Optical Marionette:
Graphical Manipulation of Human's Walking Direction

Akira Ishii, Ippei Suzuki, Shinji Sakamoto, Keita Kanai
Kazuki Takazawa, Hiraku Doi, Yoichi Ochiai
(Digital Nature Group, University of Tsukuba, Japan)

Background | Redirected Walking

- **Manipulation technique of human's walking direction for VR environment**
- **Uses only visual feedback for the manipulation**
- **Enables users to explore a virtual world that is quite larger than the real environment**

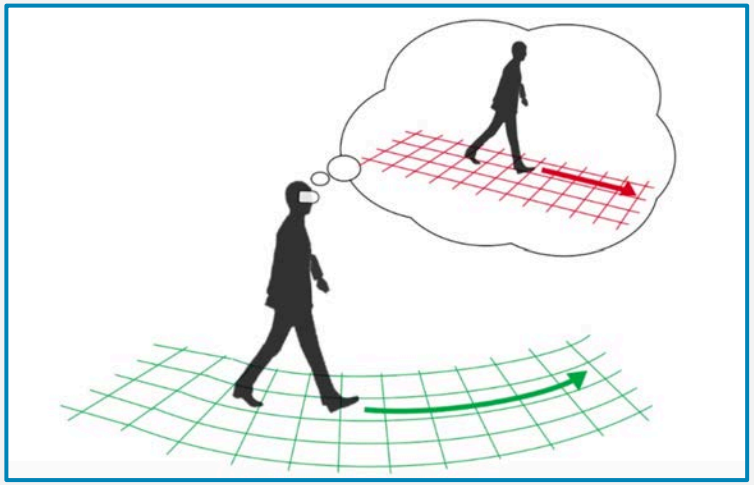


Figure by Matsumoto et al. 2016

Introduction | Motivation

- **Suspected there are possibilities that human's walking direction could be manipulated using only visual feedback in the real environment like a Redirected Walking in VR**

Our goal

To manipulate user's walking direction

using *only* visual feedback in the **real environment**

Introduction | To This End

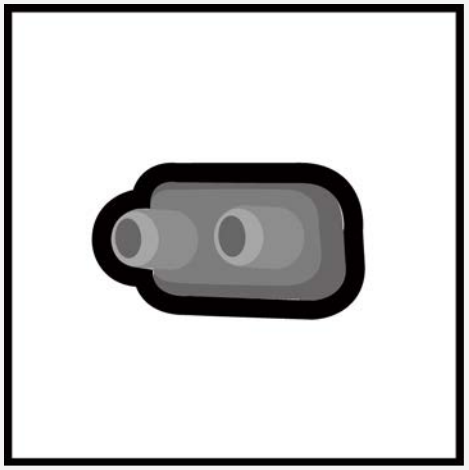
- **Examined various image-processing methods to manipulate walking path**
- **Investigated how to manipulate the walking path using the image-processing methods**

We found effective reorienting method using an HMD in the real environment

Implementation

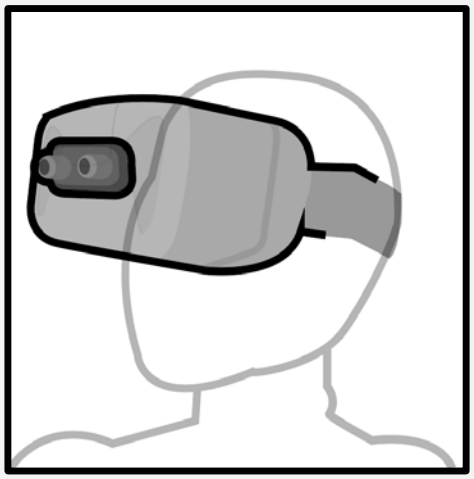
HMD

+



Stereo camera

=



See-through

- **The camera is attached to the HMD**
- **Users perceive the real world by video provided by an HMD and stereo camera**
- **So we can coordinate users' sight in this setup**

