The Role of Optic Flow in Adaptation to Visual Displacements during Walking

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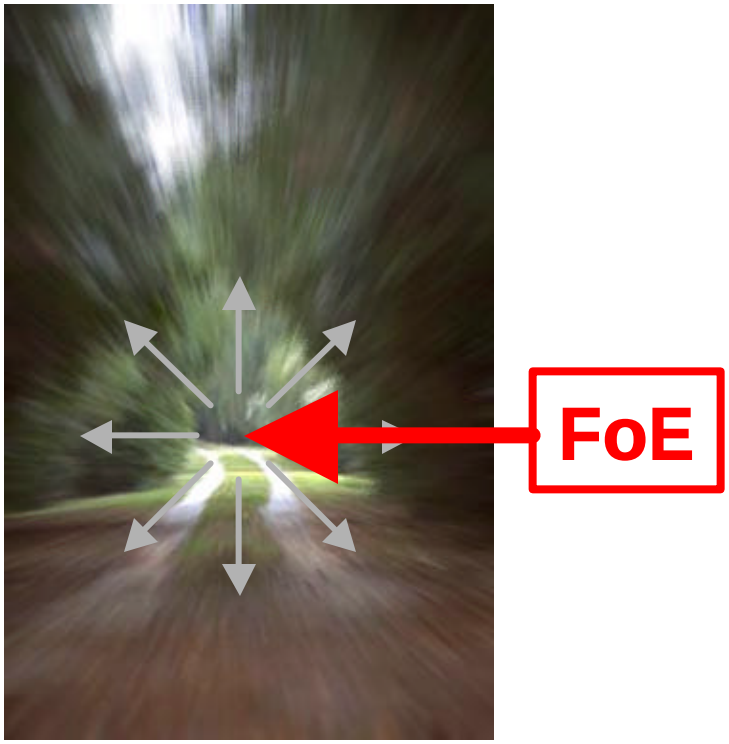
The Big Picture

Do we use optic flow when walking to a target?



What is optic flow?

? global pattern of motion vectors for elements in the visual scene induced by moving a point of observation

? Focus of Expansion (FoE) is the central point from which optic flow radiates

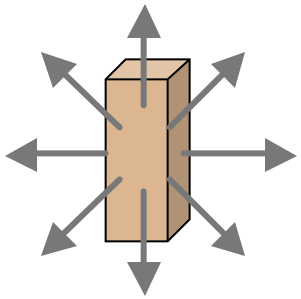
? FoE specifies current **heading**

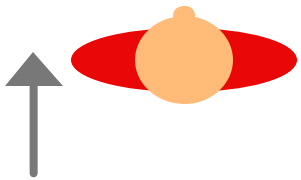
? detection of heading from optic flow is accurate to within 1° for translation (Warren, et al., 1988)

Introduction

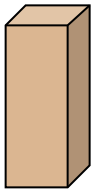
Two visual strategies for walking to a target:

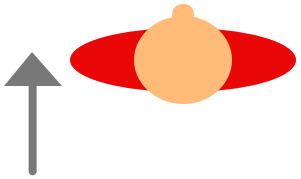
Optic Flow:
maintain FoE on target





Egocentric Direction:
walk in direction of target



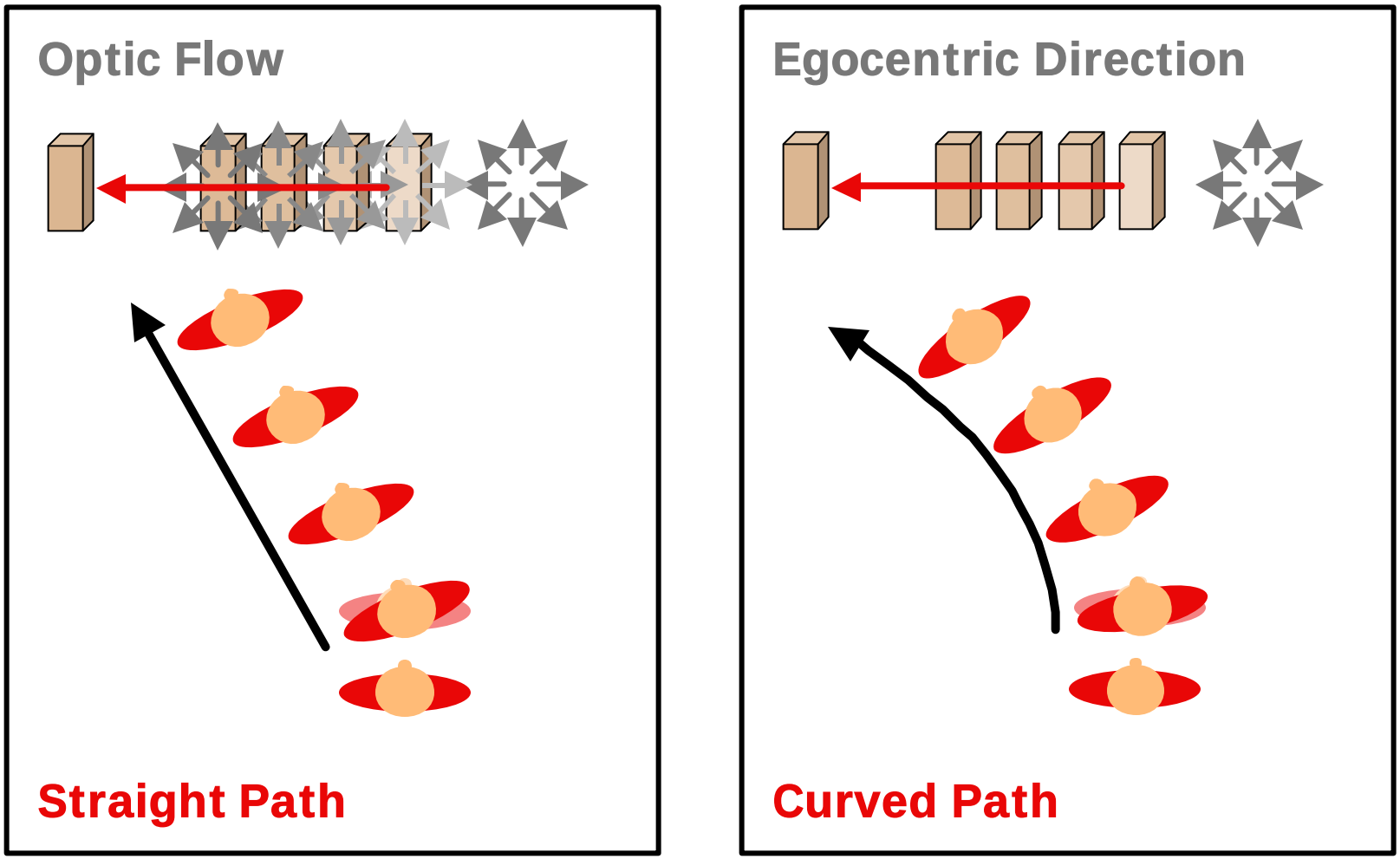


Problem: FoE and egocentric direction are usually coincident when walking towards a target

