



ARVO 4308

Optic Flow vs. Egocentric Direction in the Visual Control of Walking

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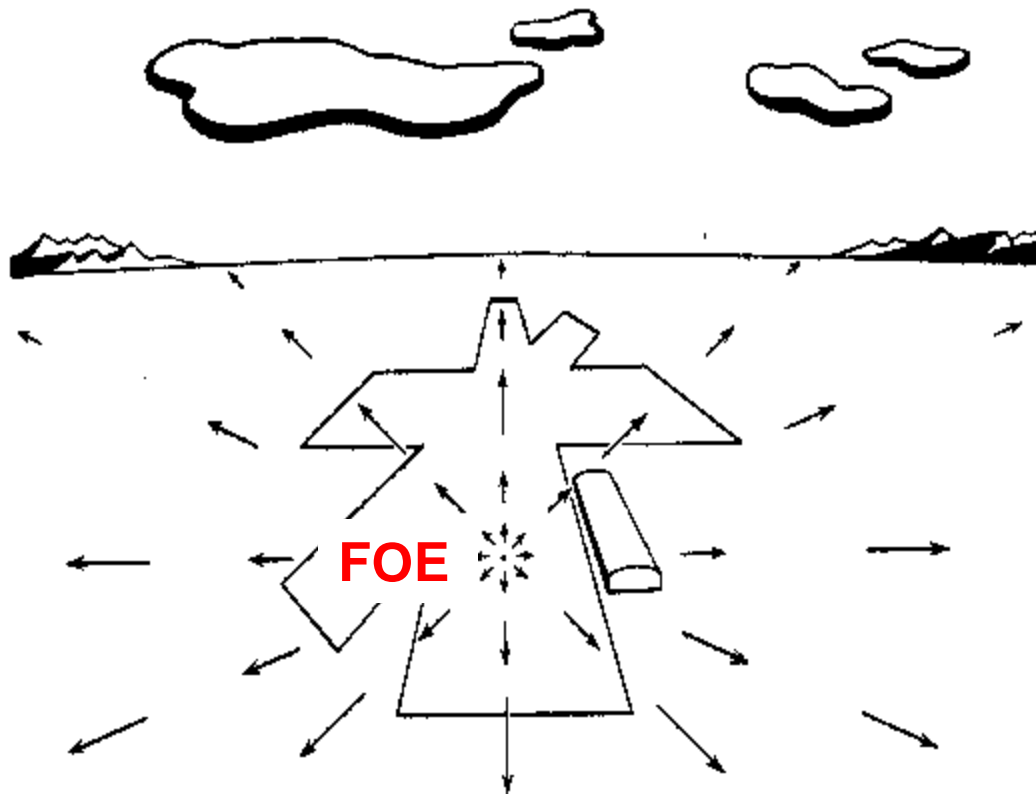
ARVO 2000

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Problem

Heading is perceived from optic flow with an accuracy of 1° . But do people actually use optic flow to guide locomotion?

