VR Headsets In-The-Wild: Qualitative Insights on Safety, Awareness, and Social Challenges from Real Train Journeys

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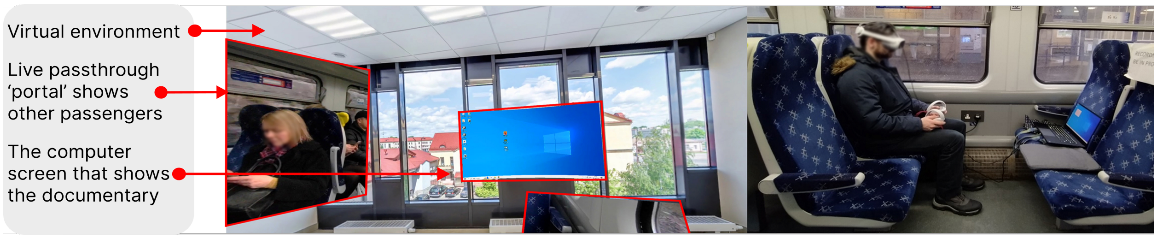

Figure 1: Left, virtual environment with 'portals' to reality; right, a participant uses a VR headset on a train.

Abstract

Virtual Reality (VR) headsets allow us to personalise how we experience reality while travelling, offering benefits over traditional devices. VR that incorporates elements of reality could be crucial to creating safe and socially acceptable VR experiences by supporting VR users to be aware of the ever-changing transit environment, and the presence and actions of bystander passengers. Our study (N=14) examines VR in-the-wild on real train journeys to explore how VR users desire to employ passthrough style 'portals' to reality, and what impact these portals have on their perceived safety, social acceptability, and more in a real passenger context. We utilised a qualitative methodology with user interviews to evaluate experiences after real train journeys. Our findings indicate a favourable response to VR use on public transport, particularly when travelling alone. Portals effectively mitigate safety, awareness, and social concerns, but also pose challenges in simultaneously engaging with real and virtual environments. Users show a preference for passive monitoring of real-world changes over the more demanding active checking of the portals. However, this can lead to 'information wormholes,' where changes in the real-world slip past the portals. This study provides ecological validity to adopting VR in real transit settings and offers insights for the further development of reality-awareness systems.

CCS Concepts

• **Human-centered computing**; • **Mixed / augmented reality; User studies**;

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Keywords

Virtual Reality, Public Transport, In-the-Wild Studies, Reality Awareness, Passengers

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1 Introduction

Passengers frequently rely on electronic devices like mobile phones, laptops, and tablets, often connected to headphones, for productivity, entertainment [24, 25], or to mitigate the discomfort of travelling in close proximity to others [17, 44, 64]. Virtual Reality (VR) headsets offer benefits beyond these traditional devices because they have the potential to dramatically redefine passenger experiences by creating opportunities to reclaim the time we spend travelling. With the ability to project virtual content all around the user, VR enables passengers to escape the physical confines of their surroundings and fully immerse in entirely different environments.

However, VR headsets also inherently detach users from their immediate surroundings, creating sensory and attentional barriers to the external world and posing significant challenges in transit settings. By blocking out reality, VR obscures personal belongings and fellow passengers, raising concerns regarding physical safety, awareness, and social acceptance [4–6, 45, 70]. These factors collectively hinder the adoption of VR in public transit environments.

There is an open challenge in how to restore elements from reality that people lose when wearing a VR headset in transit contexts. Current reality-awareness solutions, including Quest 'Guardian' and 'Space Sense' by Meta, which outline spatial boundaries, can be disruptive [53], suddenly appear in a moving environment, and are not within the user's control. These designs may not be well tailored to transit settings, and these systems have technical limitations because many headsets cannot separate vehicle and user motion, making them currently unsuitable for transit settings. Other commercial features, like the commonly used 'Passthrough' found in headsets such as the Meta Quest 1 to 3 or the new Apple Vision Pro, provide a video feed of the surrounding environment but break the immersion of the VR experience [32]. Research efforts to enhance reality awareness through techniques including visualizing nearby passersby [48], employing physical world overlays [43], or creating windows and 'gates' to reality [20, 70] are also primarily focused on controlled, static environments rather than a constantly changing transit setting. However, more recently, we explored Reality Anchors: references to objects in reality for immersive headset use in transit [5, 6]. Our prior research highlights the challenges of this specific context, which include constantly changing passengers, both familiar and unfamiliar external environments, and the need to manage the journey (e.g., identify when it is time to get off a train). Consequently, these ever-changing conditions of transit settings often lead to unexpected interactions and increased safety concerns. However, the study was conducted in a lab, where the key factors that make reality-awareness solutions like Anchors necessary—such as personal safety, journey management, and unpredictable social situations—cannot be fully evaluated due to the lack of a constantly changing real-world environment. While lab studies are valuable for informing the design of these tools, they fall short in realistically capturing how people would use them in real transit environments [12, 57, 58]. Conducting this study in-the-wild ensures that our results reflect genuine user behaviours and challenges, such as strangers getting on and off at every stop, which cannot be adequately replicated in controlled settings. By observing real people using VR headsets on a train, we gain a deeper understanding of how reality-awareness systems like 'portals' are used to meet awareness needs in everyday transit scenarios.

Employing an in-the-wild methodology, we collected qualitative data on participant experiences while using a VR headset to watch a documentary video during two 15-minute journeys on a local train. In our virtual reality setup, we provided access to passthrough-style portals designed to help users stay connected to their immediate surroundings. These portals are configurable windows that show portions of the passthrough video feed of reality overlaid on the VR scene. We used them as a means to explore what aspects of reality users want to maintain awareness of while immersed in the virtual environment.

