Dashing: Fun but Non-Ergonomic? Exploring Transition Effects in VR

Nico Feld* Trier University
Nadine Dubois † Trier University
Pauline Bimberg† Trier University
Benjamin Weyers† Trier University
Daniel Zielasko ‡ Trier University

ABSTRACT

Pointing-based teleportation over short distances is a widely used locomotion technique in virtual reality (VR) due to its ability to minimize cybersickness compared to continuous movement methods. Further, teleportation transitions, the visual effects that mediate the user's perspective change, play a critical role in influencing spatial orientation, task load, cybersickness, and overall user preferences. This study investigates the impact of four commonly used transitions (*Cut*, *Fade*, *Dissolve*, and *Dash*) on these measures. In addition it investigates the role of environmental visual cue density in supporting spatial orientation. The experiment employed a mixed-subject design, with 24 participants completing navigation tasks across distinct virtual environments using each transition type. Results indicate that spatial orientation was not significantly influenced by the density of visual cues or the transition. However, *Dash* was highly preferred by participants while associated with the highest task load and cybersickness. These findings highlight the trade-offs between ergonomics and user experience in selection-based teleportation transitions.

Index Terms: Virtual Reality, Transitions, Locomotion, Spatial Orientation, Teleportation

1 INTRODUCTION

Virtual reality (VR) technologies have significantly advanced the way users interact with virtual environments, offering immersive experiences that extend beyond the constraints of the physical environment. A central challenge in VR research and development is facilitating effective navigation within large-scale virtual environments while maintaining user comfort and engagement. Among the various locomotion techniques, teleportation has emerged as a popular choice due to its ability to minimize cybersickness. However, while teleportation reduces motion-induced discomfort, it often compromises spatial orientation and presence [4, 7]. However, there are nuances to the implementation of target-based teleportation, especially the transitions during the teleportation, that could mitigate the negative effect on spatial orientation and presence. These transitions could improve teleportation by mediating the change in perspective during movement. Previous research indicates that transitions, like a fade to black or an alpha blending, can influence spatial orientation and user experience [8, 15]. Despite these insights, studies directly comparing these transitions for pointing-based teleportation as a navigating technique remain limited.

Furthermore, the role of visual cues in the environment that aid in spatial navigation has not been thoroughly examined in the context of different pointing-based teleportation transitions. Studies such as Cherep et al. [5] highlight the importance of visual cues for improving spatial orientation, but their interaction with specific transitions in complex virtual settings remains unclear.

To address these gaps, our study investigates the impact of four widely used transitions on spatial orientation, task load, and cybersickness. By incorporating environments with varying levels of visual cues, it also explores how the visual fidelity of the environment influences spatial orientation. This dual focus on transitions and environmental design seeks to inform best practices for optimizing pointing-based teleportation in VR applications.

2 RELATED WORK

Spatial navigation in virtual environments presents unique challenges that have been the subject of extensive research over the past decades. Among the various locomotion methods, teleportation is widely used due to its ability to reduce cybersickness compared to continuous movement techniques like joystick-based steering [4, 6, 13, 15]. However, teleportation often comes at the cost of reduced presence and spatial orientation [2, 7].

Spatial orientation, or the ability to perceive and update one's position relative to the environment, is critical for effective navigation. In VR, this process relies primarily on visual cues, as vestibular feedback is absent in most locomotion techniques [9]. While environments with visual cues often improve spatial orientation, their placement and density play significant roles. Cherep et al. [5] demonstrated that visual cues significantly enhance spatial orientation, particularly when combined with fixed teleportation locations. These findings underline the importance of integrating meaningful visual cues into VR environments to support user navigation.

Further, the transition effect used during teleportation could influence user experience. Weißker et al. [17] categorized the teleportation process into stages, emphasizing the transition phase as a key component in shaping spatial orientation and comfort. Common transition effects like *Cut* (instant teleportation), *Fade* (fade to black), *Dissolve* (alpha blending), and *Dash* (fast movement toward the destination) have been developed to address specific challenges. For example, Feld et al. investigated six transition effects in tasks involving object memory, including the common *Cut*, *Fade*, and *Dissolve* transitions. Their findings suggest that while the transitions have minimal impact on task performance, they differ in user preferences for certain tasks. However, Feld et al. did not focus on short-distance locomotion or on spatial orientation, leaving open questions about how these effects interact with more navigation-focused tasks. Bhandari et al. [3] found that *Dash* improved spatial orientation compared to *Cut*, particularly in environments with limited visual cues. Similarly, Rahimi et al. [15] observed that animated transitions, akin to *Dash*, improve spatial orientation when traveling to predefined teleportation targets. However, these studies also highlighted trade-offs, such as increased sickness with animated transitions when compared to simpler transitions, like *Cut*.

Cybersickness, characterized by symptoms such as nausea, dizziness, and disorientation, remains a significant barrier to user comfort in VR [12]. Pointing-based teleportation generally induces less cybersickness than continuous movement techniques, but differences among transition effects are less clear [4, 6, 15]. Rahimi et al. [15] reported higher sickness levels with animated transitions, while Bhandari et al. [3] found no significant differences between *Dash* and *Cut*.

