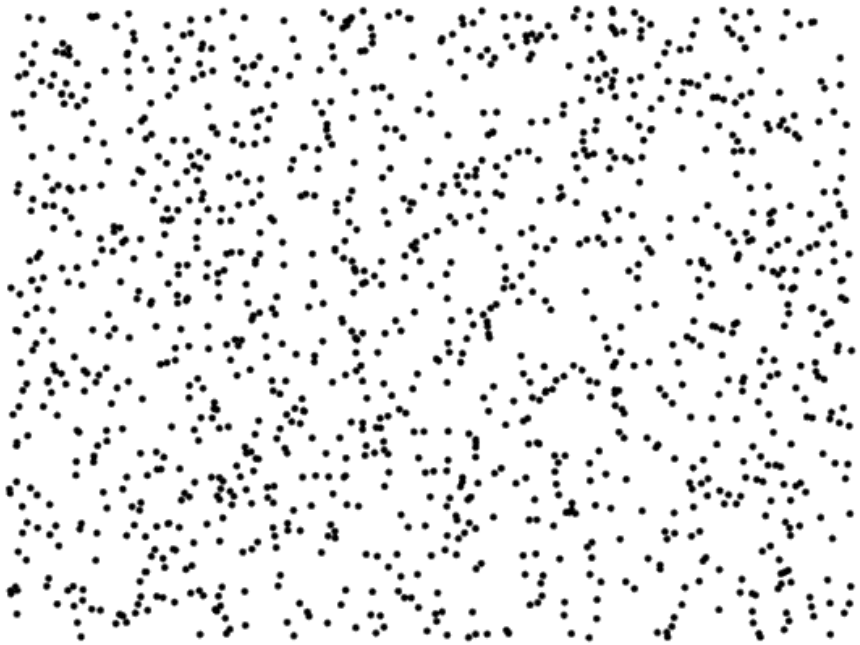
Optic Flow and Heading

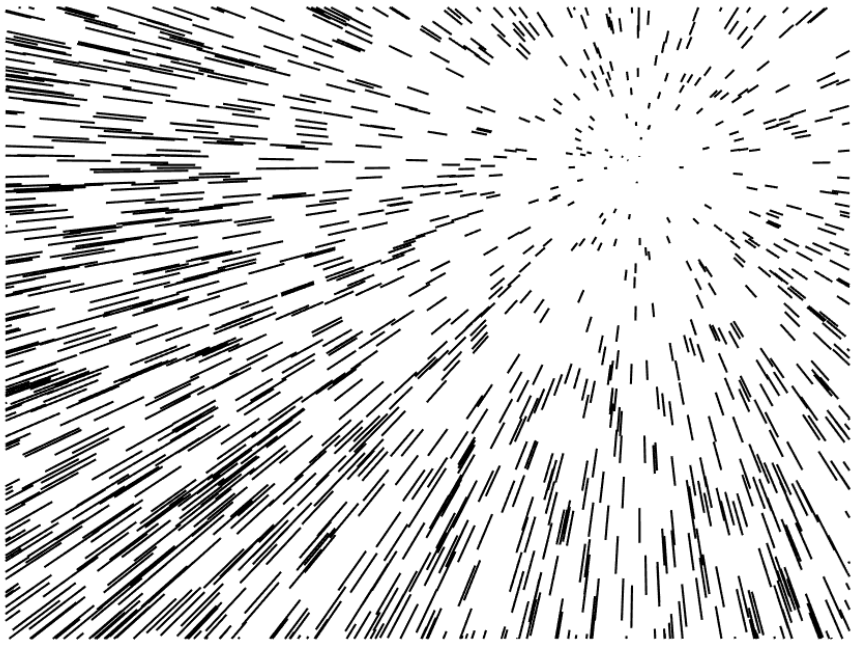
Michael Wang

What you should get out of this session

- How do behavioral scientists formulate hypotheses regarding a question?
- How do they test these hypotheses?

Last time – Optic flow and heading





Pop quiz

Focus of expansion (FOE)

Retreat

Global radial inflow

?