Overall, participants responded positively to using VR on a train, especially when considering its potential use during solo journeys where interactions with others are minimal. We found that portals can effectively alleviate concerns related to safety, awareness, and social acceptance. Nevertheless, active monitoring of both virtual and real-world environments was challenging, highlighting the difficulties of simultaneously navigating dual realities. Participants showed a preference for passive monitoring of the real environment through the portals due to its reduced mental demand. However, this method sometimes led to 'information wormholes', where significant environmental changes went unnoticed—such as another passenger sitting in a location not visible through the user's chosen portal placement, or discrepancies between auditory and visual information, like hearing other passengers but not seeing them enter nearby spaces. These issues often resulted in uncomfortable surprises upon headset removal, raising trust concerns.

This work advances our understanding of VR adoption challenges in real-world settings and offers valuable insights for future reality-aware systems designed to support transit environments. We summarize our key contributions as follows:

- Conducted an in-the-wild study to collect genuine user experiences of VR headset use on real train journeys, assessing practicality and user acceptance.
- Demonstrated how VR 'portals' enhanced safety, awareness, and reduced social concerns in transit settings.
- Identified novel challenges in adopting VR in transit, including navigating real/virtual environments that create a sense of being neither here nor there, experiencing 'information wormholes' where information unexpectedly slips through portals, and the preference for passive environmental monitoring over active checking.

2 Related Work

2.1 Passenger Use of Devices on Public Transport

A significant body of research has explored how passengers utilize technology during transit. Common behaviours, such as using laptops or headphones, often help passengers create a sense of private space. This is particularly valuable in less favourable seating positions like middle seats, where the risk of spatial intrusion and discomfort is higher [14, 49]. In these situations, passengers may use devices as a shield from others or to signal disinterest in engagement [64].

Beyond escaping confined spaces and shielding from other passengers, electronic devices are also employed to make travel time more productive [24] or entertaining [25]. Timmermans and Van der Waerden [65] noted that the choice to travel via public transport, versus a car, is often strategic, offering the chance to engage in other activities during transit. The nature of these activities often varies between work-related and non-work journeys. Lyons and Urry [38] argued that equipping passengers with technology not only empowers them but also blurs the lines between travel time and activity time, optimizing travel time for other tasks. More recent work by Malokin et al. [41] also showed that younger commuters especially value the ability to spend travel time productively, suggesting that usage of devices will only increase in transit settings.

VR headsets can provide benefits beyond traditional devices, transforming travel time into more productive, immersive, and social experiences. The current body of work has explored a range of immersive device adoption—from Augmented Reality glasses to VR—for enhancing productivity [26, 33, 50, 56], entertainment experiences [46], and socialising [52, 62] across private and shared environments such as offices and homes, with some early explorations of transit settings [50], including in-car VR use [36, 69]. Focusing on VR, Gonzalez-Franco and Colaco [22] illustrated how VR can be used to achieve higher focus and become a productivity tool, yet they also highlighted the challenge of accessing and integrating the real world into the VR environment in a blended manner as the key to its success. Knierim et al. [33] argued that VR has the potential to create truly 'nomadic' workspaces that could overcome physical constraints. For entertainment, VR transforms media consumption by enhancing immersive experiences and supporting social interactions across distances [46]. On the subject of transit environments, McGill et al. [47] have identified several unique advantages of VR, such as enhanced immersion, privacy, flexible and comfortable viewing, the perception of expanded personal space, and support for both entertainment and productivity applications. The early adoption of headsets on planes [75, 76] demonstrates the growing interest in these technologies, which will likely continue to evolve for wider use in public spaces, including ground public transport.

2.2 Barriers to Adopting Immersive Devices in Transit

2.2.1 Safety and Awareness Concerns. Engaging with VR devices on public transport raises *safety concerns*. Gestures are often required for input when using immersive devices, which can raise concerns about physical safety. These concerns include the risk of accidentally colliding with objects or other passengers [4–6, 13, 40, 59, 70]. There is also a fear of unwanted physical contact from passersby [40, 73]. Additionally, gestures used during VR interactions create a shared experience for both users and observers [18]. If observers do not understand the purpose of these gestures, it can lead to safety concerns from their perspective, making it preferable for users to employ more subtle gestures [1, 3, 29, 66].

In-transit contexts also introduce environment-specific *awareness concerns*. For instance, not being aware of one's belongings, missing a destination stop [4–6], or failing to notice important announcements [4, 6, 70] can result in unsafe situations. While most commercial VR headsets, such as Meta's Quest, include safety features designed to increase awareness—like 'Guardian', 'Space Sense', and 'Passthrough'—these are primarily tailored for static indoor environments. As a result, they are less effective in dynamic transit settings, where the sensors may misinterpret vehicle motion as user motion. Additionally, features like 'Guardian' and 'Space Sense' can introduce sudden visual boundaries within the virtual space, which users cannot control and may find disruptive to their immersive experience. 'Passthrough' offers a temporary real-time view of the user's actual surroundings, but this too interrupts the virtual experience. Consequently, these tools do not adequately address the unique needs of transit environments, particularly ground transportation, where maintaining awareness of critical external factors—such as the movements of belongings, other passengers, staff, or important travel announcements—is essential.