While the literature highlights the importance of locomotion techniques, transition effects, and environmental features in shaping user experience, key gaps remain. Few studies have directly

---

[*] e-mail: contact@feldn.com
[†] e-mail: {s4stdubo, bimberg, weyers}@uni-trier.de
[‡] e-mail: daniel.zielasko@rwth-aachen.de

compared the impact of different teleportation transition effects on spatial orientation, particularly in environments with varying visual cue densities.

2.1 Hypotheses

Based on the research gap identified in prior work regarding the effects of transition on spatial orientation in pointing-based teleportation [3, 15], we first hypothesize: **H1: The effect on spatial orientation differs by the type of transition used for pointing-based teleportation.**

Further, prior studies like Cherep et al. [5] highlight that additional visual cues of the environment can improve spatial orientation. In contrast, environments without such cues might force users to rely on internal memory or estimation, which are often less reliable [6]. These findings lead to our second hypothesis: **H2: Spatial orientation is higher in environments with a high density of visual cues compared to environments with sparse visual cues when using pointing-based teleportation.**

The cognitive load during the teleportation may also depend on the type of transition used. Rahimi et al. [15] found that transitions, like *Dash*, might require greater cognitive processing as users interpret additional visual information. Conversely, simpler transitions such as *Cut* or *Fade* could reduce cognitive demands, though potentially at the cost of spatial orientation. Based on this, we hypothesize: **H3: Task load differs by the type of transition used for pointing-based teleportation.**

Cybersickness remains a present issue in VR, and there are indications that transitions with simulated motion, like *Dash*, could increase sickness due to the visual-vestibular mismatches [15]. On the other hand, simpler transitions like *Cut* and *Fade*, which avoid simulated motion, are generally associated with lower levels of cybersickness [17]. Therefore, we hypothesize: **H4: Cybersickness levels differ by the type of transition used for pointing-based teleportation.**

Finally, user preferences for transition effects appear to vary based on individual needs and contexts [8]. While *Cut* and *Fade* may appeal to users seeking simplicity, transitions like *Dash* or *Dissolve* might be favored for their higher presence or visually continuous qualities. This leads to our final hypothesis: **H5: User preference for transition effects for pointing-based teleportation is not uniform.**

3 TRANSITIONS

In this study, we evaluated four transitions used for teleportation in VR. They were selected from prior work about pointing-based teleportation and scene transitions.

3.1 Cut

Cut is the simplest and most widely used transition effect, where the user is instantly moved from their current location to the selected destination without any intermediate visuals. Its abrupt nature has been associated with reduced spatial awareness due to the lack of contextual visual feedback during movement [3, 17]. *Cut* remains a popular choice for VR applications despite these limitations due to its speed. Its simplicity also makes *Cut* a common baseline in research on transitions [8].

3.2 Fade

The *Fade* transition softens the teleportation by momentarily fading the screen from normal to black before and from black to normal after the teleportation. In our implementation, the fade-to-black animation has a total duration of $.3s$, which is the recommended duration for *Fade* for pointing-based teleportation by Wölwer et al. [18]. *Fade* is noted for its ability to improve user experience by reducing visual disruptions [17]. Rahimi et al. [15] found *Fade* to be effective at minimizing cybersickness, especially for users who are sensitive to abrupt changes in perspective. However, it may slightly increase the task load due to the interruption of visual continuity.

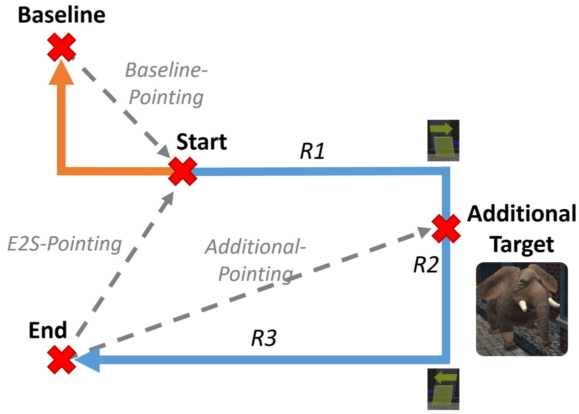


Figure 1: The task layout of each scene the participants traversed (blue). For each scene, the length of R1, R2, and R3 changed, but the total length was always equal to 300m. Along R2, the *Addition Target* was randomly placed on the sidewalk. At the beginning of each transition, the participants had to perform a short baseline task (orange) before proceeding with the actual navigation and pointing tasks.

3.3 Dissolve

Dissolve blends the view of the current location with the destination, creating a transparency effect as one fades into the other. This transition provides continuous visual feedback during teleportation, aiming to enhance spatial orientation while maintaining user comfort. While *Dissolve* offers more contextual information than *Cut* or *Fade*, its effectiveness can vary. Bhandari et al. [3] suggested that layered transitions could improve spatial orientation, but Rahimi et al. [15] found them less preferred by users due to potential increases in cognitive load.