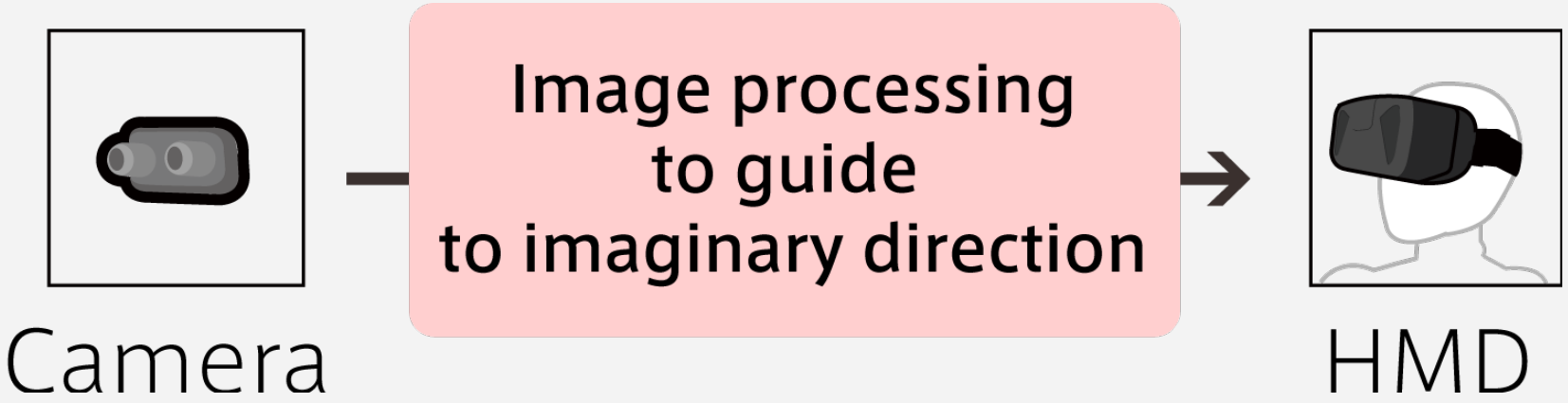
Implementation | Hardware

- **HMD: Oculus Rift DK 2**
- **Stereo camera: Ovrvision**

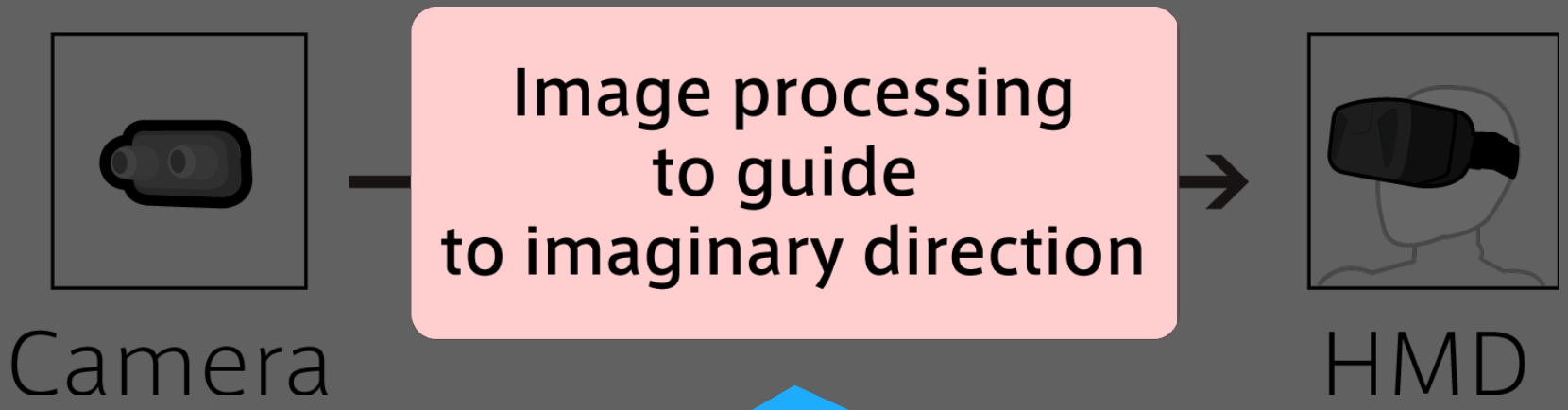
Implementation | Hardware

User's sight via HMD + camera while walking

Implementation | Flow



Implementation | Flow



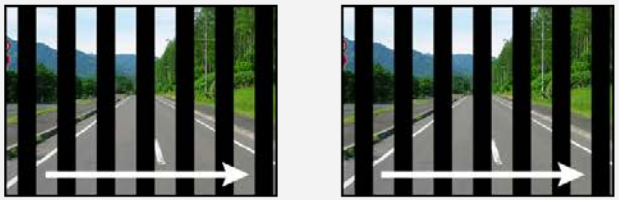
Investigated effective image processing in a pilot study

Pilot Study

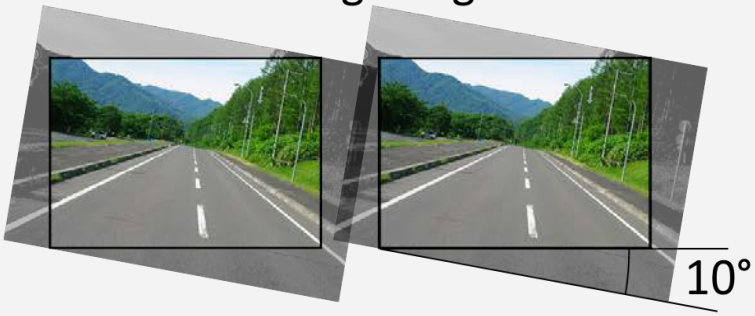
- **Purpose**
  - To determine which of the image processing methods have the most effect on a human's walking path
- **Participants**
  - 5 participants (1 female); 18-22 ages
- **6 image processing methods**
- **Task**
  - Walk straight 10 m for each image processing methods

Pilot Study | Result

Moving stripe pattern



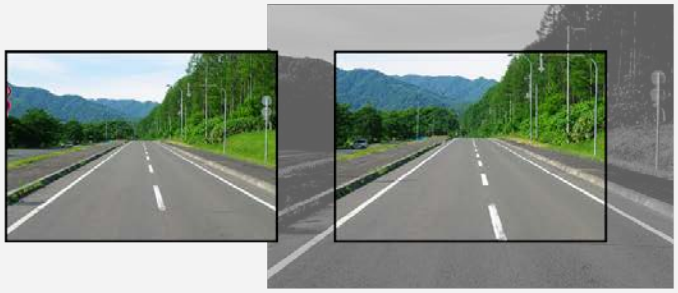
Rotating image



Delayed image (only one side)

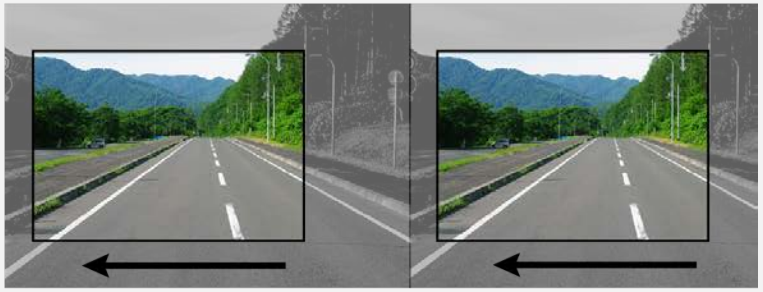
Delayed 0.5 sec

Magnification (only one side)



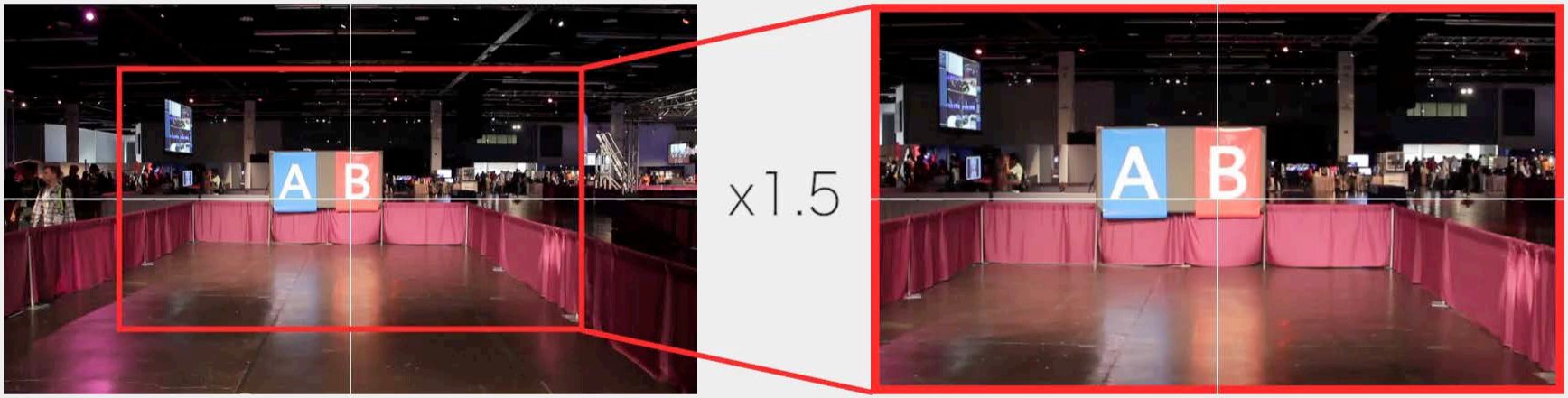
Distorted image
(only one side, trapezoid)