The academic community also explored strategies for conveying real-world information during immersive experiences. Current solutions focus on increasing the awareness of nearby people [23, 35, 42, 54], as well as augmenting the immersive experience with physical world overlays [2, 43, 72], including notifications [74], offering a view into reality [20, 70] or providing audio and haptic feedback [19, 21]. Reality awareness solutions consider factors like proximity [48], the potential for physically colliding with objects from the real world [28], user preference [15, 37], perceived risk [16] or position in reality [5, 6] for effectiveness. However, this prior work lacks specific adaptation for the transit context, and there is uncertainty about the applicability of these solutions in travelling contexts, which introduce additional concerns related to interactions with strangers, safety, property vulnerability, and time-sensitive journey management. In more recent work [5, 6], we introduced the concept of Reality Anchors—cues from reality, such as passengers and personal belongings, positioned in virtuality to enhance awareness while minimizing the impact on immersion. These anchors serve as consistent reference points to real-world objects around the user, remaining linked to reality regardless of the virtual content being displayed. While this approach is a step towards addressing VR adoption in transit contexts, the study was conducted in a lab setting, leaving it unclear whether similar awareness concerns would emerge when explored in the wild.

2.2.2 Social Acceptability. Social acceptability concerns how well a product's design aligns with cultural and societal norms, facilitating its broad adoption across society rather than merely by individuals [34]. This aspect is crucial for unconventional and emerging technologies that face potential public rejection [51], as *social concerns*, including worries about negative perceptions [13, 30] and feelings of discomfort [34, 63], can significantly influence how the technology is received. Particularly challenging are devices like VR headsets, which isolate users from their surroundings by blocking their view of reality and utilising observable gestures and voice commands. These characteristics pose additional hurdles for social integration.

Prior research on social acceptability has explored the general acceptability of new wearable technologies [31] and the use of head-mounted displays (HMDs) in public spaces [7, 13, 33, 68]. Interest in transit settings has recently prompted research that highlights acceptability challenges unique to these environments [4–6, 45, 47, 60, 70]. However, all of this research has predominantly adopted a more theoretical approach and lacks empirical studies conducted in real-world contexts. For example, [70] demonstrates the need for in-the wild studies after initial exploration, particularly for social challenges in VR use during transit. Additionally, [6] highlights that real-world contexts can yield different findings from controlled settings, especially regarding awareness and safety. This gap raises the question of whether research conducted in real-world transit scenarios might reveal new insights into the social acceptability challenges in dynamic environments. The existing in-the-wild research often utilises public spaces [7, 13], which are not representative of dynamic environments like public transit, where conditions continuously change internally (e.g., moving passengers) and externally (e.g., driving through new neighbourhoods) [6]. Addressing this gap is crucial for a deeper understanding of the social acceptability of these technologies in real transit settings.

2.3 Summary

VR headsets show potential advantages over traditional devices, with prior work highlighting distinct use cases for productivity, entertainment, or socialising, as evidenced by their early adoption during air travel (e.g., [75, 76]). However, safety, awareness, and social concerns remain critical for broader acceptance of these technologies [4–6, 45, 70]. While there are existing approaches to increase reality awareness in VR setups (e.g., [20, 43, 48, 70, 72]),

Figure 2: Comparison of 360-degree images featured in the Immersed app's virtual environment. The left image presents a moon surface setting, offering an otherworldly experience, while the right image depicts a realistic office space, creating a more familiar and professional atmosphere.

they still fall short of fully addressing the unique concerns of in-transit contexts, such as interactions with strangers, safety, property vulnerability, or the need to track the progress of the journey [4]. In our recent work [5, 6], we introduced Reality Anchors—cues from reality positioned in virtuality to enhance awareness in transit contexts. However, the work was conducted in a lab setting, leaving it unclear whether these findings would hold true in real-world conditions.

Moreover, prior works examining the adoption of immersive devices in public spaces, including transit, have primarily focused on lab-based explorations (e.g., [6, 70]) or adopted theoretical (e.g., [47]) or simulation approaches (e.g. [73]). Studies conducted in the wild were limited to settings such as university cafes or study areas (e.g., [13]), which do not capture the complexities of transit environments, particularly ground transportation, where conditions constantly change, such as passengers boarding, alighting, or travelling through various neighbourhoods [6]. This dynamic nature of transit environments is difficult to fully simulate in a lab setting, underscoring the need to examine how use in real-world transit contexts might influence the challenges associated with virtual reality device acceptance in transit scenarios.

This paper addresses both research gaps: first, by examining the reality awareness needs of real passengers through passthrough portals in a transit setting where headsets would typically be used; and second, by capturing the impact of real travel environments on VR acceptance, moving beyond lab insights.

3 Exploring VR Headset Use on Real Train Journeys

A study was designed to explore the use of VR headsets in transit, focusing on collecting participants' firsthand accounts of their experiences. The study aimed to identify the unique challenges and user behaviours that emerge from immersive experiences outside controlled environments. Additionally, it explored how headsets that incorporate views of the real world could influence the acceptance of immersive technology in transit and enhance these experiences. In the study, participants used a VR headset to watch documentary video content during two 15-minute journeys on an inner-city local train. The virtual environment provided access to passthrough-style portals (Figure 1, left), intended to help users stay connected to their immediate train environment while immersed in virtual content.

Insights from participants' real-world experiences are crucial for refining VR headsets to better suit common public spaces, thus opening the opportunity for their wider adoption. This study is the first to explore VR headset adoption on real train journeys, offering authentic insights beyond controlled research. The core goals of the study were:

- Capture participants' firsthand experiences with using VR headsets on real train journeys.
- Explore the unique challenges that arise from using VR headsets during real travel situations.
- Evaluate how the use of 'portals' for a view of reality influences the acceptance of VR headsets in transit.