3.4 Dash

Dash simulates physical movement by rapidly transporting the user along a visible trajectory to the destination. This effect retains a sense of motion, possibly aiding spatial awareness in environments [3]. *Dash* has been widely praised for improving spatial orientation by providing continuous movement cues [3]. However, Rahimi et al. [15] noted that animated transitions, like *Dash*, can induce higher levels of sickness in certain users, while Bhandari et al. [3] found no such effect. Despite these concerns, *Dash* is often favored for its increased presence in navigation tasks.

4 EVALUATION

4.1 Study Design

This study employed a controlled experimental design to investigate our hypothesis **H1-H5**. We used a mixed-subject design where every participant performed a navigation task with every transition type, but each participant was put in one of two environments. The study was approved by our institution's ethics council.

Participants were tasked with completing a navigation and pointing task based on the study designs by Weißker et al. [17] and Adhikari et al. [1]. The navigation task involves movement along a path with three segments (R1, R2, and R3) connected by two 90° right turns, as seen in Figure 1. Each path segment had a different length. At the end of each segment, there was an intermediate target location the participants had to reach, which showed the direction to the next target location. Upon reaching the final destination of

Figure 2: Distraction Task: The participants were required to count the birds of a specific color while traversing each scene.

R3, the participants finished the navigation task and immediately proceeded with the pointing task. This task required participants to point toward their starting position (E2S pointing) and an additional target (*Additional pointing*) randomly placed in the environment along R2. The *Additional Pointing* target was used to increase the amount of data points for our following analysis without significantly increasing the experiment duration. We then used the accuracy of the participant's pointing toward the specific target as an indicator of their spatial orientation. Further, we used two different pointing tasks to evaluate different cognitive processes underlying spatial orientation: rapid pointing and non-rapid pointing.

Upon reaching the end of R3, participants were immediately tasked with the rapid pointing task. They were required to make their pointing decision within one second for each target (*Start* and *Additional*) subsequently without time for any deliberations. This rapid pointing is typically used to specifically investigate spatial updating, as the participants do not have time to reflect on the environment and their navigation path before making their decision [16, 19]. Feedback was given through an auditory cue signaling the end of the decision window, and their pointing direction was recorded at that moment. After the rapid pointing task, the participants were asked again to point to both targets, but now without any time limits (non-rapid pointing). This task measured their reflective spatial understanding, enabling them to consider all available visual cues or their memory of previous movements. This task design is a variant of the commonly used triangle completion task [14] with three, instead of the commonly used two segments. This decreases the chance of false positives by increasing the possible pointing angles, as argued by Weißker et al. [17].

To get a baseline pointing error as a control variable for our analysis, we included a short baseline task before the actual main navigation and pointing task. Before navigating the environment, the participants had to navigate a short distance around another 90-degree corner to a *baseline* target, as seen in Figure 1. From there, they had to perform both the rapid and non-rapid pointing task towards the starting position. As the distance traversed is very small, this pointing error can be used as a baseline indicator for spatial orientation.

To prevent participants from relying solely on strategies like counting steps or teleports, a distractor task was introduced. Along the teleportation path, participants encountered visual stimuli in the form of colored birds and were asked to count specific colors. After both pointing tasks, they were asked to recall the number of birds and their given answer, and the correct number of birds was displayed to the user. This task's purpose was only to divert attention from purely tracking positional changes, encouraging more naturalistic navigation behavior, and, thus, is not further analyzed.

4.2 Environment Layout

The study was conducted in two virtual environments designed to examine the role of visual cues in spatial orientation: a detailed environment and a minimalistic environment. The detailed environment was designed as a realistic urban setting, with different house fronts and trees. In contrast, the minimalistic environment was intentionally sparse, featuring only the basic elements required for navigation, such as the path and walls. This design compelled participants to rely solely on internal cues, such as memory and self-motion estimation, to maintain their spatial orientation. Both environments were identical in terms of layout and are depicted in Figure 3.