Focus of contraction (FOC)

Approach

Global radial outflow

Pop quiz

Focus of expansion (FOE)

Retreat

Global radial inflow

Focus of contraction (FOC)

Approach

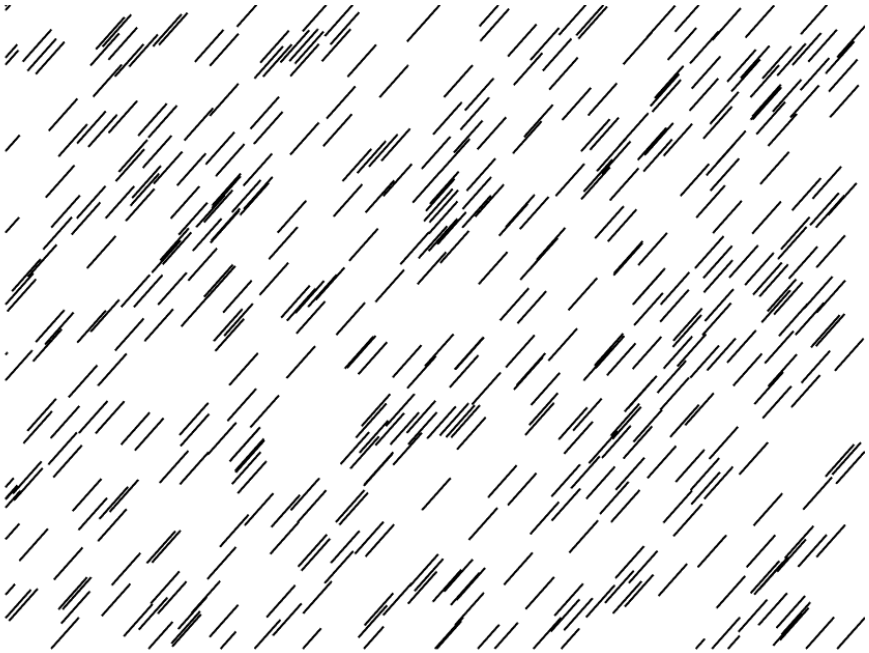
Global radial outflow

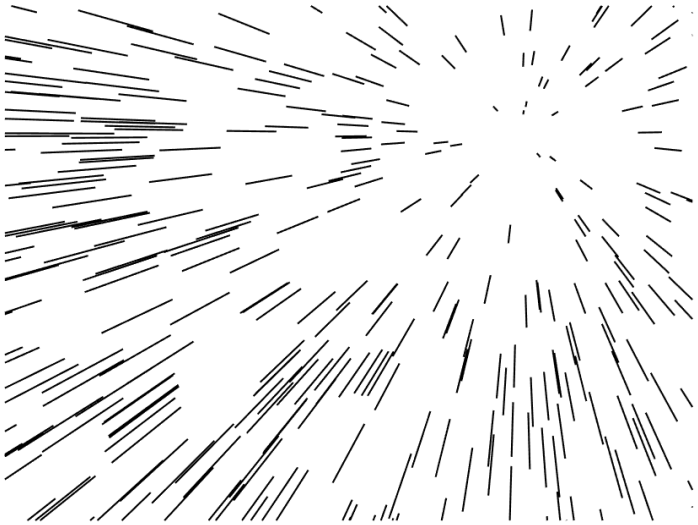
Heading direction

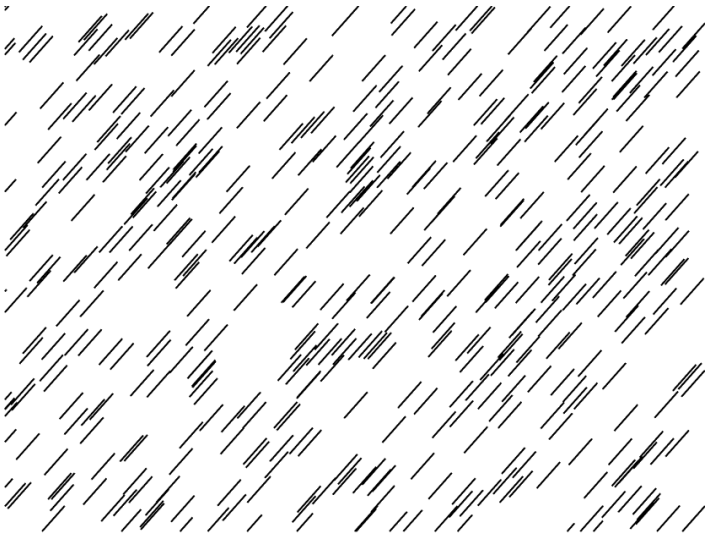
- Where we are going?
  - How to navigate through an environment.
  - How to steer a vehicle.