3.1 Study Design

The study was conducted on local trains, where participants embarked on two 15-minute trips during which they used a virtual reality headset. The study was conducted during the non-peak hours of train operations to ensure seating availability for both, the experimenter and participants. This generally involved taking trains after 10 AM and before 3 PM. The journey included a total of six stops, excluding the destination stop. While the number of passengers was not recorded, there were no instances of completely empty train rides during the study. The setup utilised any available seats on the train, ensuring the experimenter and the participant sat together, facing forward to minimise motion sickness, with the participant by the window for their physical safety. On the outbound journey, participants chose their seats, while on the return, the experimenter selected seats that were two next to each other, opposite a row of two other seats. During both journeys, participants were shown a nature documentary through the 'Immersed app' [77], which enables a VR headset to connect to a computer and display its contents on multiple resizable virtual screens. The study employed a single front-facing screen for the video. The app's passthrough feature was used as 'portals into the train environment', allowing participants to easily explore where, and what, they would choose to attend to in reality by creating and altering the portal size and position. On the outbound journey, participants could self-select and activate up to five portals using the in-app menu and handheld controllers, while on the return journey, the experimenter pre-set three portals (more details in 3.1.1). Two documentary clips were shown, one per leg of the journey, each lasting around 10 minutes. The audio was played through the

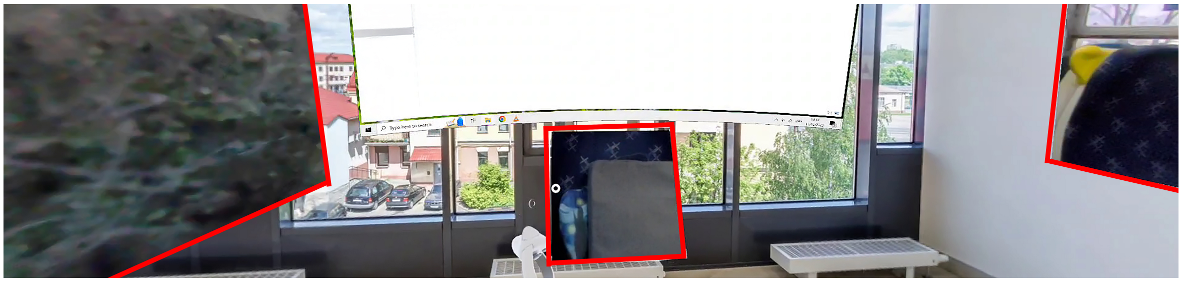

Figure 3: Pre-set portals displaying the portal drawn around the train window to the left (showing shrubbery outside), the passenger's bag in front, and a view of the aisle to the right, aimed at the passenger next to the participant (not visible in the image).

headset speakers, without earphones, as the audio setup was not a focus of the study. Participants were able to hear both the documentary and the surrounding environment. The documentary was set against a distinct 360-degree virtual backdrop—one depicting a realistic office space, and the other an imaginative moonscape (Figure 2). Both static environments occluded the train without adding additional distractions like animations or moving virtual elements. The documentary and the virtual environment together made up each experience and were presented in a counterbalanced order.

3.1.1 Portal Design. The study utilised 'passthrough' windows that displayed a real-time feed of the surrounding environment embedded within the virtual space, a feature adopted to maintain awareness without exiting the virtual content. Passthrough portals were chosen because they offer a simplified version of reality awareness solutions, such as reality anchors [5, 6], that needed to work effectively in a real-world environment and remain stable to maintain a seamless user experience.

On the outbound journey, participants had the freedom to create and place portals within the virtual environment (for example, see Figure 4), with the only requirement being that at least one portal had to be activated. The study was designed to first capture participants' uninfluenced choices by allowing them to create their own portals, ensuring that the use of pre-set portals later would not influence their initial decisions. Participants used the 'Immersed' app to enable and configure these portals. They brought up a menu, selected the number of portals, and the app created square portals showing the passthrough camera feed at that spatial location. Participants could create and manage up to five portals, which they could move and resize (square, rectangle, or sphere) using a controller, and close by clicking a cross icon.

On the return journey, however, portals were pre-positioned to specifically highlight personal belongings in front, a passenger to the side, and the view through the window (Figure 3). The researcher reset the 'Immersed' app during the break between train rides to draw these three portals, with the latter two positioned peripherally. These objects were chosen based on previous research indicating that personal belongings, nearby passengers, and travel information (conveyed via the window view) are key concerns for immersive technology adoption in transit [4–6]. This design aimed to investigate the impact of participant-controlled versus pre-defined portal placements on the immersive experience and interaction with the virtual content.

3.2 Participants

In total, 14 participants (7 females, 7 males, mean age = 26 years, SD = 7) were recruited for the study. The majority were students, 11 had used a VR headset at least once, and 3 had never used one before. Participants were compensated for their time with £25 Amazon vouchers. The study was approved by the university ethics committee.

3.3 Procedure

The experimental procedure of the study was executed in two main parts: the experiential phase, which included the training and journey, lasting approximately 1.5 hours, followed by a concluding interview session, lasting about 30 minutes. The process unfolded through several stages, as detailed below.

Initially, participants underwent a briefing and training session, where they were introduced to the study's objectives and provided with an information sheet and consent form. This 25-minute period included a detailed demonstration of how to use the Pico 4 VR headset and interact with the 'Immersed' application.

