Enhancing Evaluation of Room Scale VR Studies to POI Visualizations in Minimaps

B. Ajdadilish[1], S. Kohl[1], K. Schröder[1,2]

[1]Human Data Interaction Lab, Zuyd University of Applied Sciences, Netherlands ; [2]Human Computer Interaction Center, RWTH Aachen, Germany

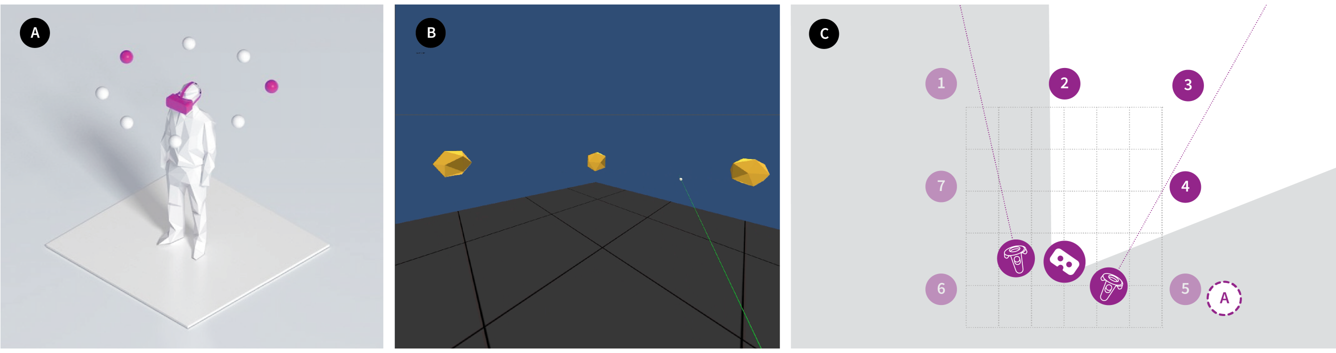

Figure 1: *Overview of the proposed minimap showing a VR user study. A) The participant in the experiment; B) Point of view of the participant within the VR environment; C) Minimap showing the points of interest for this study: the participants orientation, the point of view, the hand orientation, the seven virtual objects, and an audible cue.*

Abstract

Understanding and evaluating user behavior in virtual reality environments is challenging for researchers. Stereoscopic perception is highly dependent on the point of view, so it is necessary to account for multiple spatial positions. Robust tools and methods to analyze these spatio-temporal data are lacking. We propose a design solution for spatio-temporal data visualization for room-scale VR studies. Our result is a top-down minimap that plots 3D point of interest coordinates of room-scale virtual reality environments to a 2D visualization. The video stream from the head mount display is next to the minimap showing the top-down view of the scene, reflecting the visual stimuli that were perceivable by the user. Both views are linked such that replaying the user session is synchronized in time. The minimap enables researchers to review and replay the recorded user session for in-depth study, allowing them to gain insightful information about users' behavior in virtual environments.

CCS Concepts

• ***Human-centered computing*** $\rightarrow$ ***Visualization techniques;***

1. Introduction

With the notable maturation of virtual reality (VR) technologies over the past few years, the employment of VR technologies in research studies has increased tremendously across various research communities [PH18, KKC*20]. The availability of affordable VR devices has increased along with their popularity. Accurate methods of assessing user studies are vital to utilizing the potential of this technology. In user studies, observation of users in their context can be insightful and help researchers to understand the cause and effect relationships of user behavior [HG21]. A commonly used technique to study user behavior in 2D applications relies on recording and analyzing user interaction with the application [CI04]. Observations of 2D interfaces are relatively easy to evaluate; however, understanding what the user is observing in VR studies is complicated. This difficulty is due to the users stereoscopic perception being highly dependent on their point of view (POV). To fully understand the user's perception and behavior, the multiple individual spatial positions need consideration within their respective temporal contexts. The spatial relation between stimuli and POV is vital to judging spatial influences on the perception of things such

