

Perceiving Motion and Events



Image motion vs. Object Motion

- Image Motion – Caused by eye movements, even when scene is stationary
- Object motion – When things actually move

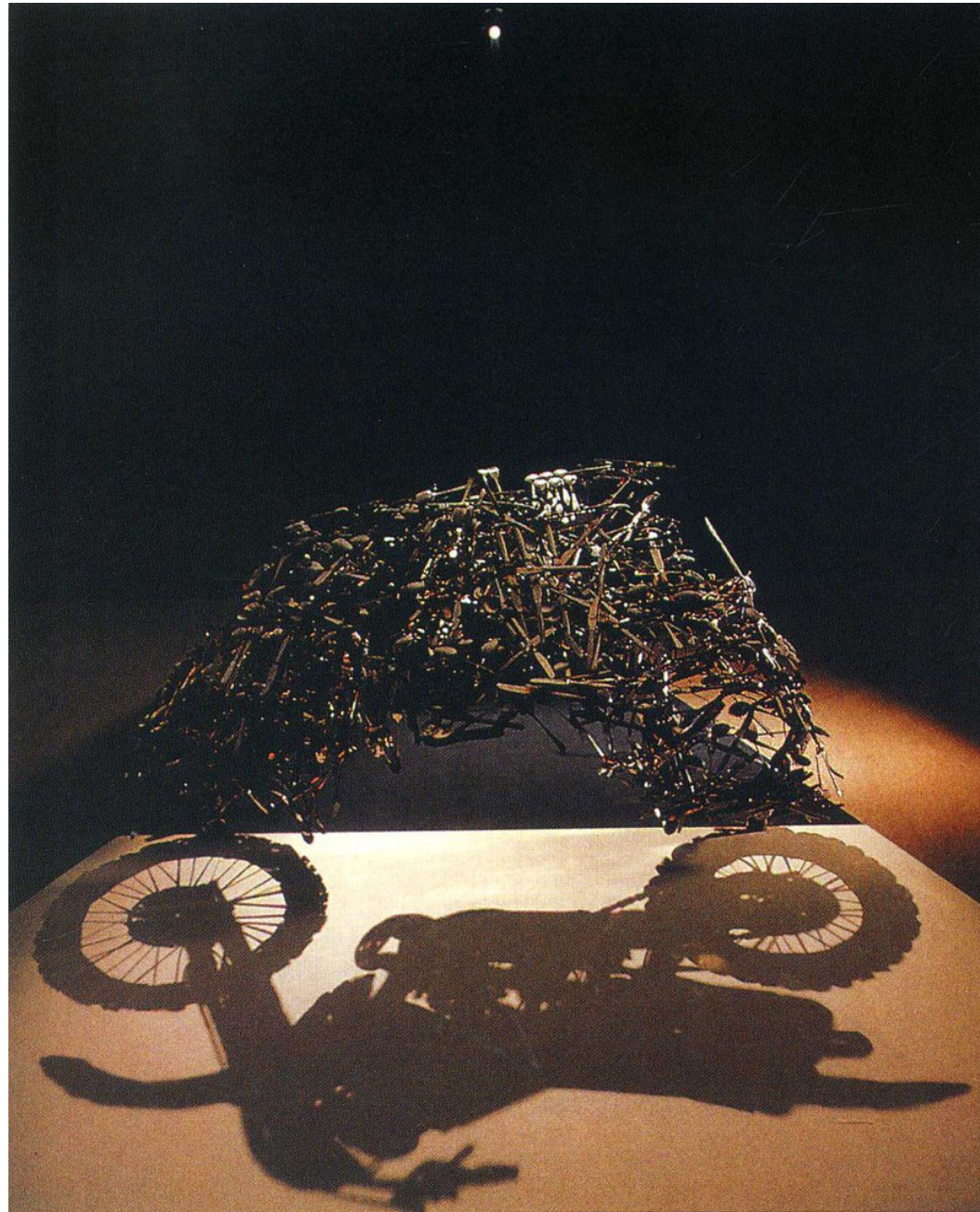
Remember Corollary Discharge?