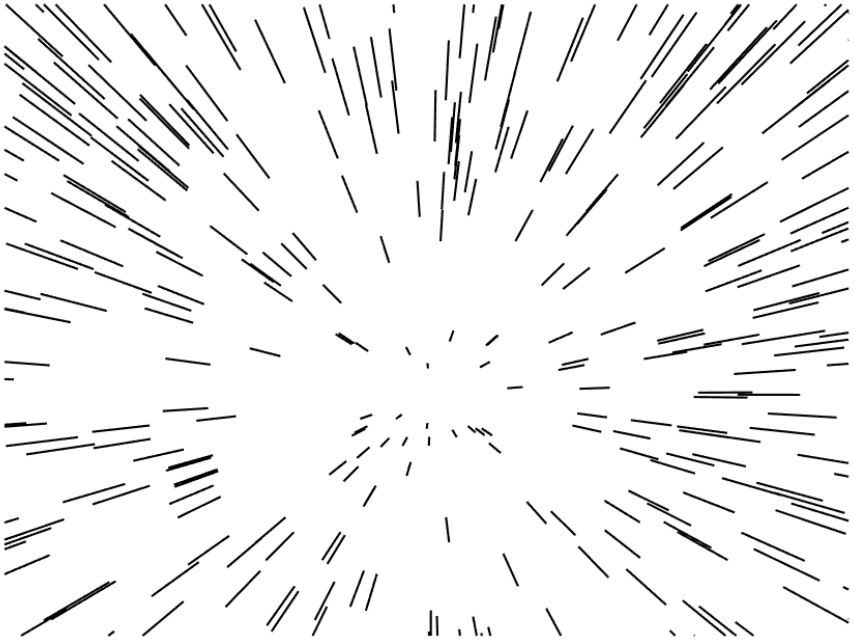
Problem

- Pursuit eye rotation
  - Introduces a uniform flow field, perturbs retinal flow patterns.









FOE is lost!!

How do humans handle this situation?

- Warren & Hannon (1990)
- General experimental method
  - Display 45 frames of optic flow at 15 Hz (3 seconds)
  - Dots did not expand with motion (controls for foreshortening information)
  - Speed is similar to fast walking (approx. 1.9 m/s from a height of 1.6m)
  - At the last frame, a vertical line appears on the horizon, participants need to judge whether the heading direction is to the left or right of the line.

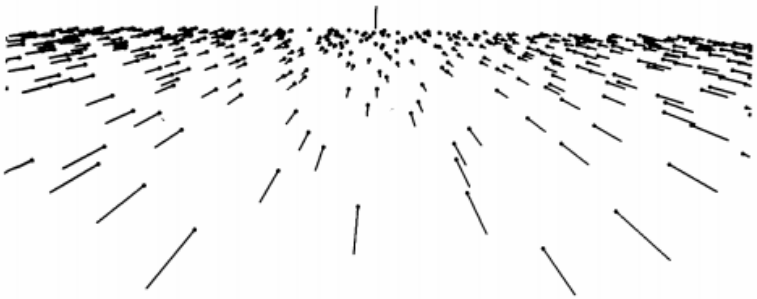


Fig. 1. Instantaneous velocity field produced by pure observer translation parallel to the ground plane. Vertical line indicates heading; vectors (line segments) indicate optical motions of environmental elements (corresponding dots).

Warren & Hannon (1990)

