

Analysis of the Effect of Vection Generated by Directional Optical Flow in the VR Redirected Walking Scenario

VR 방향 전환 보행 시나리오에서 방향성을 가지는 Optical Flow에 의해 생성되는 Vection의 영향 분석

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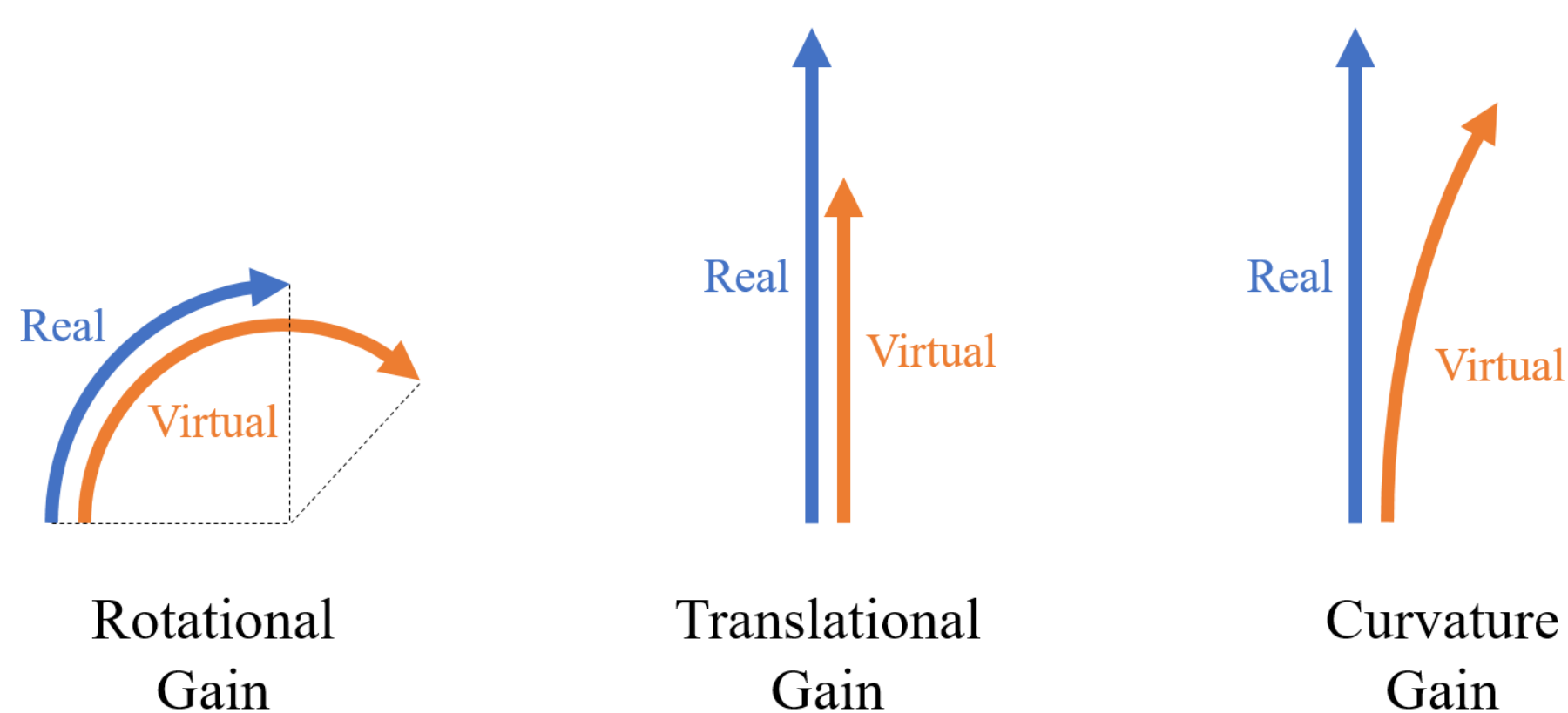
Motivation

- Human instinct is eager to explore the unexplored. The concept of Redirected Walking (RDW) was introduced to help with the aspiration of endeavoring to travel to a larger virtual environment by walking, despite the restricted play area.
- However, compared to general walking scenarios in the real world, wearing Virtual Reality (VR) headsets negatively impacts gait stability.
- Adding RDW techniques to this would increase the mismatch between visual and vestibular information, resulting in even lower gait stability and possible motion sickness.
- This study aims to discover if vection generated by Optical Flow (OF) can help improve gait stability, enlarge Detection Threshold (DT) and relieve motion sickness.

Backgrounds

Redirected Walking (RDW)

- In VR, the user can visually cut themselves off from the sight of the surrounding environment. So, for safety, the user is restricted within the limited play area.
- However, as they unrecognizably approach the virtual border of the area as they play, the system suddenly warns the users by overlaying the border grid onto the VR content.
- To make the user collide less with the boundary of the playing area, RDW redirects the user by tweaking the mapping between the walking path in the real and the virtual world.