Following the training, participants and the experimenter travelled to the train station, marking the beginning of the journey. The same train route was used for all sessions of the study. Before boarding the train, participants were instructed to choose their seats, ensuring they were forward-facing and that there were two seats next to each other. The train ride lasted around 15 minutes each way, with 10 minutes dedicated to using the VR headset. The first few minutes of the journey were used to set up the headset and the laptop, which was connected to the VR headset via a cable for a more stable connection.

During each ride, participants viewed the VR documentary video content. They were instructed to watch the documentary and interact with the portals; on the outbound journey, these portals were self-drawn, while on the return journey, they were pre-determined. To ensure safety and comfort, participants were asked to wear the VR headset only while seated. Throughout the journey, the experimenter handled interactions with the ticket inspector and managed any unforeseen events.

At the station, a break between trains allowed participants to reflect on their experiences and share initial impressions with the experimenter. The journey concluded with a return train ride, after which participants were invited to a 30-minute interview which, to minimise fatigue, could be arranged within 24 hours of the experimental phase. This session aimed to capture their detailed feedback, perceptions of immersive devices in transit settings, and their experiences and interactions with the VR headset and portals.

3.4 Data Collection

The primary data in this study came from interviews (see Appendix A for the full list of questions) that explored participants' reactions to using a VR headset during a real train journey. Participants were encouraged to elaborate on their responses with follow-up questions, such as "Why do you think that?" and "Can you tell me more about X?" when necessary. The interviews took approximately 30 minutes. All interviews were audio recorded, ensuring participant anonymity, and later transcribed for analysis. Participants' in-headset views were video recorded (with permissions) to capture their interactions within the virtual environment. While the primary data were derived from the interviews, video stills from these recordings are used to illustrate some of the arrangements and configurations made by participants.

4 Results

Once transcribed, participant statements from interview transcripts were coded using an open coding process [11]. The transcripts were annotated with brief phrases that identified key concepts in the data, and these open codes were iterated over multiple cycles, recoding the transcripts until no new codes emerged. Subsequently, the codes were organized into meaningful groups using a thematic approach [9]. Although a single researcher performed the initial coding, the codes were reviewed and refined after the first and final iterations in collaboration with another researcher. To visualize the data and create a thematic map, a Miro board was used.

The most interesting results are as follows: portals reduced safety, awareness, and social concerns (see Section 4.1) but led to difficulty in simultaneously navigating real and virtual realities (see Section 4.2). Participants wanted to passively monitor their surroundings rather than actively check the portals (see Section 4.3). They were surprised by 'information wormholes' that allowed real-world changes to slip through unnoticed, raising trust concerns (see Section 4.4).

4.1 Portals for Reducing Concerns and Maintaining Immersion

While portals have been applied in various contexts [20, 70], this study adapts them for public transit to enhance awareness. Participants' interview responses confirmed that the portals reduced safety, awareness, and social concerns.

All participants positively perceived the portal feature, reflecting on its effectiveness in reducing concerns associated with safety, awareness, and social fears about other passengers. Some participants expressed how their concerns for the journey changed as soon as they started using the portals, with one noting: "*as soon as the journey began, I could see all those things. So I didn't need to...[worry]...those concerns were unfounded*" (P5). Participants found the portals to be "*helpful*" (P1), a "*good idea*" (P3, P4), a "*nice surprise*" (P8), making the journey "*more enjoyable*" (P5), "*relieving discomfort*" (P6) and "*the only way*" to make VR work in a public space (P14). All participants reflected on the portals' ability to increase awareness of the train environment and create a sense of safety, changing their initial expectations. For example, one participant noted: "*I think the mixed reality [portals] made me a lot more comfortable than I was expecting to be*" (P6). Some noted that having the portals helped them "*focus*" (P1, P2), and reduce "*anxiety*" (P6) and "*worry*" (P1). Although several participants found setting up the portals initially "*distracting*" (P4) and that it required practice (P2, P3, P4, P5, P8), they deemed it a worthwhile compromise: "*having portals in traffic areas would distract somewhat from the content but that doesn't mean it's not important to still do. I think safety takes precedent*" (P4).

Interestingly, many participants were conscious of other passengers' perceptions, with a few noting others "*staring*" at them (P1, P7), or feeling worried about looking unusual: "*I was kind of thinking, we do look very strange right now*" (P14). However, several participants reported that their concerns ceased once they were immersed in VR and became aware of their surroundings through the portals. P6 noted, "*once I got into it, it was just like, yeah, don't really care [about other passengers]*", while P7 highlighted feeling less concerned about external opinions: "*others don't need to worry about it if they don't like it*", a sentiment shared by P3 and P4. P8 also noted that being immersed in the virtual environment helped them forget about other passengers: "*nobody actually wants to talk to each other unless you know each other, or something happens that sparks conversation. And honestly, the VR just made it super easy to forget about them [people]*".

Despite the study employing two distinct 360 backdrops—an office and a moonscape—for the virtual experience, no participants commented on their influence to their experience.

4.2 Challenges of Simultaneously Navigating Reality and Virtual Reality

Navigating between real and virtual environments presents significant challenges for users, as reflected in their experiences with VR portals. Showing simultaneous views of reality and virtual reality can create a sense of being neither here nor there, or "somewhere in-between" (P9), highlighting a new challenge for blending reality/virtuality in public spaces.