- Pursuit eye rotation
  - Asked participants to fixate on a point on the ground

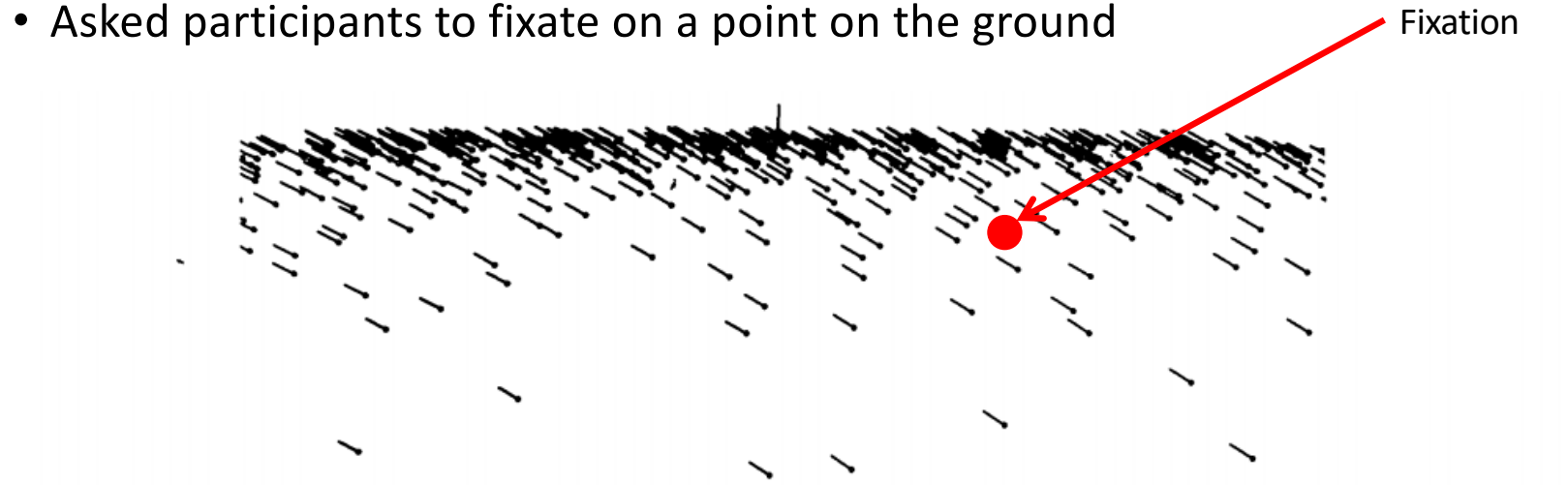


Fig. 2. Velocity field produced by pure eye rotation down and to the right. Note that this system yields approximately parallel flow in the central visual field.

Warren & Hannon (1990)

Warren & Hannon (1990)

- FOE is lost

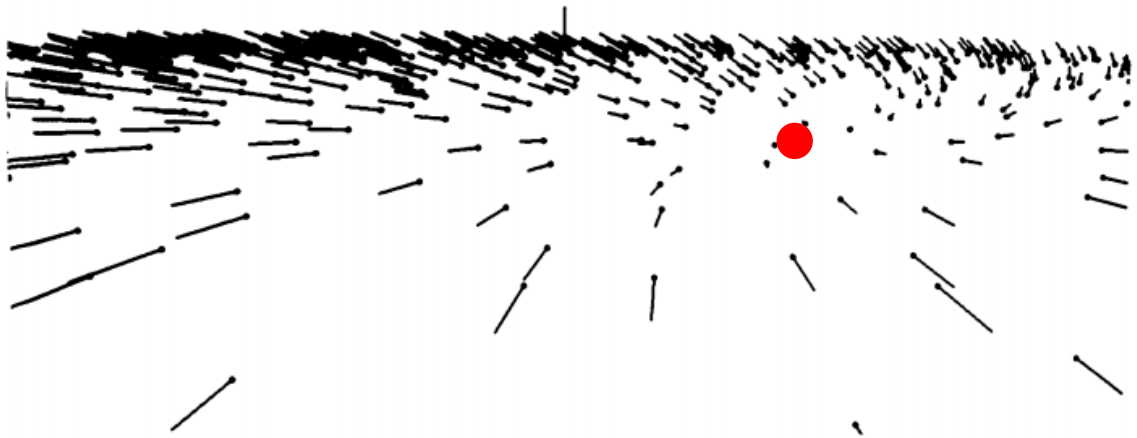


Fig. 3. Velocity field produced by combined translation and rotation, resulting from translating toward the vertical line while fixating the circle on the passing ground surface.

Warren & Hannon (1990)

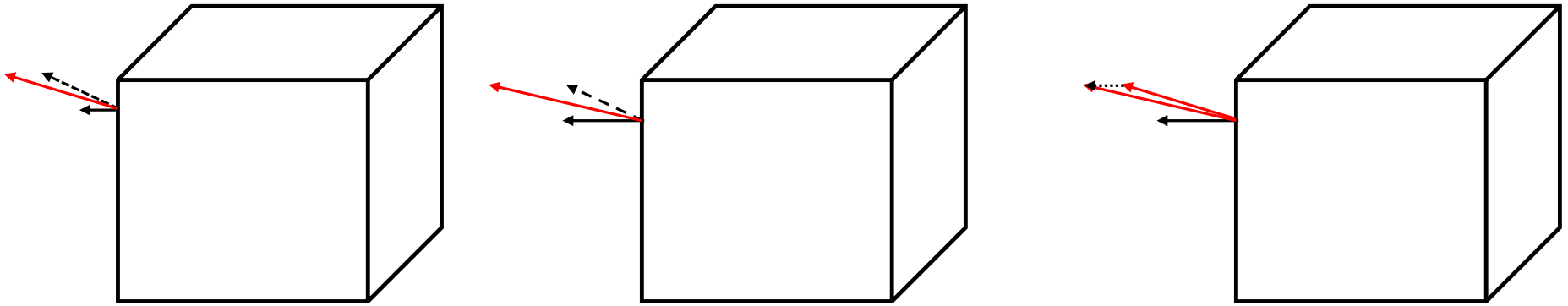
How would you solve this problem?

Possible solutions

- Solution 1: Oculomotor information
  - When we move our eyes, we obtain an efference copy of the motor signals from our eyes, which informs us about the amount of eye rotation that has occurred.
  - We can simply subtract this from the resulting flow field to obtain the original flow field.

Possible solutions

- Solution 2: Motion parallax (depth edges)
  - The closer the object, the larger the corresponding flow (magnitude)
  - Flow from eye rotation is uniform
  - Subtract the resulting vectors at a depth edge, the common rotation vector will drop out.
  - But this won't recover the magnitude of the original flow.