Changing focal region



Implementation | Changing Focal Region (CFR)

Crops the raw image
Shifts the cropped area



Raw video
from camera

Video that users see
via HMD

Implementation | Changing Focal Region (CFR)

Crops the raw image
Shifts the cropped area

Raw video
from camera

Video that users see
via HMD

User is asked to go to the B, however, actually he is going to the A

Experiment

- **Purpose**
  - To determine how to control the walking direction using Changing focal region method
- **Participants**
  - 16 participants
  - Had not prior knowledge of our experiment
- **Task**
  - Walk straight 24 m for each image processing

Experiment | Experimental Design

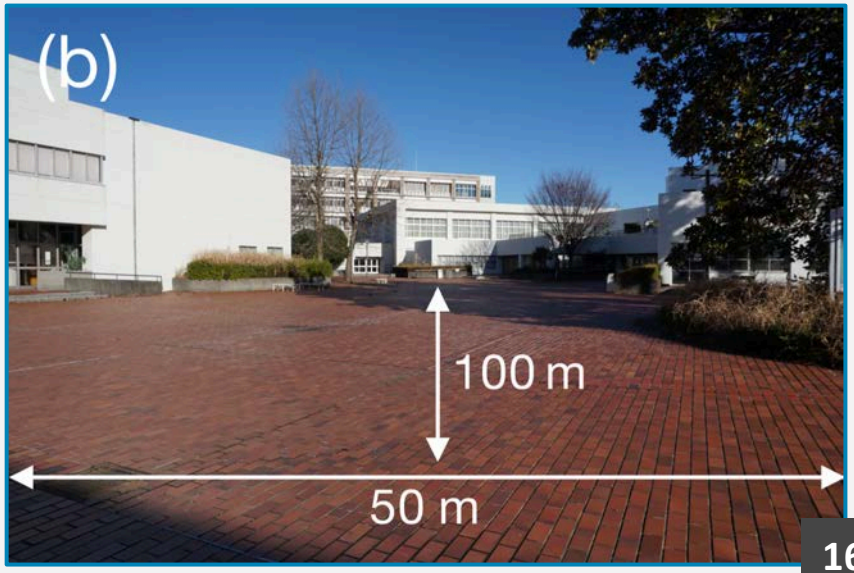
- **Image processing methods**
  - No processing (raw video)
  - Magnification
    - Magnification was added to the image-processing methods for comparison because it is used in Changing focal region method.
      This enabled us to identify the effects of image magnification and to reveal the pure effects of changing the focal region (shifting images).
  - **Changing focal region** (slow / fast)
    - Scroll speed of the cropped area in the slow condition was 0.5 px/frame
    - In the fast condition, the scroll speed of the cropped area was twice the scroll speed in the slow condition

Changing focal region

Magnification + Shifting

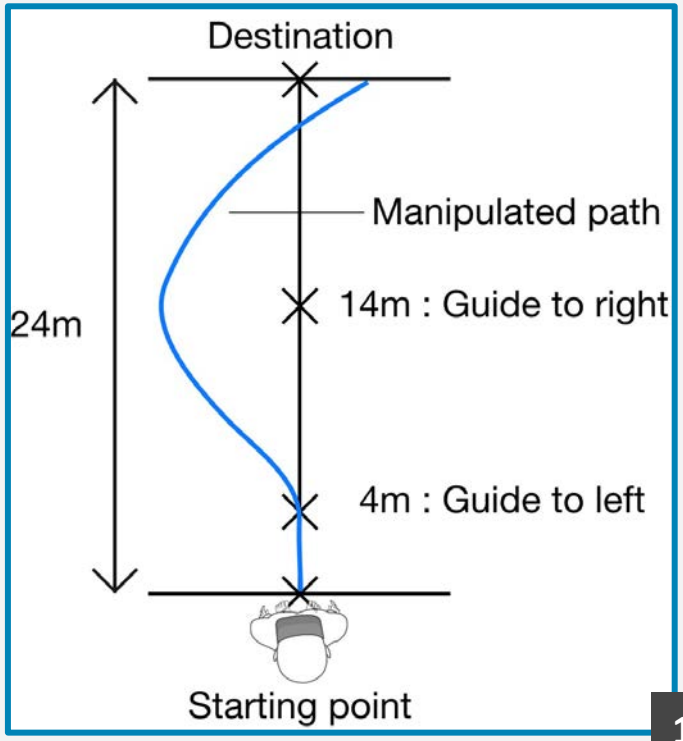
Experiment | Experimental Design

- **Locations**
  - Hallway
    - Narrow
    - Several hints for spatial perception (such as walls)
  - Outside
    - Large space
    - No hint for spatial perception



Experiment | Procedure

1. **Completed pre-SSQ (Simulator Sickness Questionnaire)**
2. **Walked straight for 24 m each of image processing at 2 locations**
   - At 4 m, guided to the left
   - At 14 m, guided to the right
3. **Completed post-SSQ**

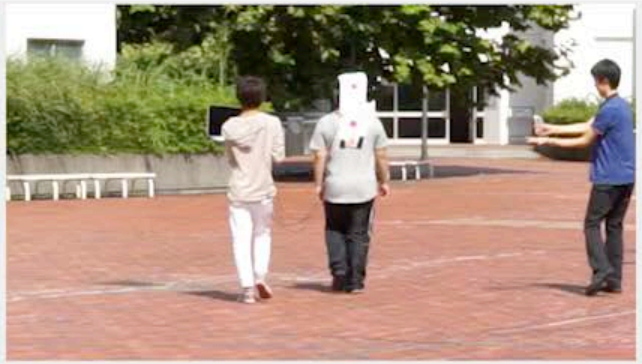
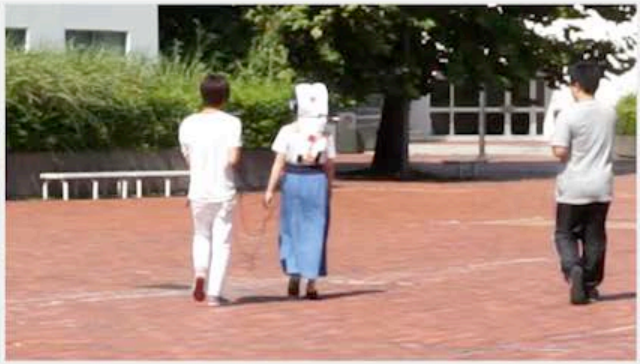


