Investigating Visual Guide Cues in VR: Impacts of Virtual Humans and Symbol-Based Navigation on Real-World Performance and Experience

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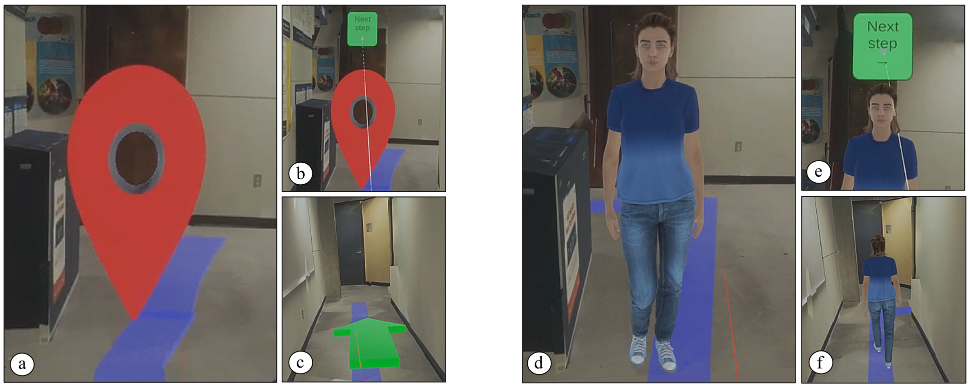

Figure 1: The two visual guide cues included in our study: (a, b, c) symbol-based guide; (d, e, f) virtual human guide.

Abstract

Virtual experiences can significantly influence our perception and behavior in the real world, shaping how we interact with and navigate physical environments. In this paper, we examine the impact of learning navigation routes in an immersive virtual environment (IVE) on navigation performance and user experience in a corresponding real-world indoor setting. We developed a guide system with two distinct audiovisual representations: a human agent guide and a symbol-based guide. A preliminary user study ($N = 10$) was conducted to evaluate the system. While no significant differences were observed between the two guide conditions, the findings reveal valuable insights into user-perceived confidence and enjoyment during real-world navigation tasks. Contrary to our expectations, the symbol-based guide elicited slightly higher positive scores compared to the human agent guide. We discuss these findings and outline directions for future research.

Index Terms: Real-virtual influence, navigation, visual cues, virtual human, enjoyment, confidence, task load.

1 Introduction

Navigation and route-learning—the process of acquiring knowledge about a path from one location to another—plays a pivotal role in many real-world scenarios. For example, the ability to navigate efficiently and safely is critical during emergency evacuations.

The integration of Immersive Virtual Environments (IVEs) with 3D reality capture technology, which enable the digital recreation of physical spaces, opens new avenues for studying and enhancing navigation behaviors [1]. By creating virtual replicas of real-world locations, these technologies allow users to engage in realistic simulations that prepare them for real-world tasks [12].

In this paper, we extend our previous publication [14] to focus on how experiences in IVEs influence users' navigation performance and user experience in corresponding real-world settings. Specifically, we investigate how different visual guide cues—an *embodied virtual human* and a *symbol-based guide*—impact navigation performance and user experience (Figure 1). To explore these effects, we developed a navigation guide system within an IVE, modeled after a real-world building using 3D reality capture technology. The study was conducted in a controlled laboratory setting, where participants first engaged with a virtual environment before completing a corresponding navigation task in the real-world counterpart of the modeled building. During the study, we measured key performance indicators such as task completion time and subjective experiences, including enjoyment, perceived confidence, task load, and consistency between the virtual and real environments.

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 IVE navigation experience impact users' real-world navigation *performance*?

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

By examining these questions, we aim to deepen our understanding of how virtual experiences shape real-world navigation and provide actionable insights for designing IVEs that effectively transfer skills to real-world contexts.