DOI: 10.2312/evp.20221136

as depth or overlapping effects. One solution to tackle this challenge is to provide the observer with the possibility of replay and reviewing the user's sessions [LFH17]. Observing users' POV allows insight into their performance, identifying usability problems, and detecting anomalies in the collected user data [HG21]. However, simply replaying the POV recordings of a user does not provide sufficient insights in many cases for two reasons: First, POV recordings do not show so-called off-screen objects - objects outside the viewpoint that can be beside or behind the user. Additionally, POV recordings do not show invisible stimuli, such as sound origin locations. Such stimuli are essential to understanding user behavior concerning these spatial positions in a VR environment due to their room-scale nature. In this paper, we propose a design solution for spatio-temporal data visualization of room-scale VR studies. The proposed solution to the design challenge presented here is a minimap used to supplement POV recordings when assessing or validating individual participants. This minimap provides researchers with review and replay functions of the room-scale VR experiment session from a top-down view with highlighted points of interest (POI). Doing so enables researchers to understand the relationships between the various spatial positions of the experiment faster and place them in context to the user behavior.

2. Related Work

One of the earliest and still most common methods of evaluating user behavior in VR is to replay POV recordings from the VR sessions [GPB*00]. This approach can be applied to usability and system evaluation, allowing experts to analyze the POV of users within the virtual environment. However, being limited to the view field of the participant in this approach has led to criticism. For example, recordings cannot guarantee knowledge of the location of the input devices when the user is not looking at them [HG21]. Research has started to utilize visualization for evaluation purposes to address this issue of scope limitation in POV recordings via utilization of the spatio-temporal data collected during VR sessions to improve upon the recordings. Outside of the VR domain, there have been proposals for various visualizations of spatio-temporal data, including trajectories of moving objects, Choropleth maps, and animated maps (minimaps) [ACM19]. A relevant challenge is understanding which visualization techniques better support VR researchers in analyzing user behavior. Cartography, such as minimaps, has played a significant role within the 2D human-computer interaction research domain; it is often used for navigation purposes and has been extensively researched in computer games [KR18, ZGHMG21, HZ22], and sports reports [ACM19, WK13]. Utilizing this type of visualization helps simplify spatio-temporal data and place users within the context of multiple POIs. However, the use of visualizations is under-explored in VR evaluations. One example of utilizing visualizations for VR evaluations is the VR evaluation kit *EVE* which includes a birds-eye map of the participant's walk path in a city [GWJ*16]. The toolkit enables researchers to inspect the participant's spatial behavior in detail with the initial focus on navigation studies. The tool only focuses on spacial position but ignores head orientation and field of view in the birds-eye map. Further, the birds-eye map does not show invisible stimuli such as sound locations but only displays a map including the participant's walking path. Another example of visualization for VR evaluations is the work by Chittaro et al. [CI04] which utilizes heat-map visualizations to illustrate how often an area was in the field of view of the user. However, these solutions are often not generalizable or provide only rudimentary functionalities. We, therefore, conclude that there is a gap in research regarding the utilization of visualization for spatio-temporal data. We believe that this type of data can be utilized to improve POV recordings by providing the lacking information from outside the participant's view but has a significant impact on user behavior.

3. The Minimap

Based on the theoretical design space evaluation and previous experience with VR research studies, a custom minimap was developed that plots 3D coordinates of room-scale VR environments to a 2D visualization. The minimap collects 3D coordinates of positions and rotations of the head-mounted display, controllers, (virtual) objects, and additional study-related POI such as audio locations within unity applications and the related time stamps. Furthermore, it records the video stream from the head-mounted display. The logged parameters and timestamps are saved in JSON format and loaded in a JavaScript application utilizing D3 and three.js to convert the 3D coordinates to a 2D canvas. Controlled by temporal links, all relevant marker positions are updated and synchronized with the correspondent mp4 video widget. A replay of individual participant sessions becomes possible by combining this data with the interaction logs, allowing researchers to understand the participant's POV concerning the entire scene at any point in time. Next to the minimap showing the top-down view of the scene, the video stream from the head-mounted display reflects the visual stimuli that were perceived by the user. Both views are linked such that replaying the user session is synchronized in time. These features are shown in Figure 1. The example chosen in the figure is of a user trying to detect an audible cue originating from one of seven virtual objects. The audible cue in the example originates from object 5; therefore, it is out of the user's field of view. Using the proposed minimap helps researchers understand the relation between the selected object by the user, audible cues, and field of view.