Result | Simulator Sickness Questionnaire

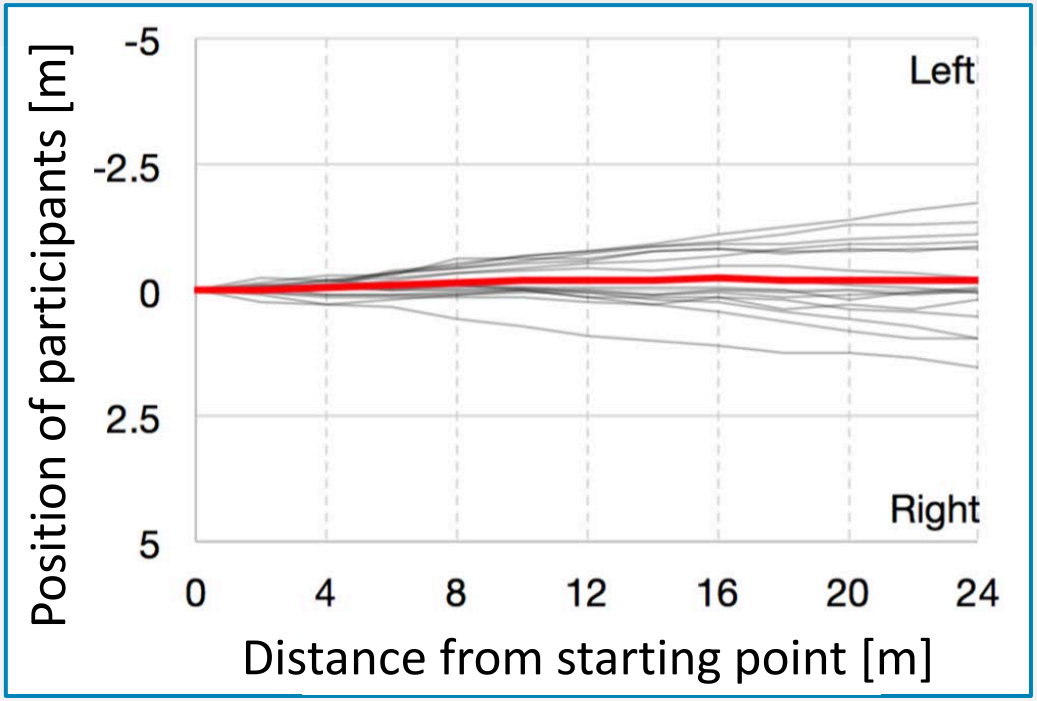
- **Analyzed the SSQ scores with t-test**
  - No significant difference between pre-SSQ and post-SSQ
  - Pre-SSQ: 4.7 (SD = 4.7)
  - Post-SSQ: 6.7 (SD = 8.3)

I did not feel
any motion sickness ☺

Result | No processing

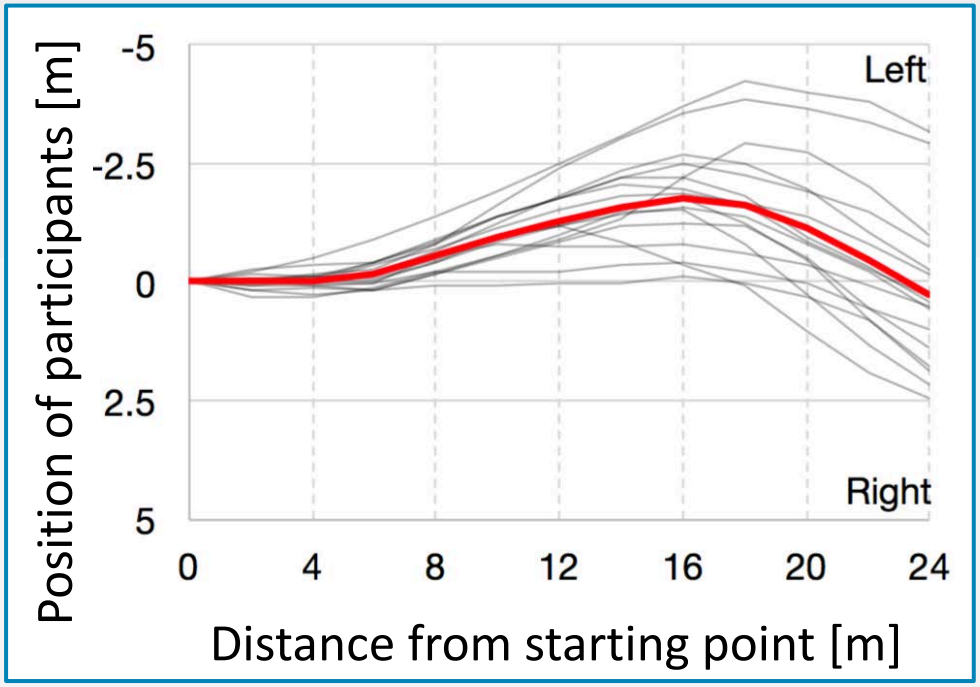
▷10x Playback speed



Result | Changing focal region (fast)