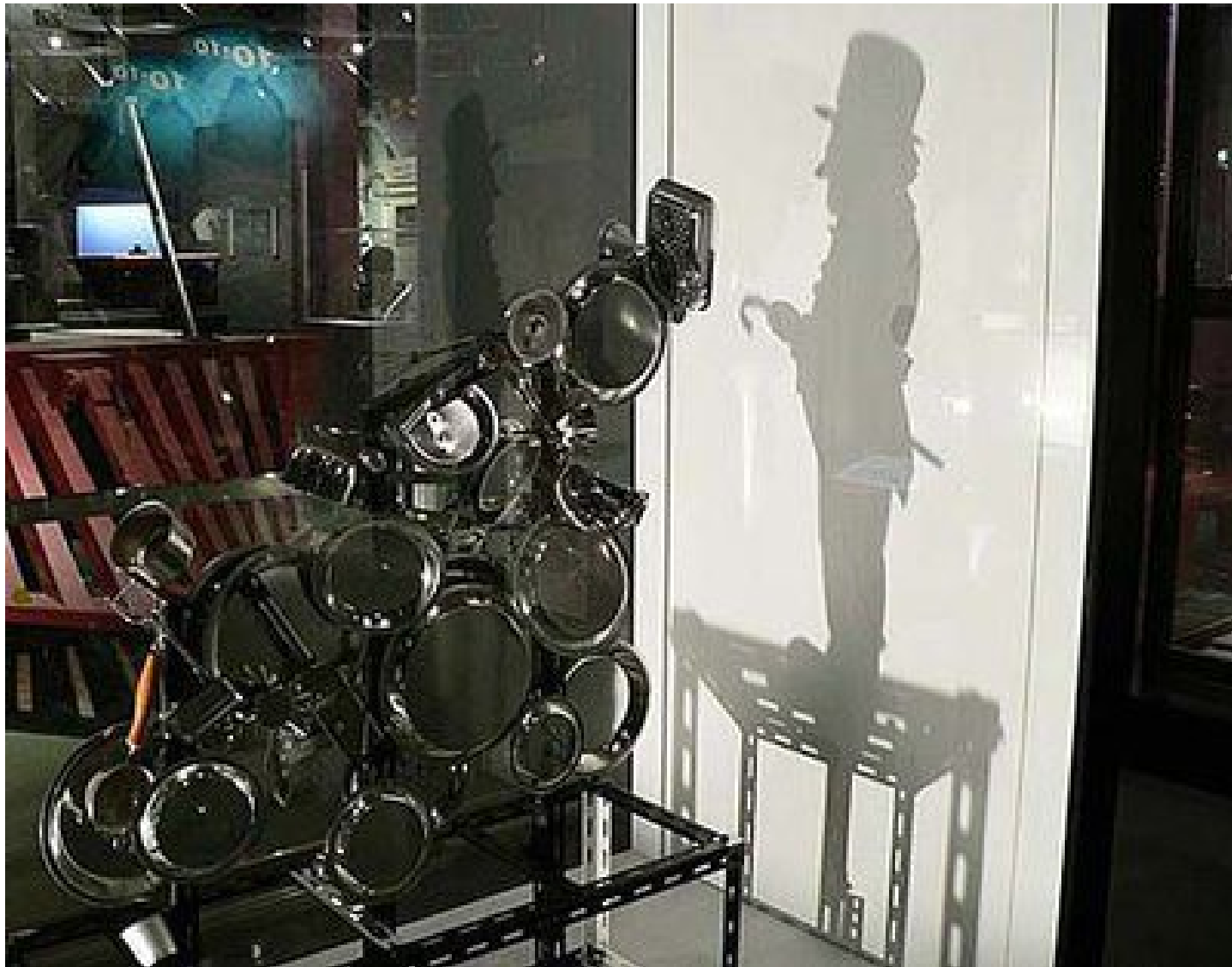
Under-constrained Problem



Under-constrained Problem

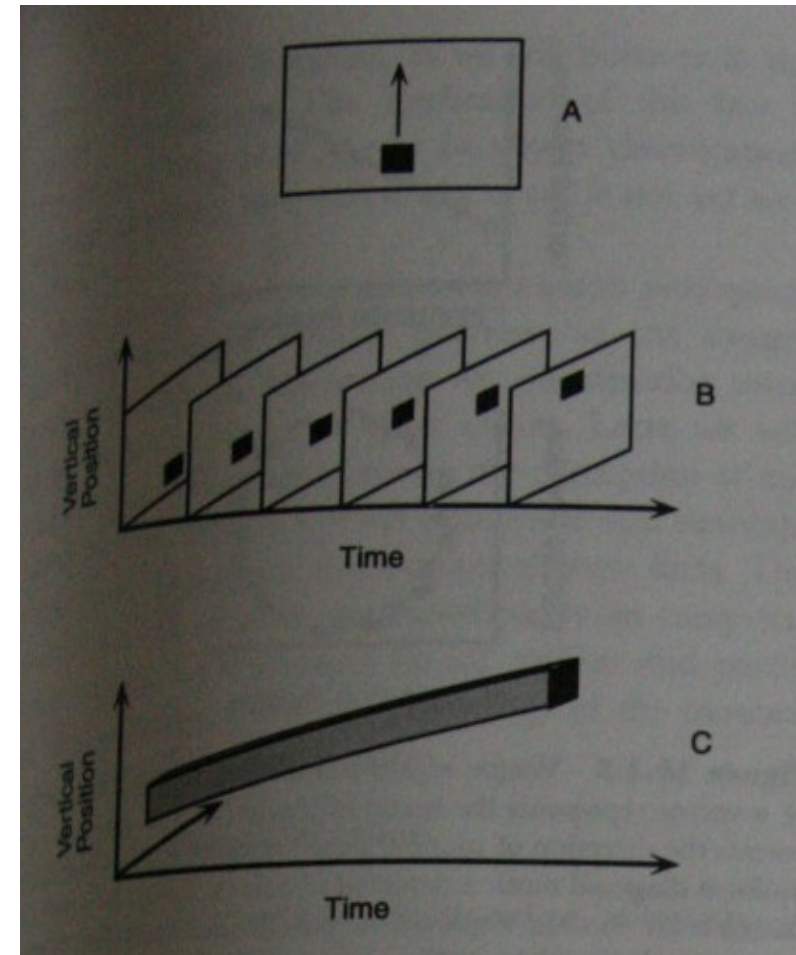


Under-constrained Problem



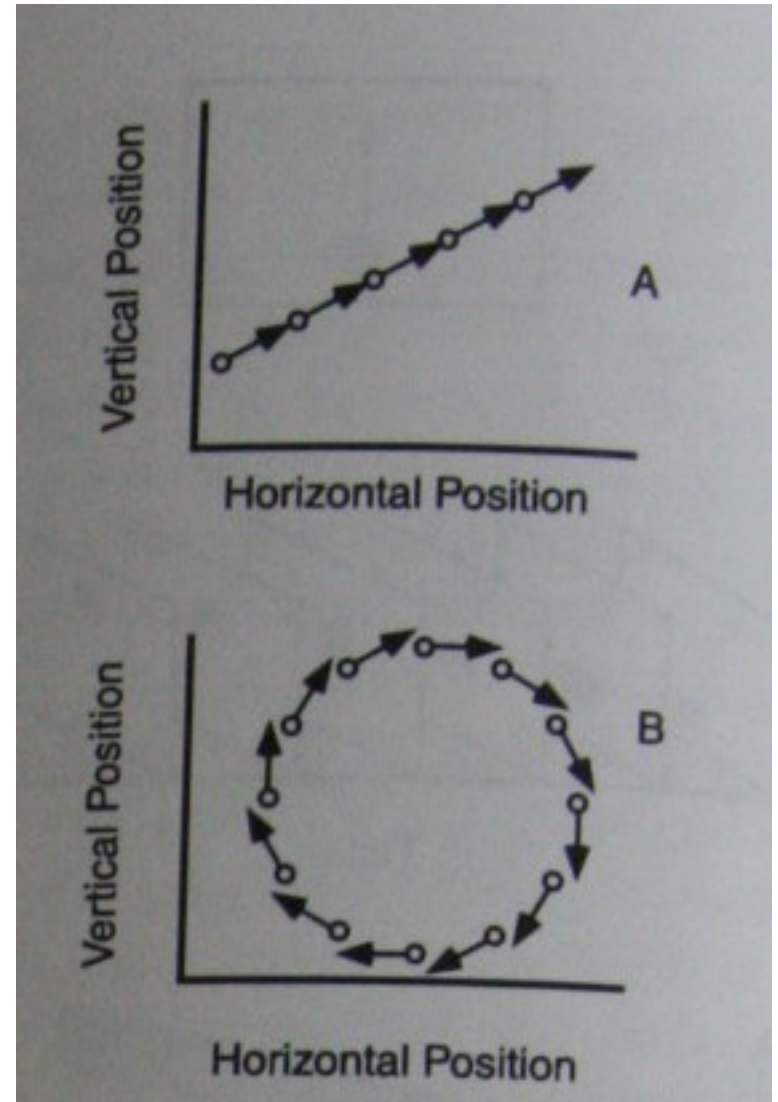
The Computational Problem of Motion

- We see moving things on the retina in 2-D
- But We want to know information about the 3D world
- *“I was standing in the park wondering why frisbees got bigger as they get closer. And then it hit me.”*
- Unknown



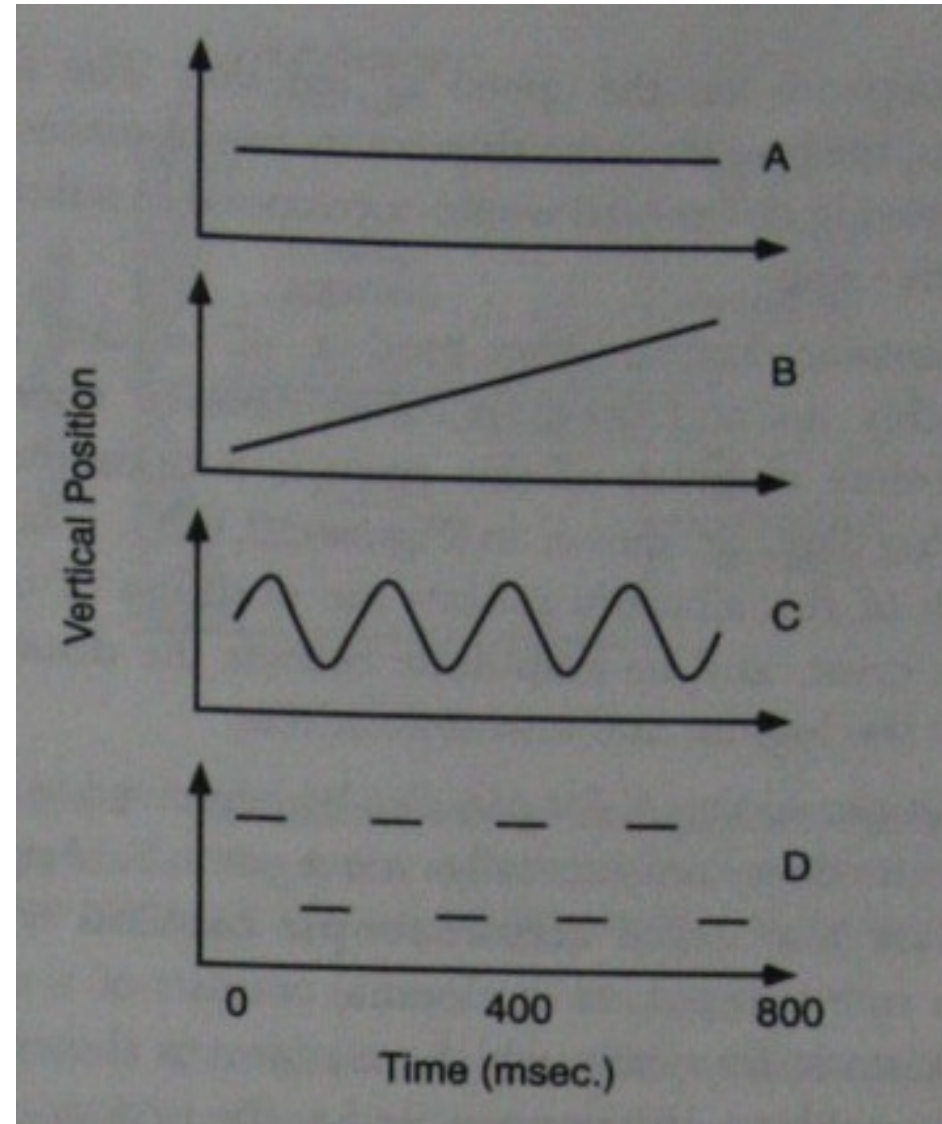
The Computational Problem of Motion

- We see moving things on the retina in 2-D
- But We want to know information about the 3D world
- Is that baseball just getting bigger? Or is it about to hit you?



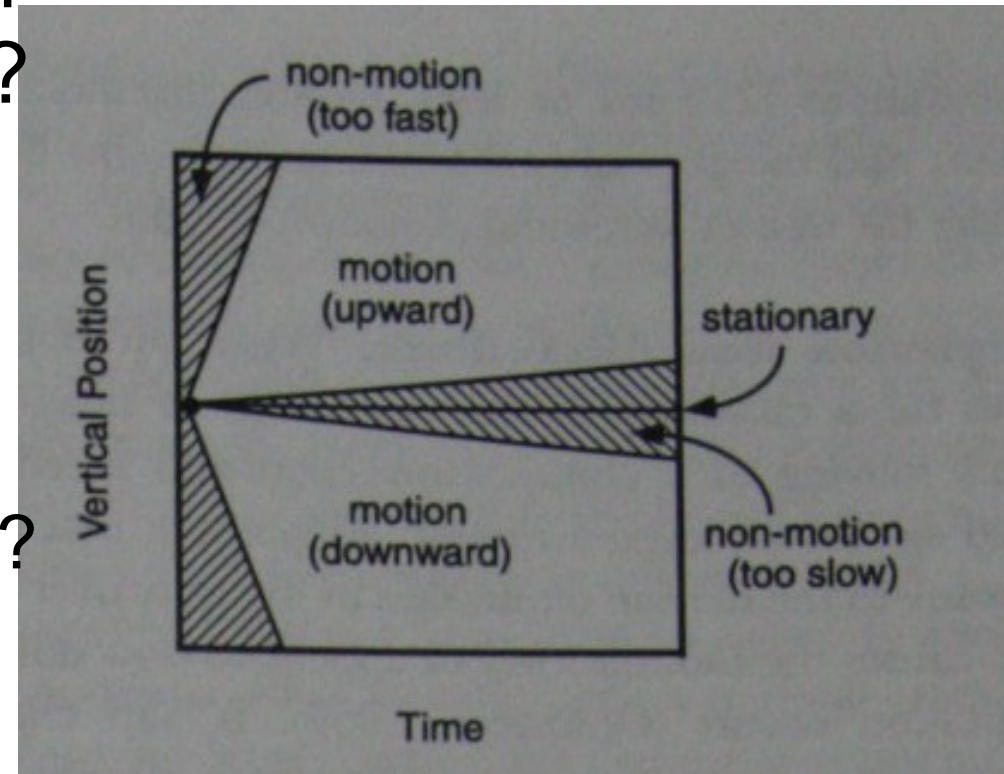
The Computational Problem of Motion

- We see moving things on the retina in 2-D
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Continuous Motion

- Object considered moving if position changes over time?
- But can we always “see” it moving?
 - What about the moon...
 - Or the blades of a helicopter?



What affects ability to perceive continuous motion?

- A light spot against a **homogeneous background** – sensitivity = roughly $1/6 - 1/3$ visual angle/second
- A light spot against a **texture background** = sensitivity = roughly $1/60$ visual angle/second

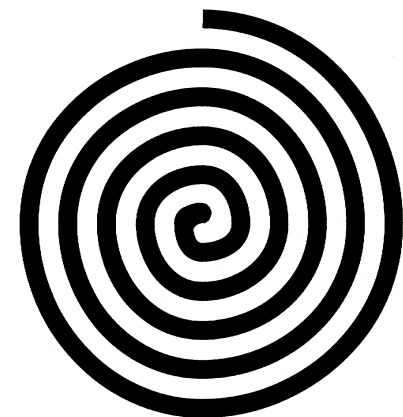
Conclusion – Much more sensitive to motion relative to another object vs motion relative to observer.

Adaptation and Aftereffects

- Prolonged exposure to a scene with constant motion desensitizes our visual system to that motion.
- Result: motion aftereffects
- http://en.wikipedia.org/wiki/File:Illusion_movie.ogg

Adaptation and Aftereffects

- Waterfall Illusion
 - Stare at a stationary object inside a waterfall (i.e. a protruding rock) for awhile. Then stare at a stationary scene → **Stationary scene appears to move upwards**
- Spiral Aftereffect
 - Watch a spiral on a turntable, then watch your friend's face spiral inward



Adaptation and Aftereffects

- Q: Where in the visual system does adaptation occur?
 - In the early monocular system?
 - Or the later binocular system?
- A: both
 - Adaptation in one eye → adaptation in other eye
 - Adapt both eyes to CW rotation. But when viewing with both → adaptation to CCW rotation

Apparent Motion

- If video is just a sequence of frames, why do we see motion?
- First Tested by Sigmund Exner in 1875
 - Regular alternation of sparks w/optimal distance and rate produced illusion of motion
 - Principle behind modern video

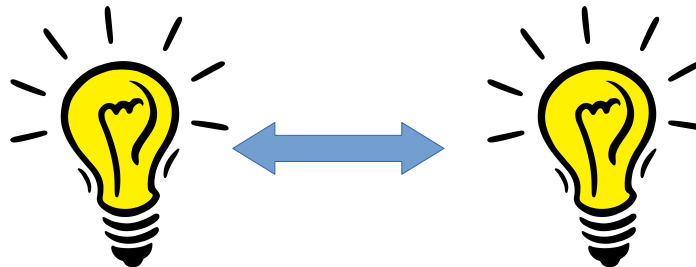


Apparent Motion

- Human eye responds to light changes ~ 10x/second
 - Changes @ twice this rate look like motion – hence 24 FPS is standard for video

Apparent Motion

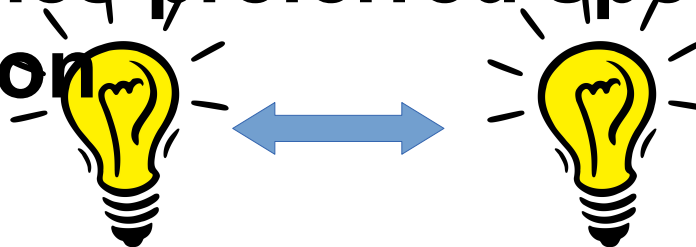
- Wertheimer's experiment (1912) with **Alternation rate** of two flickering lights
 - Alt. rate > 40 Hz – looks like 2 flickering lights
 - 10 Hz $<$ alt. rate < 40 Hz – *Phi Motion* – motion perceived, but no intermediate states
 - Evidence of motion as a fundamental component?
 - Alt ≈ 10 Hz – *Beta motion* – motion perceived, brain fills in intermediate positions