Solution: dissociate them using prisms or virtual reality (VR)

Predicted Paths

Path trajectory will depend on which visual strategy is implemented to compensate for mismatch between optic flow and direction of walking:



The Problem

Evidence from prism studies and virtual reality studies is *not* in agreement:

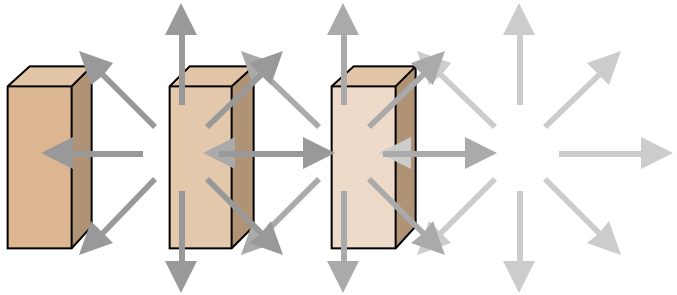
- curved trajectories implicated an egocentric direction strategy when walking outdoors with prisms (Rushton, et al., 1998)
- placing additional texture elements on the ground outdoors resulted in straighter paths with prisms (Wood, et al., 2000)
- when optic flow is incrementally added in VR, observers walked straighter paths (Warren, et al., 2001)

What are the relative contributions of optic flow and egocentric direction when walking to a target?

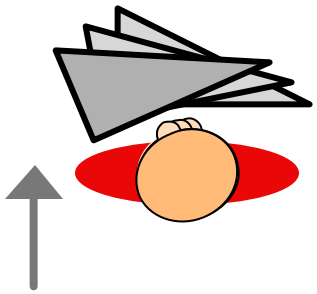
The Solution

To further elucidate the relative contributions of optic flow and egocentric direction to path trajectory, we employed an adaptation paradigm.

Adaptation: "semipermanent changes in perception or perceptual-motor coordination that reduce sensory discrepancies" (Palmer, 1999)

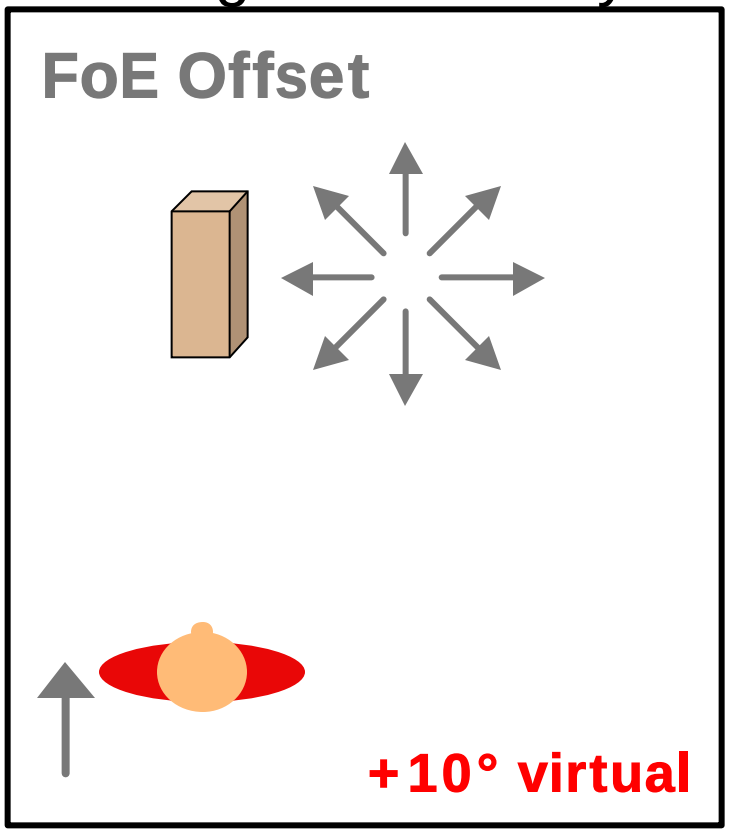


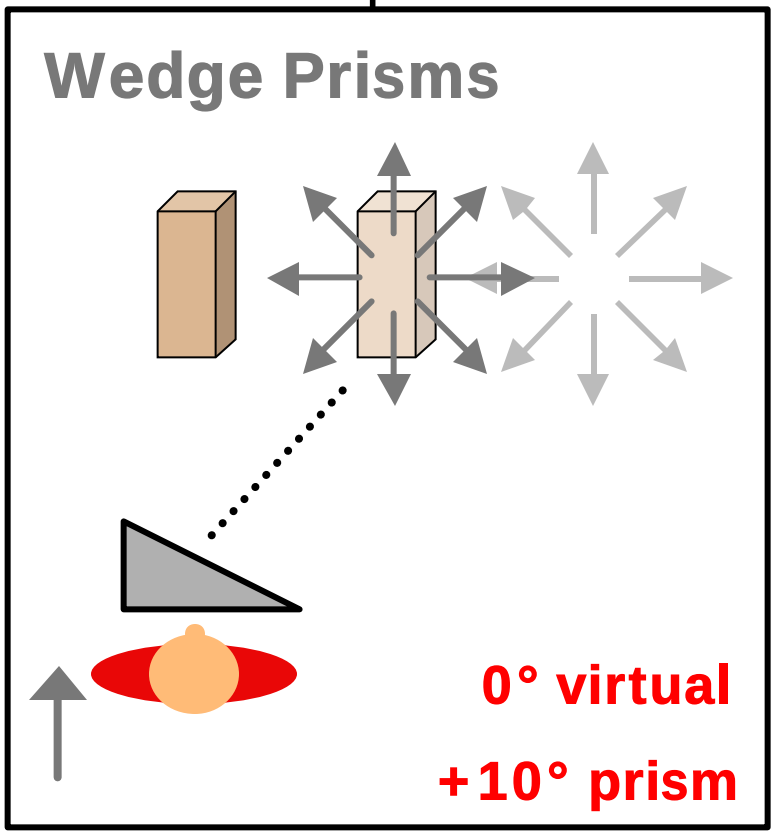
for example: a change in felt position of head relative to body to align visual information to perceived mid-line



Experiment 1

Motivation: Which strategy will observers use when walking and will they adapt to a virtual optic flow offset?