Detection Threshold (DT)

- DT is the boundary of the amount of redirection where the human vestibular sense can detect the mismatch from the visual information.
- As long as we stay below the DT, we can unconsciously provide the user with a largely perceived play area. DT poses technological limitations to the extent of expansion that RDW techniques can generate.

Gait Stability

- Low gait stability could cause a significant safety issue, such as the user trembling or falling. Gait stability is a critical factor in guaranteeing the RDW system's safety.

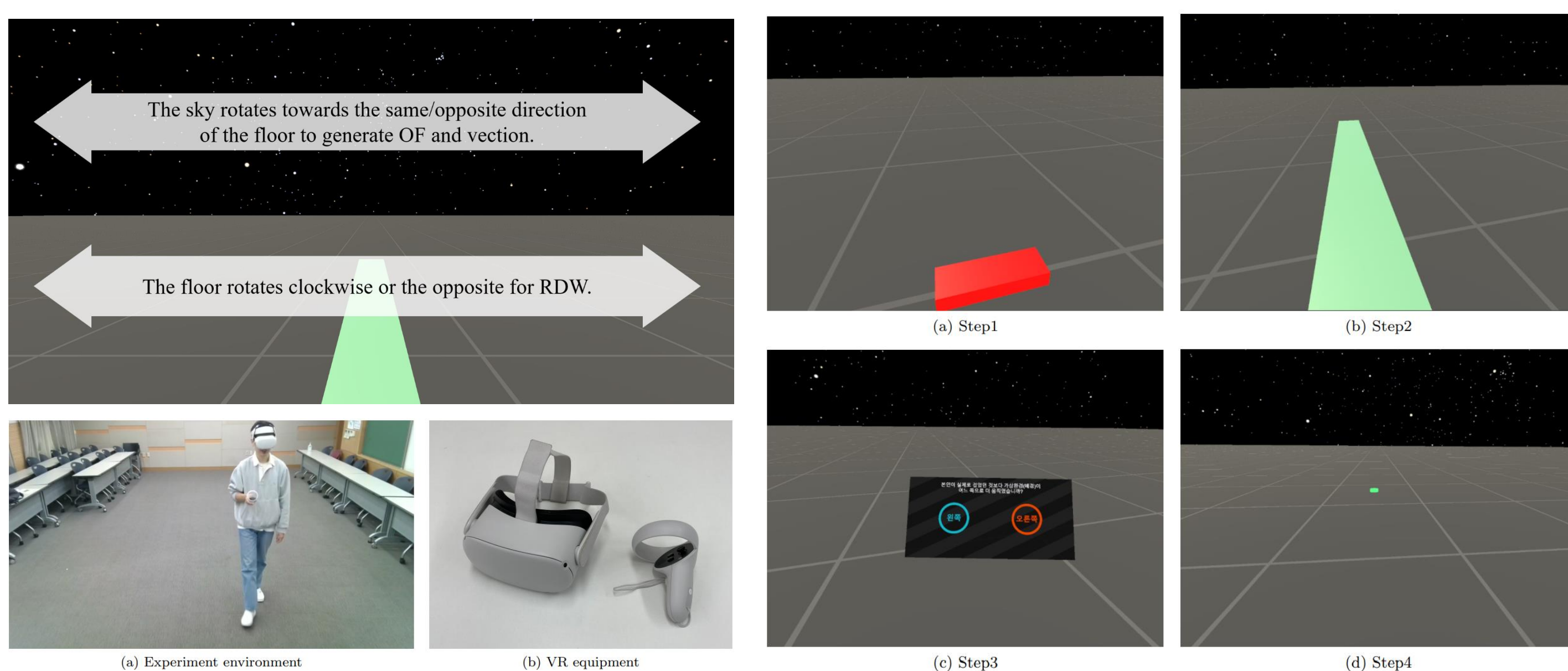
Optical Flow (OF) and Vection

- OF can create an illusion of self-motion in which the user thinks he/she is moving while they are actually not.
- This illusion then creates vection towards the opposite direction of the OF.

Implementation

Virtual Environment

- The environment mainly consisted of 2 parts: a flat floor with a lattice pattern in the lower half and a night sky full of stars in the upper half. No other unnecessary objects or decoration was placed since those themselves can act as a visual attractor for redirection.



Measurement of Detection Threshold (DT)

- Seven conditions of curvature gains were used in total: ($\pm\pi/180$, $\pm\pi/90$, $\pm\pi/45$, 0)
- The conditions were randomly presented three times each, resulting in 21 repetitions per single OF condition.
- We utilized the same methods used in Steinicke et al.'s research to obtain PSE, UDT, and LDT.