Warren & Hannon (1990)

- Experiment 1
  - Participants were able to judge heading directions equally well, with or without pursuit eye rotation.
  - How?

Warren & Hannon (1990)

- Experiment 2
  - Simulate pursuit eye rotation by adding a uniform flow field to the display (no actual eye rotation, i.e. no oculomotor information).
  - Participants were able to perform the task well

Warren & Hannon (1990)

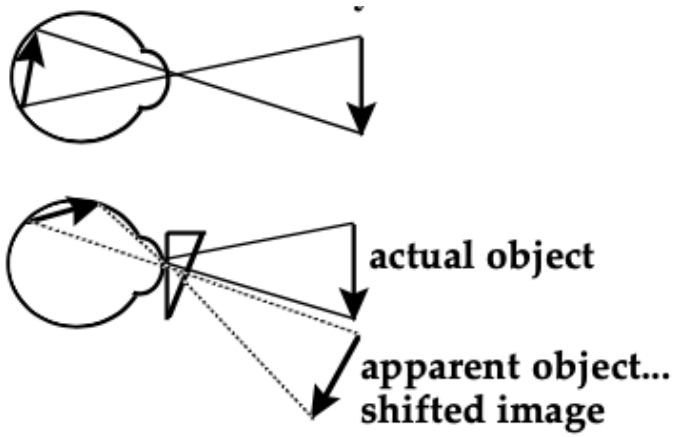
- Experiment 4
  - Simulate approach to a wall (no depth structure), but with actual eye rotation
  - Participants were able to perform the task well.
  - BUT, if approach to a wall plus simulated eye rotation (no oculomotor information), participants cannot perform the task.

Do we really use FOE to steer?

- Visual direction: the direction from which light enters the eye.
  - Walking towards a door – do you use the retinal image of the door (light that corresponds to the door) to guide where you are walking?
  - Or do you use FOE?
- Two hypotheses
  - Optic flow hypothesis: cancel the error between the heading perceived from optic flow (location of the FOE) and the goal.
  - Egocentric direction hypothesis: use the visual direction of the goal with respect to the body (e.g. midline of the body).
- How would you test this?
  - Dissociate (separate) visual direction from FOE, and test which allows for successful steering.
  - But how?

Separate FOE from Visual Direction

- Wedge prism
  - Changes the direction from which light enters the eye.
  - But does not change the relationship of light that corresponds to different objects.