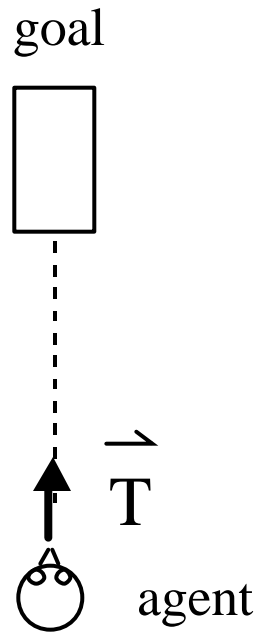


- Focus of expansion specifies heading

2

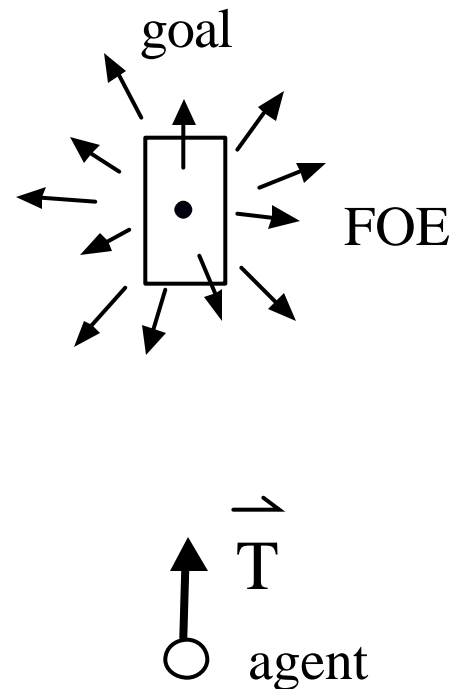
Strategies

Egocentric Direction



- Walk in the egocentric direction of the goal

Optic Flow

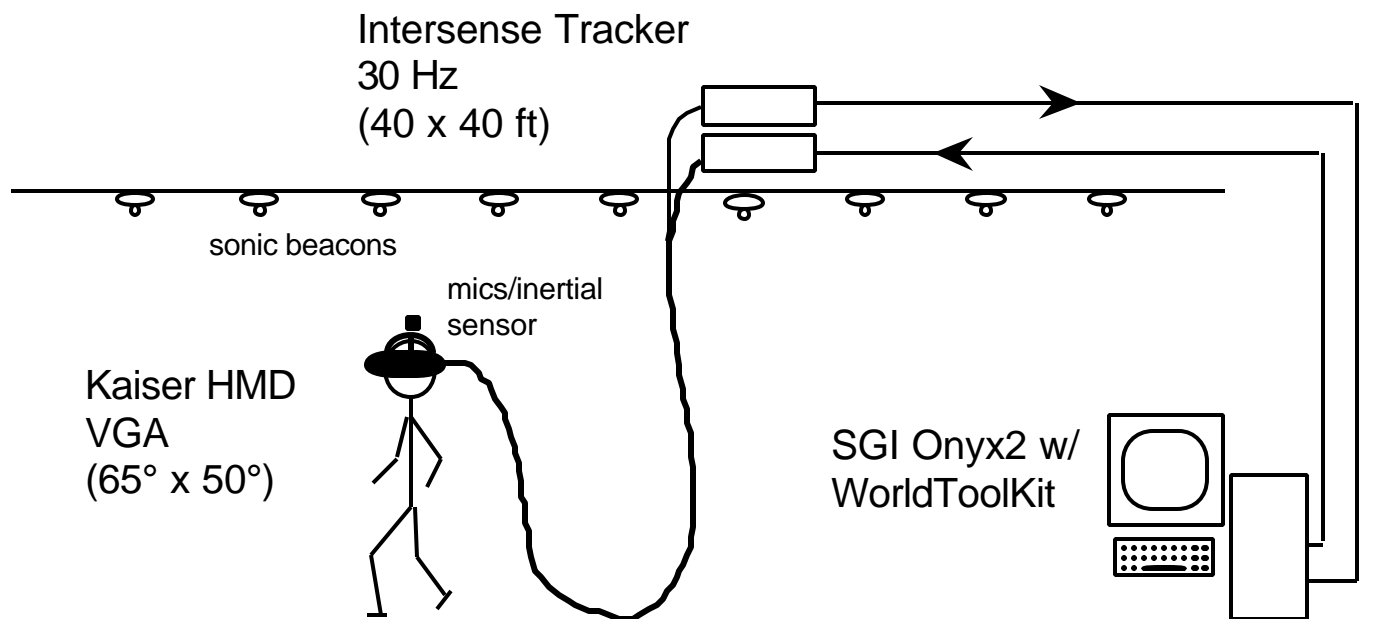


- Keep perceived heading near the goal

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Method

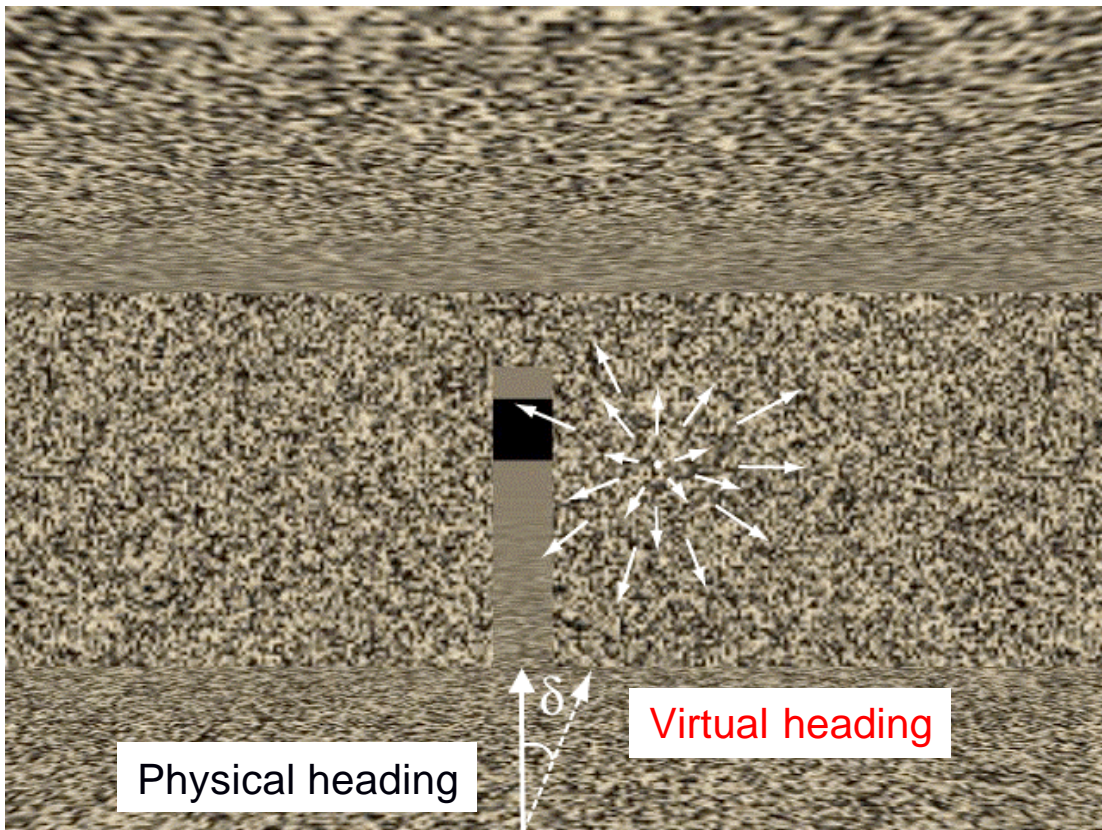
The VENLab



- Immersive virtual environment (40 x 40 ft)
- Display Latency = 1-2 frames @ 60 Hz
- Tracker Accuracy = 2-4 mm @ 30 Hz

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Dissociating Strategies

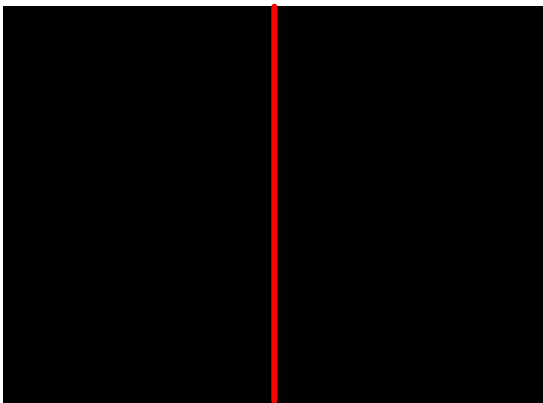


- Virtual heading: Offset FOE from the direction of walking by $\delta=10^\circ$
- Task: Walk to goal
- Record (x,z) path in virtual world

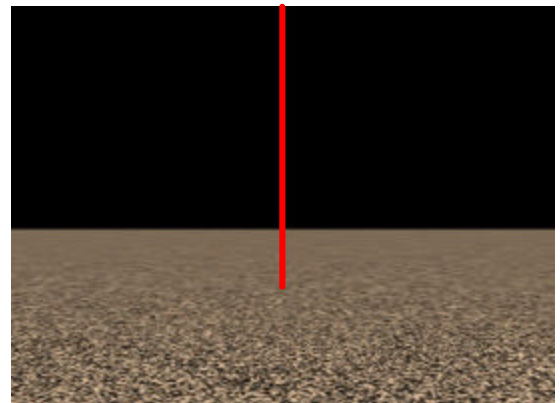
6 Exp 1: Amount of Flow

Hypotheses

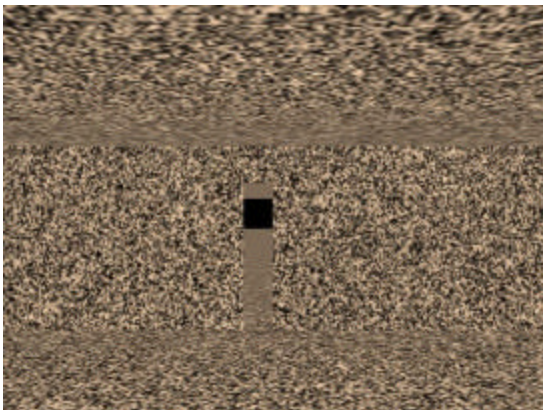
- With no flow, direction strategy should dominate
- As flow and parallax are added, optic flow strategy should take over