Apparent Motion – Korte's Laws

- 1. *Separation vs intensity* – larger separations require higher intensities
- 2. *Rate vs intensity* – slower rates require higher intensities
- 3. *Separation vs rate* – larger separations require slower rates

Third law implies preferred speed of apparent motion



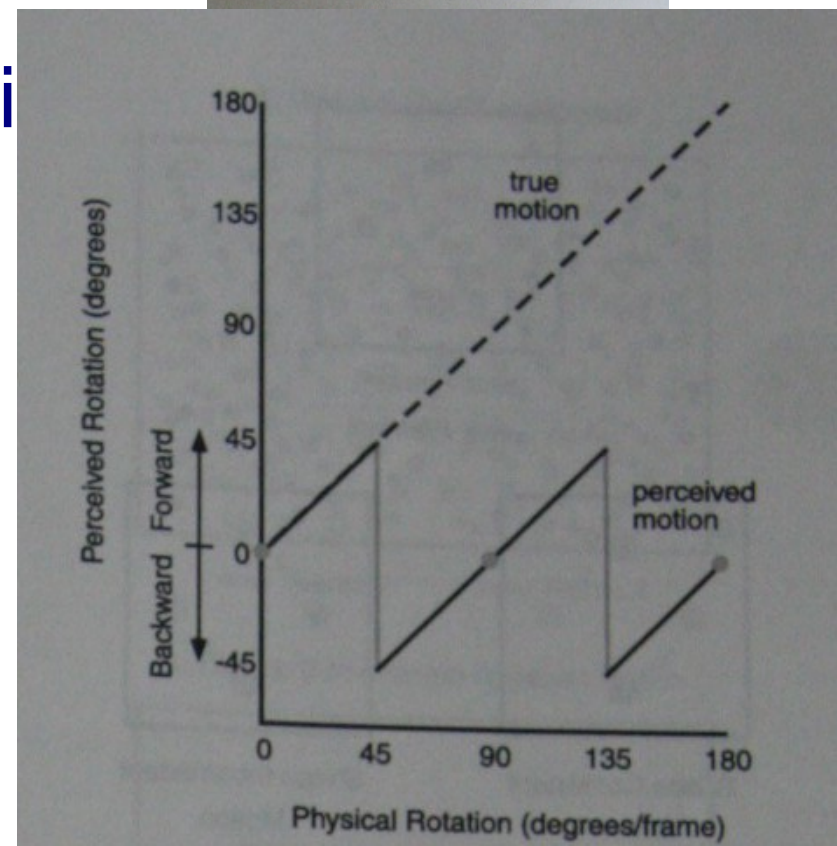
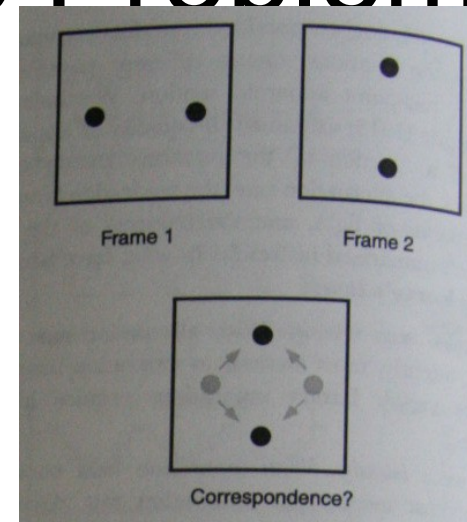
Apparent Motion – Flicker Fusion

- 24 FPS makes smooth video, but light must flicker at > 60 Hz
- Fluorescent lights: 120 Hz
- Cinema – 24 FPS, display each image 3x for a flicker rate of 72 Hz
- CRT screens – 30 FPS interlaced = flicker @ 60 Hz



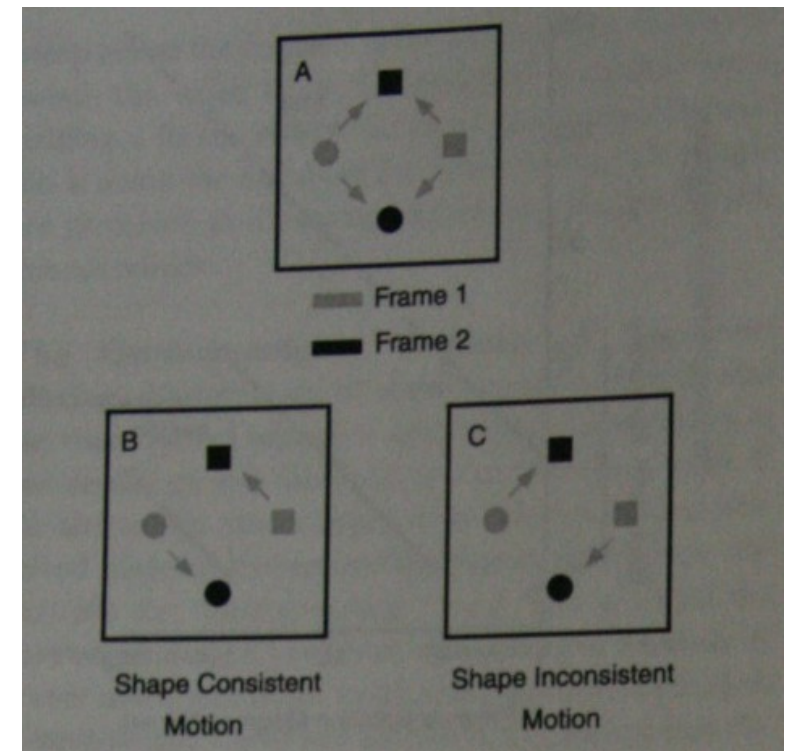
The Correspondence Problem

- Which object in frame 1 corresponds to which object in frame 2?
- Wagon Wheel Illusion:
http://en.wikipedia.org/wiki/Wagon_wheel_illusion



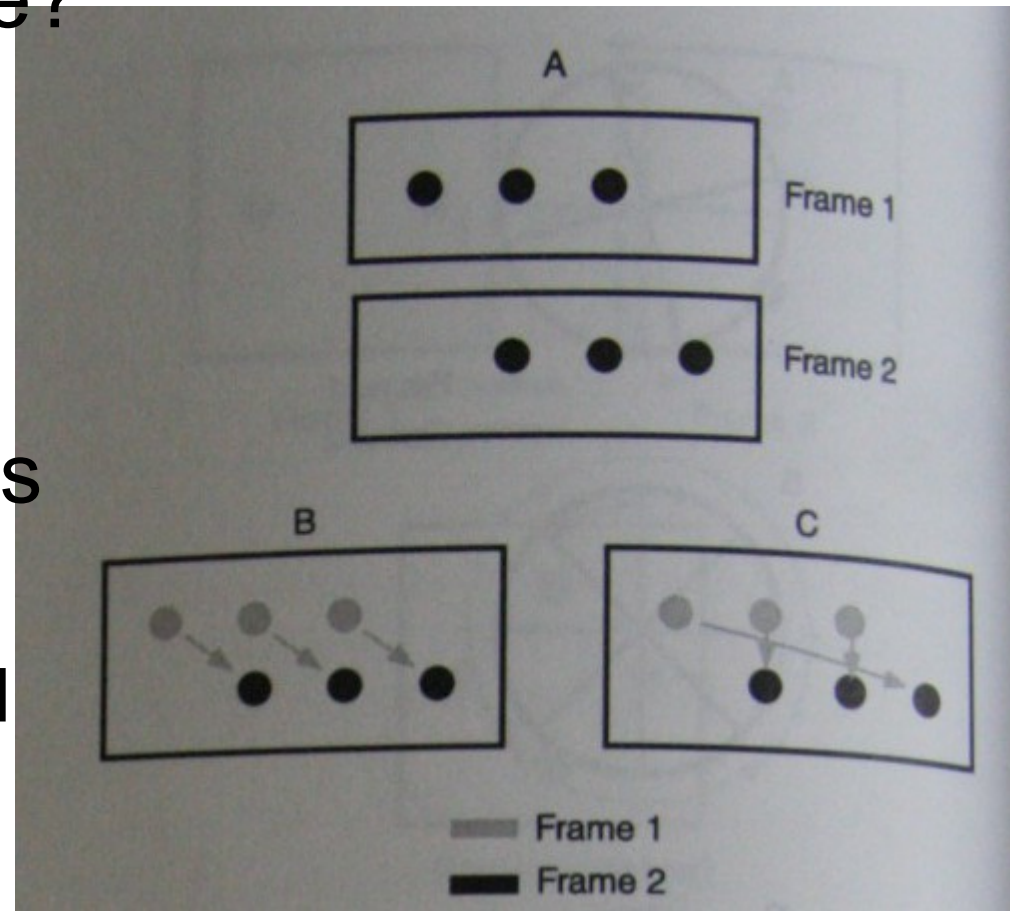
The Correspondence Problem

- Using Shape to solve correspondence problem
- $A \rightarrow B$ is preferred to $A \rightarrow C$



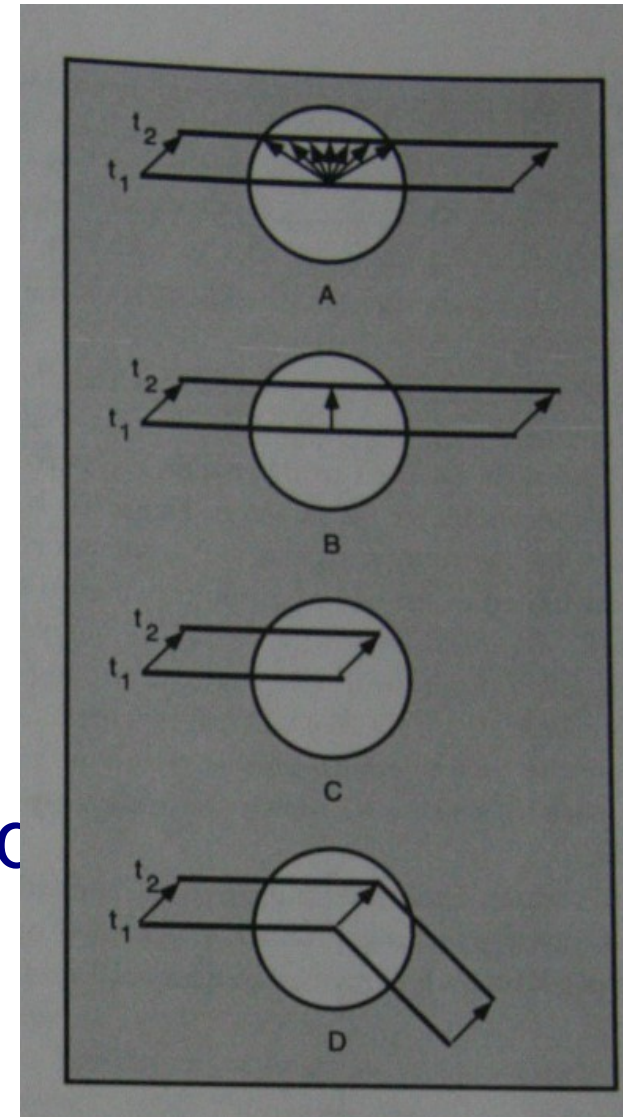
The Correspondence Problem

- But which is preferred here?
- **Slow Alternation:** $A \rightarrow B$ preferred
 - Long distances favored
- **Fast Alternation:** $A \rightarrow C$ is preferred
 - Minimum distances favored



