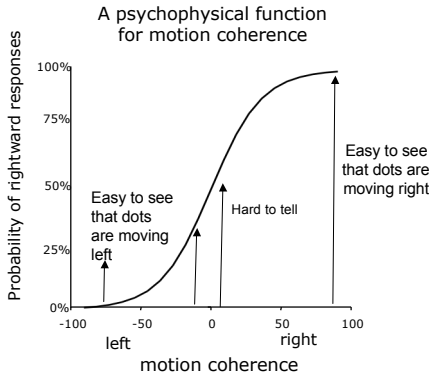
partially coherent dynamic dot displays

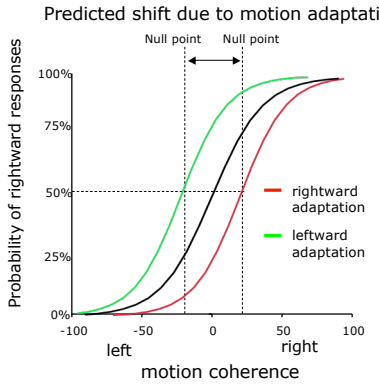


- 100 dots per test
- Limited lifetime

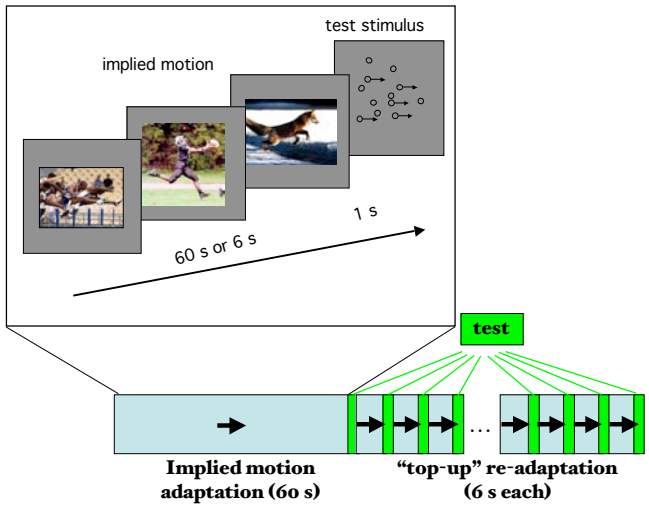
(coherent dots resampled on each frame to prevent tracking)

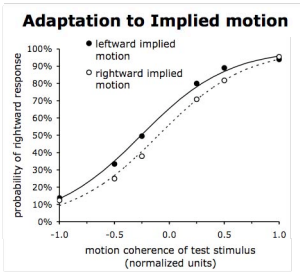
- Thought to rely into primary motion processing mechanisms
- Analogous to Random - Dot Stereograms (Bela Julesz)





Hiris and Blake (1992)
Blake & Hiris (1993)

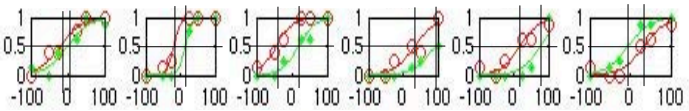




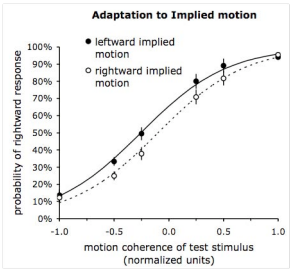
19 subjects

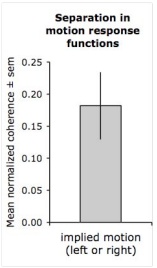
What about the
error bars?