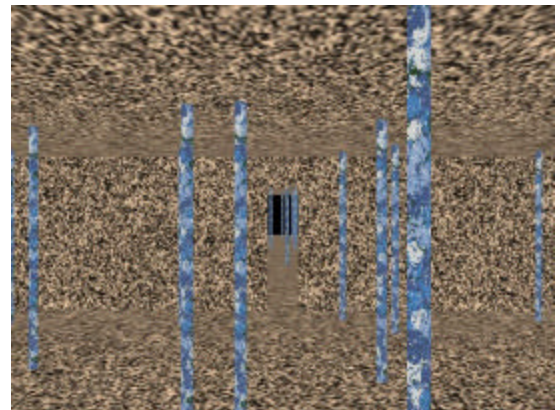
Target line: No flow



Line+Ground: Ground flow



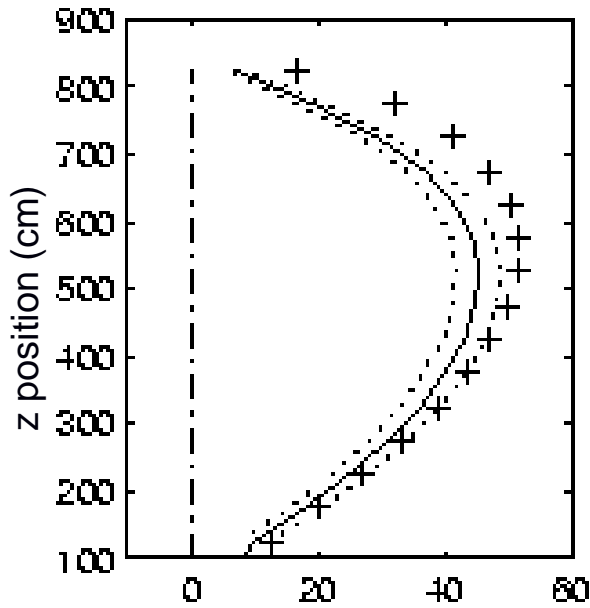
Doorway: Wall expansion



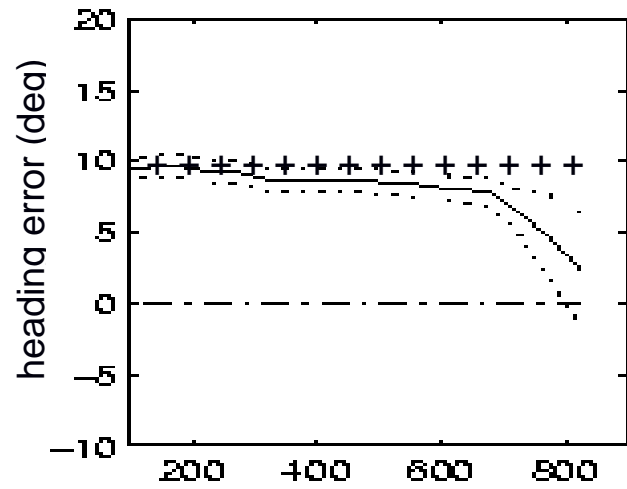
Door+Posts: Motion parallax

- Offset = 10° L or R (random)
- 16 trials per environment (blocked)
- N = 10

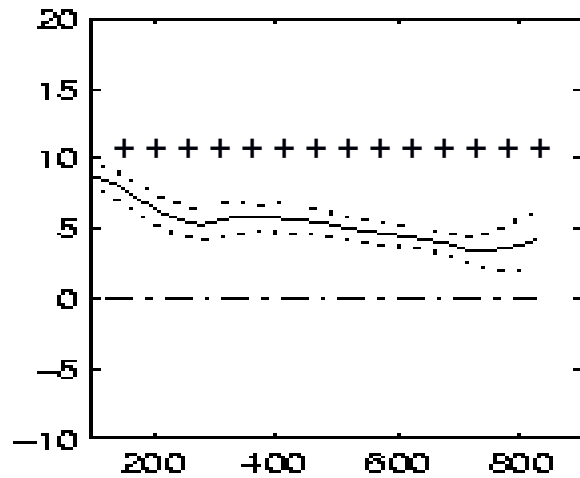
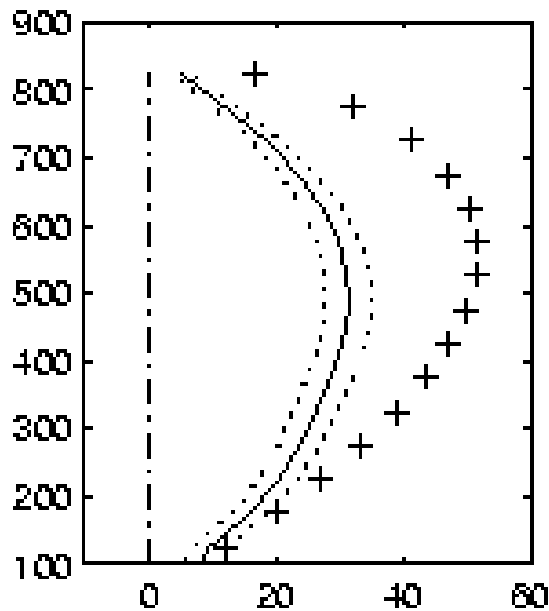
Mean Path