2 Related Work

2.1 Influence Between Real and Virtual Experiences

Previous research has shown that virtual experiences in immersive virtual reality (VR) can influence real-world perception and behaviour. Much of this research focuses on the impact of avatars. For instance, Yee et al. [23] found that after leaving a VR environment, users embodying tall avatars negotiated more aggressively in a real-world interaction, than users embodying short avatars. Similarly,

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Reinhard et al. [19] found that for a brief period of time after leaving VR, users who embodied old avatars would walk slower in real life compared to users who embodied young avatars. Hawkins et al. [11] found that White users who played as Black avatars targeting White users in a violent video game, displayed increased aggression towards White real-world partners after gameplay. This indicates that stereotypes activated in VR can carry over into real-world behaviour. Beyond the influence of avatars, a systematic review by Chang et al. [3] found that VR training experiences are effective in teaching social, safety, and professional skills, with 75% of studies showing skill generalization to real-world contexts.

Researchers have shown that the reverse also holds true—real-world stimuli can influence VR experiences. A study by Gonçalves et al. [8] found that real-world sensory stimuli (e.g., haptics, wind, scent, and vibration) enhanced immersion and presence when they were coherent with the virtual environment. These results are consistent with another study by Pouke et al. [18], which showed that place familiarity (i.e., how familiar users are with their real-world location), and real-world ambient sounds, influence presence in VR when it is coherent with the virtual experience. Chen et al. [4] showed that real-world lighting conditions directly impact visual perception in augmented reality (AR) and mixed reality (MR) experiences, affecting color appearance, chromatic adaptation, and immersion.

2.2 Navigation and Guide Cues in VR/AR

Researchers have compared different guide cues for navigation in VR and AR environments. For instance, Cogné et al. [6] investigated how different visual navigation cues, such as arrows, salient landmarks, and maps, support spatial navigation and memory in VR for individuals with Alzheimer's disease. They found that arrows resulted in the best navigation performance, followed salient landmarks and then maps. Similarly, Wu et al. [22] compared the effect of audio cues, visual cues, and combined audio-visual cues on navigation performance in VR. They found that combined audio-visual cues yielded the best navigation performance, and reduced cognitive load. Audio-only cues were the least effective. A study by Seelinger et al. [21] examined how context-adaptive visual cues, based on real-time user data and machine learning, improve AR navigation compared to static cues. They found that the context-adaptive cues improved navigation safety and reduced visual clutter, leading to better task efficiency and lower cognitive load. Schimdt et al. [20] explored a floor-based user interface for provided navigational guide cues using projections. They conducted a study which found this interface to be successful in guiding users to favorable viewpoints, thereby improving user experience. Buzard et al. [2] compared two simulated AR threat cues for enhancing safety during a city navigation task: a colour-coded ground area (GA) cue, which indicated threat zones, and screen-locked dynamic text, which indicated the distance to the threat (DT). They found the GA cue resulted in safer navigation, but the DT cue was slightly more efficient.

2.3 Virtual Humans and Engagement

There is a growing body of research demonstrating virtual humans' effectiveness in AR/VR environments for eliciting users' social behaviors and enhancing engagement across various applications. For instance, Nam et al. [16] explored the influence of a virtual agent's presence, comparing expressive and inexpressive behaviors, on user engagement during an AR video-watching experience. Their findings revealed that the agent's level of expressiveness significantly impacted how users perceived and interacted with the virtual agent in the shared experience. A study by Guimarães et al. [9] found that a virtual human in VR elicited stronger social presence than the same virtual human on a traditional flat-screen interface. Kim et al. [15] examined how subtle multimodal interactions, such as the integration of airflow effects and a virtual human's awareness of these effects, can enhance the sense of co-presence in AR environments. Their study demonstrated that these nuanced environmental interactions not only strengthened the sense of being together with the virtual human, but also positively influenced user engagement.