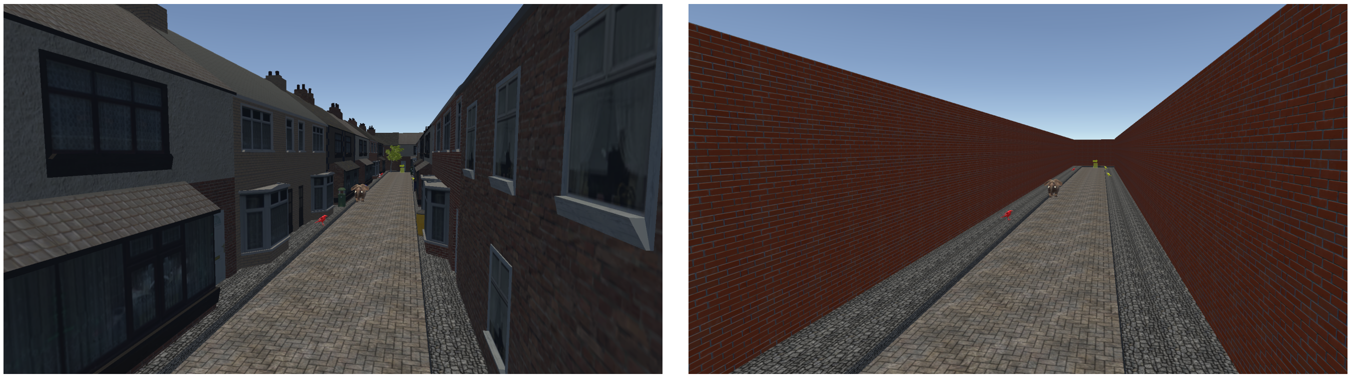
To ensure the minimalistic environment provided an appropriate sense of scale, a prestudy was conducted to determine the optimal height for the walls. The goal was to ensure that participants felt the same spatial proportions in the minimalistic environment as in the detailed environment, which featured houses with a height of 10 meters at their highest point. Discrepancies in perceived scale were noted during initial testing, as users reported feeling significantly smaller in the labyrinth environment compared to the street environment. The prestudy involved 11 participants (5 male, 6 female, aged 23–68 years, $M = 39$, $SD = 16.5$). Participants were presented with two identical scenes in terms of spatial layout: one from the detailed environment and the other from the minimalistic environment with adjustable wall heights. Participants could freely switch between the two environments and adjust the wall height in the labyrinth scene until they felt the proportions matched those of the detailed environment. The results indicated that a wall height of approximately 7 meters ($M = 6.7$, $SD = 1.68$) provided the best alignment in perceived scale. This setting was adopted for the minimalistic environment for the main study, ensuring that participants' spatial orientation and task performance would not be confounded by discrepancies in perceived scale across environments.

The additional target for the *Additional Pointing* task was positioned randomly for each trial along R2, ensuring it was always visible but located off the main navigation path on the sidewalk. By randomizing its placement, the study minimized the potential for participants to anticipate the target's location, reducing any learning effects. The additional target, a small elephant, was designed to be easily identifiable while remaining neutral in appearance to prevent it from functioning as an unintended landmark during navigation. Its color and shape were chosen to stand out against both the detailed and minimalistic environments, ensuring participants could easily locate it during the navigation task. At the same time, the target's unobtrusive design avoided interfering with the visual balance of the environment. This approach allowed for a consistent evaluation of spatial orientation across the different environmental conditions.

4.3 Determining the Speed for *Dash*

The speed of the *Dash* transition is a critical parameter, balancing travel time, user comfort, and spatial awareness. Previous studies, such as Rahimi et al. [15] and Bhandari et al. [3], tested speeds of 10 m/s, 25 m/s, and 50 m/s, finding no significant differences in pointing error or cybersickness across these values. Both studies selected 10 m/s, citing concerns about increased cybersickness with higher speeds and impracticality with slower ones, although these concerns were not backed up by data. However, these studies primarily focused on longer distances or limited teleportation instances, making their conclusions less applicable to scenarios with frequent, shorter teleports.

In this study, the *Dash* speed setting was evaluated theoretically by considering the specific requirements of the navigation task. With a maximum teleport distance of 15 meters and a total road length (R1+R2+R3) of always 300 meters, participants would require at least 20 teleports to complete a route, excluding adjust-



(a) The detailed environment

(b) The minimalistic environment

Figure 3: The two virtual environments used in the study. The detailed environment (left) features distinct objects, such as trees and house fronts, to aid spatial orientation, while the minimalistic environment (right) lacks visual cues.

ments for cornering. At 10 m/s, the *Dash* transition was projected to take approximately 30 seconds to complete a route, compared to 6 seconds for *Cut* and 13.5 seconds for *Fade* or *Dissolve*, making it disproportionately slow. Conversely, increasing the speed to 25 m/s reduced the travel time to approximately 13.7 seconds, aligning closely with *Fade* and *Dissolve*. This ensured that the duration of the *Dash* transition was competitive with other effects while still leveraging its ability to provide continuous motion cues. Therefore, a speed of 25 m/s was selected for *Dash* in this study to balance efficiency and user comfort. This setting ensured travel durations were consistent with other transition effects while maintaining *Dash*'s unique benefits for supporting spatial orientation.

4.4 Apparatus

The study was conducted in a small room with a play space of approximately 2m x 2m, using an Oculus Quest 1 headset. The headset was connected to the PC using a Quest Link Cable suspended from the ceiling. The experiment ran on a PC equipped with an Intel Core i7-9700 @3.00GHz, 32GB RAM, and an NVIDIA GeForce GTX 1050 Ti. It was implemented using Unity 2021.3.27f1 and XR Interaction Toolkit 2.3.2. Most textures and models were sourced for free from the Unity Asset Store[1] or Poly Pizza[2], while others were pre-existing within Unity. Any sound effects used in the experiment were obtained from Pixabay[3].