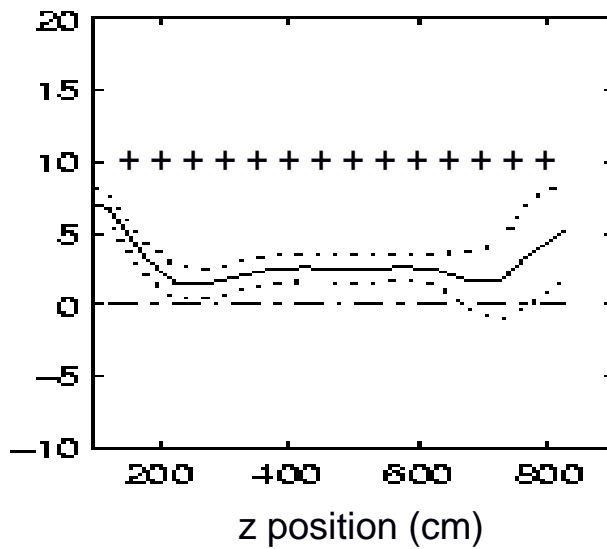
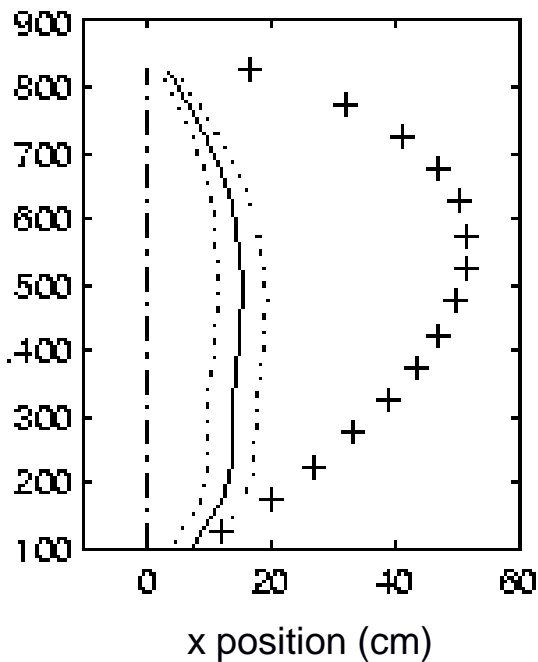
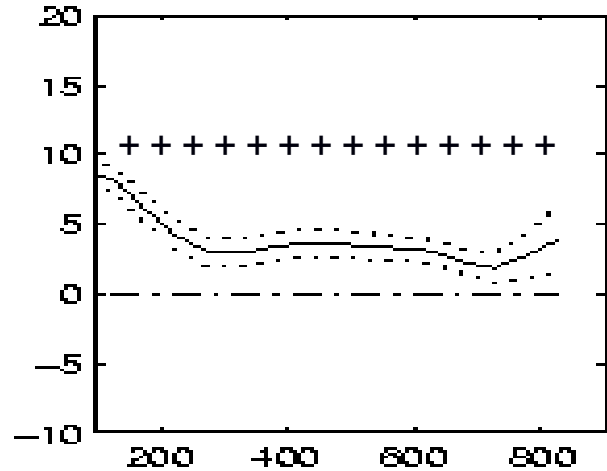
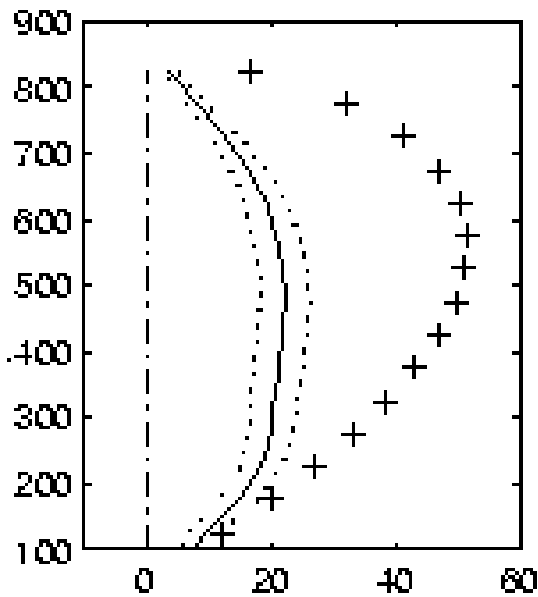


Mean Heading Error



+++ Direction strategy
--- Flow strategy
— Data





- Curved paths and large heading error with low flow. Direction strategy dominates.
 - Straighter paths and smaller heading error as flow and parallax are added ($p < .001$). Optic flow strategy dominates.
 - Not due to adaptation: offset random L/R, initially walk in direction of goal.
- ∴ Both strategies contribute.

7 Exp 2: Prisms in HMD

Question

When wedge prisms are worn to displace the FOE, paths are curved, consistent with the egocentric direction strategy (Rushton, et al, 1998; Rogers & Dalton, ARVO, 1999). Why?

Hypotheses

- Fine ground texture in open field reduces flow
- Prism distortion/blur reduce flow

Test

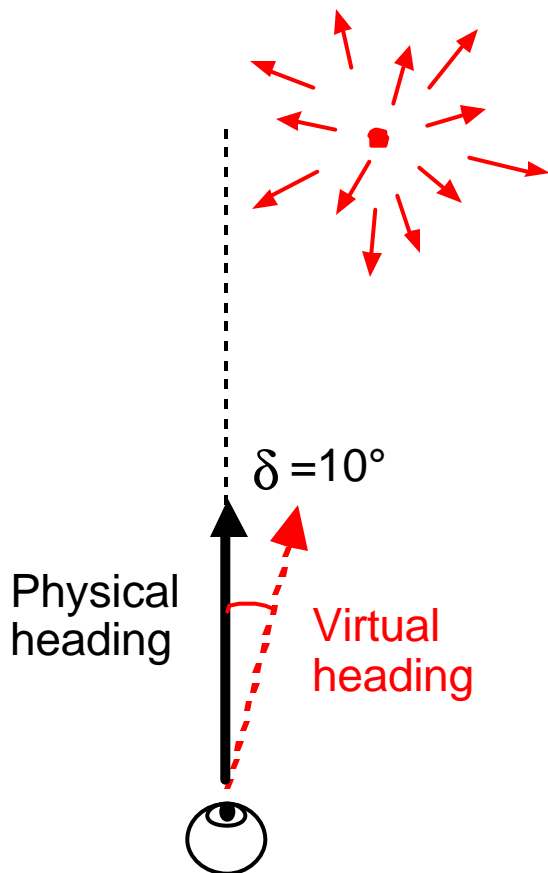
Wear binocular wedge prisms in HMD.¹

- If direction strategy is due to prisms, predict curved paths in all environments
- If direction strategy is due to low flow, predict straighter paths with additional flow