Heading

ProView SR80
$35,000.00
SXGA 80° HMD
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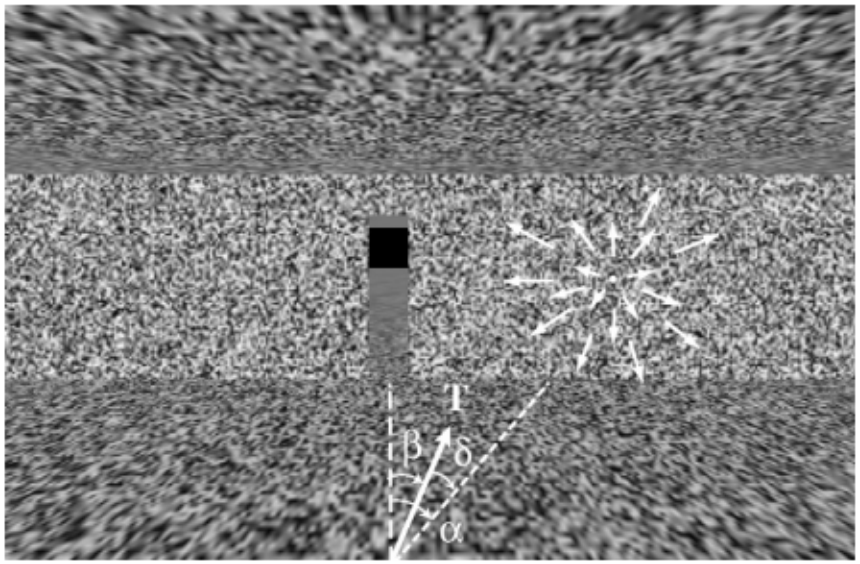
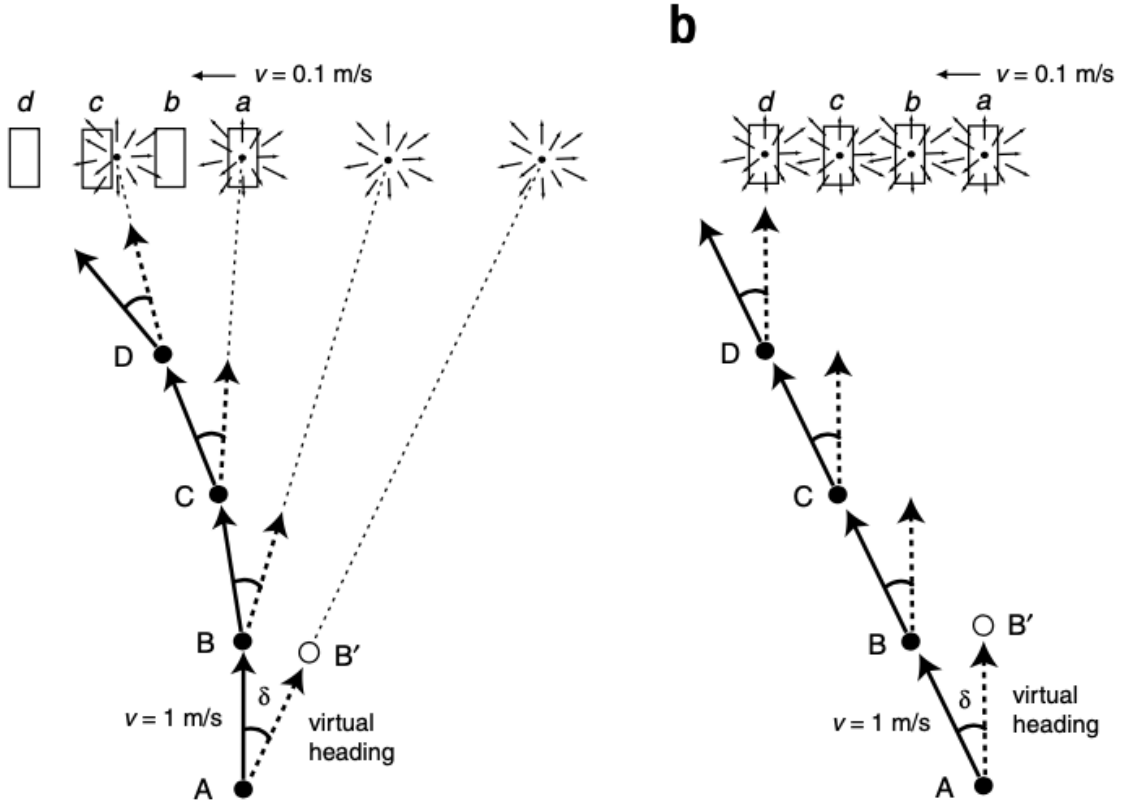
SKU: 0427

- Warren et al (2001)
- Dissociated visual direction and FOE by simulating the effect of a wedge prism using virtual reality.
- Displaced heading direction specified by optic flow by $\delta = 10°$ from the actual direction of walking.
  - If follow the image of the goal, heading error $\alpha = 10°$.
  - If place the FOE inside the image of the goal, heading error $\alpha = 0°$.