Nathan Witthoft



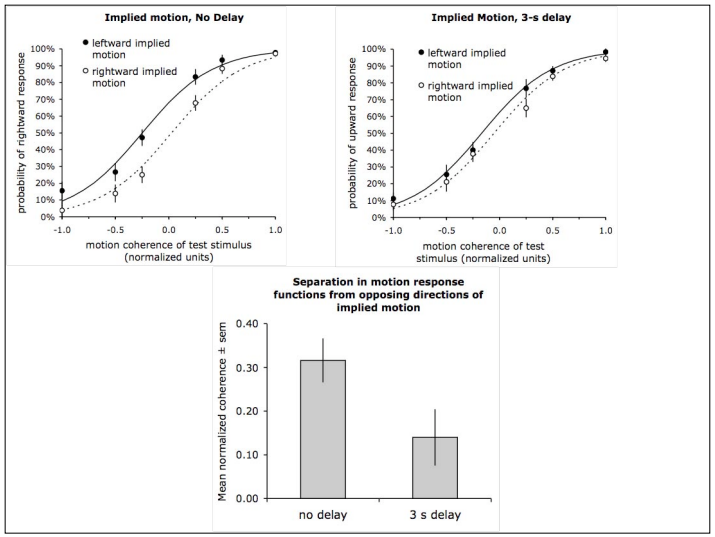
Implied motion adaptation,
individual subjects



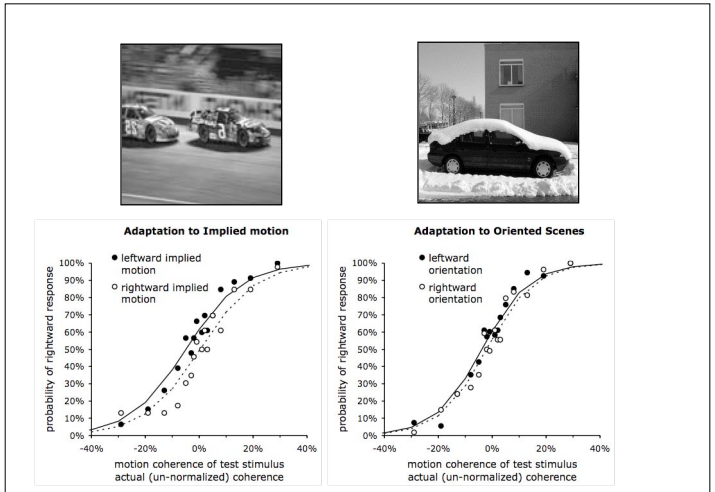


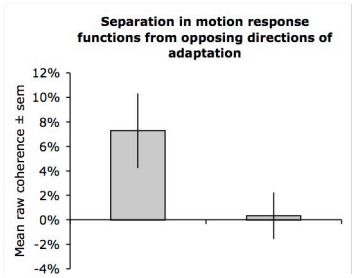
- Viewing motion depicted in photographs led to a motion aftereffect in the opposite direction
- Transfer of adaptation demonstrates that implied motion and real motion are represented by at least some shared mechanisms

- How much is the aftereffect from implied motion like the aftereffect from viewing real motion?
- Real motion aftereffects decay with time
- What about the implied motion aftereffect?



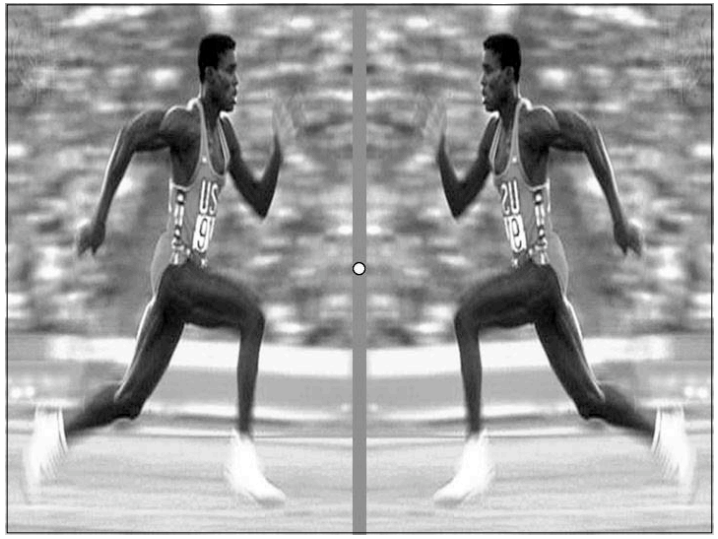
- The photos used so far have implied motion to the left or right
- How important is the motion in the picture *per se*?
- What if the foreground objects were oriented to the left or right, but were at rest?

