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Better Real-Life Space Utilization in VR Through a Multimodal Guardian Alternative

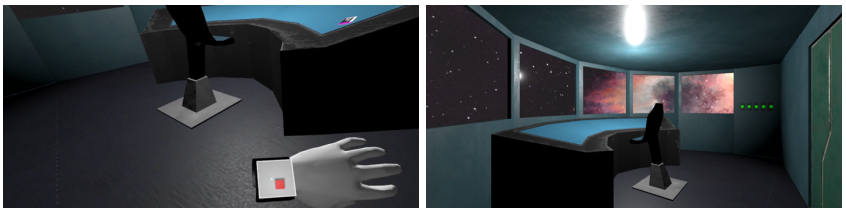
Jonas Lind[†], Kristian Sørensen[†], Arlonsompoon Lind[†], Mads Sørensen[†], Jakob Trærup, and Ivan Nikolov

Aalborg University, CREATE, Rendsburggade 14, Aalborg, Denmark
jbl20, ksaren20, alind19, mwsa17, jtraru19@student.aau.dk & iani@create.aau.dk
[†] These authors contributed equally to this work

Abstract. Space utilization and better exploration are important parts when building VR experiences that can be used by people with different play styles, requirements, and needs. A key factor in achieving this is a flexible guardian system that informs users about their position and potential hazards. We propose an alternative guardian solution that incorporates various modalities, notification types, diegetic and non-diegetic interfaces, which demonstrated improved space utilization and mobility compared to a standard system. However, this alternative solution may come with a higher cognitive load. We believe this system demonstrates that a better more immersive alternative to the Guardian solution is possible, which would maximize the utilized real-world space while adding better immersion. We plan to use this initial research as a basis for developing more robust versions, utilizing different combinations of the proposed features.

Keywords: VR · Space utilization · Diegetics · Guardian · Exploration

1 Introduction



(a) Diegetic Watch Component (b) Escape Room Puzzle

Fig. 1: An example proposed guardian component - a diegetic pull visual notification in the form of a watch for self-positioning (Figure 1a) and a room from the space-themed escape room used to test the proposed solution (Figure 1b).

Virtual reality (VR) is a rapidly expanding research field that spans entertainment, design, training, and mental health treatment. However, the nature of VR headsets, which isolate users from the real world, requires methods to orient them and prevent injury or environmental damage. Research has explored solutions such as integrating real-world elements and alerting users to potential dangers, but these often require additional non-standard hardware [2, 5, 3, 4]. Although these methods provide high levels of immersion, they have the drawback of requiring non-standard hardware. Conversely, the Meta Quest2 VR headset includes a built-in solution called the VR guardian, which is lightweight and easy to use but may disrupt immersion by showing real-world borders when users get too close.

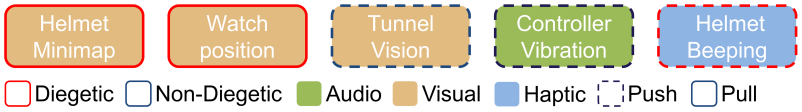


Fig. 2: Components of the proposed VR guardian alternative. The five components are a combination of diegetic and non-diegetic interfaces, push and pull notifications and visual, audio and haptic modalities.

Our paper introduces a novel system that combines diegetic and non-diegetic methods with push and pull notifications of various modalities. We draw on previous research by Medeiros et al [1] and Kanamori et al [6], which shows that users prefer multiple types of guidance to help them navigate VR environments. Our solution not only enhances playspace utilization and different playstyles but also minimizes immersion-breaking visuals. We evaluate our system through an interactive virtual escape room that requires users to explore the environment and approach the play borders. Our results demonstrate that our approach provides better real-world space utilization than the Meta VR guardian, although some tradeoffs in usability and straightforwardness are observed. The different components of our system can be used in various VR scenarios, such as education, training, architecture, and gaming.

2 System Design

We have selected five components to build our guardian alternative solution, representing different modalities (audio, visual, or haptic), diegetic or non-diegetic interfaces, and push or pull notifications. The diegetic interfaces were designed to promote immersion in a space station scenario. These components can be viewed in Figure 2. We selected three modalities to complement each other and assist users, regardless of their sensory state. The push and pull notifications were chosen to suit different play styles and immersion preferences, enabling users to either focus on other tasks or check their location if they feel disoriented. Lastly,

non-diegetic components were chosen as last-minute push notifications designed to fully capture users' attention and prevent them from going out of bounds. An example of the diegetic watch component is shown in Figure 1a.

To test the guardian components, a virtual reality escape room with a space station theme was created. The rooms are separate square spaces, the same size as the physical playfield, connected by long narrow hallways. This design forces users to move around the playfield, reach the borders, and interact with the guardian components. An example of one of the rooms can be seen in Figure 1b.

3 Experiments and Results

A comparison was conducted between the developed guardian feature (DGF) and the Quest 2 guardian or standard guardian feature (SGF) to determine how the proposed components would impact users' space utilization and exploration in VR. The experiment had 30 participants, with 15 for both tests, who had time to get used to both guardian features before playing through the experience with a 15-minute timer. Users walked in a 4 by 4-meter physical space and could manually turn once they reached a boundary. The X and Y position of the users was captured using their head-mounted display, along with the overall completion time, and a heat map was generated based on the captured positions (Figure 3). The heat maps revealed that the DGF users utilized 9.33% more of the total play area compared to SGF users. In addition, single red point "clusters" representing users standing in one location were less prevalent and more spread out in the DGF test, indicating that users were more likely to explore rather than stay in one place. DGF participants took 23.9% more time to go through the escape room, which can be attributed to both longer exploration and more interaction with the guardian.