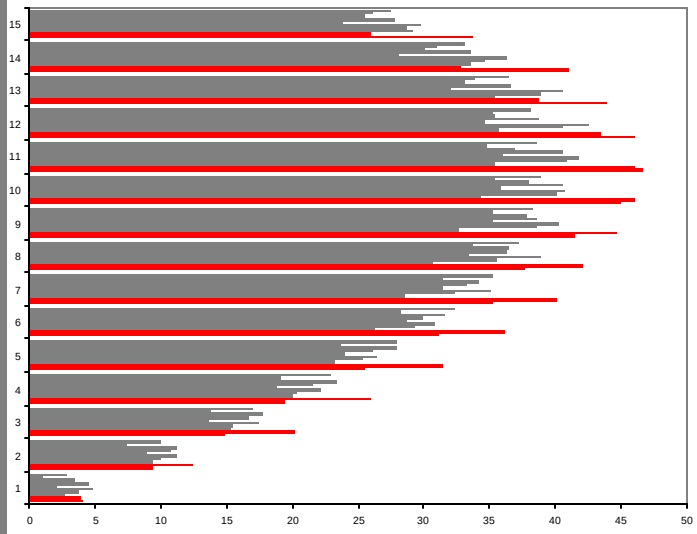
Design: directly compare a virtual optic flow (FoE) offset with a prism displacement in VR

Experiment 1

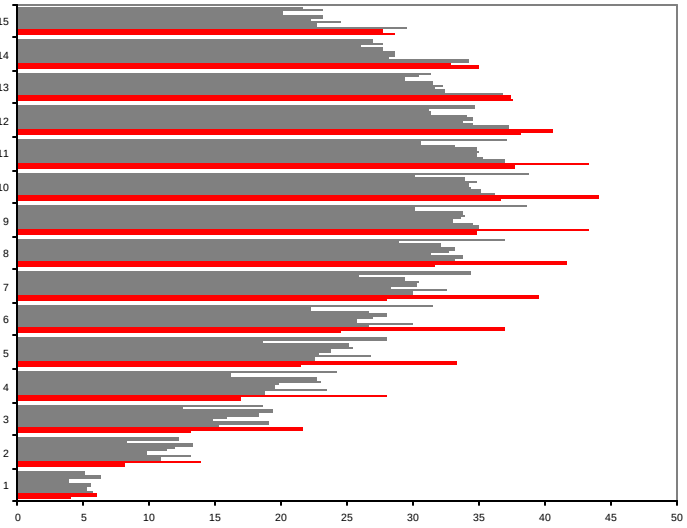
- manipulate the amount of optic flow available in 4 virtual worlds
- 2 conditions:
  - FoE Offset: +10° virtual
  - Wedge Prisms: 0° virtual, +10° prism
- 13 trials:
  - 10 with displacement (adaptation trials)
    prediction: reduction in lateral deviation over trials
  - 3 without displacement (aftereffect trials)
    prediction: aftereffect in opposite direction