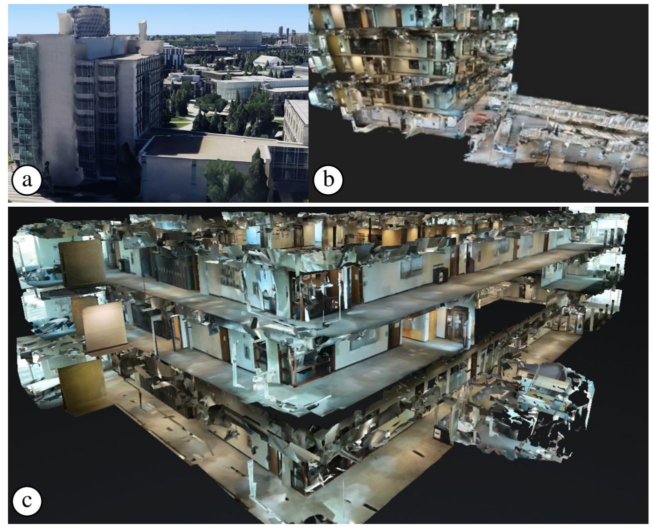

Figure 2: Immersive virtual navigation environment: (a) exterior view of the building; (b) virtual interior representation of the building; (c) close-up view of selected floors.

Research has also increasingly focused on the educational potential of virtual humans. Khan et al. [13] investigated the role of virtual humans in fostering learning engagement within AR-based physical education settings. Their study highlighted how virtual humans could provide personalized lessons and immersive learning experiences, bridging the gap between digital and physical learning environments. Similarly, Chheang et al. [5] explored the impact of a generative AI-embodied virtual assistant in a VR-based anatomy education context. Their findings underscored the potential of generative AI and virtual assistants in enhancing engagement and supporting educational outcomes in immersive environments. Peterson et al. [17] found that pedagogical agents with high behavioural realism yielded higher social presence in users.

3 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 created a 3D model of the interior of a campus building using 360° photos captured with the Insta360 X3 camera[1]. These photos were processed with the Matterport reality capture software[2] to generate a 3D mesh model of the building (Figure 2).

The reconstructed virtual environment includes seven floors, but our study focused only on the first and fifth floors. The experience begins on the first floor, where users read a set of slides providing instructions on navigating the virtual environment using point-and-click teleportation. Once users are familiar with the controls and environment, they are informed that their main task is to follow a virtual guide to learn a route within the building, and memorize the locations of three sticky notes placed along the route.

[1]Insta360: https://www.insta360.com (Accessed: 2024-12-12)

[2]Matterport Developer SDKs: https://matterport.com/platform/developers (Accessed: 2024-12-12)

After this orientation, users are teleported to the starting location for the task, which corresponds to a room on the fifth floor where the real-world study is conducted.

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 female virtual human, which we created in Character Creator 4[3]. The virtual human exhibits various animations, e.g., idle, 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, which the participants in our study were already accustomed to.

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(b, e)). 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.

4 Preliminary Study

4.1 Participants

As a preliminary study approved by the University of Calgary Research Ethics Board (REB23-0849), we recruited participants from our university community ($N = 10$; 2 female, 8 male; age $M = 20.50$, $SD = 1.20$). Beyond the general demographics, we 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.

4.2 Study Design and Hypotheses

We designed a between-subject study to evaluate the effects of two virtual guide representations in VR, i.e., the *virtual human* and *symbol-based* guides described in Section 3, on the real-world navigation performance and experience of participants.

- **Virtual Human (VH) Guide:** A human-like guide featuring realistic appearance and locomotion behaviors.
- **Symbol-Based (SB) Guide:** A minimalistic guide using visual changes (e.g., arrows for movement) to represent navigation cues.

Participants first completed a navigation task in VR, where they memorized a route and identified three key landmarks marked with virtual post-its. Guided by intermittent audio explanations from a virtual guide, they developed a spatial understanding of the environment. Following the VR task, participants moved to a real-world navigation task, retracing the learned route using their memory and understanding from the VR experience.

We hypothesize that the VH guide, with its human-like appearance and interactive behavior, will enhance users' confidence in navigation by leveraging the social interaction and reassurance it provides during the virtual task. Additionally, the engaging experience with the VH guide in the virtual environment is expected to positively influence real-world navigation performance, reduce task load, and enhance enjoyment. Users are likely to draw on their memories of the interactive and immersive guidance provided by the VH, making the transition to real-world navigation more seamless and satisfying.

4.3 Procedure

The study followed a structured procedure to ensure consistency. Upon arrival, participants were welcomed, provided with an overview of the study, and asked to complete a consent form. Afterward, they filled out a questionnaire collecting demographic information and assessing prior VR/AR and navigation experience.