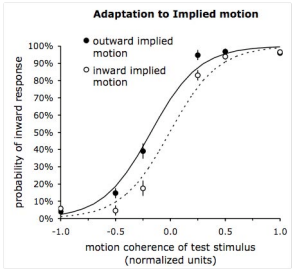


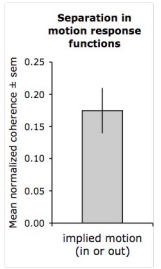


The depiction of motion, and not just the orientation of the objects, was critical for the MAE

- The photos used so far have implied motion to the left or right
- Could the stimuli have led subjects to make systematic eye movements in the direction of implied motion?
- Could this explain the MAE?

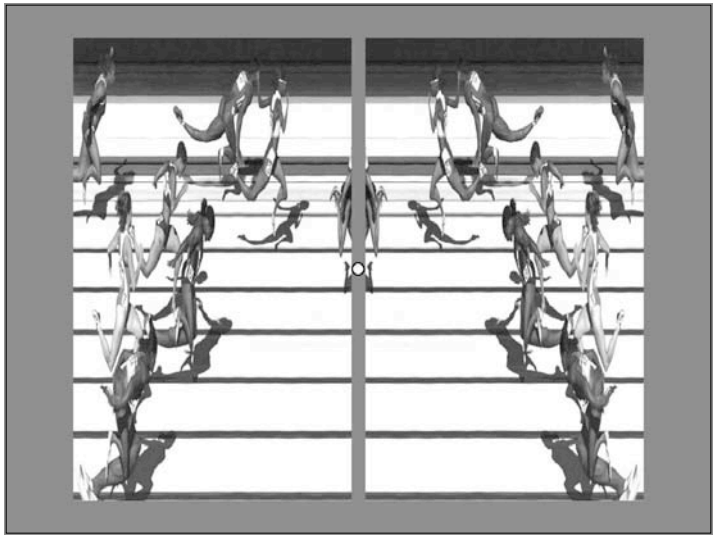


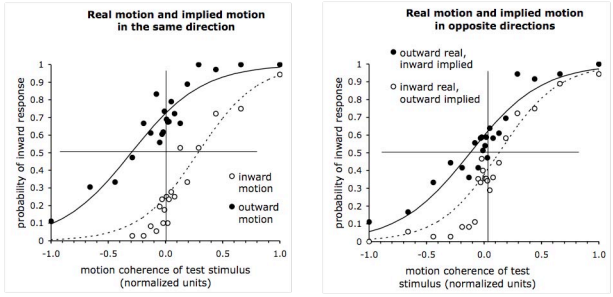


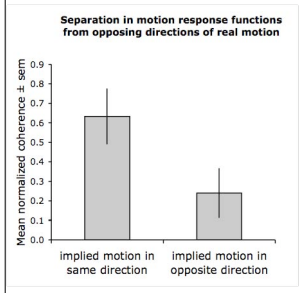


- Inward and outward implied motion caused a motion aftereffect, arguing against explanations based on eye movements

- Does adaptation to implied motion interact with adaptation to simultaneous real motion?