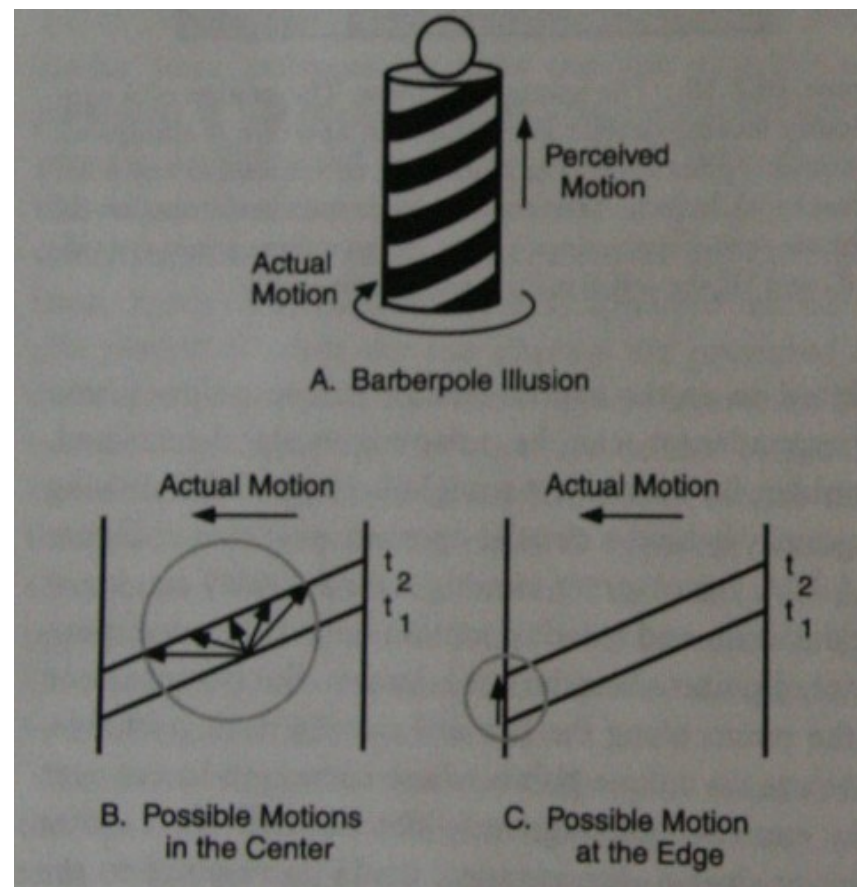
The Aperture Problem

- Which points correspond to which?
- Figures A & B are ambiguous
- Figures B & C are unambiguous due to the **unique-point heuristic**
- <http://upload.wikimedia.org/wikipedia>



The Barber pole illusion

- “ends” of stripes appear to give a unique point, moving upwards
- BUT: Hans Wallach (1935) defeated the barber pole illusion with a horizontal aperture.
 - Horizontal motion at bottom & top took over



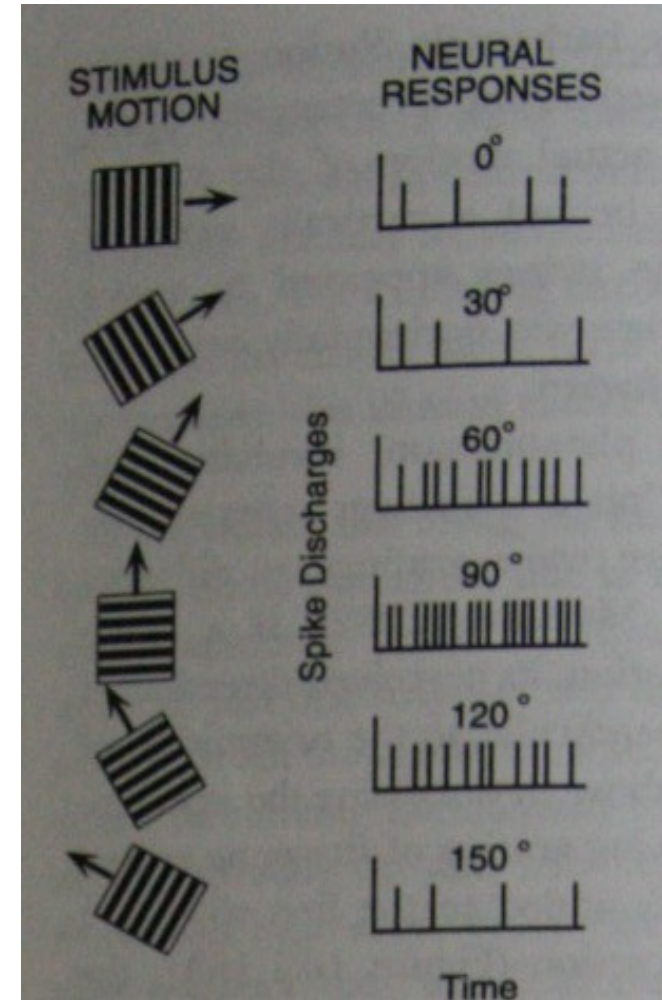
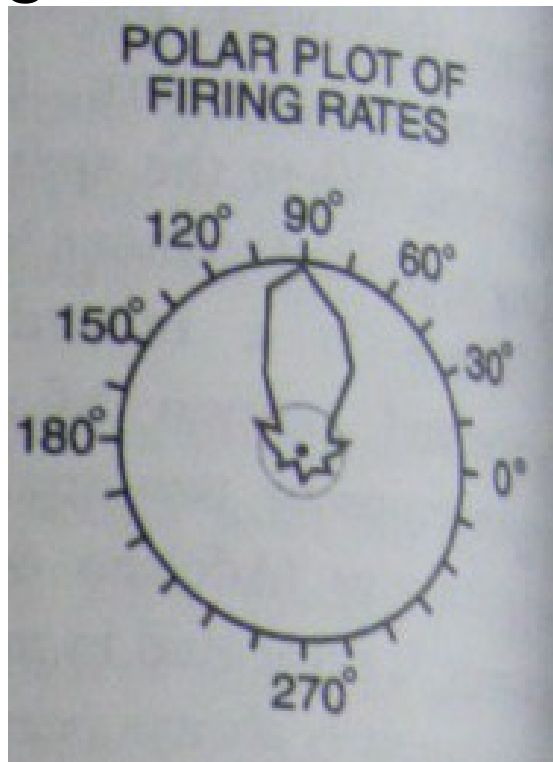
<https://www.youtube.com/watch?v=VmqQs613SbE>

Physiological Mechanisms of Motion Perception

- Magnocellular (M) cell – part of the visual cortex
- M Cells:
 - Are very sensitive to differences in luminance
 - Have large receptive fields
 - Connect directly layers in V1 → MT → MST, which are heavily used in motion detection

Primary Visual Cortex

- V1 has cells that fire based on motion of stimulus
- Different cells specialize in different motions
- Results of neuron firing is sent to MT and MST for further processing

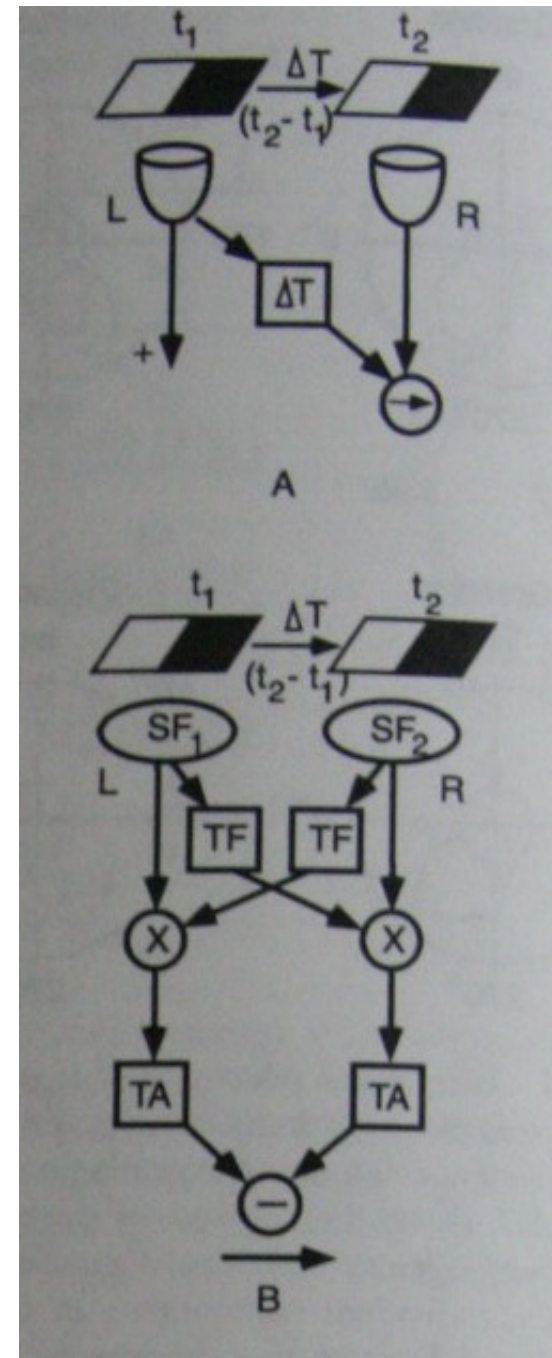


A Patient Case Study

- Patient admitted to hospital – complained of inability to perceive motion
- World appears as series of snapshots
- However, still able to recognize objects such as cup, car, face, etc.
- Damage region: MT and MST, **primary Visual Cortex undamaged**

But how does motion detection work?

- Delay-and-compare networks
 - **Idea:** compare image at time t with image at time delta-t
 - If same pattern appears at some distance way later, we have motion
- But physiological method of doing this is unclear



Perceiving Motion

- Why don't closer cars appear to be moving faster?
- This is called **velocity constancy**

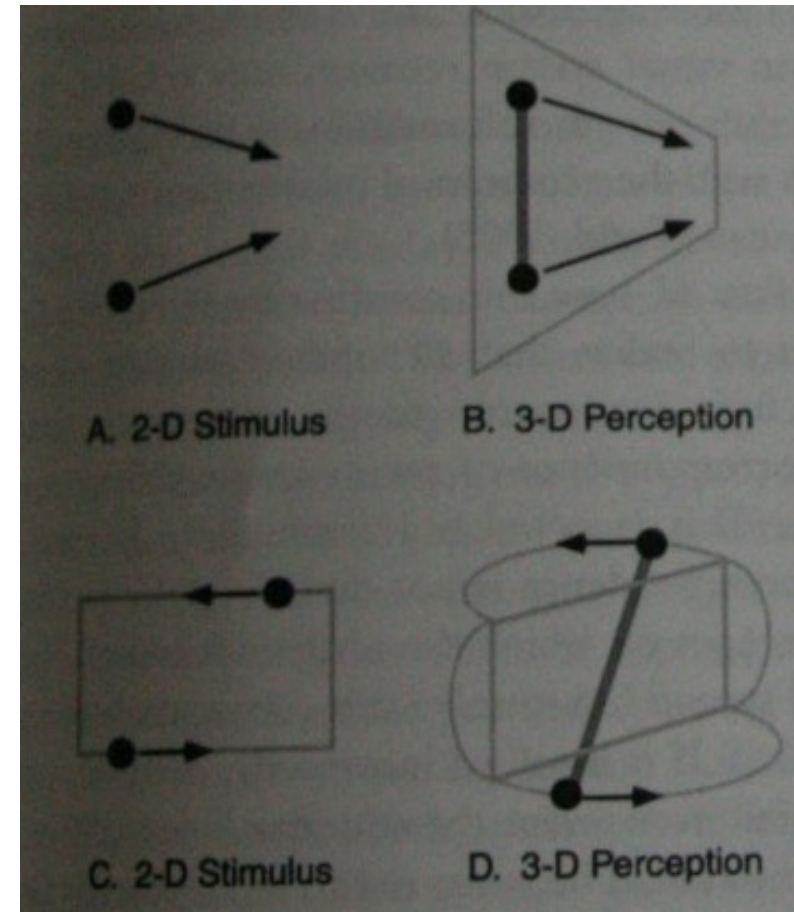


Velocity Constancy Experiment – Rock, Hill & Fineman (1968)

