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

William Warren, Wendy Zosh, Stephanie Sahuc, Andrew Duchon, & Bruce Kay

Brown University

ARVO 2000

Bill_Warren@brown.edu
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
• Immersive virtual environment (40 x 40 ft)
• Display Latency = 1-2 frames @ 60 Hz
• Tracker Accuracy = 2-4 mm @ 30 Hz
• Virtual heading: Offset FOE from the direction of walking by $\delta=10^\circ$
• Task: Walk to goal
• Record (x,z) path in virtual world
Predictions

Egocentric Direction

- Curved path
- Virtual heading error $\rightarrow 10^\circ$

Optic Flow

- Straight path
- Virtual heading error $\rightarrow 0^\circ$
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

z position (cm)

heading error (deg)

+++ 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.
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

• 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

<table>
<thead>
<tr>
<th>z position (cm)</th>
<th>heading error (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>60</td>
<td>0</td>
</tr>
</tbody>
</table>

+++ 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

z position (cm)

heading error (deg)

+++ Direction strategy

Flow strategy

Data
• 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.
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 (\(\alpha\)), weighted by the amount of optic flow (\(w\)).
• **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

**Solution Phase portrait**

No flow direction dominates

Moderate flow intermediate solution

High flow flow dominates
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