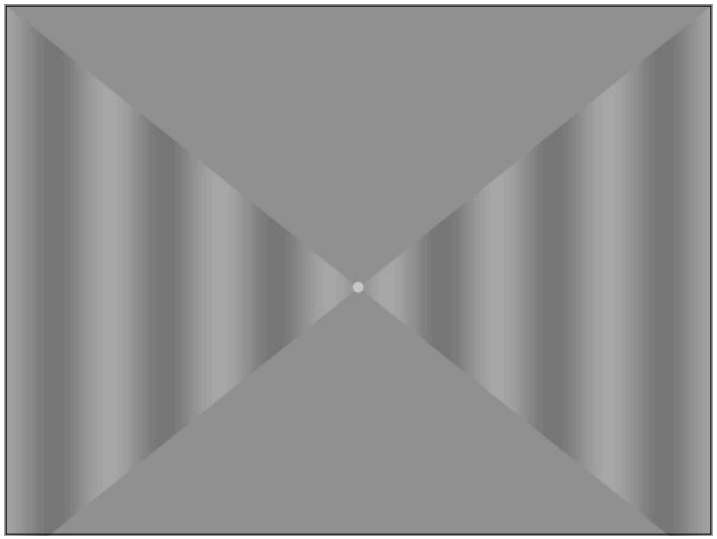


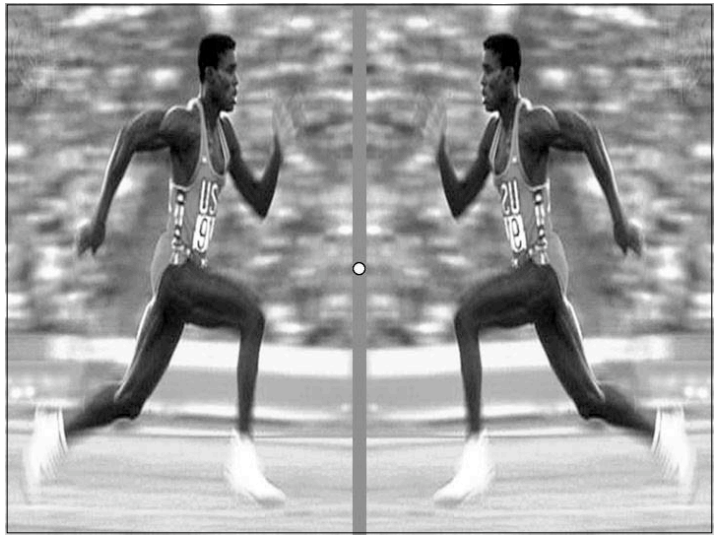


- Simultaneous viewing of real motion and implied motion interact:
  - If they are in the same direction there is a robust MAE
  - If they are in opposite directions the MAE is significantly reduced

Another way to measure real and implied MAEs

- Ambiguous, counterphase gratings
  - has been used to measure MAEs:
  - von Grunau (1986)
  - Culham et al. (2000);
  - Nishida & Sato (1995);





Summary - Implied Motion

- Motion implied in photographs produces direction-selective adaptation which
  - has an effect on subsequent on visual perception
  - decays with a brief delay
  - depends on depicted motion (and not just direction) in images
  - occurs with L/R as well as In/Out implied motion
  - interacts with the effect of simultaneous real motion adaptation

Part 2

- Motion aftereffects from mental imagery of motion

- Can imagination of motion, in the absence of any sensory input, activate direction-selective motion neurons?
- If you picture something moving up, will you preferentially recruit upward selective motion neurons?

