Validating applicability of VR technology to predict guidance effectiveness of crowd-control measures: A VR experiment to reproduce an empirical experiment

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Abstract Various factors, such as congestion and environmental conditions, need to be considered in predicting the guidance effectiveness of crowd-control measures. Although it is expected that virtual reality (VR) can be used to simulate these complex contexts, further research is required to validate the applicability of the technology. In this study, an online nonimmersive VR experiment that reproduced an empirical experiment near a stadium was conducted. The route selection preferences between both experiments are compared. Compared to the empirical data, the VR data show a similar trend in guidance effectiveness but overestimated compliance rate, necessitating further analysis to fill the gap.

Keywords Crowd-Control Measures, Route Selection Preferences, Compliance Rate, Online Nonimmersive virtual reality (VR) Experiment, Empirical Experiment

Introduction

Crowd control needs to be properly designed to ensure the safety and comfort of visitors at event venues. Several factors that can influence the route selection preferences of visitors, such as congestion and environmental conditions, need to be considered to effectively predict the guidance effectiveness of crowd-control measures. Although it is expected that virtual reality (VR) can help designers simulate such complex contexts, further research is required to validate the applicability of VR technology [1].

In this study, we conducted an online nonimmersive VR experiment that reproduced an empirical experiment in the vicinity of a stadium after baseball games. In the VR experiment, we replicated crowd-control measures, pedestrian flow, and spatial layout. We compared the route selection preferences between the VR and empirical experiments, and validated whether VR technology can be used to predict the guidance effectiveness of crowd-control measures under the complex contexts.

Experiments

Empirical experiment near a stadium after baseball games

We conducted an empirical experiment near a stadium after baseball games. Figure 1 (left) shows a snapshot of the experiment. Two routes can be adopted to make it to the train station, left and right. The right route is faster but tends to get congested; therefore, we guided stadium visitors to the left route. We investigated four crowd-control measures: 1) *no control*, 2) guidance using *handheld signs*, 3) guidance via *announcements*, and 4) guidance via a *combination* of handheld signs and announcements. We used each pattern on a different day and counted visitors passing each route.

VR experiment to reproduce the empirical experiment

We conducted an online nonimmersive VR experiment that replicated the crowd-control measures, pedestrian flow, and spatial layout of the empirical experiment. Figure 1 (right) shows an example of a VR scene. We gathered 1,026 participants that had visited the stadium within the past three years.

The VR experiment reproduced the same four patterns of crowd-control measures as in the empirical experiment. Accordingly, 165 VR scenes were generated for each pattern; therefore, we had 660 scenes in total. We presented 10 randomly selected scenes to each participant, and the participants answered with their preferred route—left or right—for each scene. We collected a total of 10,260 samples, but owing to differences in the number of samples for each scene, we randomly extracted eight samples for each scene.

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Figure 1: Snapshot in the empirical experiment (left). Example of a reproductive VR scene (right).

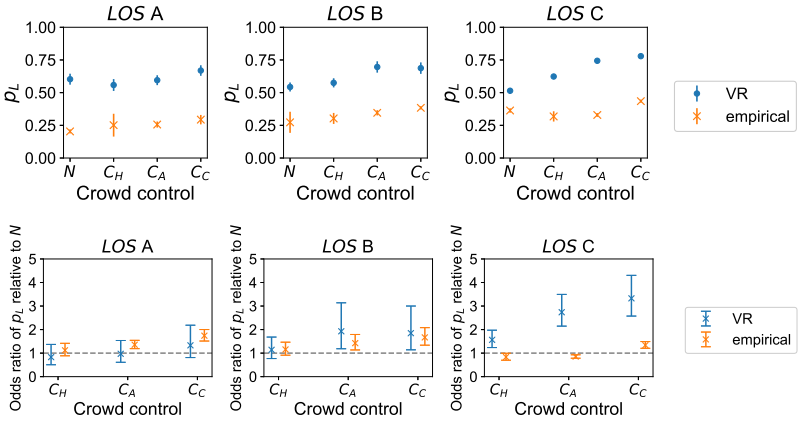

Figure 2: Left-route selection rate p_L (upper row) and odds ratio of p_L relative to *no control* cases (lower row) with congestion levels, represented as *levels of service* (*LOS*) [2]. N, C_H, C_A, and C_C denote *no control*, guidance using *handheld signs*, guidance via *announcements*, and guidance via a *combination* of handheld signs and announcements, respectively.

Owing to the lack of empirical data on pedestrian walking positions, we randomly assigned the walking position of the participant avatar. The avatar was set on a random point, 20 m from the junction, and it was moved along the path to a point 5 m from the junction. Pedestrian agents were walking around the avatar. Flow of pedestrian agents were set to have a range similar to that measured empirically. We randomly determined the number and route selections of agents in the flow range for each scene.

Results and discussion

Figure 2 shows the left-route selection rate p_L and odds ratios of p_L relative to *no control* cases for each crowd-control measure and congestion level. We consistently guided pedestrians to the left route, thus, p_L also denotes compliance rate, and the odds ratios reflect the guidance effectiveness. We calculated *LOS* [2] as congestion levels; *LOS* C was observed in the most congested conditions.

Figure 2 shows that p_L was overestimated in the VR experiment compared to that of the empirical experiment. The odds ratios of p_L diverged significantly in *LOS* C. However, the order of the odds ratios among crowd-control measures exhibited a similar trend for both experiments.

The similar trend of odds ratios suggest that the guidance effectiveness can be predicted using the VR data with some correction for the overestimation. The significant divergence in *LOS* C suggests that some factors associated with congestion caused the gap in the route selection preferences; for instance, real pedestrians in crowded conditions may have faced difficulty in changing their routes owing to interference from other pedestrians around them. Additionally, the walking position is another factor that may have caused the overestimation. We are currently conducting an analysis that considers these factors.

Conclusion

In this study, we conducted a VR experiment that reproduced an empirical experiment and compared the route selection preferences between both experiments. We found a similar trend of the guidance effectiveness for both experiments. However, the VR data overestimated the compliance rate compared to that of the empirical experiment, necessitating further analysis to fill the gap.

Bibliography

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