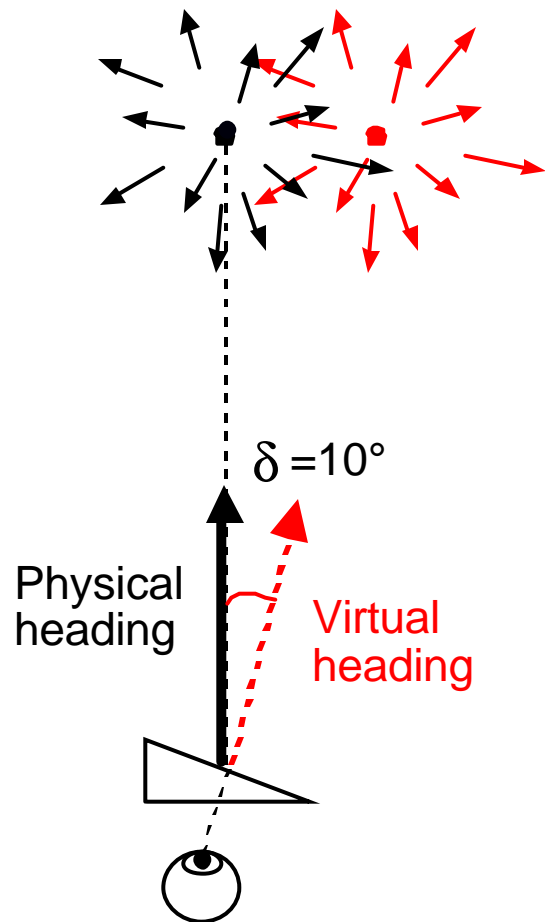
¹ Thanks to Tom Freeman for this suggestion!

Method

Offset Condition



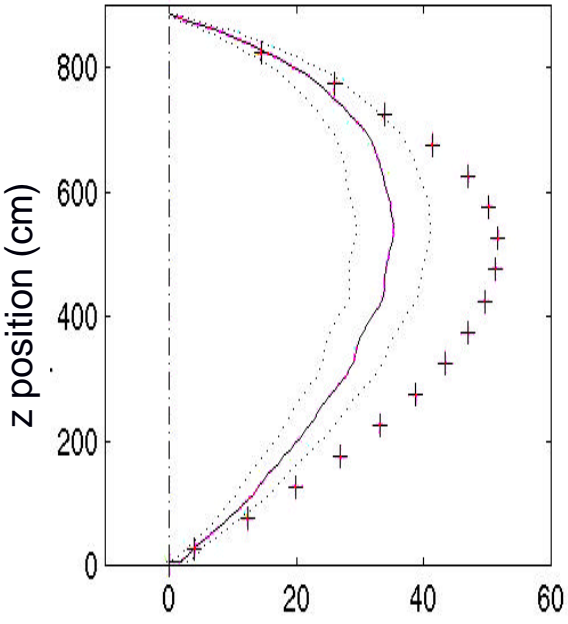
Prism Condition



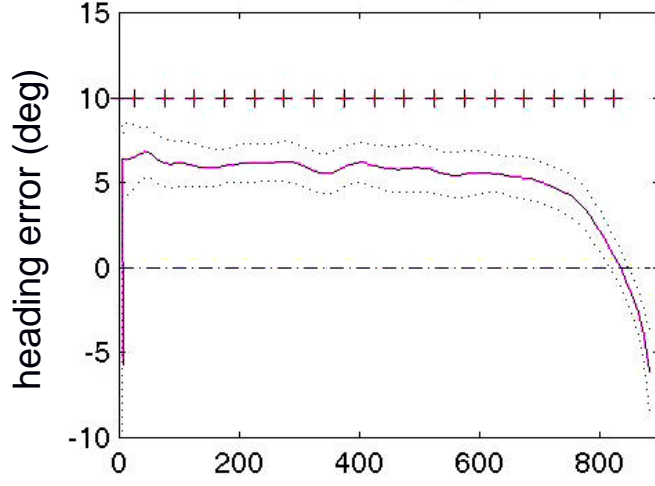
- Deflection angle = 10° R
- Offset/Prism x 4 Environments
- 10 trials per condition (blocked)
- 3 trials w/o offset (counter-adaptation)
- N = 12

Offset Condition

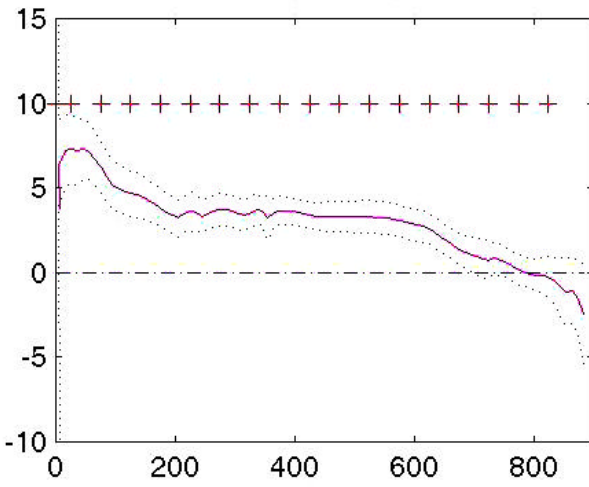
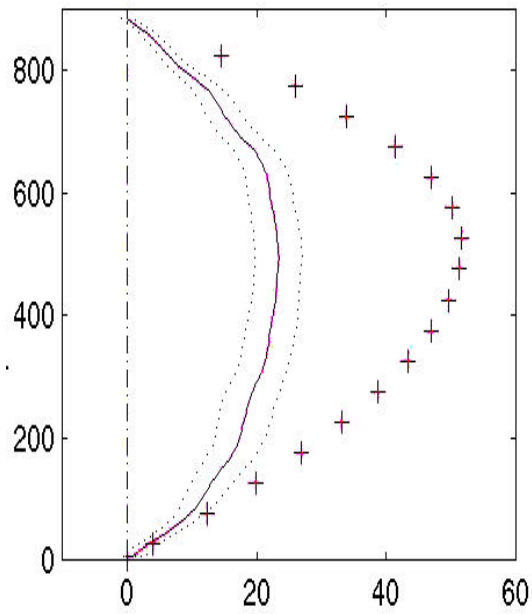
Mean Path