4. Conclusion and Future Work

We present a first step on how minimaps can enhance user studies in VR. Our minimap enables researchers to review and replay the recorded VR experiment data for in-depth evaluation studies. This minimap will help researchers get insightful information about users' dynamic behavior in VR environments. Furthermore, the ability to analyze and understand user behaviors in context will improve design choices. The relationship between the subjective and objective POV in space is especially important for enhancing the understanding of the users's perception of stimuli in a stereoscopic study setting. Future research needs to conduct qualitative and quantitative evaluations of this minimap across various research contexts to ensure high usability and generalisability of the tool. Multiple design challenges are still unexplored such as how the spatial height of objects could be presented optimally. One possible approach could involve multiple views of individual perspectives.

References

[ACM19] AFONSO A. P., CARMO M. B., MOUCHO T.: Comparison of visualization tools for matches analysis of a moba game. In *2019 23rd International Conference Information Visualisation (IV)* (2019), IEEE, pp. 118–126. 2

[CI04] CHITTARO L., IERONUTTI L.: A visual tool for tracing users' behavior in virtual environments. In *Proceedings of the working conference on Advanced visual interfaces* (2004), pp. 40–47. 1, 2

[GPB*00] GREENHALGH C., PURBRICK J., BENFORD S., CRAVEN M., DROZD A., TAYLOR I.: Temporal links: recording and replaying virtual environments. In *Proceedings of the eighth ACM international conference on Multimedia* (2000), pp. 67–74. 2

[GWJ*16] GRÜBEL J., WEIBEL R., JIANG M. H., HÖLSCHER C., HACKMAN D. A., SCHINAZI V. R.: Eve: a framework for experiments in virtual environments. In *Spatial cognition x*. Springer, 2016, pp. 159–176. 2

[HG21] HOWIE S., GILARDI M.: Virtual observations: a software tool for contextual observation and assessment of user's actions in virtual reality. *Virtual Reality 25*, 2 (2021), 447–460. 1, 2

[HZ22] HORBIŃSKI T., ZAGATA K.: View of cartography in video games: Literature review and examples of specific solutions. *KN-Journal of Cartography and Geographic Information* (2022), 1–12. 2

[KKC*20] KOURTESIS P., KORRE D., COLLINA S., DOUMAS L. A., MACPHERSON S. E.: Guidelines for the development of immersive virtual reality software for cognitive neuroscience and neuropsychology: the development of virtual reality everyday assessment lab (vr-eal), a neuropsychological test battery in immersive virtual reality. *Frontiers in Computer Science* (2020), 12. 1

[KR18] KHAN N., RAHMAN A. U.: Rethinking the mini-map: A navigational aid to support spatial learning in urban game environments. *International Journal of Human–Computer Interaction 34*, 12 (2018), 1135–1147. 2

[LFH17] LAZAR J., FENG J. H., HOCHHEISER H.: *Research methods in human-computer interaction*. Morgan Kaufmann, 2017. 2

[PH18] PAN X., HAMILTON A. F. D. C.: Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape. *British Journal of Psychology 109*, 3 (2018), 395–417. 1

[WK13] WALLNER G., KRIGLSTEIN S.: Visualization-based analysis of gameplay data–a review of literature. *Entertainment Computing 4*, 3 (2013), 143–155. 2

[ZGHMG21] ZAGATA K., GULIJ J., HALIK Ł., MEDYŃSKA-GULIJ B.: Mini-map for gamers who walk and teleport in a virtual stronghold. *ISPRS International Journal of Geo-Information 10*, 2 (2021), 96. 2