4.5 Procedure

Participants began by receiving an explanation of the study objectives, potential risks, and compensation. They signed a consent form and completed a demographics questionnaire, which included information on their age, gender, VR experience, and field of study or occupation. Then, the participants were assigned to either the detailed environment or the minimalistic environment balanced by gender.

Each participant experienced all four teleportation transitions sequentially throughout the experiment. Before starting the main tasks for a new transition, participants completed two tutorial scenes to familiarize themselves with the current transition. These tutorials allowed participants to practice navigating with the transition effect and the pointing tasks without recording any data. Then, each participant completed the navigation and pointing task in five distinct scene layouts with different lengths for R1, R2, and R3 for each transition, while the total road length remained 300m. Each layout was repeated twice, resulting in a total of 10 trials for each transition. The order of transitions was counterbalanced across participants using a Latin square design to minimize potential order effects. After completing the tasks for each transition, cybersickness was assessed using the FMS [11] while the participants were still immersed via a virtual questionnaire to get the most immediate results. After completing the FMS, the participants took off the headset and filled out the NASA TLX questionnaire [10] on a PC to assess the task load of the transition.

At the end of the experiment, participants ranked the four transitions based on overall preference, comfort, practicality, and likelihood of future use. To aid recollection, GIFs showing each transition effect were presented during the final ranking process.

4.6 Participants

The analysis included 24 participants (14 female, 9 male, 1 nonbinary) aged between 21 and 49 (M=26.38, SD=6.34). All participants were either students or employees of our university. Regarding VR usage habits, 1 participant reported using VR regularly, 8 used it occasionally, and 15 had no prior VR experience. The gender distribution across the two environments was balanced as much as possible: in the detailed environment, there were 7 female and 5 male participants; in the minimalistic environment, there were 7 female, 4 male, and 1 nonbinary participant.

4.7 Results

The study analyzed the effects of teleportation transitions and environmental conditions on spatial orientation, task load, cybersickness, and user preferences. The findings are detailed below.

To evaluate **H1 and H2**, two mixed-design ANOVAs were conducted to analyze the effects of transition type (*Cut*, *Dash*, *Dissolve*, *Fade*) and environment type (detailed vs. minimalistic) on pointing accuracy for both non-rapid and rapid pointing tasks. For both hypotheses, the interaction effect between transition type and environment type was examined first, followed by the main effects of transition type (H1) and environment type (H2). For non-rapid pointing, the interaction effect between transition type and environment type was not significant ($F(1.594, 35.077) = 0.664, p = .488$). The main effect of transition type (H1) was also non-significant ($F(1.607, 36.959) = 1.005, p = .396$), indicating that transition type did not significantly influence spatial orientation. Similarly, the main effect of environment type (H2) showed no significant differences ($F(1, 22) = 0.662, p = .425$), suggesting that spatial orientation was not significantly impacted by the density of visual cues.

---

[1] https://assetstore.unity.com/

[2] https://poly.pizza/

[3] https://pixabay.com/

For rapid pointing, the interaction effect between transition type and environment type was also not significant ($F(2.147, 45.097) = 0.281, p = .772$). The main effect of transition type (H1) remained non-significant ($F(1.936, 40.658) = 1.109, p = .342$), as did the main effect of environment type (H2) ($F(1, 21) = 1.818, p = .192$). These results indicate that neither transition type nor environment type significantly affected spatial orientation, and no interaction effects were observed for either pointing task. As we found no effects in spatial orientation, we did not further investigate the baseline pointing errors. In summary, these results do **not provide sufficient evidence to support H1 or H2**.

For **H3**, Task load was compared across teleportation transitions using a repeated-measures ANOVA. The analysis revealed no significant effect of transition type on task load ($F(3, 69) = 2.714, p = 0.051, \eta^2 = 0.106$). Given the still small p-value and an indicated medium effect size, we conducted exploratory post-hoc tests to further investigate potential differences between the conditions. The results showed indications that *Dash* had a marginally higher task load compared to *Cut* ($t(23) = -1.622, p = 0.472$), *Dissolve* ($t(23) = 2.265, p = 0.132$), and *Fade* ($t(23) = 2.089, p = 0.192$), although none of these differences reached statistical significance after correcting for multiple comparisons. Other pairwise comparisons between transitions also did not reveal significant differences. Despite the lack of a clear statistical significance, the results indicate a trend suggesting that *Dash* may result in a higher task load compared to the other transitions. There is **not enough evidence to accept H3**, as no significant results were found. However, the results still indicate that *Dash* may have an impact on task load, which should be explored further in future research.

For **H4**, a repeated-measures ANOVA was conducted to examine the effect of transition type on cybersickness. The results revealed a significant effect of transition type ($F(2.060, 47.377) = 3.447, p = 0.039, \eta^2 = 0.130$). Post hoc pairwise comparisons, corrected for multiple testing, indicated that *Dash* resulted in marginally higher cybersickness compared to *Cut* ($t(23) = 2.468, p = 0.081$), *Fade* ($t(23) = 2.104, p = 0.112$), and *Dissolve* ($t(23) = 2.397, p = 0.093$). No significant differences were found between the other transitions. While these differences were not statistically significant after correction, the results still indicate that *Dash* may result in higher levels of cybersickness compared to the other transitions. Since the ANOVA showed a significant difference between the four transitions, we **accept H4**. The post hoc tests indicate that this difference is primarily due to the negative effect of *Dash*.