Adaptation Trials

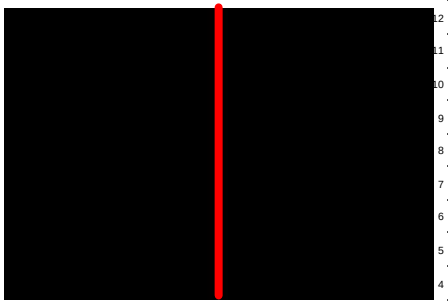
FoE Offset

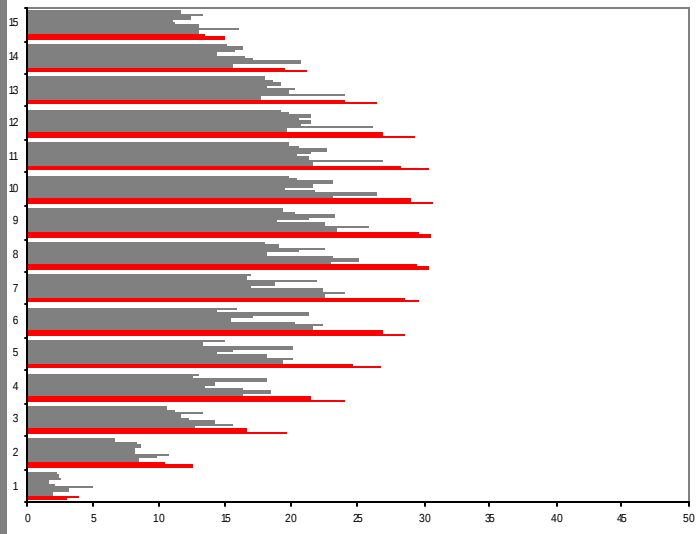


Wedge Prisms

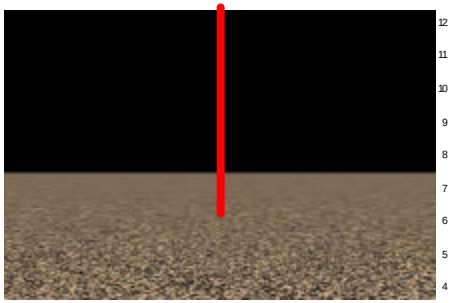


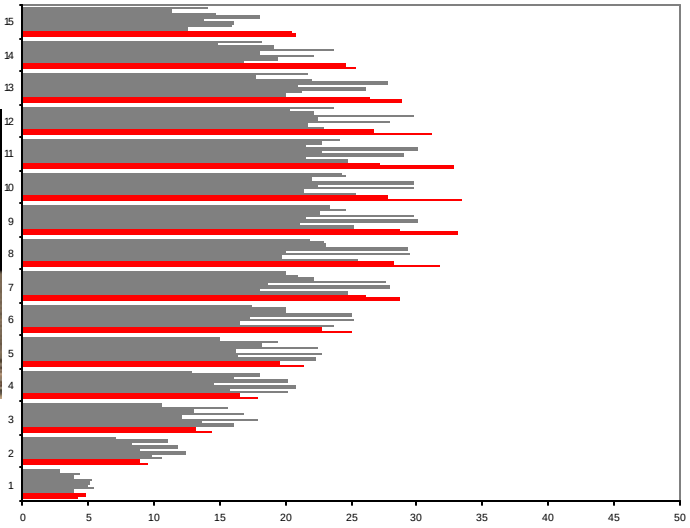
Red Line





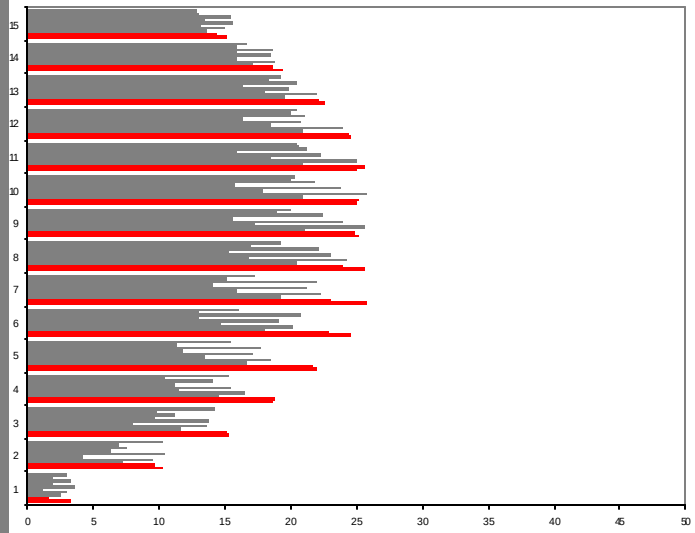
Red Line + Ground



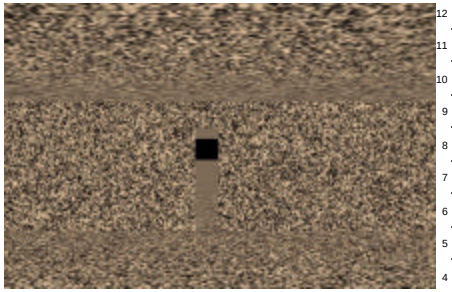


Adaptation Trials

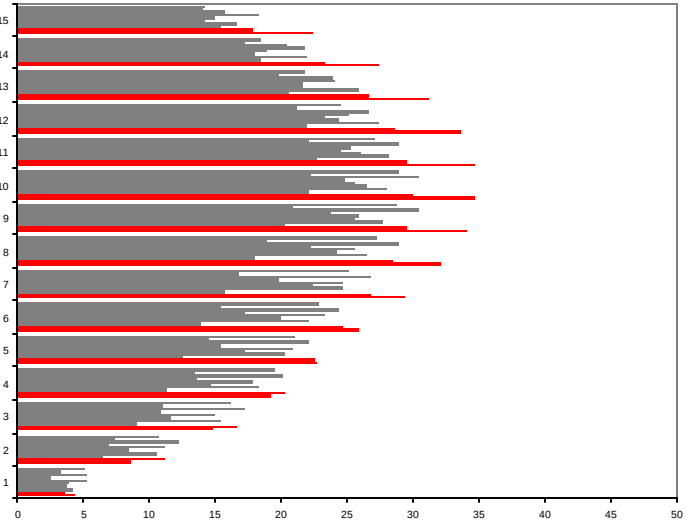
FoE Offset

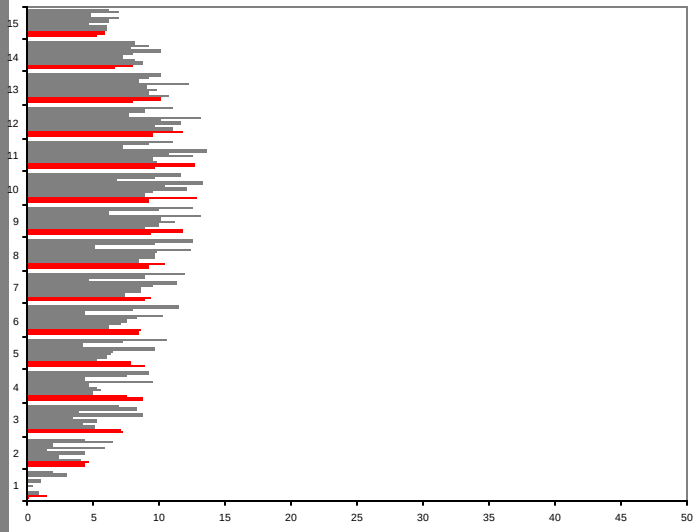


Doorway

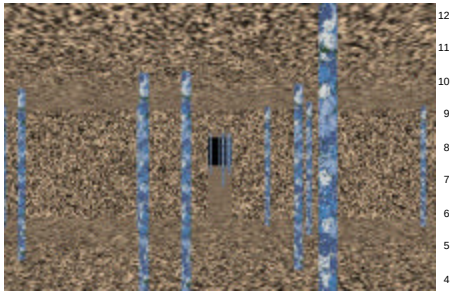


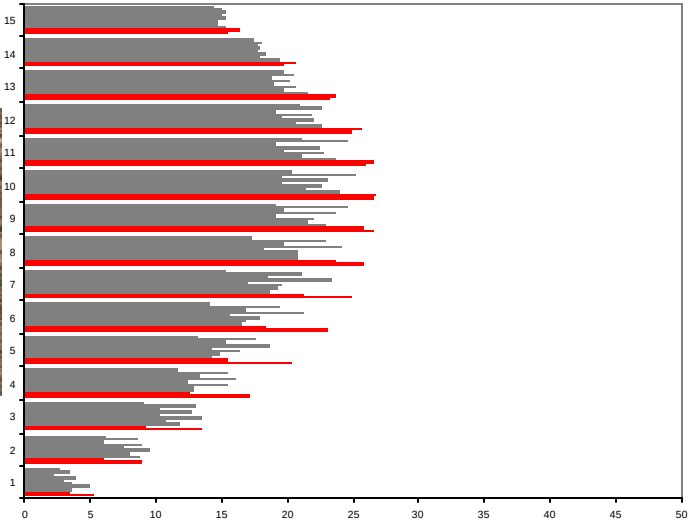
Wedge Prisms





Doorway + Posts





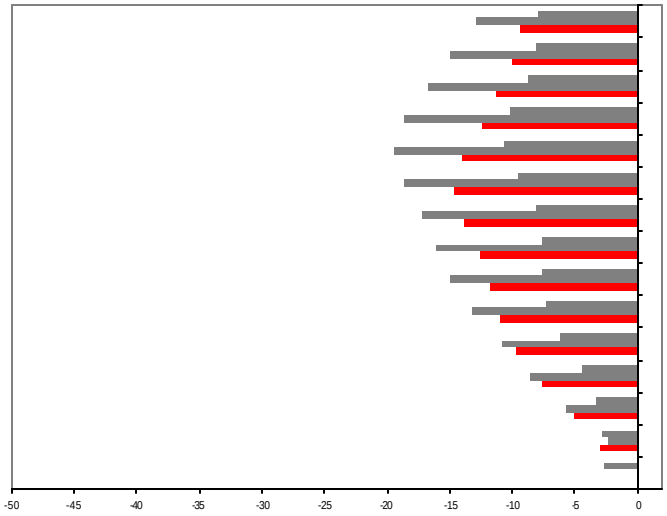
Adaptation Results

- varying optic flow influences path, suggesting that observers rely on optic flow as it becomes more salient (main effect of world, $p<0.001$)
- observers appear to be walking similar trajectories in FoE and prism displacement conditions (*no* main effect of display type, $p>0.05$)
- small interaction may support claim that observers rely more on egocentric direction with prism due to prismatic distortion of optic flow (world x display type, $p=0.045$)
- trajectories suggest that observers are making a quick adjustment in the first few trials, and possible evidence of adaptation (main trial effect, $p<0.001$ drops out when first 2 trials are removed, $p=0.077$)

