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SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Investigating a Sparse Peripheral Display In a Head-Mounted Display For VR Locomotion

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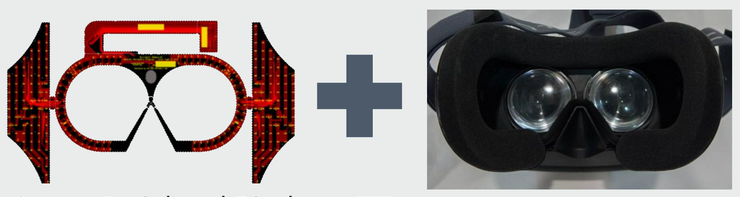
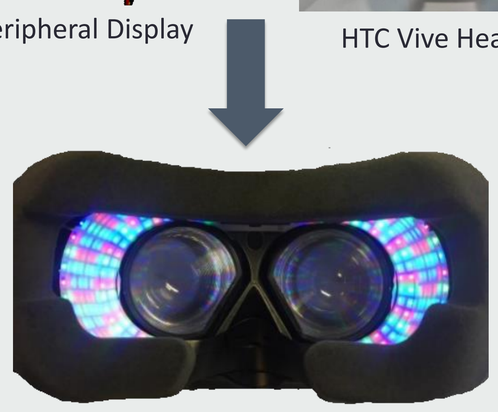
MOTIVATION

Recent head-mounted displays (HMDs) have lower field of view (FoV) (about 90° horizontally) comparing to the human eyes (about 210° horizontally). As a low-cost approach to increase the FoV of HMDs, Xiao and Benko [1] presented Sparse Peripheral Display (SPD), a low-resolution RGB LED arrays assembled inside HMD (see figure). We designed a new SPD for the HTC Vive headset to increase its FoV to 180° horizontally.



Sparse Peripheral Display

HTC Vive Headset



Assembled SPD into the HTC Vive Headset

RESEARCH QUESTIONS

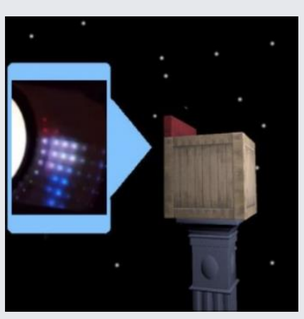
We investigate if SPD visuals can improve user experience during VR locomotion in terms of:

- Motion Sickness
- Sensation of Self-Motion (AKA vection)
- Presence
- Immersion
- Believability of Motion
- Naturalness of Motion
- User Preference

SPD VISUALS

We compared three types of SPD visuals in our study:

- **No-SPD**, where SPD was inactive similar to a regular HMD.
- **Extended SPD**, where the SPD provided visual cues consistent with and extending the HMD's main screen (see figure).
  - **Hypothesis:** Extended SPD improves overall measures but increases the motion sickness.
- **Counter-Vection SPD**, where the SPD's visuals were flipped horizontally during VR travel to provide optic flow in the opposite direction of the travel.
  - **Hypothesis:** Counter-vection SPD null the vection caused by the HMD main display, and thus cancel the motion sickness.



STUDY #1

Study Design: Within-Subject, Mixed Methods

Participants: 29 Student Volunteers (Mean Age: 27.8)

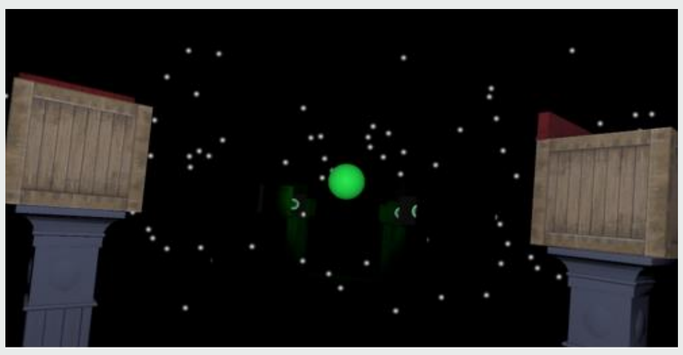
Procedure: Three trials, each contains three SPD visuals conditions i.e., No-SPD, Extended, and Counter-vection SPD, randomized by Latin Squared.

Task: Participants experienced passive linear forward motion and reported when they felt vection.