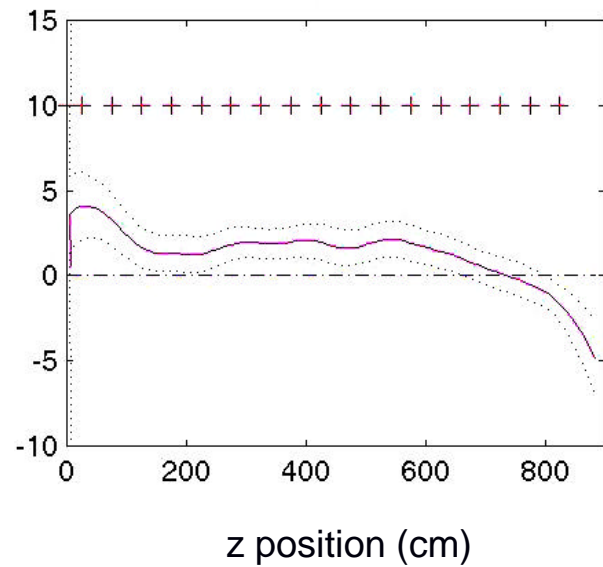
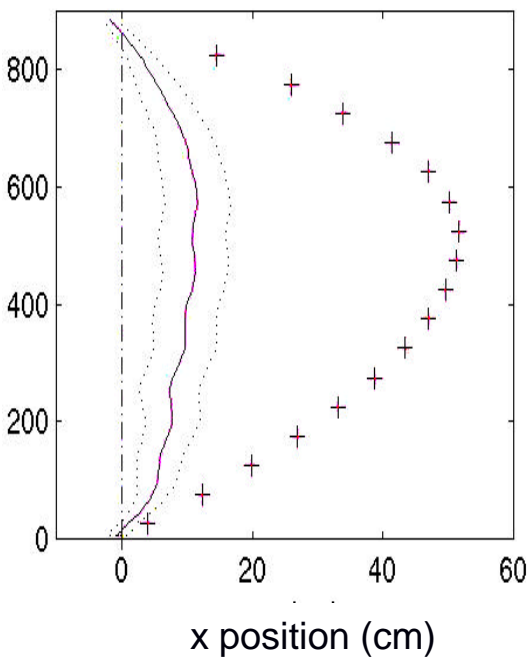
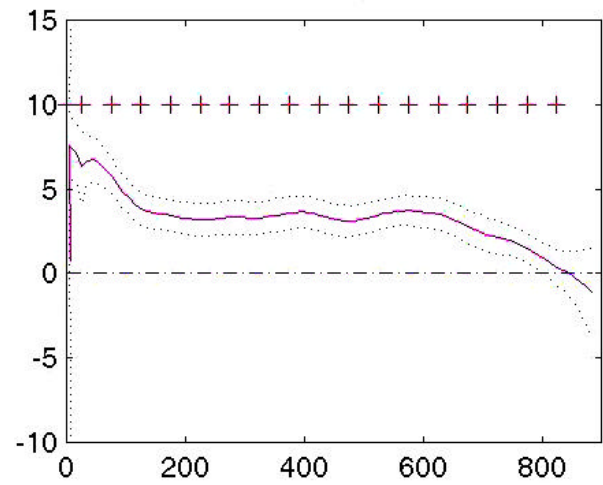
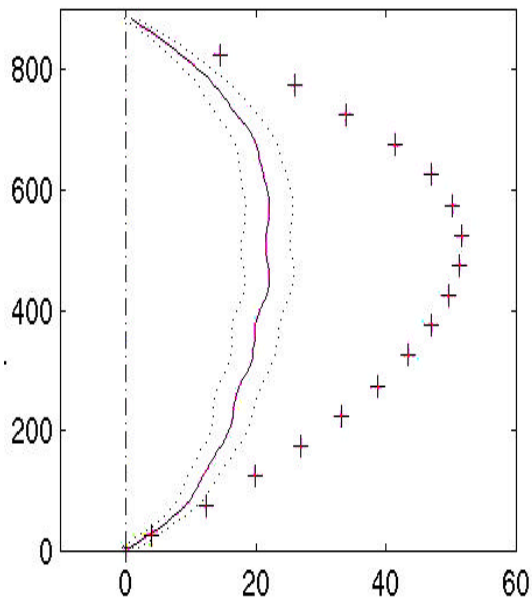


Mean Heading Error



+++ Direction strategy
--- Flow strategy
— Data

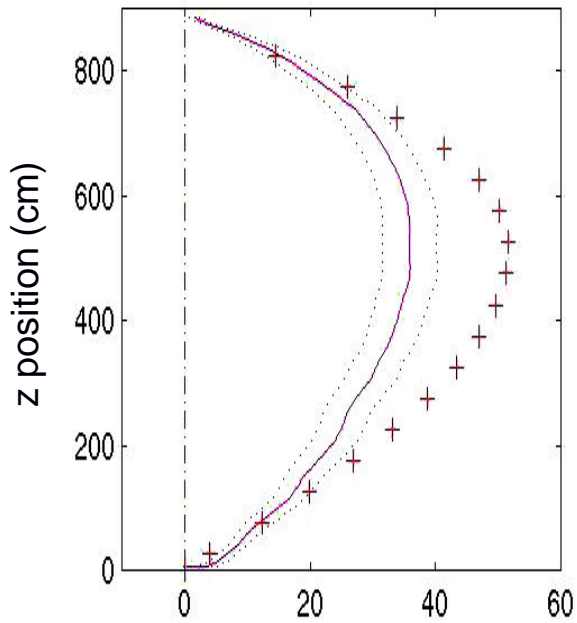




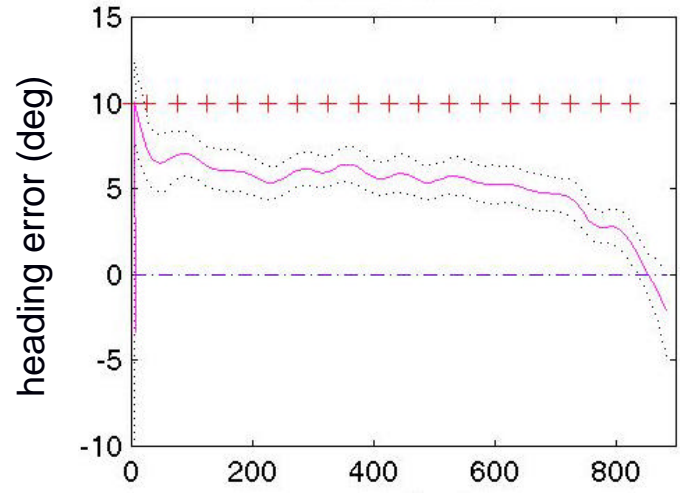
- Paths straighter and heading error smaller as flow and parallax are added ($p < .001$).