Although the experience included portals to the real train environment, some participants felt more "*immersed in the virtual environment*" (P5), describing it as "*more of a virtual experience*" (P7) and noting they *"didn't really feel"* like they were on a train (P8). A few compared the portals to "*CCTV*" (P8) or "*moving pictures*" (P4), which were "*not like seeing reality*" (P4), where "*you are not there*" (P9). Some even forgot that they were on a train (P8) or wearing a headset (P5). However, other participants made a conscious effort to stay aware of both environments (P1, P3, P5, P6), noting it was important to "*focus on what is happening, surrounding*" (P1) and felt the portals served as a "*reminder*" of being on a train (P5, P8), helping them connect to "*the real world*" (P8).

Staying aware of both realities proved to be challenging. Participants often encountered difficulties in multitasking and managing their attention between two co-existing realities, describing being only "*half*" present in each environment (P1). Similarly, P2 found that viewing both real and virtual content simultaneously disrupted their immersion. Echoing this sentiment, P4 highlighted the challenge, noting "*too much going on*" as the video and the portals made it hard to pay attention to both realities at the same time. P10 commented on the difficulties of navigating between two complex worlds, describing it as "*distracting having the two complex worlds mixed together*". This blending of realities also led P11 to feel detached from the primary content of the VR experience, noting, "*it did sort of deter me away from what the documentary was... and then I had to force myself to focus*". Overall, participants found the experience busy and noted that it took time to adapt to the "*dual demands*" (P4) of the environments.

4.3 User Interactions with the Portals

During the journey, participants adjusted the size of the portals according to their preferred level of immersion. They expressed a preference for passive monitoring of moving passengers and those in close proximity, considering them as the most important elements of the train environment.

4.3.1 Resizing the Portals for Immersion and Passive Monitoring of the Environment. Participants engaged more deeply in discussions about choosing and modifying portals based on their needs, revealing a strong preference for the ability to freely customise their portals. This customisation allowed them to tailor their experiences to specific changes in the environment, enhancing their immersion or awareness as needed. The following reflections explore what influenced their choices and how pre-set portals differed in meeting their expectations.

In particular, participants adjusted the sizes of self-chosen portals to increase or decrease their awareness of the train environment. Larger portals were seen to "*increase presence in reality*" (P3), while smaller portals kept attention more on the virtual environment being displayed: "*if it's about focusing on the actual VR video playing, having the smaller boxes was slightly better, keeping my attention more on that*" (P12) and "*helped focus more on the video*" (P14). P11 indicated that maintaining an equal view of both realities would involve choosing portals and virtual environments of similar sizes, giving an "*equal…view into reality and virtuality*". On the whole, participants expressed a need to resize the portals based on certain events, such as wanting to quickly check what was happening around them, especially if people were nearby: "*I would just move my portal face to those people. Enlarge the size of the portal, so I can know what they are doing there*" (P1). Particularly when a new passenger entered the nearby space, adjustments were made: "*I was aware of the gentleman seated in front of me… So I had moved one of the portals slightly more towards the window and resized it, made it larger to… see the gentleman's leg, just so I knew that I wasn't encroaching on his space*" (P5).

All participants appreciated the control over customizing their reality, particularly through customizing the portal shapes. Some used multiple portals to create shapes that "*fit around the virtual environment*" (P6) to maintain focus on the content, cover specific areas like the "*aisle space*" (P8), or form "*curved panoramas*" (P13) for passive awareness. While customization was preferred, some participants found value in starting with a pre-set configuration, as choosing the right setup from the beginning could be challenging. As one participant reflected, "*in hindsight, [I] didn't maybe align the portals to where I would have them if I was using it regularly…I noticed that on the way back with the pre-designated portals that perhaps I hadn't used that functionality to its full capacity*" (P5). Another participant noted that setting up the portals themselves "*took away a bit from my concentration on the video itself*" (P4). This suggests that while the ability to customize is valuable, having pre-set portals that highlight key objects of interest could provide a useful starting point, which users could then further customize as needed.

Overall, larger portals not only increased the awareness of the train environment but were also seen as a way to passively monitor the real world rather than actively checking the portals, and were the preferred choice by participants. Participants discussed wanting to have fewer but larger portals in "*strategic places*" (P4) to get: "*an easy overall impression of what's happening*" (P8) and felt that smaller portals were "*more distracting*" (P12), because they require active monitoring: "*when they were small, I had to focus more on what was in them and look more carefully*" (P8). Several participants noted that having to turn their heads to actively look at portals was tiring and expressed a preference for portals in the periphery, where they "*don't have to totally turn my head…like how in real life…you still have your peripheral*" (P9). While two pre-set portals were positioned in the periphery, their smaller, more focused sizes necessitated more active checking, which participants found less ideal. Despite this, small portals were still valued for specific tasks, such as checking something particular. As one participant noted, "*there was a point where I was able to check my phone in the real world through that. That was quite cool…And it was quite convenient*" (P8).

