Exploring the Impact of Virtual Human and Symbol-based Guide Cues in Immersive VR on Real-World Navigation Experience

Omar Khan*
Department of Computer Science
University of Calgary

Anh Nguyen†
Department of Computer Science
University of Calgary

Michael Francis‡
Department of Electrical and
Software Engineering
University of Calgary

Kangsoo Kim§
Department of Electrical and
Software Engineering
University of Calgary

Figure 1: Excerpts of the VR route-learning task the participants performed, and the two virtual guide representations. (a) symbol-based guide cues, (b) a virtual human-based guide, and (c) a part of our 3D reconstructed virtual environment.

Abstract

In this paper, we explore how navigation performance and experience in a real-world indoor environment is impacted after learning the route from various guide cues in a replicated immersive virtual environment. A guide system, featuring two distinct audiovisual guide representations—a human agent guide and a symbol-based guide—was developed and evaluated through a preliminary user study. The results do not show significant differences between the two guide conditions, but offer insight into the user-perceived confidence and enjoyment of the real-world navigation task after experiencing the route in immersive virtual reality. We discuss the results and direction of future research.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Human-centered computing—Human computer interaction (HCI)—HCI design and evaluation methods—User studies

1 Introduction

Navigation and route-learning, acquiring knowledge about a path from one location to another, plays a pivotal role in numerous real-world tasks. For instance, the ability to navigate designated routes efficiently and safely during an emergency evacuation is crucial.

The integration of Immersive Virtual Reality (IVR) with reality capture technology—a set of tools and techniques for digitally capturing and recreating physical environments—allows for innovative possibilities [1]. This combination facilitates the creation of virtual replicas of real-world locations, allowing for the simulation of scenarios and the enhancement of route-learning experiences [3]. The potential benefits of leveraging IVR for route-learning extend beyond emergencies, offering a versatile, immersive platform for improving navigation skills in various contexts.

In this paper, we investigate how different visual guide cues in IVR could influence the user's real-world navigation experience, e.g., confidence in navigation performance, cognitive load, perceived enjoyment, etc. For the study, we developed a guide system in an IVR environment based on a real-world building using reality capture technology. The system incorporates two distinct audiovisual guide representations: (1) an *embodied virtual human* with human-like appearance and locomotion behavior, and (2) a *symbol-based guide* that undergoes visual changes based on its state, e.g. representing movement with an arrow (Figure 1). Through the study, we aim to address the following research questions (RQs):

RQ1. How do different visual cues (i.e., virtual human and symbol representations) in the IVR navigation experience impact the user's navigation *performance* in the real world?

RQ2. How do the visual cues in IVR influence the general *user experience* in real-world navigation tasks?

2 Immersive Virtual Navigation Environment and Visual Guide Cues

For our study, we created an immersive virtual environment for users to explore and developed a navigation guide system for this environment with an embodied virtual agent and directional symbols, using the Unity game engine (v2021.3.8f1) and Meta Quest 2 VR headset.

Reconstructed Indoor Environment and Navigation We constructed a 3D model of the interior of one of our campus buildings by capturing 360° photos with the Insta360 X3 camera[1]. These photos were then passed to the Matterport reality capture software[2] to generate a 3D mesh model of the building (Figure 1(c)). The reconstructed indoor environment consists of seven floors, but we used only the first and fifth floors in our study. The experience starts on the first floor where the user is instructed to read a set of slides containing instructions on how to move around in the virtual environment (point-and-click teleportation). Once the user is familiar with the environment and controls, they are told that the main task of the system is to follow a virtual guide to learn a route in the building, and to memorize the locations of three sticky notes placed along the route. The user is then teleported to the starting location of the task, which corresponds to the room on the fifth floor, in which the study is taking place in the real world.

Virtual Human and Symbol-based Guide Cues We developed two visual guides, which the user needs to follow during the navigation task in the virtual environment. The first form of the guide is an animated virtual human (female and racially ambiguous),

*e-mail: omar.khan2@ucalgary.ca
†e-mail: anh.nguyen5@ucalgary.ca
‡e-mail: mjfranci@ucalgary.ca
§e-mail: kangsoo.kim@ucalgary.ca (correspondence)

[1]Insta360: `https://www.insta360.com/` (Accessed: 2023-12-12)
[2]Matterport Developer SDKs: `https://matterport.com/platform/developers` (Accessed: 2023-12-12)

which we created using Character Creator 4[3]. The virtual human exhibits various animations, e.g., idle, speaking, walking, and lip-syncing, which match the guide's instructions. The second form is a symbol-based representation, which alternates between three 3D models based on the state of the guide—a green arrow sliding across the floor in a moving state, a red stop sign when the guide stops to await user input, and a red location marker when the guide reaches any of the sticky notes. We chose this iconography because it is commonly used in most navigation applications, such as Google Maps, to which the participants in the study are already accustomed.

Both forms of the virtual guide feature a green interactive button located directly above them, with the text "next step →" overlayed onto it (Figure 1(a, b)). Upon clicking this button, a pre-loaded audio instruction clip is played explaining the next set of directions in the route. For example, if a user clicks on the green button, an audio clip may play which instructs the user to "turn left and walk to the end of the hall". Then, the virtual guide, either the virtual human or the symbols, will turn left and walk/move to the end of the hall for the user to follow. After this is complete, the green button reappears above the guide, which will play the next set of directions. This loop of interaction repeats until the user has fully traversed the route, and the three sticky notes have been found and checked off by the user.