- Subjects viewed two moving objects, one object at 4x further distance
- Subjects tasked with adjusting speed of further object to match speed of closer
 - With binocular vision: correct adjustment
 - Without binocular vision: set further object to ~4x velocity

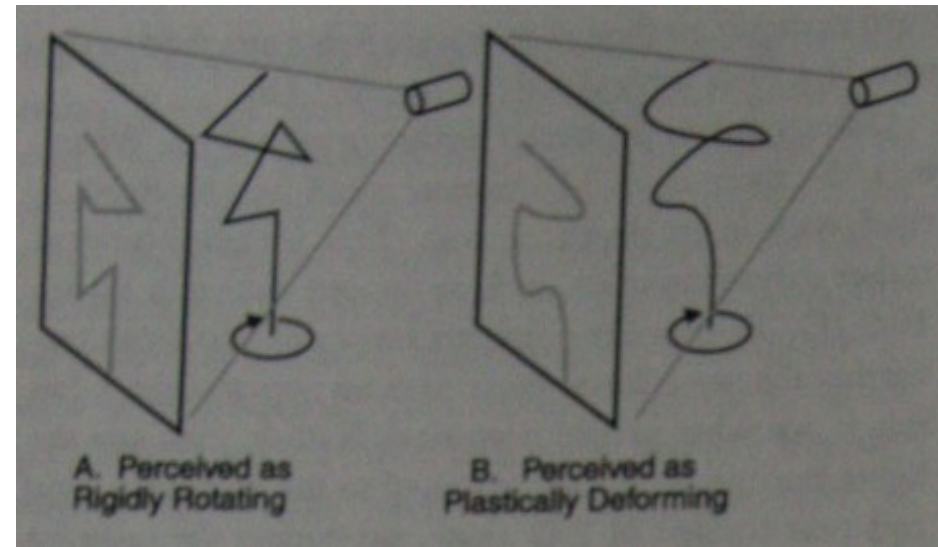
Rigidity Heuristic

- Tendency to see rigid motion
- Experiments with moving lights
- Lights perceived as attached to a rigid pole



Kinetic Depth Effect

- A more complex demonstration of the rigidity heuristic
- Subjects shown 2-D images of wireframe object
 - When stationary, object looks like 2D image
 - When rotated, object appears 3D



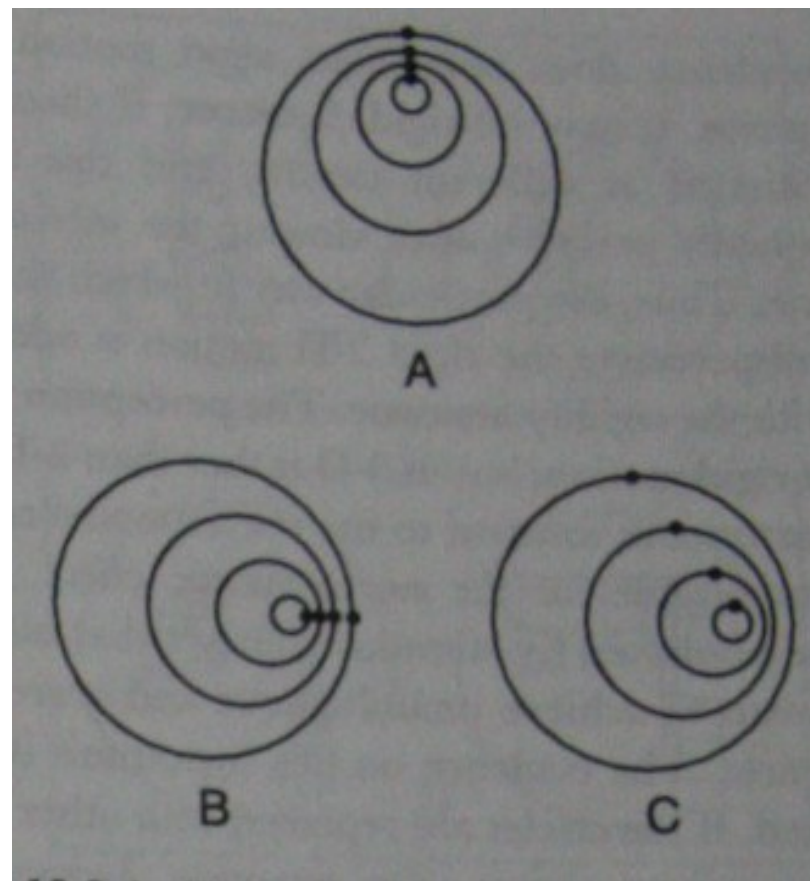
<https://www.youtube.com/watch?v=syl5Yk25E-g>

Stereo Kinetic Effect

- Perceiving motion of an object in depth when it's really just rigidly rotating
- <https://www.youtube.com/watch?v=XGfMB76U5ts>

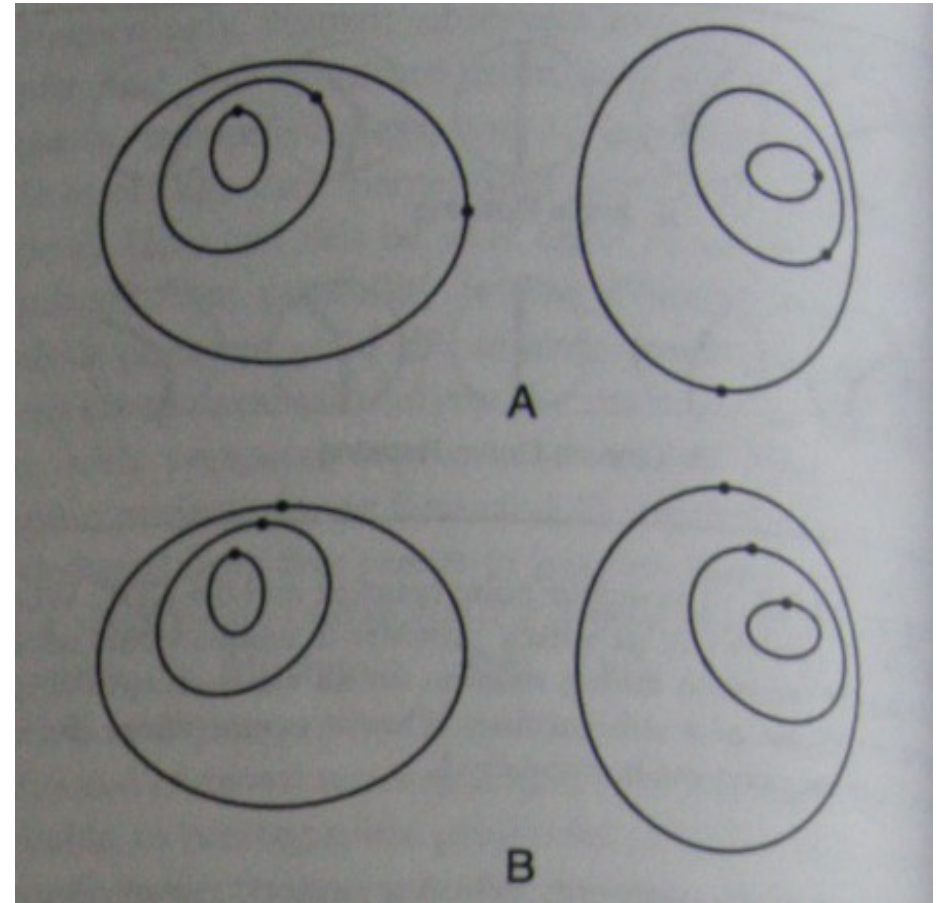
The Stereo Kinetic Effect

- Q: So why does this effect happen?
- A: The correspondence problem – your brain solves is like figure C, not B.



Nonrigid Motion Perception

- When rotating, viewer perceives squashing and stretching of ellipses
- Sorry, couldn't find a video
- With squares instead, **corners provide unambiguous points**, effect is lost

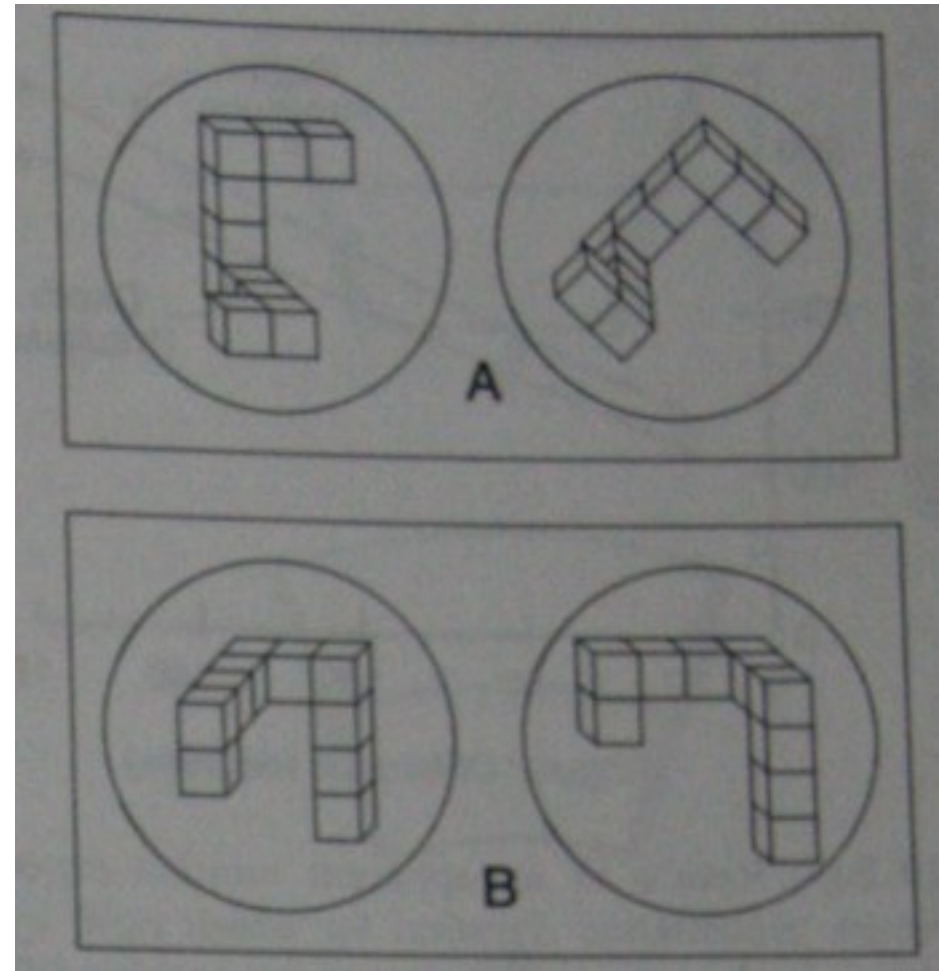


Transition to Long Range Apparent Motion

- Short range apparent motion: image level
 - Correspondence problem
 - Aperture problem
 - Etc.
- Long-Range apparent motion: object level
 - 3-D reasoning & processing