Prism Condition

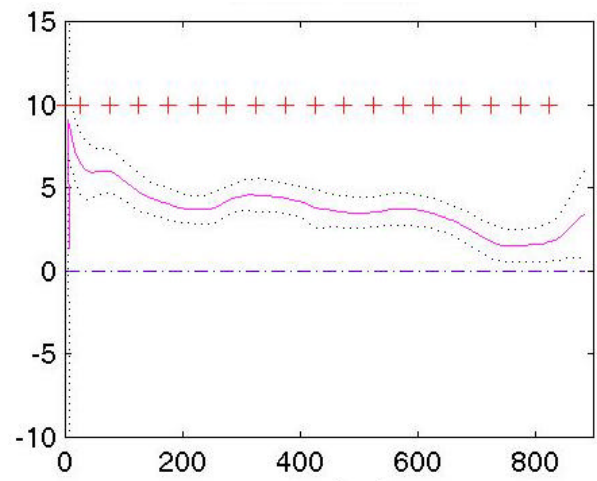
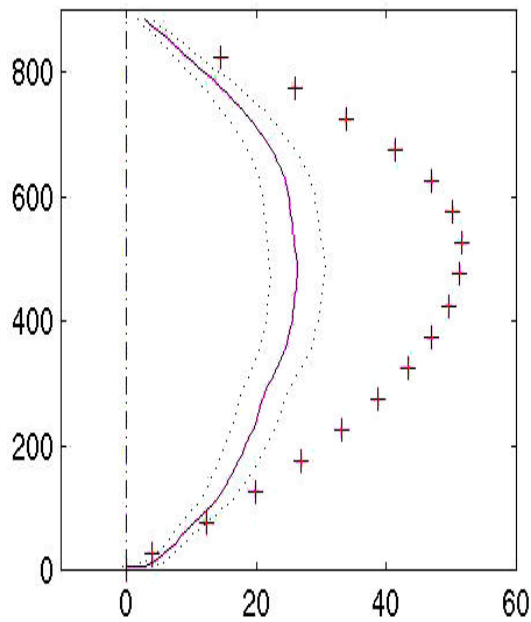
Mean Path

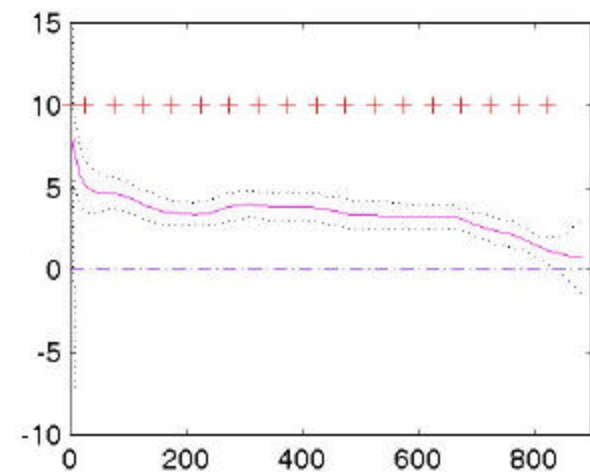
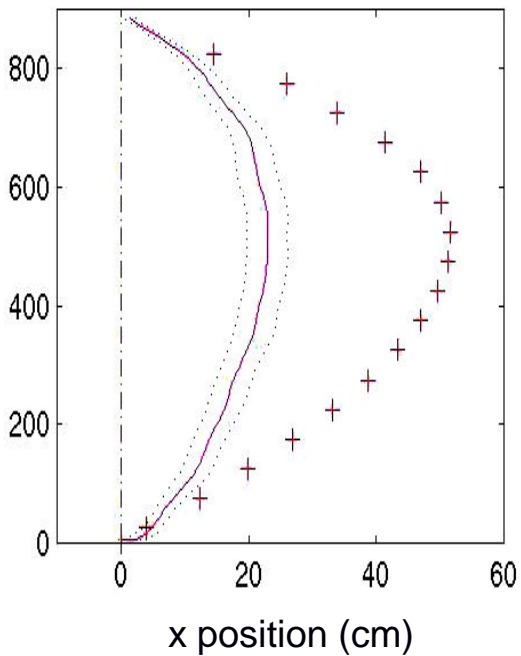
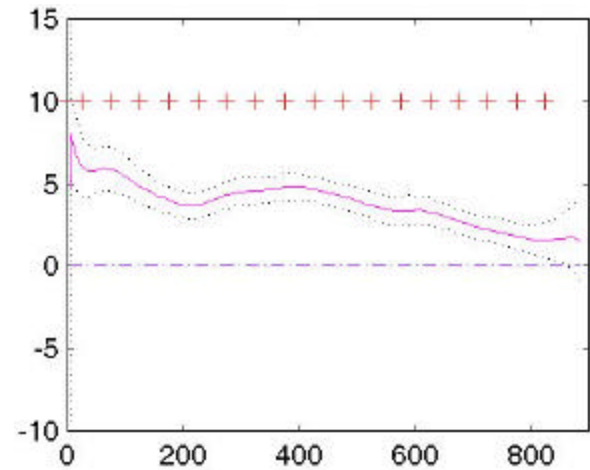
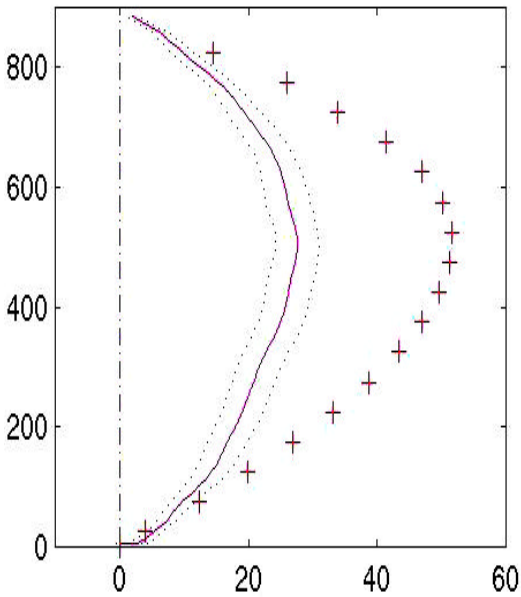