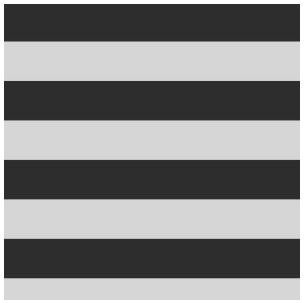
Part 2

- Motion aftereffects from mental imagery of motion

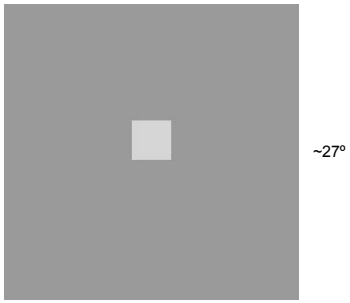
Predictions

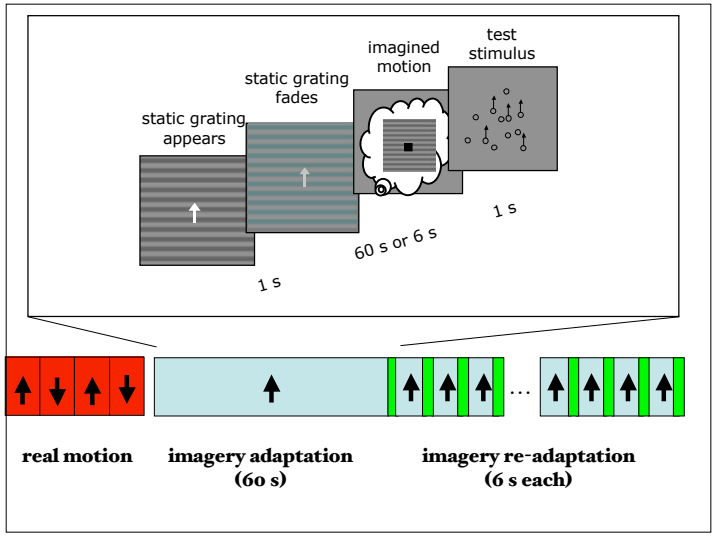
- IF imagery of motion relies on some of the same direction selective mechanisms used for perception
- AND these mechanisms are engaged and adapted during imagery
- THEN imagery of motion would cause adaptation and an MAE when tested with real visual motion

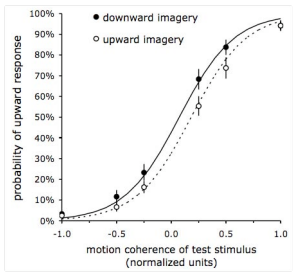
This is what subjects had to imagine

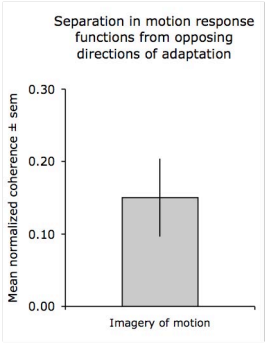


Imagination Phase



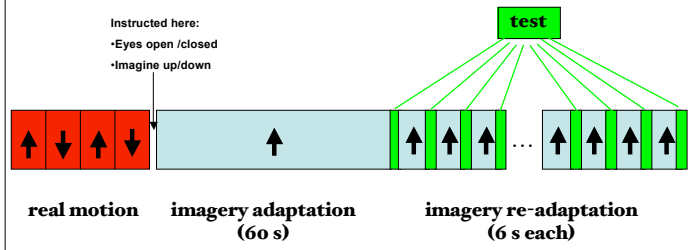


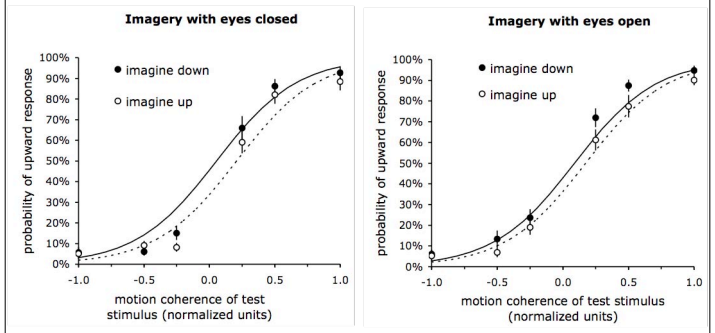




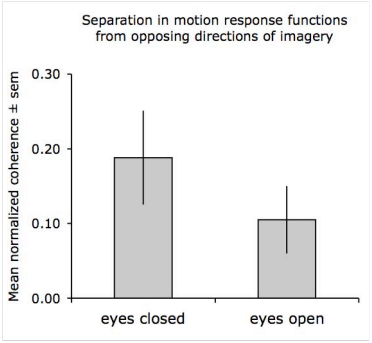
- Is it necessary to have the eyes open during imagery to produce an MAE?
- Might the subjects have learned about the MAE during the occlusion blocks?