4.3.2 Most Important Elements of the Train Environment. Interviews with participants revealed a strong preference for portal placement facing moving passengers, staff members and those in close proximity. Participants prioritized predicting changes in passengers, particularly when the train was getting busy, over maintaining a constant visual, emphasizing that "*safety and anticipation go hand in hand with each other*" (P9) and that it is crucial not to have "*your space invaded without being able to be prepared*" (P5). Less importance was placed on "*non-moving*" passengers further away (P1), with most portals positioned on the aisle side. One participant described this as the "*social side*" (P7) of the train, providing a most useful view. Conversely, portals focusing on personal belongings were consistently highlighted as vital for safeguarding possessions. P6 stressed the importance of "*keeping an eye*" on them, especially in a moving environment. Yet, some participants felt they could monitor their belongings without visual aid by keeping items "*super close*" (P9), as "*you're more likely to feel if somebody does anything*" (P11). Portals aimed at windows were generally seen as less useful, except for specific purposes such as estimating the distance "*from reaching my destination*" (P2), monitoring the "*journey progress*" (P5), assisting in "*reducing motion sickness*" (P5), or simply for a "*change of scenery*" (P8). Interestingly, participants' reflections align closely with the objects selected by the pre-set

Figure 4: a-c) Participants' use of portals, marked in red for clarity: a) custom shapes (P6), b) "curved panoramas" (P13), and c) smaller portals for focused attention, e.g., glancing at a phone (P8).

portals, which focused on the passenger on the aisle side, personal belongings, and the window—though, as noted by participants, the window was only useful to some for specific purposes.

4.4 Information 'Wormholes' and Trust in the Headset

The concept of 'information wormholes' emerged as a notable phenomenon during our study. It highlights instances where changes in the dynamic real-world environment slip past the portals of the VR headset, presenting an unexpected challenge and raising concerns about trusting the headset.

A clear example occurred when P8 did not realize a passenger had sat down directly in front of them, leading to unexpected discomfort. P8 reflected on the experience, stating: "*would have liked to know he moved into the space*" after the passenger had "*snuck through a gap*" in the portals. Having auditory information but no visual to match it also added to the confusion, with P9 questioning when a passenger sat in front: "*should I try and move the thing so I could see his face?*" and P10 finding it disorienting: "*knowing that when you're sitting there, there is more to see, but all you can see is this like one person or this one small segment is quite disorienting*". This demanded mental effort to "*trying to like fill in the small gaps in between*" (P12). Similarly, P10 expressed frustration over having to "*deduce from what you can hear and a smaller snippet*" instead of recognizing events as they occurred. Knowing that there was a change in the surrounding environment evoked a sense of unease: "*I didn't expect someone to sit in front of me. . . I couldn't see the guy's face while I was watching the stuff, which was okay. . . but also a little bit like, weird*" (P9).

Such experiences underscored trust concerns with the VR device, as participants expressed doubts about its ability to reliably represent the real world. P3 particularly noted a preference for real life visuals over those offered by VR, saying, *"I would obviously prefer seeing it in real life rather than, you know, in a virtual context"*. P4 echoed this sentiment, remarking that portals are not "*like seeing reality*". Participants felt the responsibility to detect environmental changes themselves, as P11 stated, "*I trusted myself to be able to tell if something happened in the cameras*", or expected to be notified by other passengers: "*I kind of trust them to, I don't know, be looking out for me*" (P14) rather than the headset.

4.5 VR Advantages Over Traditional Devices

Participants' interviews confirmed that VR headsets are seen to offer advantages over traditional devices, providing benefits to using one on a journey.

Participants reflected on using various devices such as phones, laptops, or headphones during their typical journeys (P3, P4, P5, P6, P7, P9, P10, P12, P13, P14), to stay entertained or feel productive: "*I can catch up on my games or movies so. . . I feel like I'm doing something productive with the time rather than just sitting and . . . wasting it*" (P3). VR headsets were perceived to offer advantages over traditional devices, primarily due to being more "*engaging*" (P6), the "*privacy*" they provide (P5), and their flexibility—for example, they can be used even "*without a tray table*" (P6). Their unlimited screen size could make work easier compared to using a phone (P2, P6), making it a suitable "*workspace*" (P2), with one participant noting, "*the phone's going to make it difficult because you might have to correct those typos that you make. . .the screen is really small*" (P2). Additionally, a few participants observed that the experience resembled that of traditional devices during journeys, as both primarily draw the user's attention: "*just the way that people interact with tablets and mobile phones in public. . .is a completely immersive experience*" (P5) and consequently limit their awareness of the surrounding environment: "*sometimes I'll sit on my laptop and. . .be very tunnel-visioned on the laptop, so it felt like that kind of thing*" (P6).

4.6 Expectations of Social Interaction on Public Transport

Participants' interviews revealed an overall positive experience with using a VR headset on a train, attributing this to the limited interaction expected when travelling alone. However, VR is still perceived as a hindrance to communication when communication is expected, such as when travelling with friends or family.

4.6.1 Travelling Alone. Whilst participants viewed public transportation as a shared space, the majority noted that only minimal interaction with others is expected and viewed other passengers as "*strangers*" (P1, P2, P3, P4). However, opinions on disconnecting from the environment delivered mixed results. Some considered it normal not to feel socially "*connected*" to other passengers (P2, P3, P4, P9), and had no expectations of being approached by others (P2, P3, P5, P6, P8), or of approaching others themselves: *"I don't* *owe anybody any social interactions"* (P5) unless it was a brief interaction: "*maximum maybe one minute of interacting"* (P2). However, a few felt that wearing a VR headset might lead them to miss out on spontaneous social interactions: "*I do quite like just the random interactions that you get with strangers on public transport. It's one of the reasons why I like to take it*" (P14) or the sense of being part of a communal setting: *"I think it's nice to go and have an awareness of your surroundings, of the people around you... just having the ability to connect to others through kind of awareness of the communal space that you're sharing"* (P12). This sentiment was echoed by P10, who saw the value in simply acknowledging other passengers even if no immediate interaction takes place: "*nice to have that sort of acknowledgement of each other and like if the need arises, being able to ask a question*" (P10).