For **H5**, user preferences for the teleportation transitions regarding H5 were assessed using Chi-square tests for four preference criteria: Overall Preference, Comfort, Practicality, and Likelihood of Future Use. Significant differences were found for all criteria:

- Overall Preference: $\chi^2(3, N = 23) = 14.043, p = 0.003$
- Comfort: $\chi^2(3, N = 24) = 8.333, p = 0.040$
- Practicality: $\chi^2(3, N = 24) = 17.000, p < 0.001$
- Likelihood of Future Use: $\chi^2(3, N = 24) = 15.000, p = 0.002$

These results indicate that participants exhibited distinct preferences for the transition types. *Dash* (N=12) was most favored in terms of practicality and likelihood of future use, followed closely by *Cut* (N=10/9). For comfort, *Cut* (N=10) was slightly preferred over *Dash* (N=9), while for overall preference, both *Cut* and *Dash* were rated equally highly with N=8. In contrast, *Dissolve* and *Fade* received minimal support across all criteria, suggesting that participants generally favored simpler or more practical transitions. Therefore, we **accept H5**.

Table 1: Results for H1–H4: Spatial Orientation, Task Load, and Cybersickness

H1 & H2: Orientation	**Test**	**Statistic**	**p-value**
Non-Rapid Pointing	Transition × Environment	F=0.664	.448
	Main Effect: Transition	F=0.990	.365
	Main Effect: Environment	F=0.662	.425
Rapid Pointing	Transition × Environment	F=0.281	.772
	Main Effect: Transition	F=1.058	.360
	Main Effect: Environment	F=1.818	.192
H3: Task Load		**Statistic**	**p-value**
NASA TLX-Score	One-Way ANOVA	F=2.714	.051
	Cut vs Dash	t=-1.662	.472
	Cut vs Dissolve	t=0.626	.999
	Cut vs Fade	t=0.373	.999
	Dash vs Dissolve	t=2.265	.132
	Dash vs Fade	t=2.089	.192
	Dissolve vs Fade	t=-0.407	.999
H4: Cybersickness		**Statistic**	**p-value**
FMS-Score	One-Way ANOVA	F=3.447	.039
	Cut vs Dash	t=-2.333	.116
	Cut vs Dissolve	t=-0.378	.999
	Cut vs Fade	t=0.850	.999
	Dash vs Dissolve	t=1.741	.380
	Dash vs Fade	t=2.329	.116
	Dissolve vs Fade	t=1.175	.999
H5: Preference		**Statistic**	**p-value**
Overall Preference	Chi-square	χ^2=14.043	.003
Comfort	Chi-square	χ^2=8.333	.040
Practicality	Chi-square	χ^2=17.000	<.001
Future Use	Chi-square	χ^2=15.000	.002

5 DISCUSSION

This study aimed to investigate the effects of different teleportation transitions on spatial orientation, task load, cybersickness, and user preferences, as well as the effect of visual cue density on spatial orientation during navigation. The findings offer insights into the interaction between these factors, revealing several unexpected results and trends.

Contrary to our expectations, our study revealed no significant differences in spatial orientation across the four teleportation transitions (*Cut*, *Fade*, *Dissolve*, and *Dash*). This result is surprising, as prior research, such as Zielasko et al.'s work [19] on discrete virtual rotations, observed differences in spatial orientation depending on the rotation method. In their study, directional methods demonstrated better support for spatial orientation compared to selection-based methods, attributed to the iterative and consistent movement patterns of directional methods. However, the consistent movement of *Dash* seemed to not have an effect on our results. One possible explanation for the absence of significant effects in our study is the inherent differences between rotational and translational movement paradigms. Unlike the fixed and repetitive nature of directional and discrete rotations studied by Zielasko et al., [19], teleportation transitions in our experiment may provide sufficient consistency and visual feedback to mitigate orientation errors across all conditions. Further, Bhandari et al. [3] found that *Dash* improved spatial orientation, particularly in environments with sparse visual cues. However, a key difference is that they used completely flat environments with no details, requiring participants to rely solely on optical flow for spatial updates. In contrast, both the minimalistic and detailed environment in our study included visual cues, like walls and roads, which might have mitigated the effect of the optical flow for *Dash*, potentially explaining the discrepancy in results.