Mean Heading Error



+++ Direction strategy
--- Flow strategy
— Data





z position (cm)

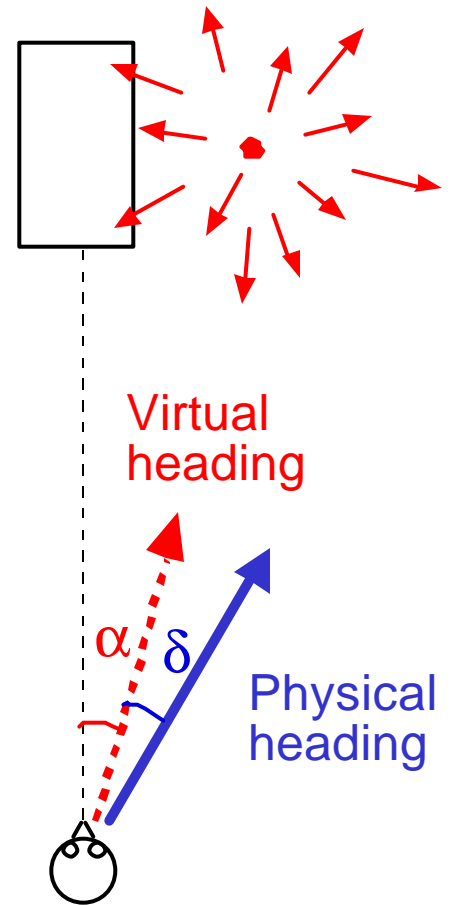
- Paths straighter and heading error smaller as flow and parallax are added ($p < .001$).
- Prism different from Offset condition in Door+Post environment only ($p < .05$).
- ∴ Direction strategy dominates in prism experiments because of both low flow and distortion/blur.

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Model

Control Law for steering to goal:

$$\dot{\alpha} = -(\alpha + \delta) - w(\alpha)$$

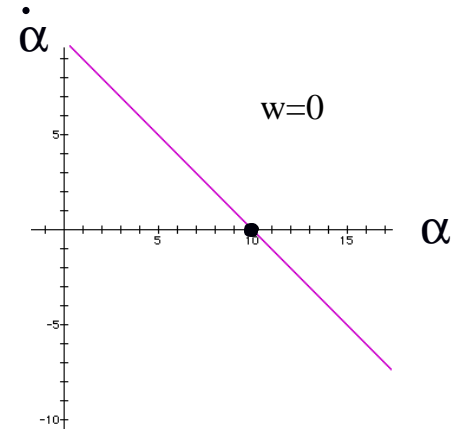
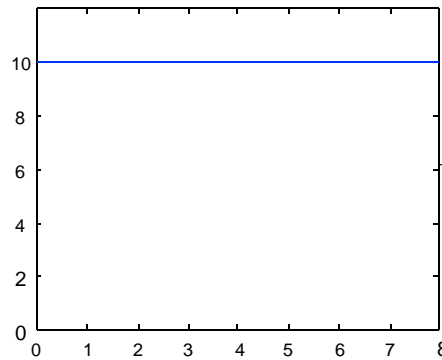


Turning rate is a linear sum of egocentric direction ($\alpha + \delta$) and virtual heading error (α), weighted by the amount of optic flow (w).

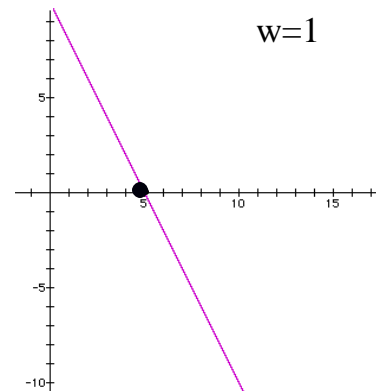
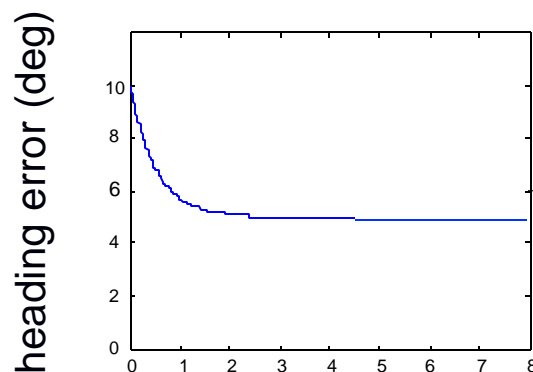
Solution

Phase portrait

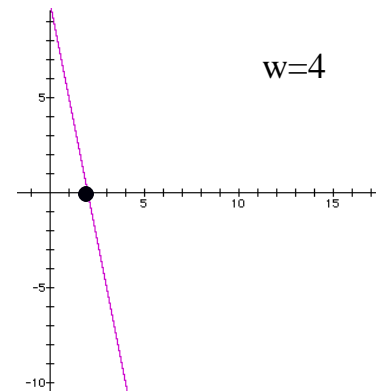
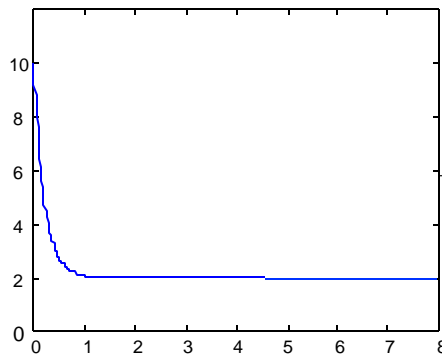
No flow
direction
dominates



Moderate flow
intermediate
solution



High flow
flow
dominates



t (s)

- Initial conditions:
 - ↗ Offset 10° R ($\delta = 10^\circ$)
 - ↗ Walk in direction of goal ($\alpha + \delta = 0^\circ$)
- Heading error decreases with amount of flow
- Relaxation time decreases with amount of flow

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Conclusions

- Both strategies contribute to locomotor control
 - Egocentric direction dominates with low flow
 - Optic flow dominates with increased flow
 - Complementary
- Open field prism experiments are misleading
 - Fine ground texture and prism distortion/blur conspire to reduce flow
 - So egocentric direction strategy appears to govern behavior
- Optic flow is used to control active locomotion