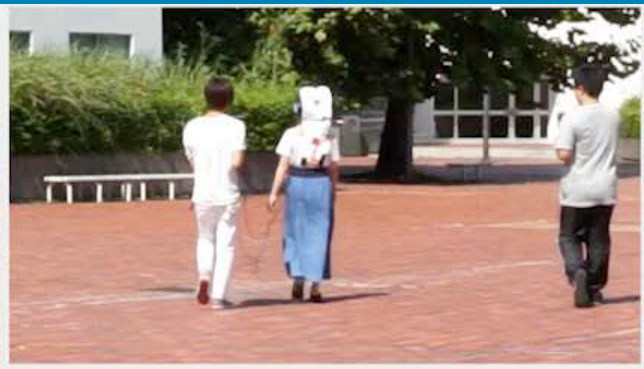


▷10x Playback speed

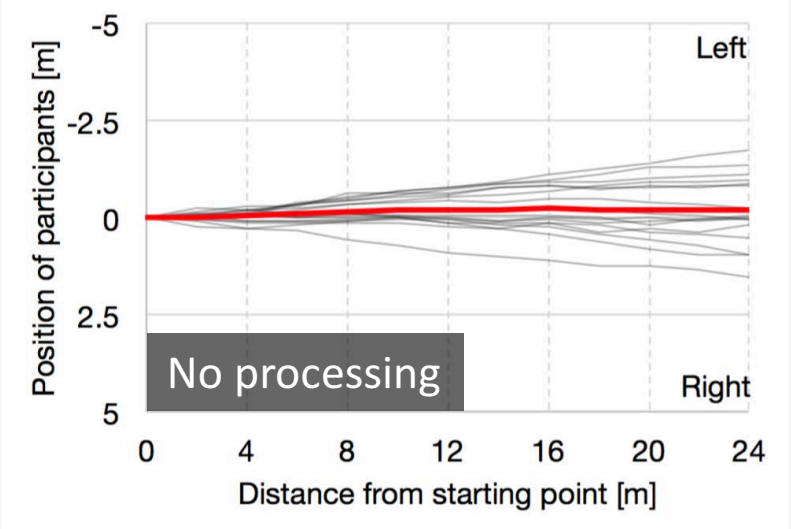


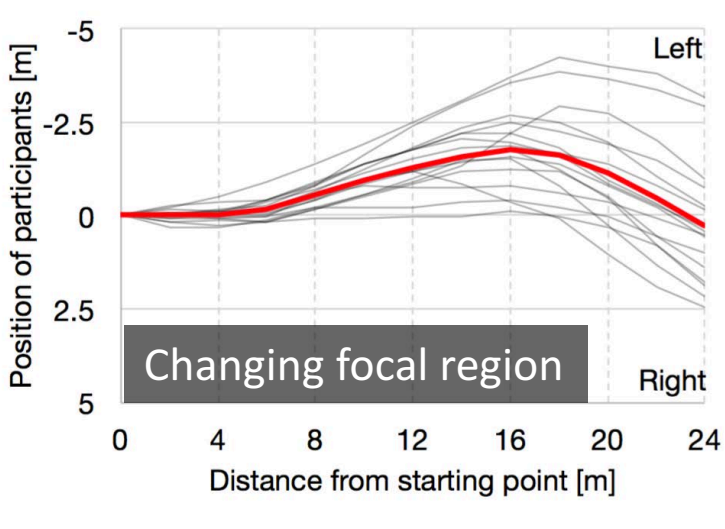
Result

No processing



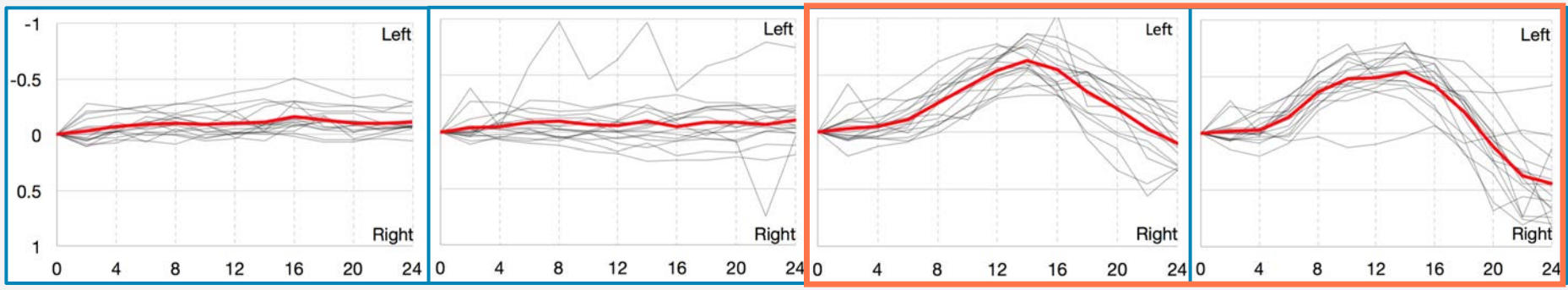
Changing focal region





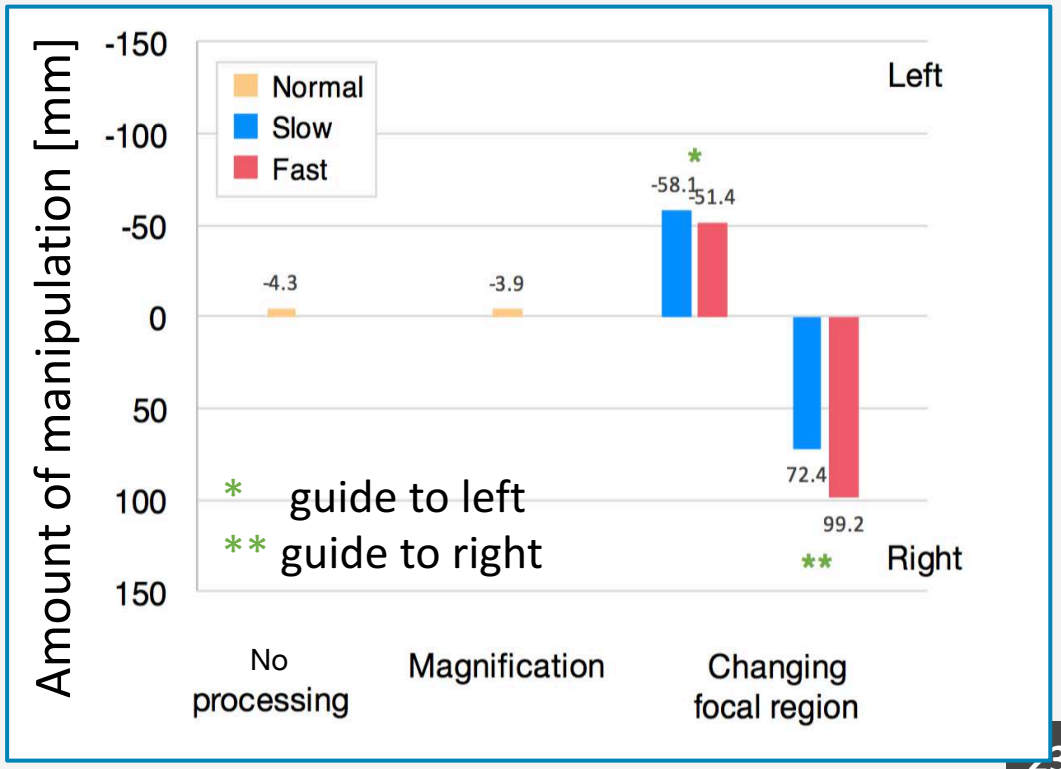
Result | Hallway

- **Significant effect**
  - No processing — Changing focal region (slow/fast)
  - Magnification — Changing focal region (slow/fast)
- **No significant effect**
  - No processing — Magnification