Another unexpected outcome was the lack of significant differences in spatial orientation between the detailed environment and the minimalistic environment. While prior research, such as that by Cherep et al. [5], emphasizes the importance of landmarks for spatial orientation, our environments relied on general visual cues, such as textures and structures, rather than explicit landmarks. This distinction may explain the lack of observed effects, as landmarks serve as salient reference points, whereas subtler visual cues may

Transition	Cut	Dash	Dissolve	Fade
Non-Rapid Pointing				
Detailed Env.	M=4.91, SD=1.84	M=4.43, SD=2.16	M=4.87, SD=2.65	M=5.12, SD=3.45
Minimalistic Env.	M=5.78, SD=4.51	M=6.33, SD=6.00	M=7.07, SD=8.67	M=6.78, SD=7.65
Rapid Pointing				
Detailed Env.	M=33.10, SD=21.29	M=34.33, SD=21.51	M=33.36, SD= 18.91	M=36.97, SD=26.81
Minimalistic Env.	M=24.56, SD=7.44	M=24.61, SD=8.52	M=25.86, SD=9.69	M=26.85, SD=10.96
Non-Rapid Pointing (Baseline)				
Detailed Env.	M=2.63, SD=1.88	M=1.94, SD=1.70	M=2.84, SD=2.64	M=3.10, SD=4.06
Minimalistic Env.	M=3.78, SD=3.48	M=3.29, SD=3.48	M=3.48, SD=3.35	M=3.15, SD=3.09
Rapid Pointing (Baseline)				
Detailed Env.	M=35.05, SD=38.15	M=30.00, SD=27.28	M=30.25, SD= 29.05	M=24.07, SD=32.50
Minimalistic Env.	M=35.50, SD=24.05	M=24.15, SD=24.08	M=30.26, SD=25.53	M=25.32, SD=20.46
NASA TLX-Score				
Mean	M=46.04, SD=11.29	M=50.63, SD=13.34	M=44.69, SD=11.07	M=45.35, SD=12.21
FMS-Score				
Mean	M=2.67, SD=2.16	M=3.92, SD=3.02	M=2.83, SD=1.88	M=2.38, SD=1.88
Preference Frequency				
Overall	8	12	1	2
Comfort	10	9	3	2
Practicality	10	12	1	1
Future Use	9	12	0	3

Table 2: Descriptive statistics of each measure used in the analysis of H1-H5.

be less effective in aiding spatial orientation. These findings suggest that the absence of clear, distinguishable landmarks might limit the potential benefits of visual cues in supporting orientation during teleportation. Future research should investigate how the salience and type of visual cues influence spatial orientation and whether combining transitions with stronger navigational aids could enhance user performance.

One of the most intriguing findings concerns the *Dash* transition. While *Dash* was associated with higher task load and cybersickness compared to other transitions, it was also rated highly in user preferences for its practicality and overall immersive quality. This highlights a notable trade-off: participants appeared willing to tolerate higher levels of discomfort to gain the engaging benefits provided by *Dash*. This result aligns with prior findings, such as those by Rahimi et al. [15], who noted the immersive advantages of animated transitions despite their ergonomic drawback, or Bhandari et al. [3], while finding no effect on cybersickness, state that *Dash* benefits from being a transition that supports path integration by providing an optical flow. The dichotomy between ergonomic measures and user experience underscores the complexity of designing VR systems, as developers must balance immersion with comfort to meet diverse user needs.

These findings offer valuable insights for VR developers and researchers. First, the unexpected absence of differences in spatial orientation across transitions and environments suggests that teleportation mechanisms may be robust to variations in transition type and environmental cue density under certain conditions. Second, the popularity of *Dash*, despite its ergonomic shortcomings, highlights the need for transition designs that integrate immersive qualities with enhanced comfort, such as adaptive transitions that adjust based on user sensitivity.

Future studies should explore these findings further by incorporating more varied tasks, larger environments, and diverse participant samples to better understand the interplay between transitions, environmental design, and user experience. By addressing these gaps, researchers can help optimize teleportation mechanisms for a broader range of VR applications.

6 CONCLUSION

This study examined the effects of teleportation transitions and environmental visual cue density on spatial orientation, task load, cybersickness, and user preferences in virtual reality. Contrary to expectations and prior research, no significant differences were observed in spatial orientation across transition types or between environments with varying visual cue densities. These findings suggest that participants relied primarily on internal navigation strategies or the inherent stability of teleportation transitions rather than external environmental cues. The results further highlighted the trade-offs between ergonomic factors and user experience. *Dash*, while associated with higher task load and cybersickness, was highly favored for its practicality and immersive qualities. In contrast, simpler transitions like *Cut* and *Fade* were better rated in ergonomic measures but received less user preference overall. This contrast highlights the challenges in designing VR locomotion systems that effectively balance user comfort with engaging experiences. The findings provide valuable guidance for VR developers, offering a deeper understanding of the complex interplay between transition effects and user experience. Future research should explore adaptive transition designs to mitigate ergonomic drawbacks while retaining immersive benefits, alongside investigating individual differences and task-specific demands. By addressing these areas, VR systems can be better tailored to meet the diverse needs of users across applications.