Participants then performed a virtual navigation task. Equipped with a VR headset, Meta Quest 2, they received instructions on navigation and completed a brief practice session. During the main task, they followed a guide along a designated route in the virtual environment, memorizing key landmarks.

After the VR task, participants completed a questionnaire evaluating their confidence in the navigation task. They then transitioned to a real-world navigation task, where they retraced the route learned in VR within the corresponding physical environment. Task completion time was recorded as a performance metric.

Following the real-world task, participants filled out another questionnaire assessing their perceived consistency between VR and real-world environments, and overall impressions. Finally, they provided general feedback on the study before being thanked and dismissed with a monetary compensation (CAD $15).

4.4 Measures

4.4.1 Quantitative Measures

To evaluate the effects of the virtual navigation experience on participants' real-world navigation performance and user experience, we employed a range of quantitative measures collected either after the virtual navigation experience or the subsequent real-world navigation task (Table 1):

Task Completion Time Participants' performance in retracing the learned route in the real-world environment was assessed using task completion time. This metric captured how efficiently participants navigated the building after experiencing the virtual guide, and collected during the real-world navigation.

Enjoyment Participants' enjoyment of the real-world task was measured using a modified version of the Intrinsic Motivation Inventory (IMI) [7]. This scale included items assessing the participants' interest and satisfaction, capturing their emotional engagement during the navigation process.

Confidence Custom confidence ratings were used to gauge participants' self-perceived ability to successfully complete the real-world navigation task. These ratings provided insights into participants' trust in their navigational skills after using the virtual guide. The ratings were collected after the virtual navigation experience was completed but before the real-world task began.

Task Load Task load during the real-world navigation task was evaluated using the NASA Task Load Index (TLX) [10]. This widely used instrument includes six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration, providing a detailed understanding of the cognitive challenges encountered by participants. These dimensions were averaged to compute a single representative task load value.

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

Table 1: Questionnaires used in the study.

Measure	Question
Enjoyment	- I enjoyed doing this activity very much - This activity was fun to do. - I thought this was a boring activity. - This activity did not hold my attention at all. - I would describe this activity as very interesting. - I thought this activity was quite enjoyable. - While I was doing this activity, I was thinking about how much I enjoyed it.
Confidence	- How well have you constructed a mental map of the route? - How confident are you that you will be able to recall and navigate through the same route, in real life?
Task Load	- (Mental) How mentally demanding was the task? - (Physical) How physically demanding was the task? - (Temporal) How hurried or rushed was the task? - (Performance) How successful were you in accomplishing what you were asked to do? - (Effort) How hard did you have to work to accomplish your level of performance? - (Frustration) How insecure, discouraged, irritated, stressed, and annoyed were you?
Consistency with VR	- How well did the virtual guide prepare you for the real world component of the study? - How much did your experiences in the virtual experience seem consistent with your real world experience?

Consistency with VR To evaluate how well the virtual navigation experience prepared participants for the real-world task, participants rated the consistency between their experiences in the virtual and real environments after the real-world experience. This measure explored the alignment between the two contexts and its impact on task performance.

All ratings, except for task completion time measured in second, were collected using 7-point Likert scales, with higher scores indicating stronger agreement with the evaluated attributes. These detailed measures enabled a comprehensive analysis of the transfer of navigation skills and user experience from virtual to real-world settings.

4.4.2 Qualitative Feedback

To collect participants' qualitative feedback after experiencing the navigation in VR and the real-world, we used open-ended questions to explore the positive and negative aspects of their experience—*"Describe how the virtual guide (succeeded at preparing / failed to prepare) you for the real-world component of this study. What aspects of the virtual guide did you (like / dislike)?"* Participants were provided with text boxes to freely write their responses.

5 Results

5.1 Quantitative Measures

Considering the small sample size (five participants per group) and non-normality of our test group, we analyzed the data using nonparametric Mann-Whitney U tests with the significance level ($\alpha = .05$). An open-source statistical analysis software, JASP v0.18.1[4], was used for the analysis.

The results did not reveal any statistically significant differences in the measures between the visual guide conditions (see Table 2); thus, they should be interpreted with caution. Nevertheless, the descriptive statistics suggest patterns worth discussing (see more details in Figure 3).