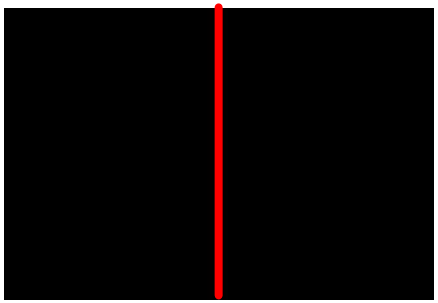
Aftereffect Trials

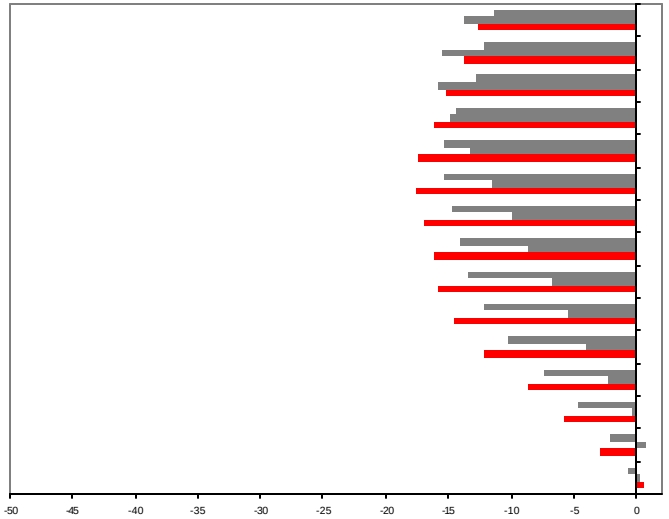
FoE Offset

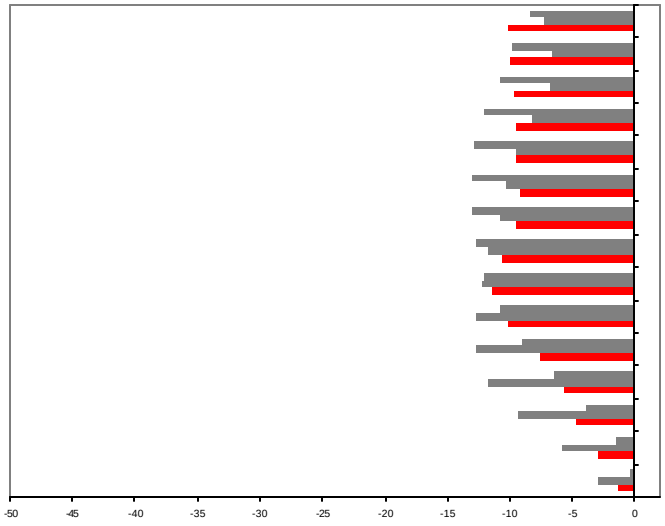
Wedge Prisms



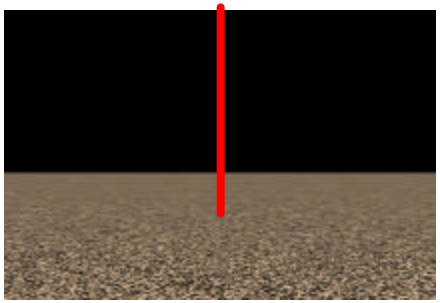
Red Line

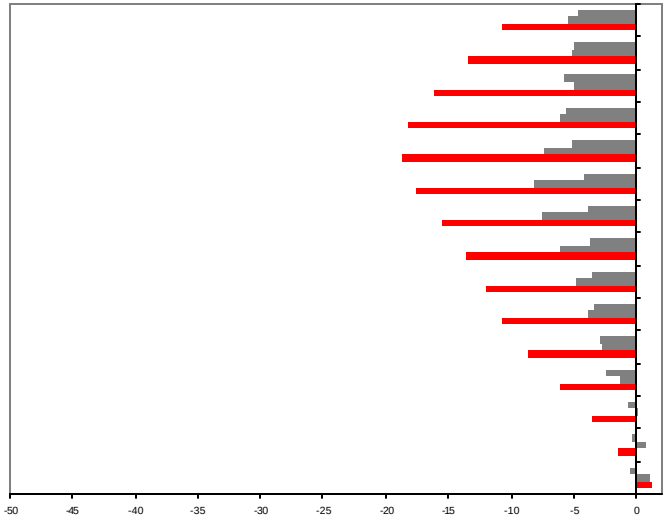






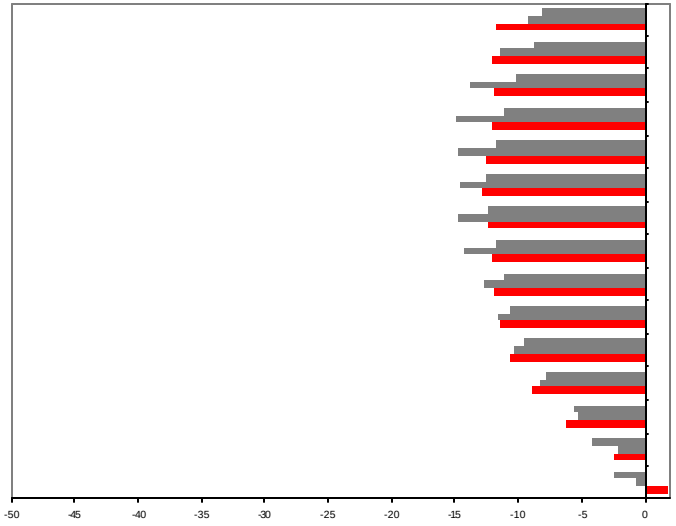
Red Line + Ground



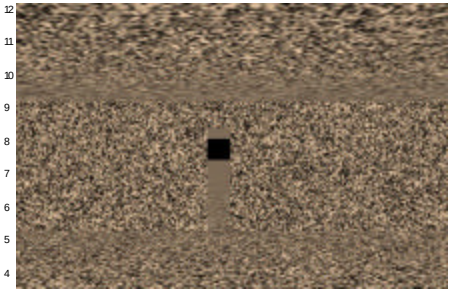


Aftereffect Trials

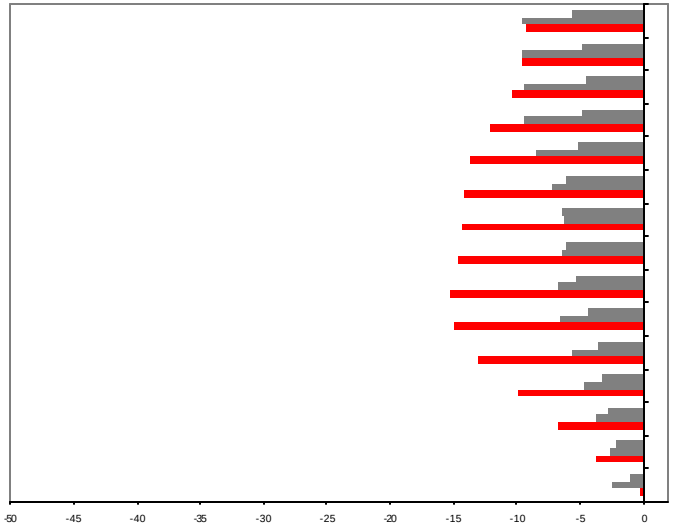
FoE Offset

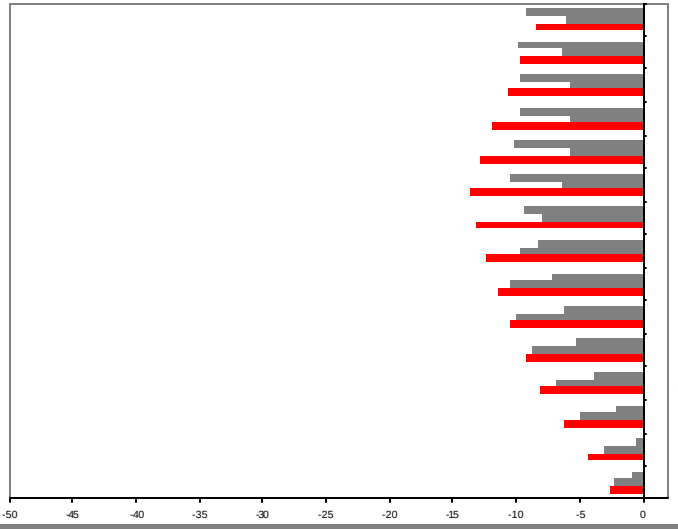


Doorway

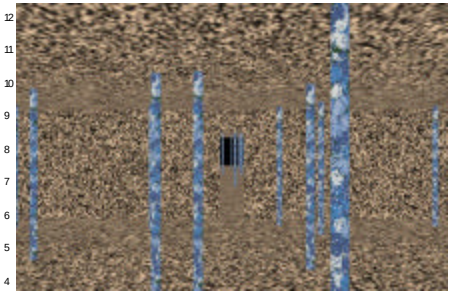


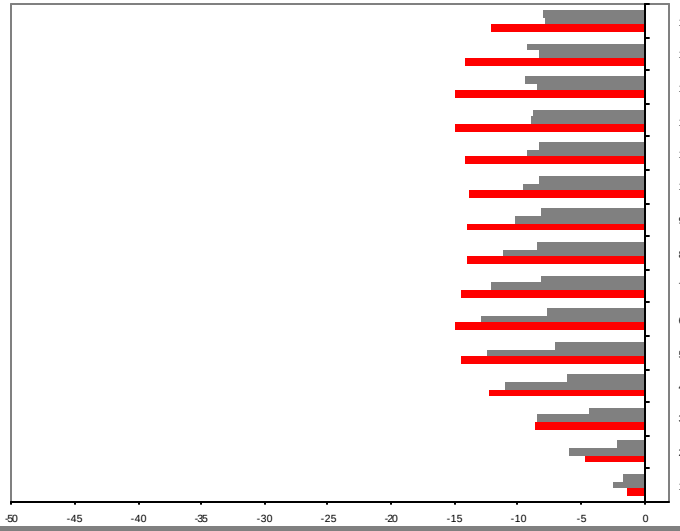
Wedge Prisms





Doorway + Posts





Aftereffect Results

- an aftereffect is shown in opposite direction upon removal of dissociated visual information (nearly half the magnitude of normal trajectory)
- quick adjustment also appears in aftereffect, although mainly restricted to first trial
- the magnitude of the aftereffect is reduced over 3 trials (main effect of trial, $p<0.001$)
- interaction suggests that people may be acting differently depending on the amount of optic flow in scene (world x trial interaction, $p<0.001$)
- small interaction may again be the result of prismatic distortion (trial x display type interaction, $p=0.048$)

Motivation for Experiment 2

preliminary evidence warrants a closer look...

? 10 trials may be insufficient for the time course of adaptation to FoE offset

? 3 trials are insufficient to examine decay of aftereffect

? quick adjustment in first few trials does not represent the general notion of adaptation

? how would observers behave when adaptation trials are in a different virtual world than aftereffect trials?