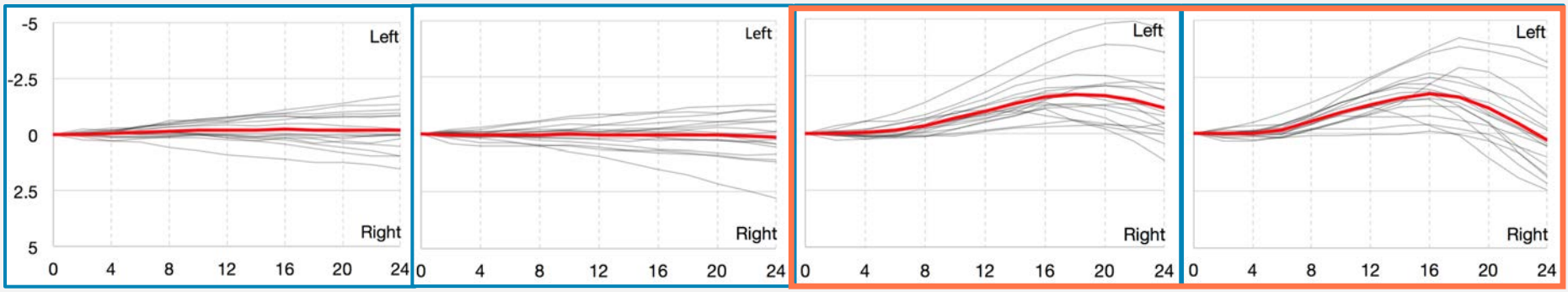
Result | Hallway

- **Amount of the manipulation for Changing focal region**
  - Slow: 65.3 mm/m
    - If you walk 2 m, your position moves by 10 cm horizontally
  - Fast: 75.3 mm/m



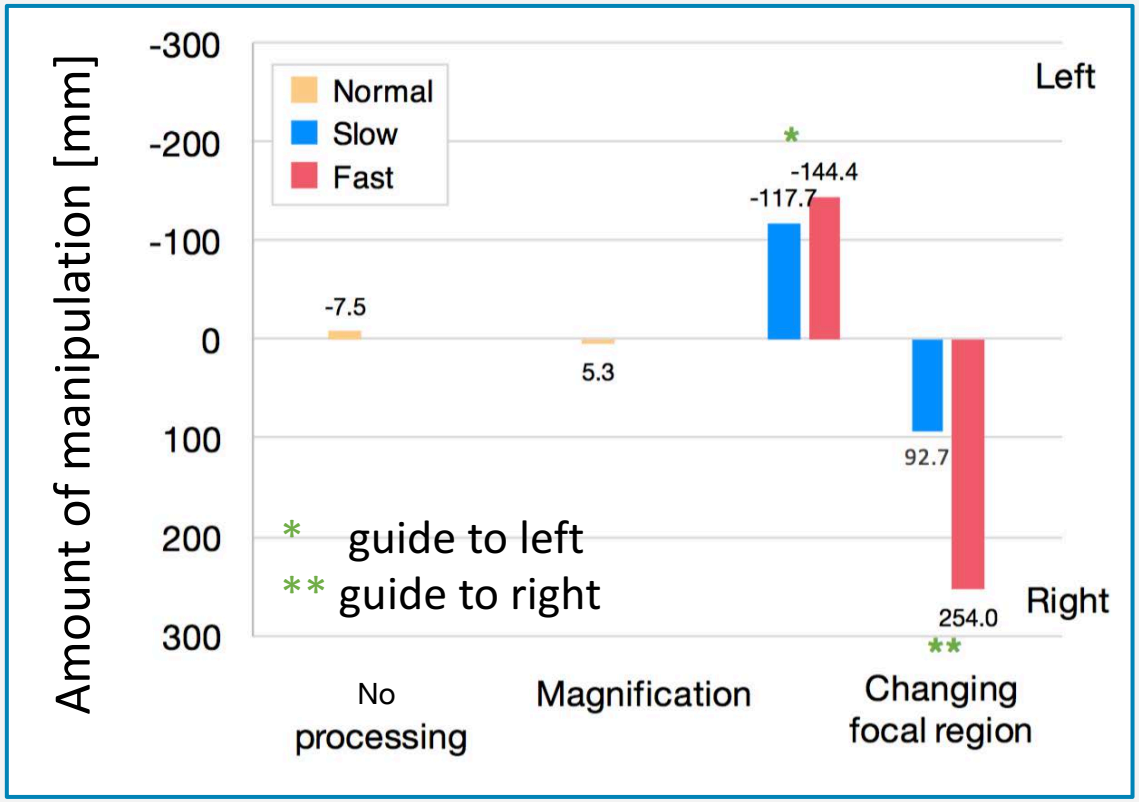
Result | Outside

- **Significant effect**
  - No processing — Changing focal region (slow/fast)
  - Magnification — Changing focal region (slow/fast)
- **No significant effect**
  - No processing — Magnification



Result | Outside

- **Amount of the manipulation for Changing focal region**
  - Slow: 105.2 mm/m
  - Fast: 199.2 mm/m



Result | Pure Effect of CFR

- **No significant effect**

  between No processing and Magnification

  - This indicates that the cropped image by itself did not affect the participants' walking paths
  - It is clear that the participants' walking paths were **affected by movement of the cropped area** of Changing focal region

Result | Hallway vs. Outside

- **Significant effect within the locations**
  - The outside participants were affected more by the manipulation method
    - In the hallway, the participants could not move more than 1.1 m because the with of the hallway is 2.2 m
    - Thus, the mean value of the position change in the hallway was smaller than that in the outside

Result | Slow vs. Fast

- **Changing focal region (fast) was significantly more effective than the slow condition**
  - Slow: 105.2 mm/m
  - Fast: 199.2 mm/m (at outside)

Discussion | Spatial Perception

- **Past research reported Changing the FOV has effects on spatial perception [1, 2]**

In this study

- **No horizontal spatial perception effect on our result**
  - because no significant difference between No processing and Magnification
- **By contrast, we could not determine whether there was any depth perception effect**

[1] Campos, J., Freitas, P., Turner, E., Wong, M., and Sun, H. The effect of optical magnification/minimization on distance estimation by stationary and walking observers. Journal of Vision 7, 9 (June 2007), 1028.
[2] Kuhl, S. A., Thompson, W. B., and Creem-Regehr, S. H. HMD calibration and its effects on distance judgments. ACM Transactions on Applied Perception 6, 3 (September 2009), 19:1–19:20.