Quantitative Data Inquiry:

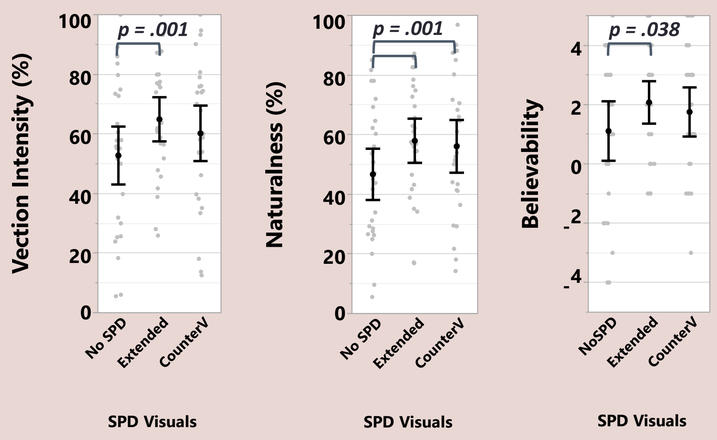
- Motion Sickness assessed by Simulator Sickness Questionnaire (SSQ) before and after the study.
- Vection Intensity and Naturalness measured after each trial using visual analog scale (0-100%).
- Other measures assessed after study using Likert Scale [-5, 5]

Qualitative Data Inquiry: Post-experiment Open-Ended Interview



STUDY #1 RESULTS

Extended-SPD resulted in higher natural experience of locomotion as well as stronger vection intensity and higher believability of motion (see figure). However, no significant difference observed in terms of other measures.



STUDY #1 DISCUSSION

Because our experimental results showed no significant effect of counter-vection peripheral visuals on vection as well as motion sickness, we hypothesised that providing counter-vection visuals only on the SPD might not be enough to null vection or reduce it significantly. To test this hypothesis, we conducted the second study to compare the strength of vection caused by SPD comparing to the vection caused by the HMD's main display.

STUDY #2

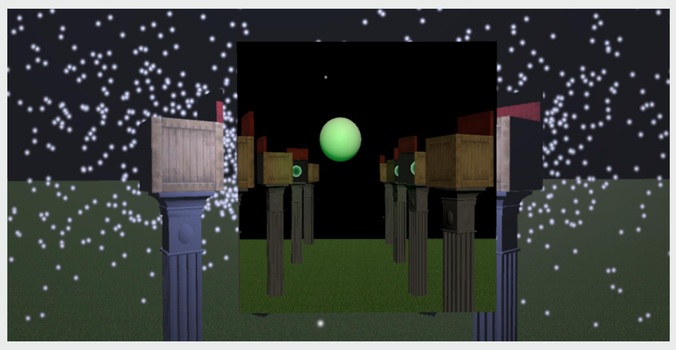
Study Design: Within-Subject, Quantitative

Participants: 15 Student Volunteers (Mean Age: 24.6)

Procedure: Three trials, each contains three SPD visuals conditions i.e., No-SPD, Extended, and Counter-vection SPD, randomized by Latin Squared.

Task: Participants experienced passive linear forward motion, while see what is behind them through a simulated mirror on HMD's main display, and see what is in front of them through a window in the mirror center. They needed to adjust the window FOV to null vection.

Quantitative Data Inquiry: The average field of view for the window at the center of the mirror, which shows the amount of vection versus counter-vection visuals are needed on the center of the HMD's display to null the vection.



STUDY #2 RESULTS

The results show no significant effect of SPD visuals on the central display window's FOV, which was between 13°-46° for all participants. The remaining area of the HMD's main display was still showing counter-vection visuals to null the vection. Thus, it seems that counter-vection cues displayed only on the SPD were not strong enough for any participants.

CONCLUSIONS

Extended-SPD visuals: The extended SPD appears promising, in terms of providing stronger vection, naturalness and believability of movement, while at the same time not significantly increasing motion sickness, which is a concern when using a wide FOV display.

Counter-vection Visuals: Despite providing strong counter-vection visuals by adjusting contrast and speed of counter-vection PD, these cues did not reduce vection or motion sickness. Our second study showed that SPD visuals could not provide strong enough vection compared to the HMD's main display. Thus, cancelling motion sickness by counter-vection visuals might need stronger visuals, which can be distracting. Instead, we can provide counter-vection visuals on part of the HMD's main display.

Future Works: Future work could investigate how the lack of sensation of self-motion affects behavioural and other perceptual measures.

[1] R. Xiao and H. Benko, "Augmenting the Field-of-View of Head-Mounted Displays with Sparse Peripheral Displays," in *ACM CHI*, New York, NY, USA, pp. 1221–1232, 2016.

IEEE VR – Reutlingen, Germany, 2018