REFERENCES

[1] A. Adhikari, D. Zielasko, A. Bretin, M. von der Heyde, E. Kruijff, and B. Riecke. Integrating continuous and teleporting vr locomotion into a seamless "hyperjump" paradigm. *2021 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, pp. 370–372, 2021. doi: 10.1109/VRW52623.2021.00074 2

[2] N. H. Bakker, P. O. Passenier, and P. Werkhoven. Effects of head-slaved navigation and the use of teleports on spatial orientation in virtual environments. *Human Factors: The Journal of Human Factors and Ergonomics Society*, 45:160 – 169, 2003. doi: 10.1518/hfes.45.1.160.27234 1

[3] J. Bhandari, P. MacNeilage, and E. Folmer. Teleportation without spatial disorientation using optical flow cues. In *Graphics Interface*, 2018. doi: 10.20380/GI2018.22 1, 2, 3, 5, 6

[4] D. Bowman, D. Koller, and L. Hodges. Travel in immersive virtual environments: an evaluation of viewpoint motion control techniques. In *Proceedings of IEEE 1997 Annual International Symposium on Virtual Reality*, pp. 45–52, 1997. doi: 10.1109/VRAIS.1997.583043 1

[5] L. A. Cherep, A. Lim, J. W. Kelly, D. Acharya, A. Velasco, E. Bustamante, A. G. Ostrander, and S. B. Gilbert. Spatial cognitive implications of teleporting through virtual environments. *Journal of exper-*

imental psychology. Applied, 2019. doi: 10.31234/osf.io/cx9vt 1, 2, 5

[6] C. G. Christou and P. Aristidou. Steering versus teleport locomotion for head mounted displays. pp. 431–446, 2017. doi: 10.1007/978-3-319-60928-7_37 1, 2

[7] J. Clifton and S. Palmisano. Effects of steering locomotion and teleporting on cybersickness and presence in hmd-based virtual reality. *Virtual Reality*, 24:453 – 468, 2019. doi: 10.1007/s10055-019-00407-8 1

[8] N. Feld, P. Bimberg, B. Weyers, and D. Zielasko. Simple and efficient? evaluation of transitions for task-driven cross-reality experiences. *IEEE transactions on visualization and computer graphics*, PP, 2024. doi: 10.1109/TVCG.2024.3356949 1, 2

[9] I. Frissen, J. L. Campos, J. Souman, and M. Ernst. Integration of vestibular and proprioceptive signals for spatial updating. *Experimental Brain Research*, 212:163–176, 2011. doi: 10.1007/s00221-011-2717-9 1

[10] S. G. Hart and L. E. Staveland. Development of nasa-tlx (task load index): Results of empirical and theoretical research. *Advances in Psychology*, 52:139–183, 1988. doi: 10.1016/S0166-4115(08)62386-9 4

[11] B. Keshavarz and H. Hecht. Validating an efficient method to quantify motion sickness. *Human Factors*, 53:415–426, 2011. doi: 10.1177/0018720811403736 4

[12] Y. Y. Kim, E. Kim, M. JaePark, K. Park, H. D. Ko, and H. T. Kim. The application of biosignal feedback for reducing cybersickness from exposure to a virtual environment. *PRESENCE: Teleoperators and Virtual Environments*, 17:1–16, 2008. doi: 10.1162/pres.17.1.1 1

[13] E. Langbehn, P. Lubos, and F. Steinicke. Evaluation of locomotion techniques for room-scale vr: Joystick, teleportation, and redirected walking. *Proceedings of the Virtual Reality International Conference - Laval Virtual*, 2018. doi: 10.1145/3234253.3234291 1

[14] J. Loomis, R. Klatzky, R. Golledge, J. Cicinelli, J. Pellegrino, and P. A. Fry. Nonvisual navigation by blind and sighted: assessment of path integration ability. *Journal of experimental psychology. General*, 122 1:73–91, 1993. doi: 10.1037/0096-3445.122.1.73 3

[15] K. Rahimi, C. Banigan, and E. Ragan. Scene transitions and teleportation in virtual reality and the implications for spatial awareness and sickness. *IEEE Transactions on Visualization and Computer Graphics*, 26:2273–2287, 2020. doi: 10.1109/TVCG.2018.2884468 1, 2, 3, 6

[16] B. Riecke and H. Bülthoff. Spatial updating in real and virtual environments: contribution and interaction of visual and vestibular cues. pp. 9–17, 2004. doi: 10.1145/1012551.1012553 3

[17] T. Weissker, A. Kunert, B. Fröhlich, and A. Kulik. Spatial updating and simulator sickness during steering and jumping in immersive virtual environments. *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pp. 97–104, 2018. doi: 10.1109/VR.2018.8446620 1, 2, 3

[18] M. Wölwer and D. Zielasko. The relationship between time and distance perception in egocentric and discrete virtual locomotion (teleportation). *arXiv preprint arXiv:2406.19895*, 2024. 2

[19] D. Zielasko, J. Heib, and B. Weyers. Systematic design space exploration of discrete virtual rotations in vr. *2022 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pp. 693–702, 2022. doi: 10.1109/VR51125.2022.00090 3, 5