[4]JASP: https://jasp-stats.org/ (Accessed: 2024-12-12)

Table 2: 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
Task Load	4.50	0.11	−0.64
Consistency w/ VR	6.50	0.23	−0.48

Completion Time Descriptive statistics show that the VH group ($M = 105.20$, $SD = 14.79$) completed the real-world navigation faster than the SB group ($M = 119.60$, $SD = 26.88$); no statistical significance ($W = 18.00$, $p = .15$).

Enjoyment The enjoyment scores tended to approach the significance level ($W = 21.00$, $p = .08$). Participants in the VH group ($M = 5.60$, $SD = 0.89$) reporeted lower enjoyment compared to those in the SB group ($M = 6.50$, $SD = 0.87$), contrary to our expectations. This suggests that the VH condition might have lacked certain elements that contributed to a positive user experience compared to the SB condition.

Confidence Confidence scores were high in both groups, with participants in the SB group ($M = 6.60$, $SD = 0.65$) reporting slightly higher confidence than those in the VH group ($M = 6.40$, $SD = 0.55$). However, this difference was not statistically significant ($W = 20.00$, $p = .12$).

Task Load Task load scores also approached significance ($W = 4.50$, $p = .11$). Participants in the VH group ($M = 2.60$, $SD = 0.65$) reported higher task load compared to those in the SB group ($M = 1.80$, $SD = 0.76$).

Consistency with VR The VH group ($M = 6.60$, $SD = 0.55$) reported higher scores for consistency with VR compared to the SB group ($M = 5.90$, $SD = 0.96$). Although this difference was not statistically significant ($W = 22.00$, $p = .09$), the descriptive statistics suggest that the VH guide provided a more immersive or coherent experience within the virtual environment.

5.2 Qualitative Feedback

Participants provided detailed feedback on their experiences with the two guide types, offering insights into their strengths and limitations.

In the VH group, participants consistently praised the immersive and realistic features of the guide. Many noted that the detailed animations and lifelike navigation cues helped them connect their virtual experiences to the real-world task. For instance, one participant stated, *"The detailed features in the virtual guide were very useful in identifying where I am in the real world."* Others appreciated the smooth pacing and visual fidelity of the VH guide, with one participant commenting, *"I really liked how immersive it was and the way the virtual character guided me."* However, some challenges emerged, particularly regarding the absence of real-world dynamic elements in the VR environment. One participant remarked, *"The VR application didn't include any people (other than the VH agent) in the model, whereas navigating around real-world people slowed me down."* highlighting a gap between the VR and real-world experiences.

Feedback from the SB group highlighted its simplicity and effectiveness in helping participants memorize routes. Participants appreciated the straightforward visual cues and the ability to control their pace. One participant shared, *"Having the ability to look at different landmarks (things to remind me of certain spaces) really helped,"* while another noted, *"Letting me take my own pace helped a lot."*

Additionally, the inclusion of audio instructions referencing specific areas, such as "kitchen" or "hallway," was cited as particularly