(i.e. are adaptive processes specific to the information contained in the visual scene or can they be transferred to a new environment)

Experiment 2

? manipulate the pairing between the virtual worlds used in adaptation trials and aftereffect trials (training vs. testing)

? 4 conditions using the FoE offset in 2 virtual worlds:

Training Trials / Testing Trials

– Red Line / Red Line
– Red Line / Doorway + Posts
– Doorway + Posts / Red Line
– Doorway + Posts / Doorway + Posts

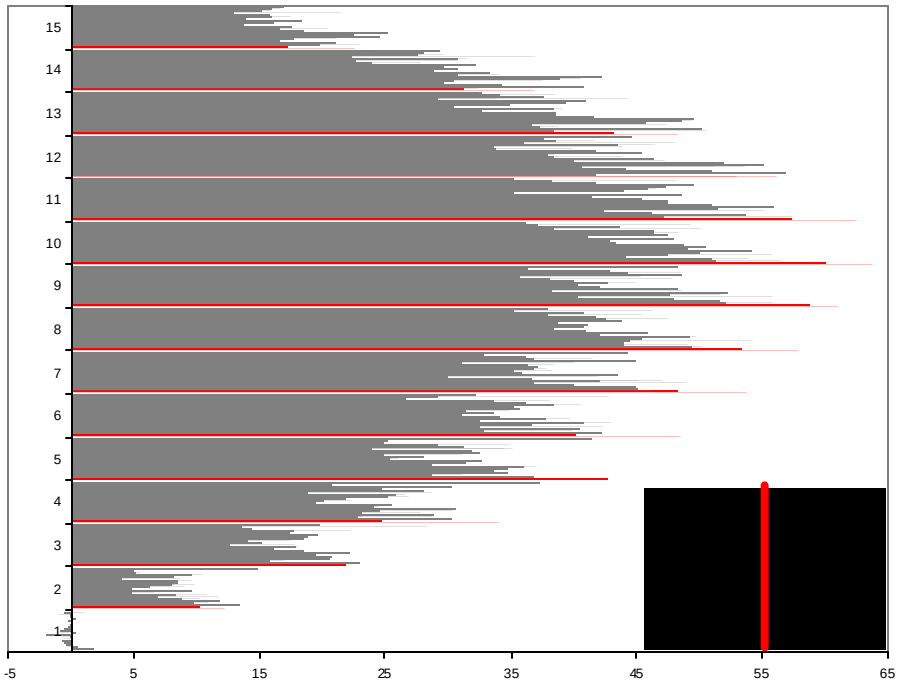
? 48 trials:

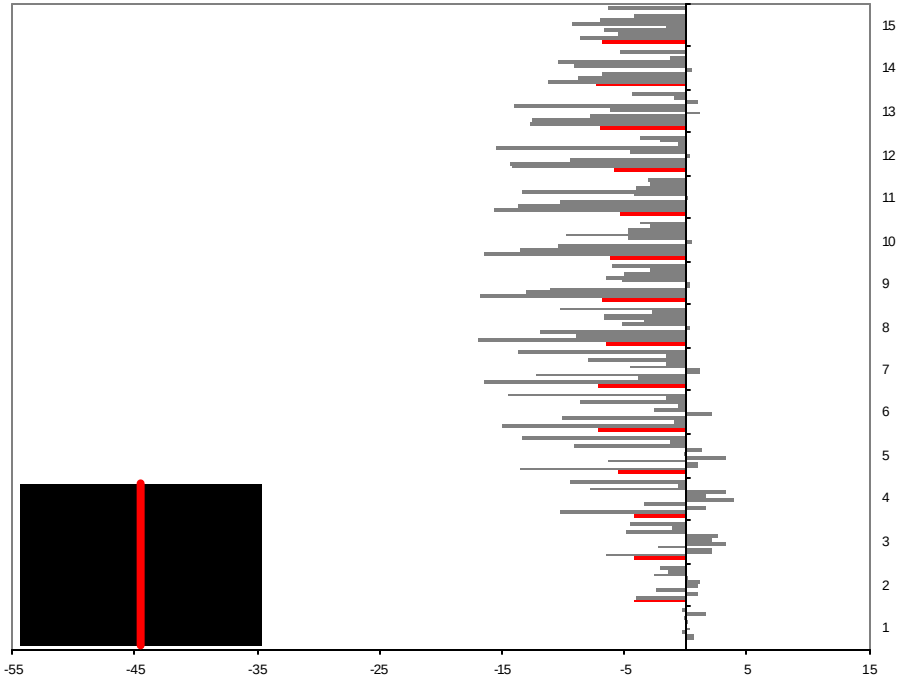
– 38 with FoE displacement
– 10 without FoE displacement