3 Preliminary Study and Hypotheses

As a preliminary study approved by the University of Calgary Research Ethics Board (REB23-0849), we conducted a between-subject study ($N = 10$; 2 female, 8 male; age $M = 20.50$, $SD = 1.20$) to evaluate the effects of two virtual guide representations in VR, i.e., the aforementioned virtual human (VH) and symbol-based (SB) guides, on the real-world navigation performance and experience of participants. Beyond the general demographics, we also measured participants' prior VR experience ($M = 3.10$, $SD = 1.29$) and familiarity with the campus building where the study was conducted ($M = 2.33$, $SD = 1.89$), on a 7-point scale.

Upon completing the navigation experience in VR and learning the route, participants were asked to retrace the route in the real world, i.e., inside the building where the study was conducted. During the real-world navigation task, we collected the task completion time as a performance measure. After completing the real-world navigation, participants were given a questionnaire that evaluated their confidence to complete the navigation task, their cognitive load during the task, their enjoyment of the task, and their perceived consistency of the real world with the virtual experience. We used the NASA TLX to evaluate cognitive load, a modified version of the Intrinsic Motivation Inventory [2] to evaluate enjoyment, and a set of custom ratings for the confidence and consistency measures. All measures were on a 7-point scale.

We hypothesize that the VH guide would be perceived as more enjoyable than the SB guide, due to the VH guide's human-like appearance. This would in turn increase the participants' confidence in their ability to perform the real-world task.

However, the VH guide may also result in a higher cognitive load because participants may feel social pressure/anxiety from the presence of the human-like virtual agent, or because the agent's nonverbal behavior may cause discomfort [4].

4 Results

Because of the small sample size and non-normality of our test group, we analyzed the data using nonparametric Mann-Whitney U tests. An open-source statistical analysis software, JASP v0.18.1[4], was used for the analysis. The results did not show any statistically significant differences in the measures between the visual guide conditions (see more details in Table 1). However, participants generally expressed that the virtual experience assisted them in comprehending the real-world layout and navigating effectively. One participant commented, *"The VR map of the building was identical to the real building, and I was able to remember characteristics from my surroundings in the VR to use in real life."* In addition, the cognitive load ($W = 4.50$, $p = .11$) and enjoyment ($W = 21.00$, $p = .08$) tended to approach the significance level ($\alpha = .05$). The descriptive stats in Table 2 show that the participants with the VH guide ($M = 2.60$, $SD = 0.65$) reported a higher cognitive load than those with the SB guide ($M = 1.80$, $SD = 0.76$), which is in line with our hypothesis. The enjoyment in the VH group ($M = 5.60$, $SD = 0.89$) was lower than in the SB group ($M = 6.50$, $SD = 0.87$), which is different from what we expected. However, we note that these results are not statistically significant; further research is required.

Table 1: Results of Mann-Whitney U Tests.

Measure	W	p	Rank-Biserial Correlation
Completion Time	17.00	0.42	0.36
Enjoyment	21.00	0.08	0.68
Confidence	15.00	0.65	0.20
Cognitive Load	4.50	0.11	−0.64
Consistency w/ VR	6.50	0.23	−0.48

Table 2: Descriptive statistics in the VH and SB groups. All the measures except Completion Time are on a 7-point scale.

Measure	Group	N	Mean	SD	SE
Completion Time (sec)	SB	5	119.60	26.88	12.02
	VH	5	105.20	14.79	6.61
Enjoyment	SB	5	6.50	0.87	0.39
	VH	5	5.60	0.89	0.40
Confidence	SB	5	6.60	0.65	0.29
	VH	5	6.40	0.55	0.25
Cognitive Load	SB	5	1.80	0.76	0.34
	VH	5	2.60	0.65	0.29
Consistency w/ VR	SB	5	5.90	0.96	0.43
	VH	5	6.60	0.55	0.25

5 Conclusion

In this paper, we investigated the effects of different visual guides in VR on a user's real-world navigation experience, comparing virtual human and symbol-based guide cues. Although the preliminary results did not show statistically significant differences in the performance and perception measures, they provide insights into the potential impact on user-perceived confidence and enjoyment. We plan to extend the research with a larger sample size and additional comparisons using different guide conditions.

Acknowledgments

We acknowledge the support of the Natural Sciences and Engineering Research Council of Canada (NSERC), [RGPIN-2022-03294] and Undergraduate Student Research Awards.

References

[1] F. Bruno et al. From 3d reconstruction to virtual reality: A complete methodology for digital archaeological exhibition. *Journal of Cultural Heritage*, 11(1):42–49, 2010.

[2] E. L. Deci and R. M. Ryan. *Intrinsic Motivation and Self-Determination in Human Behavior*. Springer US, Boston, MA, 1985.

[3] L. Hejtmanek, M. Starrett, E. Ferrer, and A. Ekstrom. How much of what we learn in virtual reality transfers to real-world navigation? *Multisensory Research*, 33(4-5):479–503, 2020.

[4] I. Wang and J. Ruiz. Examining the use of nonverbal communication in virtual agents. *International Journal of Human–Computer Interaction*, 37(17):1648–1673, 2021.

[3]Reallusion Character Creator 4: `https://www.reallusion.com/character-creator/` (Accessed: 2023-12-12)

[4]JASP: `https://jasp-stats.org/` (Accessed: 2023-12-12)