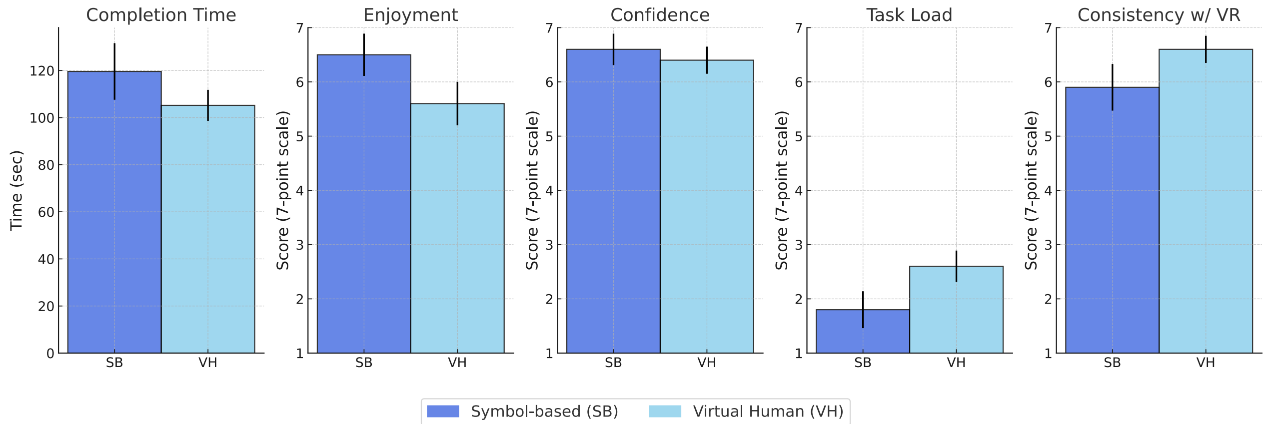

Figure 3: Comparison of descriptive statistics for task completion time, enjoyment, confidence, task load, and consistency with VR between the VH and SB guide groups. Error bars represent the standard error of the mean. Results highlight notable patterns despite the absence of statistically significant differences.

helpful for route recall. However, some participants identified limitations, such as the lack of sensory detail and context in the SB guide. One participant mentioned, *"The virtual guide didn't help me get an idea of the smell or unexpected elements like garbage in one corner,"* indicating areas for potential improvement.

6 Discussion

As mentioned before, we note that these results are not statistically significant; therefore, the interpretation requires caution to draw conclusions and further research is required. However, the results of our study revealed interesting patterns in the data when connecting the quantitative findings with participants' qualitative feedback.

The findings of this study highlight how virtual navigation experiences influence real-world navigation performance, as reflected in both quantitative measures and qualitative feedback. Previous research has emphasized the role of VR in enhancing task transfer to real-world contexts [3, 12]. In this study, the VH guide's faster completion times and higher consistency with VR suggest that its immersive and detailed design facilitated stronger spatial recall during real-world navigation. Participants' comments about the guide's detailed feature and realism support this interpretation, aligning with studies showing that realistic avatars improve spatial presence and task performance [19].

Conversely, the SB guide's higher enjoyment and lower cognitive load reflect its success in making the navigation process user-friendly and intuitive. Participants' appreciation for its simplicity, as evidenced by qualitative comments, aligns with literature suggesting that minimalist navigation aids reduce cognitive effort while supporting effective route learning [6, 22]. However, its lack of sensory richness may have limited its ability to fully prepare participants for real-world conditions as pointed out in Section 5.2.

The contrast between the guides underscores a trade-off between immersion and usability in virtual navigation design. Hybrid approaches that integrate different immersive elements into a simplified framework could address these trade-offs. For example, combining symbolic cues with a virtual human guide might enhance both spatial fidelity and user satisfaction. Qualitative feedback also highlights opportunities to improve guide designs. Incorporating dynamic elements, such as moving avatars, into the VR environment could better align virtual and real-world experiences. Similarly, adding sensory elements, such as sound and smell, could enhance immersion and aid in contextual spatial memory.

These findings contribute to a broader understanding of how virtual experiences influence real-world navigation, emphasizing the importance of tailoring guide designs to specific user needs and contexts. Future research should explore these dynamics in larger, more diverse populations and investigate hybrid solutions to optimize virtual navigation systems for real-world applications.

7 Conclusion

In this paper, we investigated the effects of virtual navigation guides—virtual human and symbol-based guide cues—on real-world navigation performance and user experience. While our preliminary findings did not yield statistically significant differences, they uncovered interesting patterns and insights. Participants using the virtual human guide reported higher perceived consistency between virtual and real-world environments, reflecting the immersive potential of detailed and realistic designs. Conversely, the symbol-based guide demonstrated advantages in simplicity, yielding higher enjoyment and lower task load scores during the real-world task.

Considering the possible trade-off among different visual cues in the design of virtual navigation systems, and its impact on real-world navigation performance, future research should investigate hybrid approaches that combine the strengths of both guide types. Expanding the study to include larger, more diverse participant samples and additional guide conditions will further refine our understanding of how virtual navigation systems can effectively support real-world applications.

Acknowledgments

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