2nd imagery experiment:
Imagery with eyes open or closed (blocked)



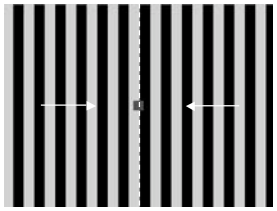


30 subjects

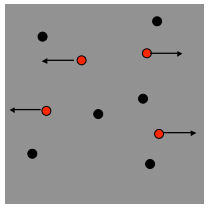


- Mental imagery of motion again led to a motion aftereffect
- The aftereffect did not depend on subjects having their eyes open

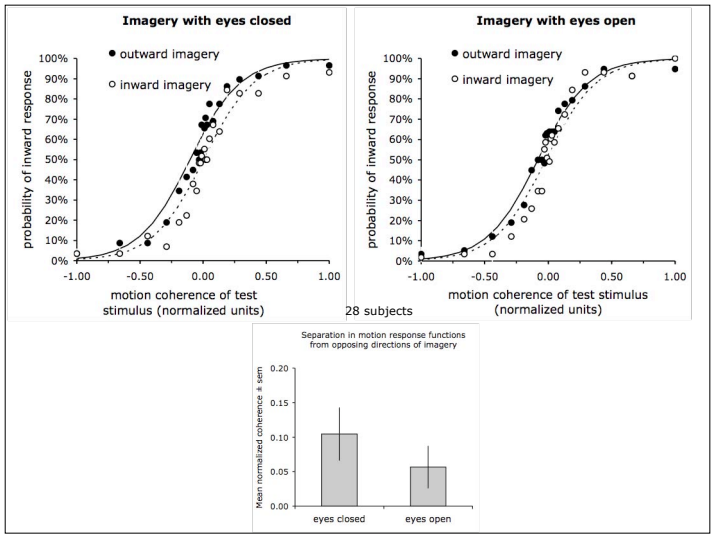
- Question: Is it possible that subjects made systematic eye movements during imagery?
- If so, could this have caused the motion aftereffect?

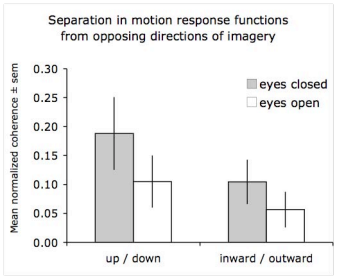


Imagery
In / out



Test stimulus
In / out

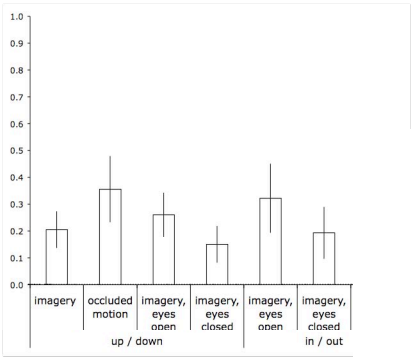




- The aftereffects cannot be explained by pursuit eye movements
- Across 2 experiments, the MAE was stronger with the eyes closed than open

Summary 2- Mental Imagery

Size of MAE compared to real motion adaptation



Summary 2- Mental Imagery

- Imagined motion produces direction-selective adaptation
  - has an effect on subsequent visual perception
  - effect is 15-30% of real MAE
  - occurs with eyes open and closed
  - is not mediated by eye movements
- Transfer of adaptation from imagery to perceived motion suggests that imagining motion involves some direction-selective processing mechanisms shared with perceiving actual motion

Summary: Seeing beyond the image

Inference of motion

•Knowing what is in a picture influences the way we see it

•Implicit, high-level information can be represented by early perceptual mechanisms

Imagination of motion

• active imagination shares neural substrates and neural mechanisms with perception

Thanks

- Collaborators:

  Lera Boroditsky

  Alex Huk

- Research assistants:

  Jesse Carton (MIT) and Taraz Lee (Stanford)