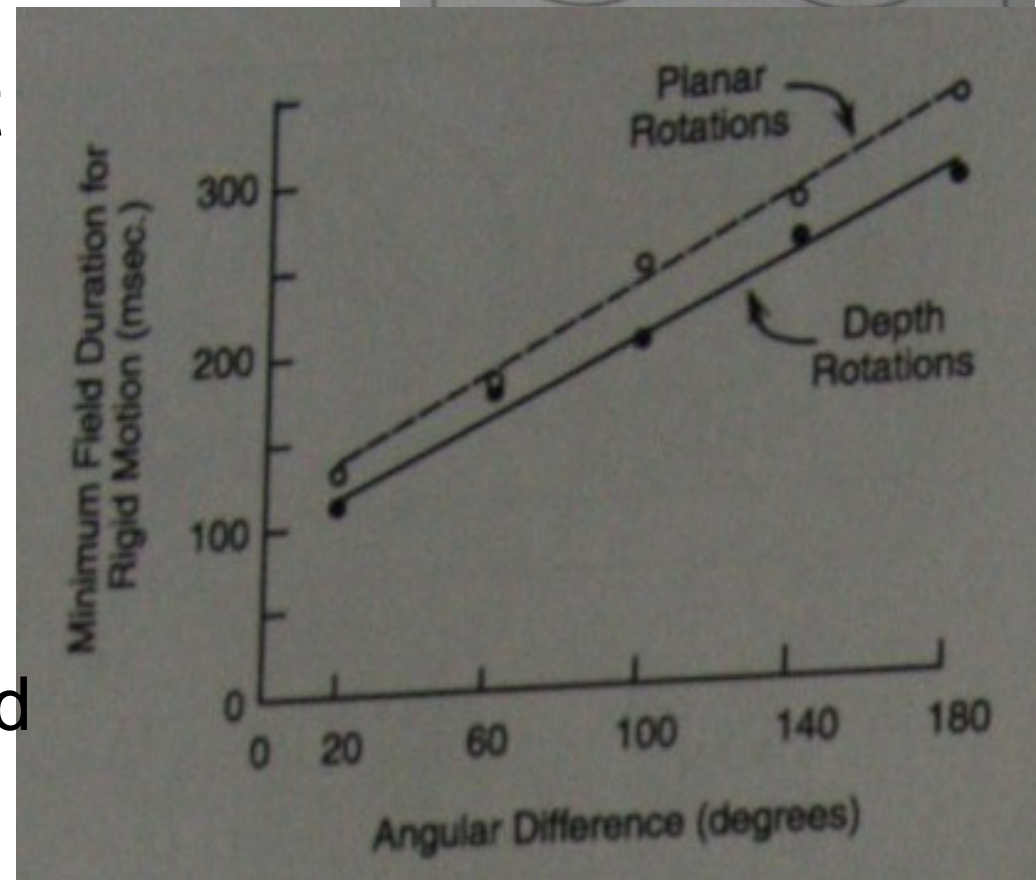
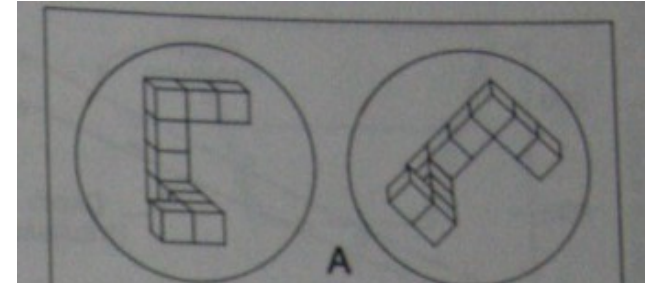
Apparent rotation

- Alternative images of 3-D objects at different rotation produces rotation perception
- Alternate too fast – effect is lost
- **So what is the max alternation rate?**



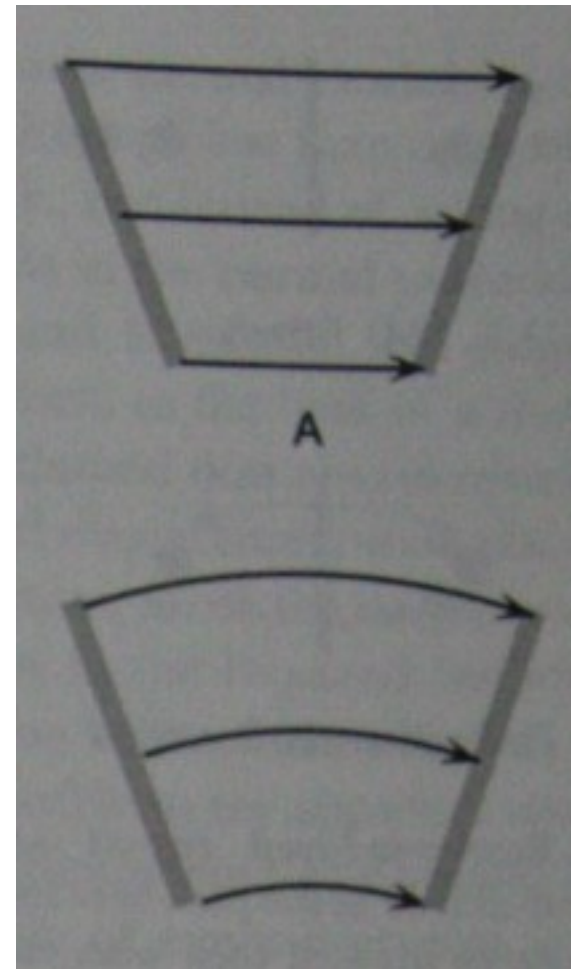
Apparent rotation

- Shephard & Judd tested max alternation rate (1976)
- Max flicker rate for effect increases linearly with angular difference
 - Even when rotated out of page
 - Indicates 3D representation in our head



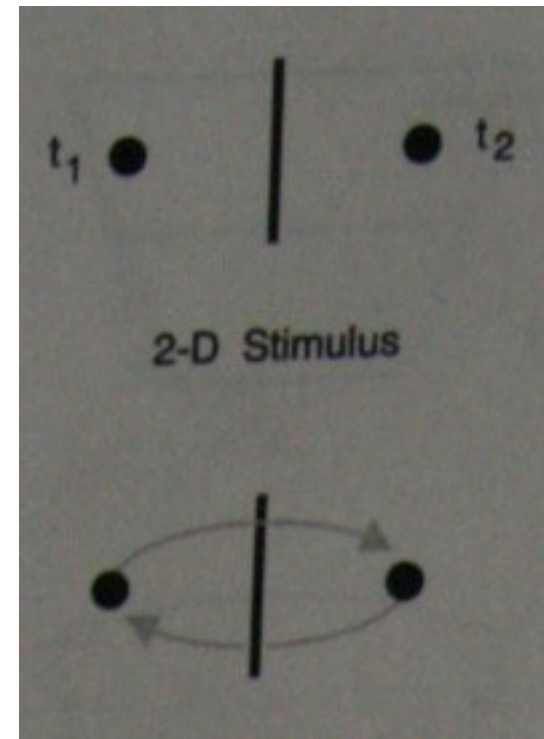
Curved Apparent Motion

- So Far: assume motion follows straightest possible path
- Can we induce perception of curved motion?



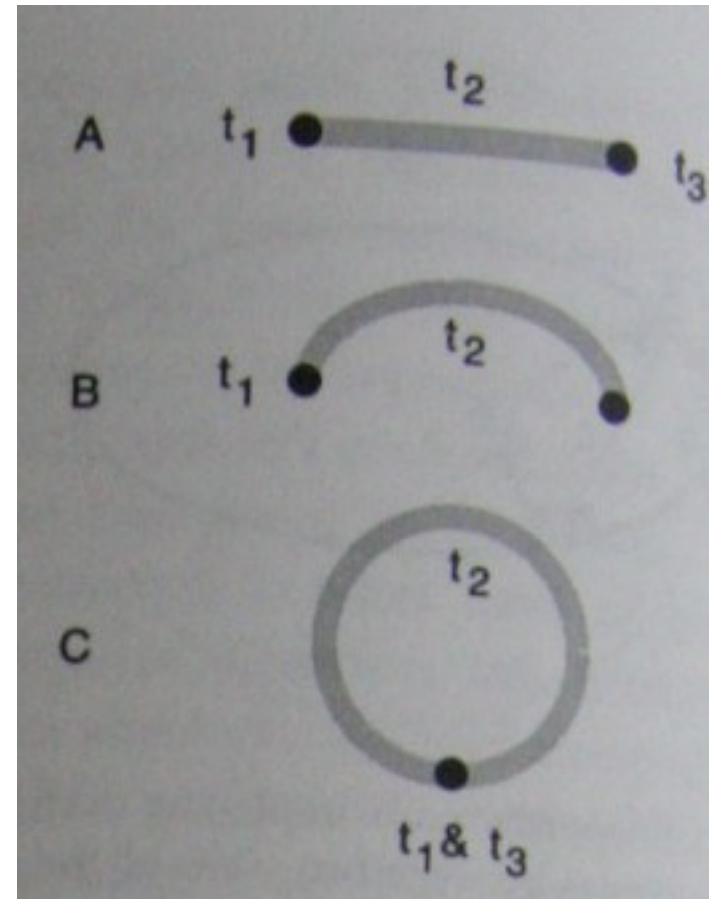
Curved Apparent Motion

- Barrier-Induced curved-apparent motion
- Presence of barrier – path bends to avoid it
- No rotation of stimuli, just translation



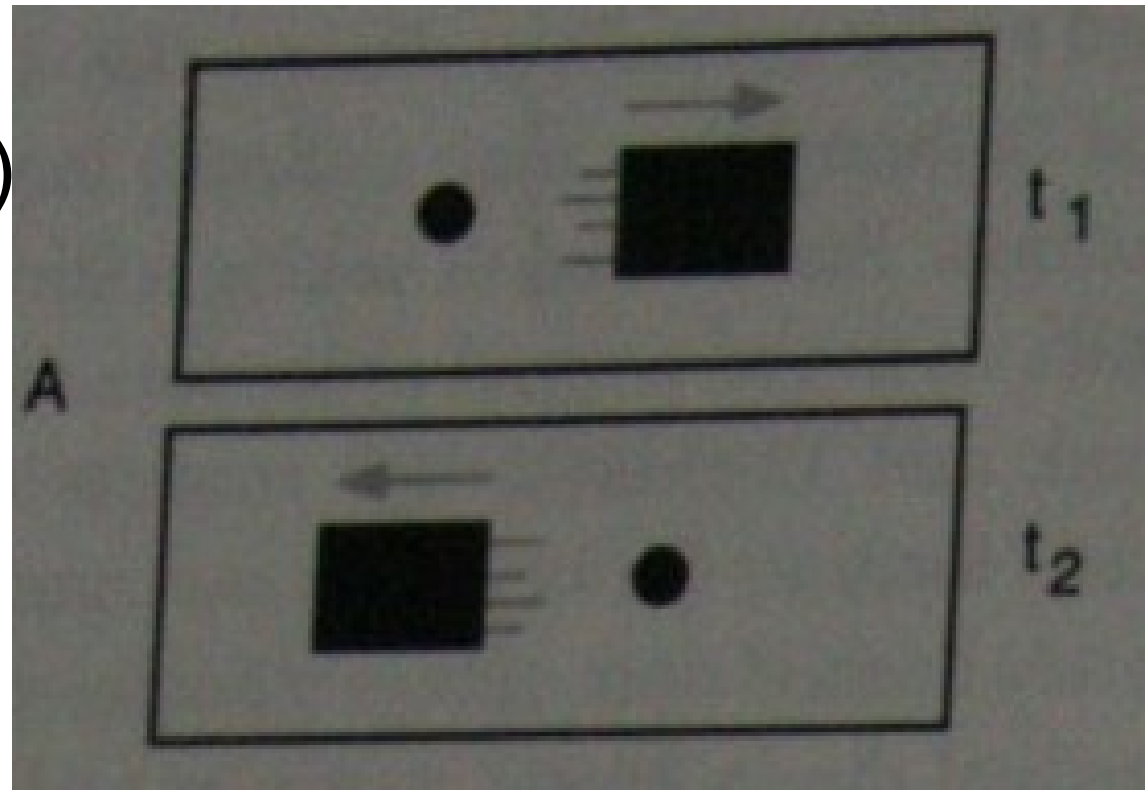
Path Guided Apparent Motion

- Graph path flashed btw alternating black dots
- Even full-circle motion can be induced
- What would expect for max Hz for alternation?