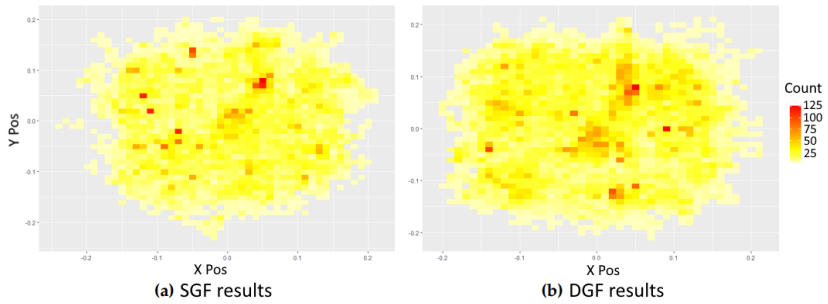
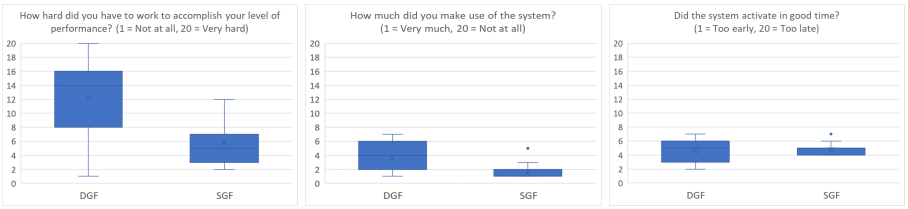


Fig. 3: Heat maps generated from user physical space utilization. The Meta VR guardian or standard guardian feature (SGF) results are shown in Figure 3a, while our proposed developed guardian features (DGF) are shown in Figure 3b.

After the experiment, users were asked to evaluate their experience with the system they used, through the Raw Nasa TLX [7]. Users reported that they

felt they needed to do more work overall using the DGF system, resulting in a higher physical and mental load (Figure 4a). This could be because users had to manually bring up DGF solution, forcing them to actively think about their position instead of using the passive approach of the SGF Meta guardian. However, users also reported that they needed to use the DGF system less, indicating that the system helped orient them better (Figure 4b). The participants then filled in a System Usability Scale test, with the SGF achieving a score of 73.5 and the DGF only scoring 51.7 points. This suggests that more work is needed to optimize and combine the proposed diegetic and non-diegetic guardian features. The DGF system activation time was overall comparable to the SGF, but it had a larger deviation in user responses as seen in Figure 4c. Therefore, fine-tuning when and how the different components are initialized and creating cascades of warning depending on user proximity would be necessary to improve the system.



(a) (b) (c)

Fig. 4: Results from the Raw Nasa TLX. The DGF system required more involvement from users, because of the presence of both push and pull notifications (Figure 4a), while also requiring less overall interaction than the SGF solution (Figure 4b). The two systems have comparable activation time, with the DGF showing a larger deviation (Figure 4c).

4 Conclusion

In this research, we tested a combination of modalities, notifications, and interfaces to see their impact on space utilization and VR exploration. Our solution integrated push and pull notifications with diegetic and non-diegetic interfaces, which could be activated by the user or triggered automatically to provide warnings. Three notification modalities were used to provide location information, regardless of the user's cognitive load. We compared our system to the Meta VR guardian and found that while our system resulted in higher space utilization and mobility, users reported higher mental and physical load. Moving forward, we aim to optimize and refine our system to improve its effectiveness. To do this we will focus on an iterative user testing methodology where we will create different combinations of components based on the visual, audio, and haptic modalities. We test the usability and any perceived problems by users through

a series of Rapid Iterative Testing and Evaluations (RITE). We will look at use cases for training personnel in specified 3D spaces, where work area utilization is required, as well as for educational purposes for creating escape rooms utilizing larger spaces and boosting user teamwork.

References

1. Medeiros, D., Anjos, R., Pantidi, N., Huang, K., Sousa, M., Anslow, C. & Jorge, J. Promoting Reality Awareness in Virtual Reality through Proxemics. *2021 IEEE Virtual Reality And 3D User Interfaces (VR)*. pp. 21-30 (2021)
2. Saker, M., & Frith, J. Coextensive space: virtual reality and the developing relationship between the body, the digital and physical space. Media, Culture & Society, 42(7-8), 1427-1442 (2020).
3. Faltaous, S., Neuwirth, J., Gruenefeld, U., & Schneegass, S. SaVR: Increasing Safety in Virtual Reality Environments via Electrical Muscle Stimulation. In Proceedings of the 19th International Conference on Mobile and Ubiquitous Multimedia (pp. 254-258) (2020, November).
4. Valentini, I., Ballestin, G., Bassano, C., Solari, F., & Chessa, M. Improving obstacle awareness to enhance interaction in virtual reality. In 2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR) (pp. 44-52). IEEE (2020, March).
5. Hartmann, J., Holz, C., Ofek, E., & Wilson, A. D. Realitycheck: Blending virtual environments with situated physical reality. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (pp. 1-12) (2019, May).
6. Kanamori, K., Sakata, N., Tominaga, T., Hijikata, Y., Harada, K. & Kiyokawa, K. Obstacle Avoidance Method in Real Space for Virtual Reality Immersion. *2018 IEEE International Symposium On Mixed And Augmented Reality (ISMAR)*. pp. 80-89 (2018)
7. Hart, S. G., & Staveland, L. E. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In Advances in psychology (Vol. 52, pp. 139-183). North-Holland. (1988)