Discussion | Cognitive Resource

- **Conventional navigations require users to recognize information (go to the right) and then follow directions**

- **Our method directly affects users' bodies so that it can control them without requiring user recognition process**

Does our method have lighter burden than conventional navigations?

Discussion | Cognitive Resource

- **Significant amount of cognitive resources is required for redirected walking in VR [3]**

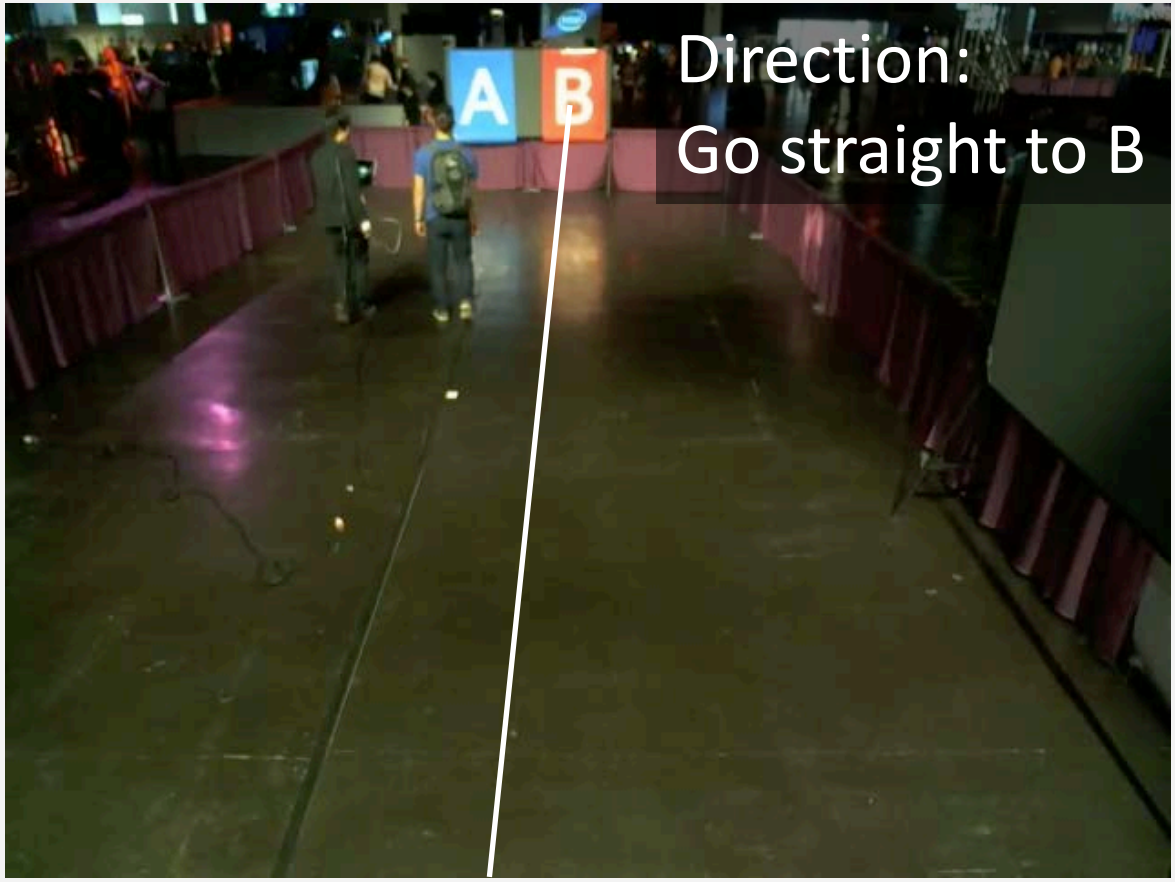
  Similarly, our method might require some cognitive resources

We plan to investigate how much cognitive resources are really required by users to follow the manipulation

[3] Bruder, G., Lubas, P., and Steinicke, F. Cognitive resource demands of redirected walking. IEEE Transactions on Visualization and Computer Graphics 21, 4 (April 2015), 539–544.

Discussion | Feasibility

- **Demonstrated our method at SIGGRAPH 2016 E-Tech**
- **Over 700 people were successfully manipulated**



Applications | AR Contents

- **In see-through AR contents,**

  to control of human's walking path is important

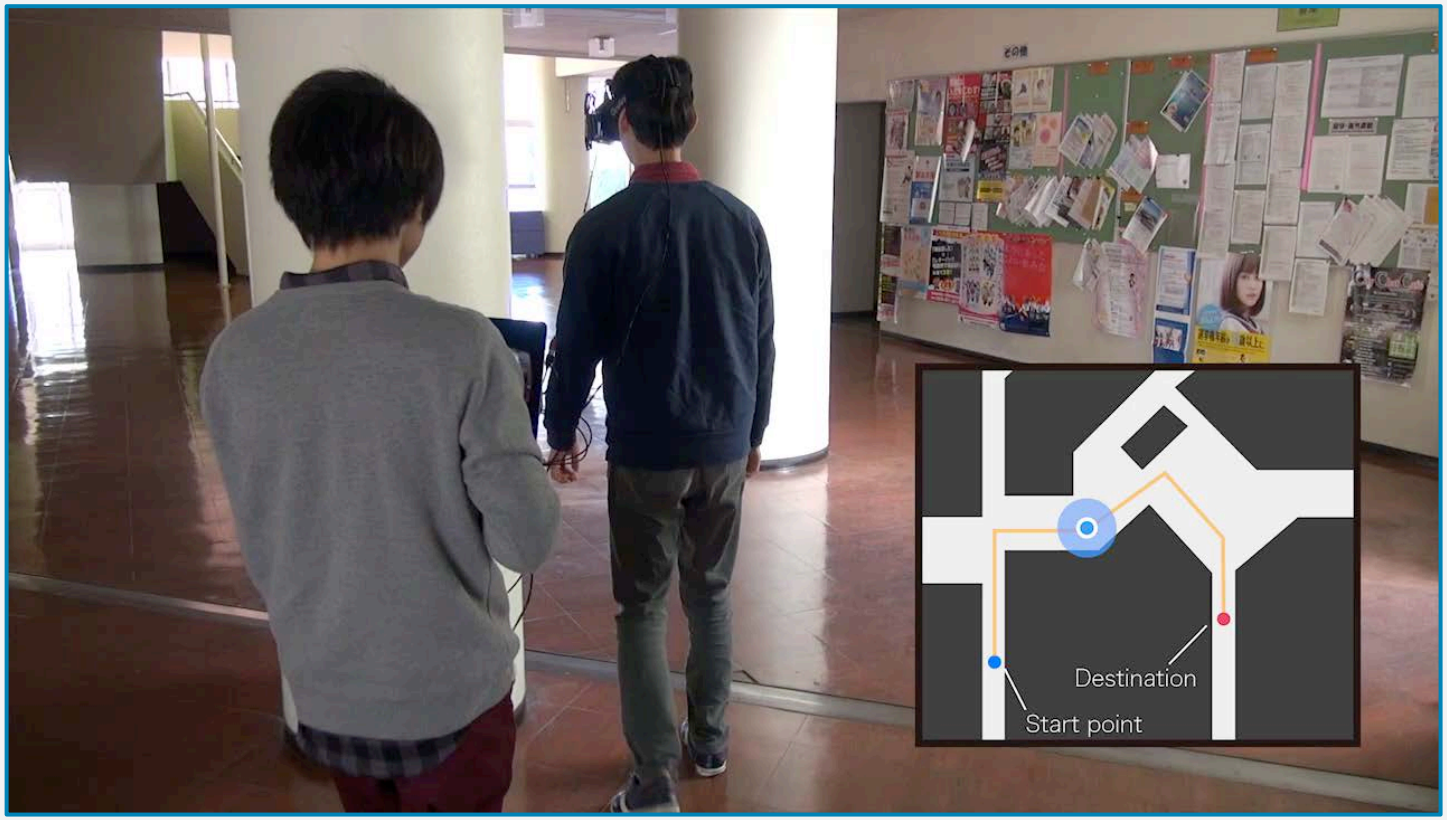
  because users might conflict each other