Disruption to Long Range App. Motion

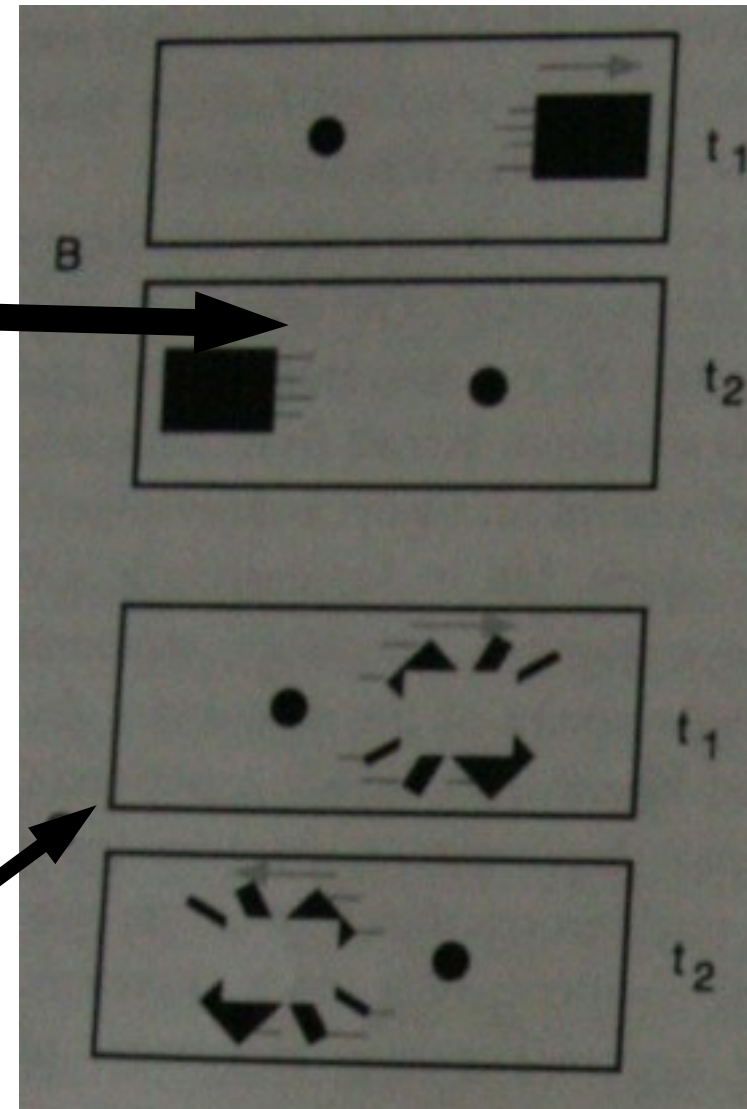
- Can certain conditions disrupt the long-range apparent motion?
- Sigman & Rock (1974)
 - Block explains dot disappearance
 - Effect disappears



Maybe it's just the block edge moving over dot?

Disruption to Long Range App. Motion

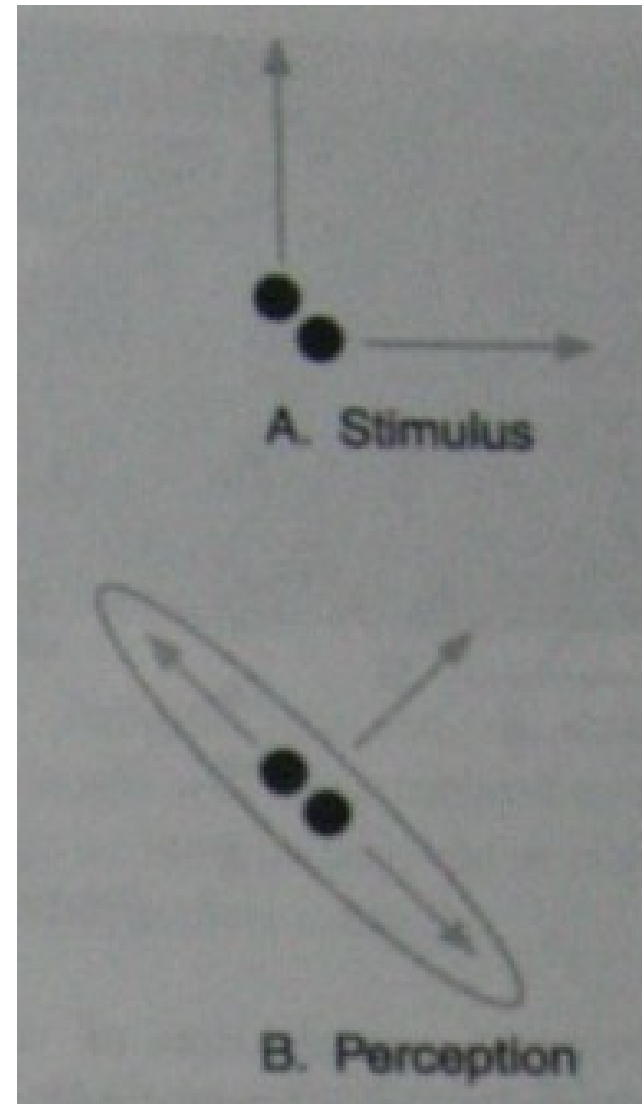
- Now, dot should re-appear as box keeps going, but it doesn't
- Apparent motion effect returns



More proof: illusory rectangle – apparent motion still suppressed⁴²

Grouping by Movement

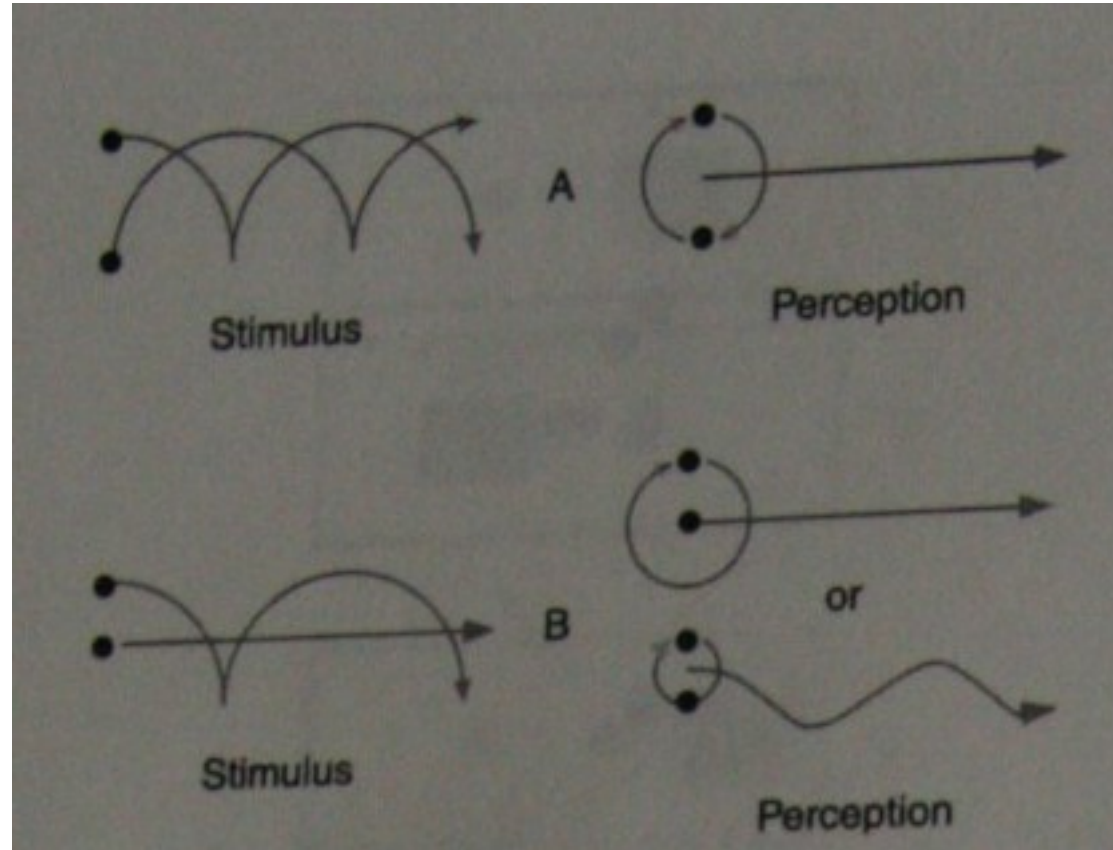
- When different motions are shown together, weird things happen
- Dots rotating around central axis grouped
- Not just linear motion



L-Configuration example

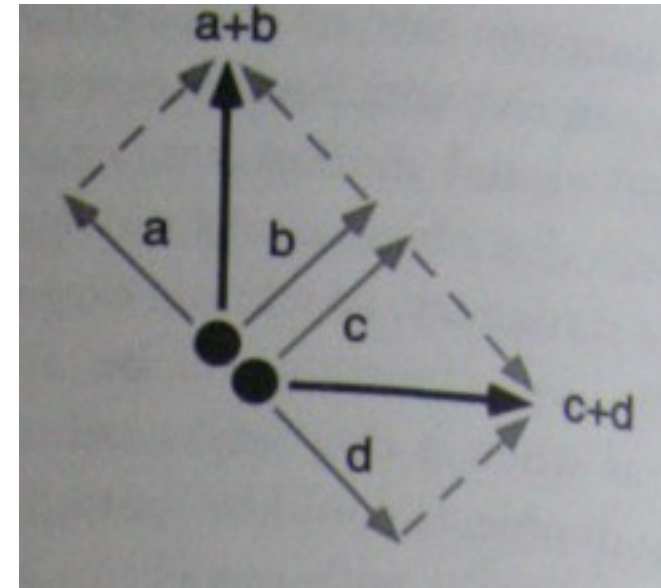
Grouping by Movement

- Why do we see it this way?