Heading



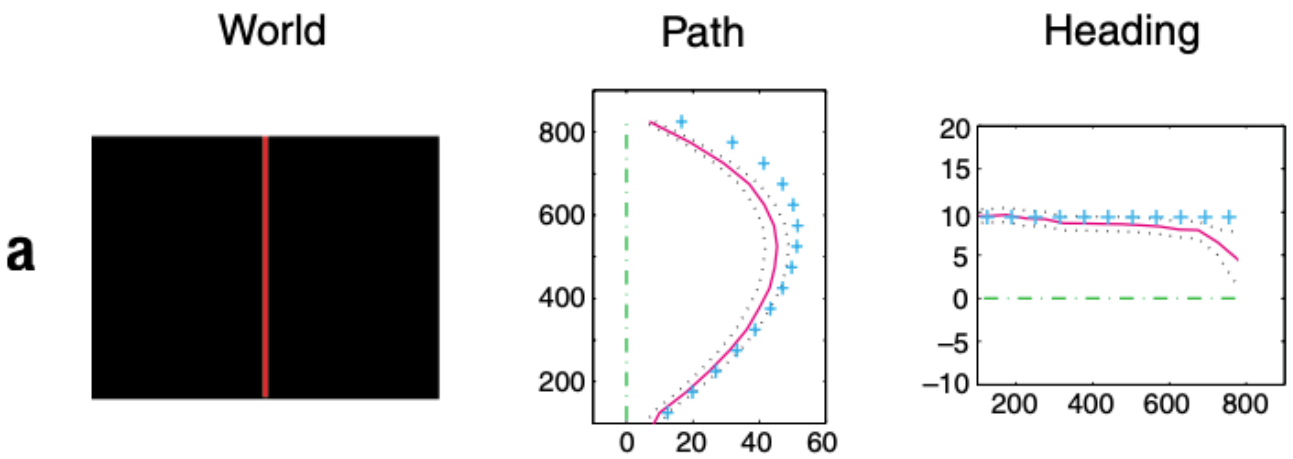


Warren et al., 2001

Heading

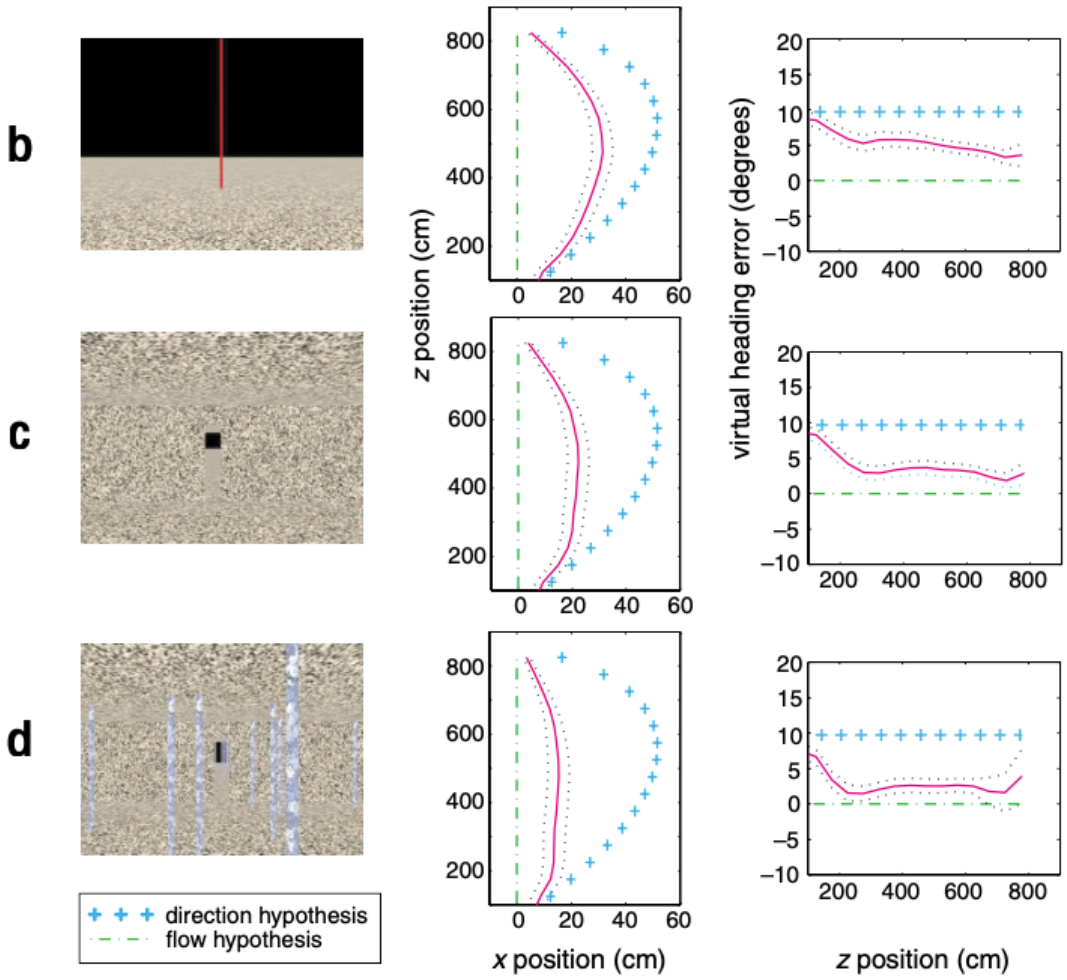
- People started by using visual direction
  - Walking towards the image of the door
- Then, they started to rely on FOE
  - Placing the FOE inside the image of the object to be approached

Heading



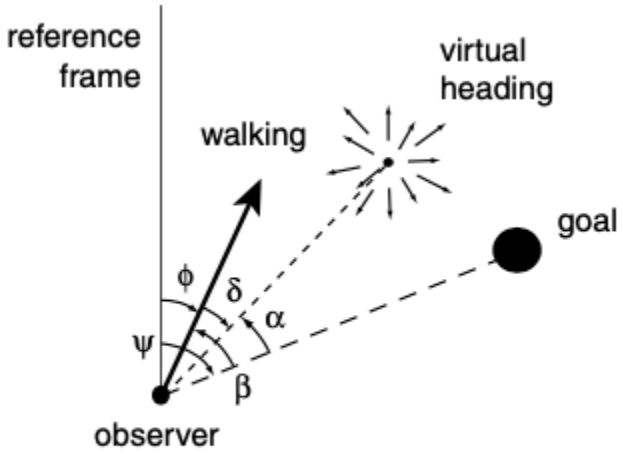
Warren et al., 2001

Heading



Warren et al., 2001

Heading



Visual control law

$$\frac{d\phi}{dt} = -k(\beta + wv\alpha)$$

ϕ: the walking direction in an extrinsic reference frame.