Experiment 2

Adaptation Trials

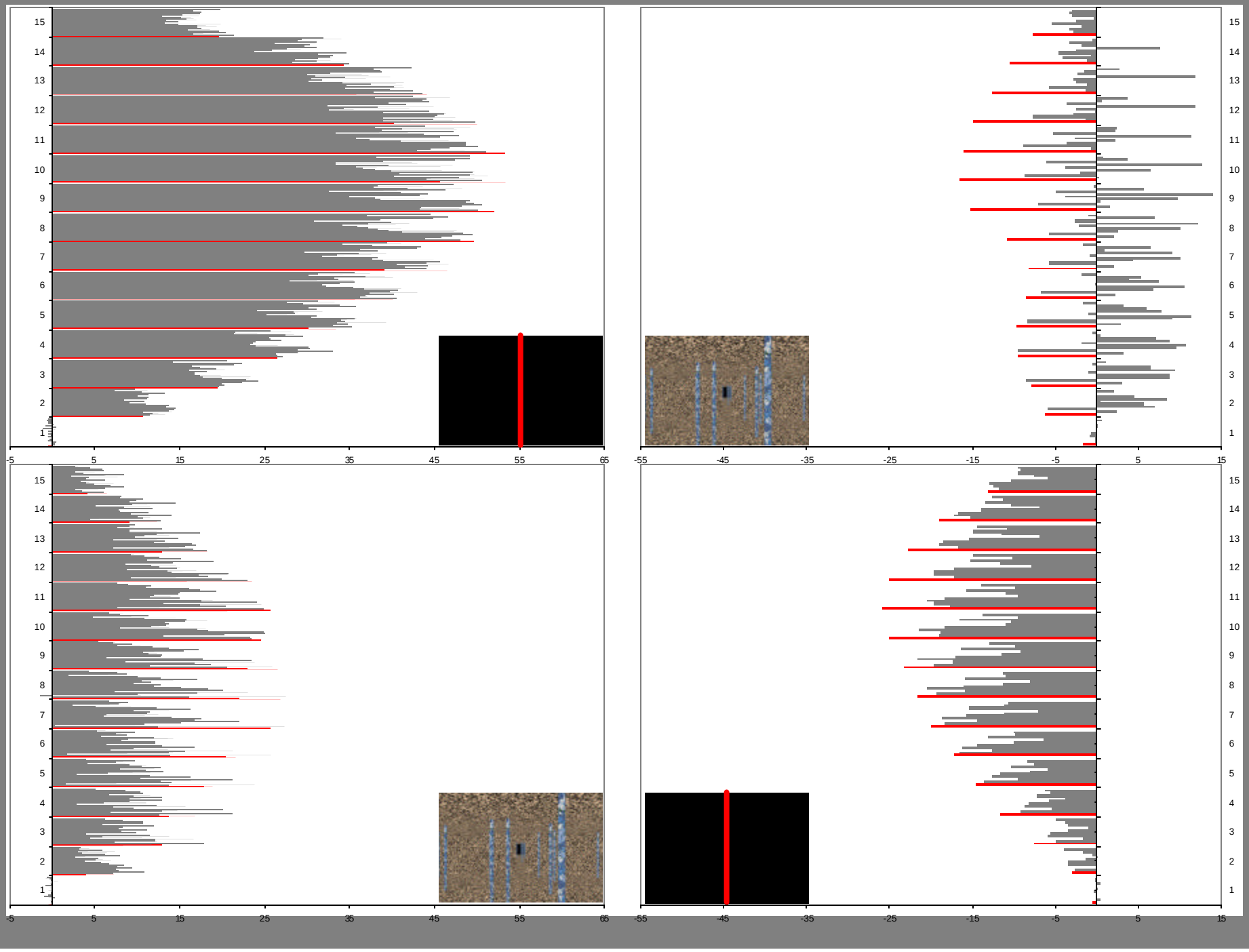
Aftereffect Trials





training world

testing world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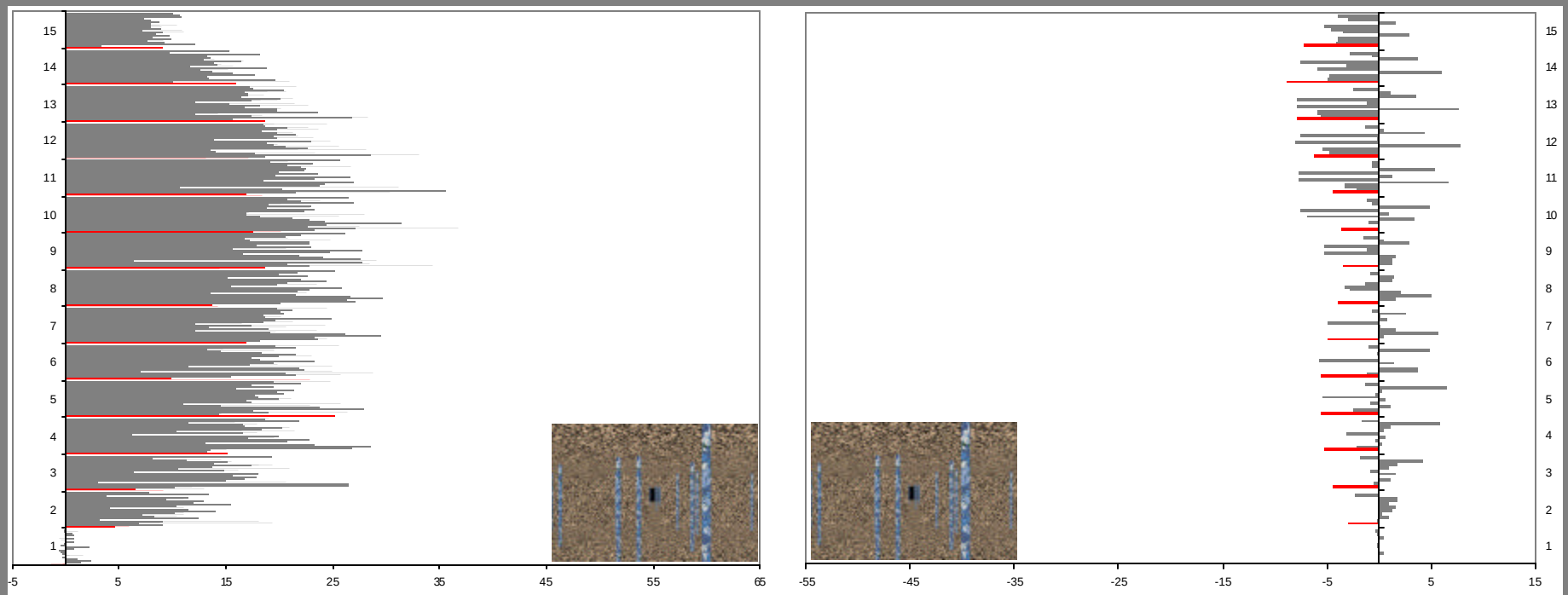

Are there trial effects indicating adaptation?

Training Trials / Testing Trials

- Red Line: NO / Red Line: NO
- Red Line: YES / Doorway + Posts: NO
- Doorway + Posts: YES / Red Line: YES
- Doorway + Posts: NO / Doorway + Posts: NO

Experiment 2 Results

? in both virtual worlds, observers may be exhibiting two different adaptive responses:

- calibration: motor
  - quick motor adjustment to visual information
  - no remapping of sensory-motor systems
- adaptation: kinesthetic
  - gradual decrease in error as a result of repeated exposures
  - possible remapping of sensory-motor systems

? results are inconclusive, but aftereffect is disrupted when optic flow is available (congruent information is available immediately for calibration, whereas, incongruent information requires a few trials)

Conclusions

- both optic flow and egocentric direction are used in walking to a target
- optic flow dominates as it becomes more salient in the visual scene
- adaptation appears to occur when information in the visual scene is mismatched, but the relative contributions of optic flow and egocentric direction remain undetermined
- re-calibration may rely more on optic flow information to quickly adjust for discrepancies between what we see and how we move

References

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