Measurement of Gait Stability

- We used flat wireless fabric pressure sensors OpenGo Moticon. These were in the shape of a shoe insole so that it could measure gait stability without disturbing the user experience.
- To support the participants with various feet sizes, we provided three pairs of different sizes of sensors and shoes: 240mm, 260mm, and 280mm. Every participant was asked to wear the same style of shoes to avoid deviations possibly caused by different designs of the shoes.
- Through plantar pressure measurements by the sensor, we acquired anterior/posterior (A/P) and media/lateral (M/L) gait stability



Optical Flow (OF)

- Three distinct conditions of the directions of vection: None, Same, and Opposite, were applied as independent variables (IV).
- None: No additional vection other than the amount of redirection is provided. However, in this experiment, the participant can distinguish whether the floor is relatively rotating or not by observing the relative movement of the two components: floor and sky.
- Same: Additional vection towards the direction of redirection is given.
- Opposite: Vection was given towards the opposite direction of the redirection.

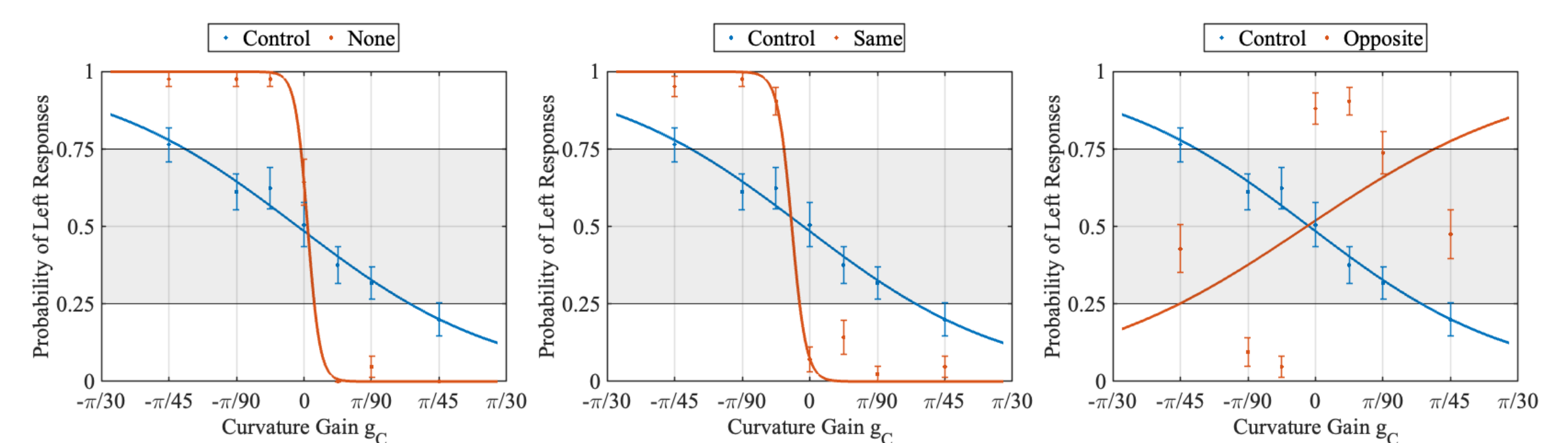
Results & Discussion

Participants

- N = 14, with the range of age 19~25, mean 22.4, and standard deviation 2.03.

Detection Threshold (DT)

- Both UDT and LDT converged to 0 in 'None' and 'Same' cases. This means that the participants were very sure about the direction of the redirection and were all very right, while they were very wrong with the 'Opposite' case.
- The reason for this could be found in the way OF was implemented. The biggest hurdle would be that in order to generate the OF, it is likely that the object that generates OF itself would be the most trivial visual cue.
- People heavily rely on their visual cues while still paying at least minimal attention to their vestibular information when detecting changes in the virtual environment.
- This supports the necessity of the novel method to measure DT in the scenario in which both RDW and vection are applied. From oral feedback from the participants, we figured out that the 'Opposite' settings did actually confuse them in perceiving the directions.
- DT measurement methods that do not rely heavily on visual cues would help relieve this situation. Alternatively, if it was not 2AFC, for instance, if there was explicitly a choice alternative representing confusion in the direction, the result might have been different.



Gait Stability

- All 3 cases of vection proposed in this research had statistically significant hindrances in M/L gait stability. This can mean that adding vection actually deteriorates gait stability.
- Still, one limitation is that the control group consisted of different participants than in this experiment, and the sky material was also different.

Simulator Sickness & Presence

- The Simulator Sickness Questionnaire (SSQ) was used to monitor motion sickness.
- The Igroup Presence Questionnaire (IPQ) was used to measure immersion and presence, simulator sickness, and discomfort.
- A small increase in SSQ scores and a slight decrease in IPQ scores compared to the case without any vection.
- However, considering the nature of the virtual environment, this result seem reasonable because the entire background of the sky rotated as if the participant thought he/she was walking straight. It should have caused cognitive dissonance.
- It is also interesting that all three conditions show quite similar tendencies in the result. It could be further utilized to redirect the user regardless of the direction of the redirection in the virtual environment.