β: egocentric direction of the goal defined with respect to the axis of thrust.

α: visual angle between the FOE and the goal.

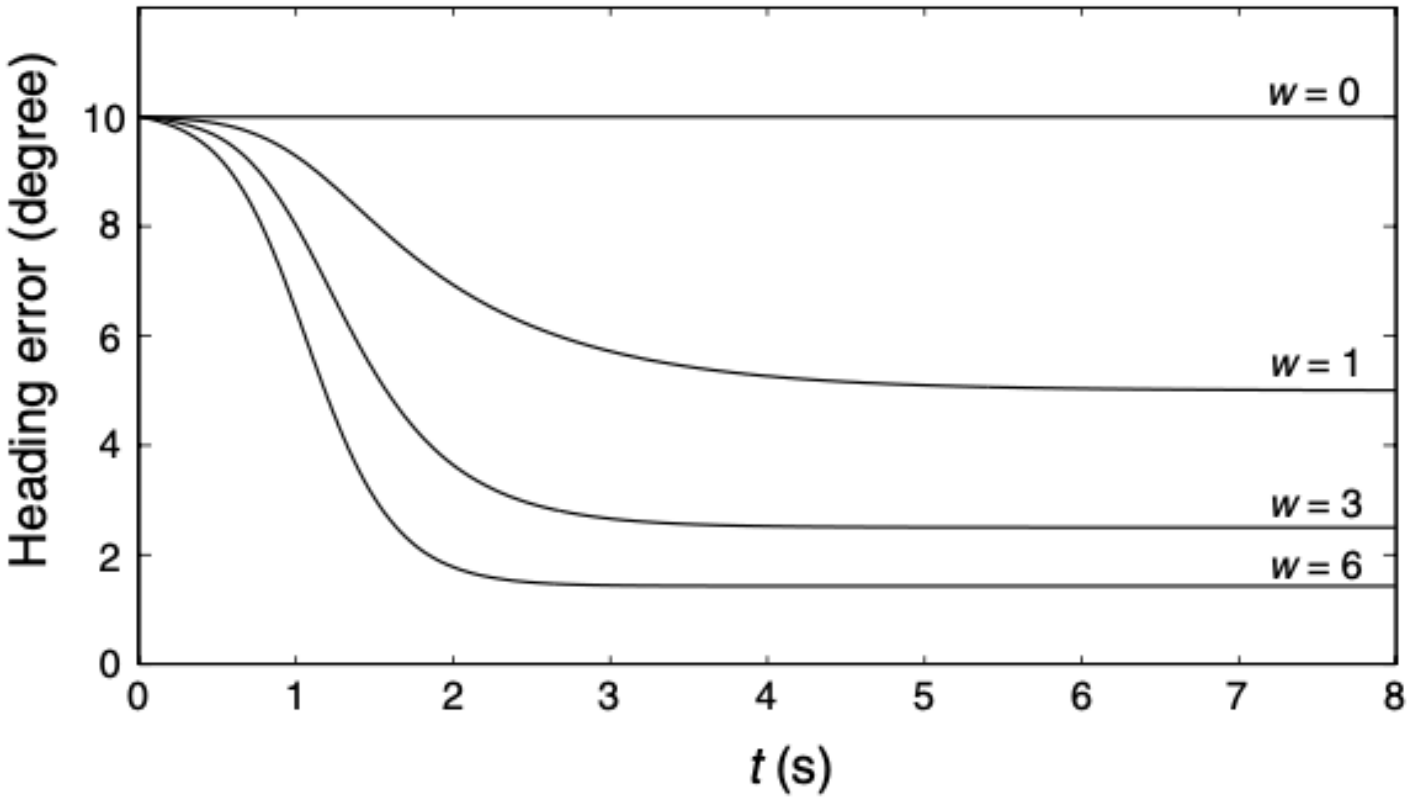
w: a measure of the magnitude and angular area of flow due to environmental structure.

v: observer velocity.

k: turning rate constant.

Warren et al., 2001

Heading



Warren et al., 2001

What you should get out of this session

- How do behavioral scientists formulate hypotheses regarding a question?
  - They can use geometry!
  - In fact, a lot of ideas that behavioral scientists have come from other fields.
- How do they test these hypotheses?
  - Empirical methods
  - Need to control for a lot of extraneous variables so that the results that they have can only be attributed to the experimental manipulations.
- Also think about redundancy!
  - Visual direction and FOE.

See you next time!