Johansson's Generalized Theory of Common Fate

- Motion is split into:
 - (1) *Common motion* – shared movement vectors
 - (2) *Relative motion* – motion vectors independent from group



Vector Decomposition

Visual System does a vector analysis? How is not yet known

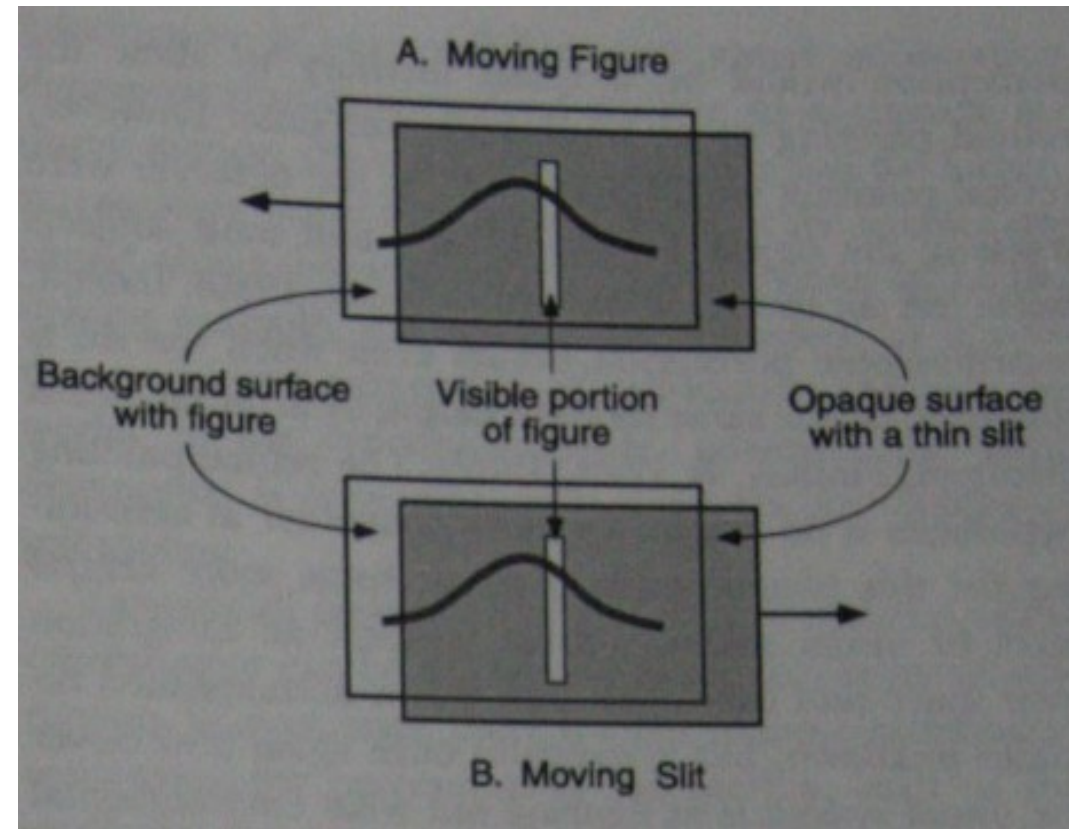
Induced Motion

- Small stationary object appears to move when large moving object passes by
- (1) visual system more sensitive to relative motion than absolute
- (2) smaller object assumed to move vs. larger object



Anorthoscopic Perception

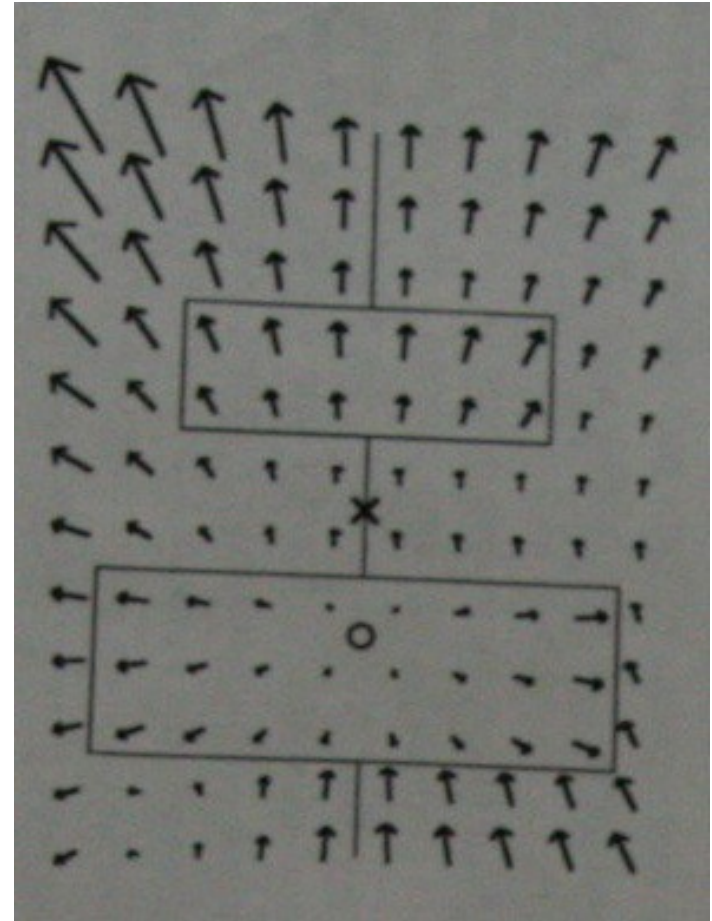
- Experiment 1: Slit is stationary, figure moves
- Experiment 2: slit moves, figure is stationary



- Either way, subject can determine figure
- Each part of figure goes on fovea? How do we make out the image?
- Mechanism remains unknown

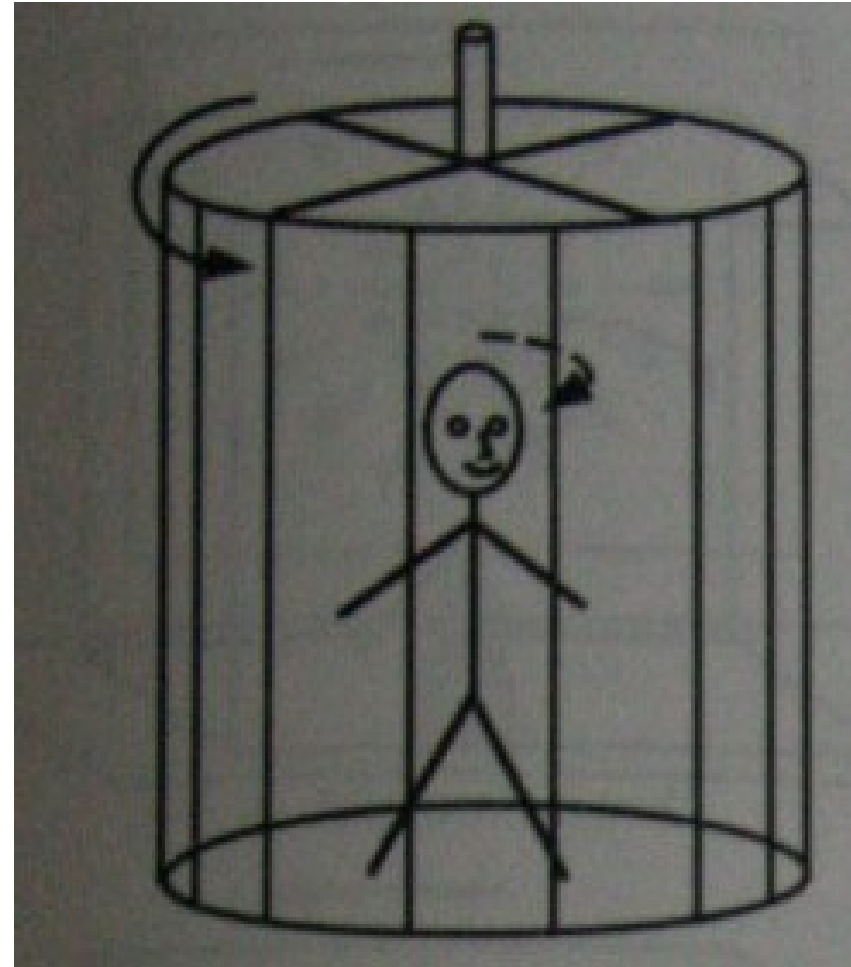
Optical Flow

- Basis for all navigation through world
- Used to judge all motion and changes to scenery



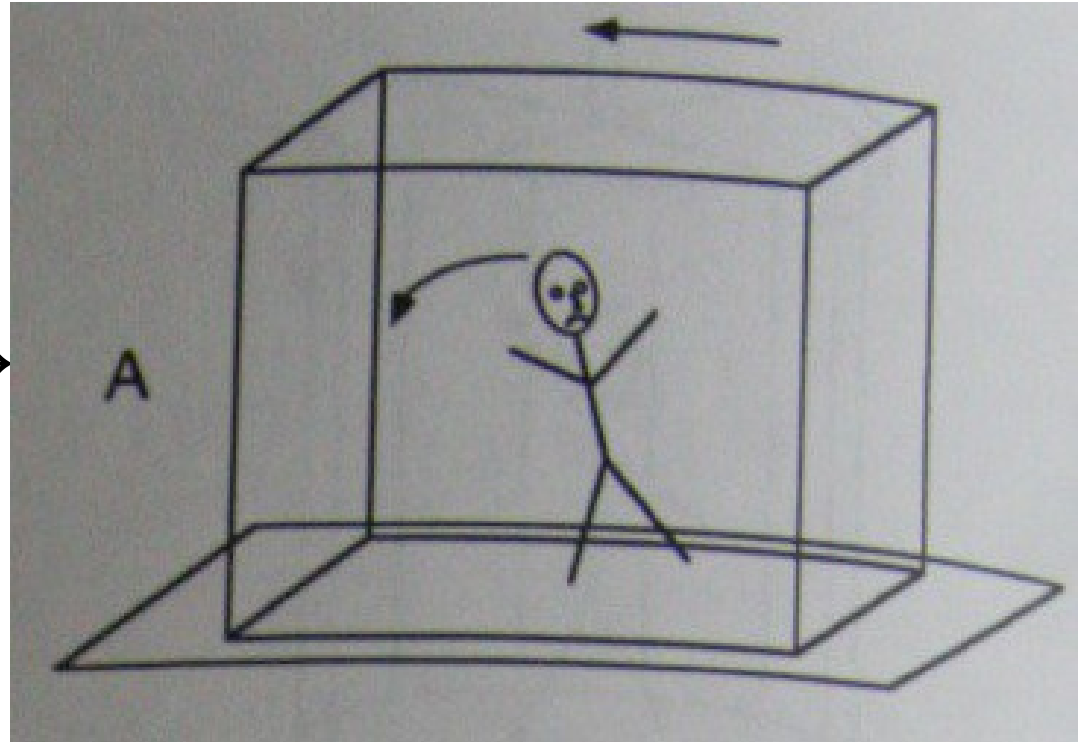
Induced Self Motion

- The feeling that you're moving even when you're not
- Watching the train next to you start moving
 - Creates illusion that you're moving
- Stationary person inside CCW rotating drum → feels like they're rotating opposite direction



Perception and Balance

- Balance on one foot, eyes open
 - Now try with one foot → much harder
- The swinging room
 - Moving walls create perception of falling forward/backwards



Biological Motion

- Recall our tendency to perceive points moving as if rigidly connected
- Actor in chair in dark with lights attached to joints
 - When sitting, looks like meaningless of lights
 - But recognized as human immediately upon motion
 - Even discriminated between walking, jogging, etc.
 - And could recognize two people in a folk dance
 - Could also tell gender