Applications | Walker Navigation

- **There is possibility of walker navigation system,**

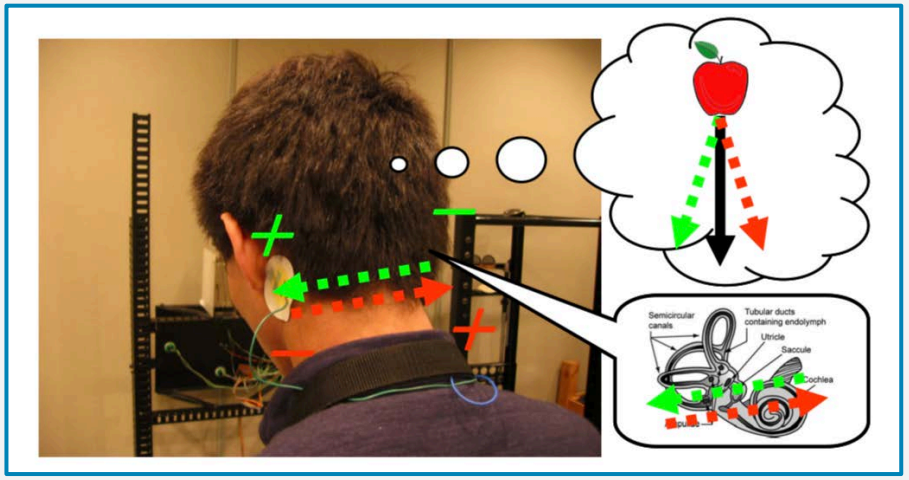
  if we can increase

  the amount of manipulation of users' walking direction



Related Work | Galvanic vestibular stimulation (GVS) [4]

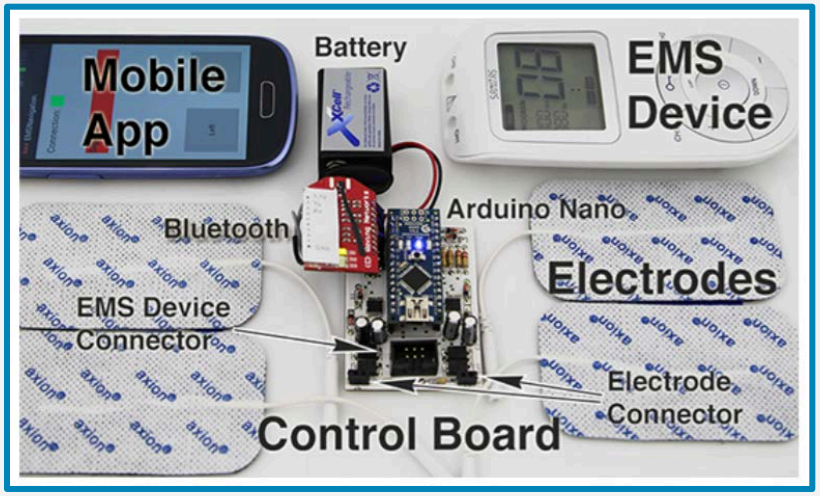
- **Administers electrical stimulation to the back of ears (the vestibules)**
- **Controls the walker's sense of balance**



[4] Maeda, T., Ando, H., Iizuka, H., Yonemura, T., Kondo, D., and Niwa, M. Parasitic humanoid: The wearable robotics as a behavioral assist interface like oneness between horse and rider. In Proc. AH '11, 18:1–18:8.

Related Work | Electrical Muscle Stimulation (EMS) [5]

- **EMS-based walker navigation system**
- **Controls walker's legs using EMS**



[5] Max Pfeiffer, Tim Du¨nte, Stefan Schneegass, Florian Alt, Michael Rohs. Cruise Control for Pedestrians: Controlling Walking Direction using Electrical Muscle Stimulation. CHI 2015, pp.2505-2514, 2015.

Related Work

- **These methods use electrical stimulation**

- **Our method is vision-based manipulation technique of human's walking direction using *only* visual feedback**

[4] Max Pfeiffer, Tim Du¨nte, Stefan Schneegass, Florian Alt, Michael Rohs. Cruise Control for Pedestrians: Controlling Walking Direction using Electrical Muscle Stimulation. CHI 2015, pp.2505-2514, 2015.

Optical Marionette:
Graphical Manipulation of Human's Walking Direction

- We found effective image-processing methods for walker movement control with an HMD
- We investigated of the effects of the image-processing methods via a user study
- Changing focal region method was most effective, and changed walking path by about 200 mm/m

Akira Ishii, Ippei Suzuki, Shinji Sakamoto, Keita Kanai
Kazuki Takazawa, Hiraku Doi, Yoichi Ochiai (University of Tsukuba)
ishii@akira.io