4.6.2 Travelling with Others. Interaction issues between the VR user and other passengers become more pronounced when effective communication with companions is expected or desired. Participants noted that VR headsets could prevent "*normal conversations*" (P1) and "*reduce*" the ability to communicate (P1), creating a substantial "*barrier to socializing*" (P3). This barrier manifests as an extra layer of separation between the user and other passengers, complicating interactions that could easily occur with traditional devices (P4). Communicating effectively while using VR was overall seen as more challenging (P4), as VR headsets make it difficult to divide attention between real and virtual (P4) and result in the loss of social cues, crucial for effective communication (P6). While the earlier section noted that interaction is not a prerequisite for public transport, this changes when the user is travelling with friends or family.

Participants' answers showed that when travelling with friends or family, communication is expected. The dynamic changes significantly when the interaction involves familiar passengers—the VR acceptability hinges on collective participation. Participants noted that wearing VR headsets is not as acceptable when travelling with someone unless the whole party can share the experience (P2, P6), whilst collaborating (P2, P6), watching content, or playing together (P4, P6). However, it would be considered rude to wear a headset if it isolates the user from friends or family who are not participating (P3, P5, P11, P12, P13), and expect real-world interaction with the user: " *if you'd gone with friends on a train and one of them just pulled out a VR headset and disappeared into that, you'd feel a bit like, huh?, that's not really what I was expecting*!" (P10). Generally, participants expressed that they would remove headphones or put away phones to engage more directly when travelling with someone they know (P4), underscoring the expectation to interact more personally in such contexts, including instances when a VR headset is being used.

4.7 Seating Choices for VR Use on Public Transport

As part of the outward journey, participants were asked to choose their seats. They predominantly selected seats further away from other passengers, in quieter parts of the train.

Interviews revealed several reasons for participants' seating choices. Sitting near a window was preferred because it provided more room: "*sitting by the window is my first choice because I can have more space to use the VR*" (P1), or felt less exposed: "*aisle... felt a bit more on the outside*" (P11). Participants also sought to distance themselves from other passengers: "*was looking for a place that was further away from other people*" (P10) or to minimize interaction: "*[sitting further away] so I don't have to interact with people*" (P4). Choosing a quieter spot was also seen as a way to avoid bothering others. P3 chose a place "*where I wouldn't disturb people*", while P12 preferred picking a spot where they "*don't feel like [they're] intruding into someone else's space*". This minimised disruptions and allowed for better concentration on the virtual content, as P3 noted, choosing "*somewhere that wouldn't be too loud so I can concentrate on the documentary*". Additionally, sitting further from the aisle was seen as a way to have more time to react to environmental changes: "*further away from the aisle because . . . this way. . . if somebody came to talk to us, I could, like, see them move over*" (P8).

5 Discussion

5.1 Balancing Dual Worlds and 'Information Wormholes'

Prior research has detailed the disorientation and surprises associated with exiting virtual environments, which often lead to intermediate states where individuals experience confusion about which reality they are truly in [32, 61]. Our study, however, expands on this by identifying that simultaneous navigation of both real and virtual realities can also induce feelings of being *in between realities*. Participants' experiences varied significantly: some felt more present in the virtual space, describing themselves as "*not there*" (P9) in the real world. Others felt "*half*" (P1) in each reality, not fully immersed in the virtual environment nor completely engaged with the real world. Meanwhile, a different subset of participants consciously focused their efforts on remaining aware of the train environment, actively resisting the pull of the virtual experience. Engaging with both realities required additional effort which aligns with previous work arguing that handling parallel realities is difficult [67]. The need to monitor both realities leads to instances where changes in the real world slip past the portals and might be unnoticed by the participants, creating the phenomenon of 'Information Wormholes'.

Instances where information "*snuck through a gap*" (P8) in the portals were discussed by a few participants. P8 was surprised when someone sat in front, wishing they had known the person had moved into the space. P9 echoed this, emphasising the need to see the person's face if they came close. These comments underscore the need for alerts about significant real-world changes. Concerns also arose when audio changes were noticed without matching visual cues (P9), with the need to 'fill the gaps' being frustrating, contrasting with the prior work by McGill et al.[43], which advocated for limiting reality to selectively viewed elements. However, our findings suggest that participants often preferred broader peripheral views of the environment that provided a passive monitoring experience, rather than a more active checking of selective elements explored through our pre-defined portals.

These findings underscore the need for better support for users in navigating transitional states without confusion. The sensation of being lost between realities suggests that current passthrough reality blending may not adequately anchor users in either reality, leading to a disrupted sense of presence. Grounding in reality is crucial, particularly when dealing with reality mismatches that can disorient users and diminish their trust in the virtual experience.

5.2 Focusing on What is Important in Reality Awareness Systems for Transit

Our findings highlight that reality-awareness systems are crucial in transit environments. The passthrough portals we adopted for this setting effectively reduced participants' concerns related to safety, awareness, and social fears. Key information participants preferred to track included moving passengers, those in close proximity, and personal belongings, with some also wanting to track journey progress. The most important elements align with our prior work [6], which showed that passengers and personal belongings are crucial for reality awareness needs in transit. However, our study further reveals that perceptions of the transit environment are not uniform; it can be divided into areas of greater social activity, where heightened awareness is necessary, and more secluded areas, such as seats next to a window, which demand less vigilance. These findings identify archetypal spaces—social, secluded, and hybrid—within transit environments. These archetypes, applicable to varying degrees, can extend across different modes of transport. Seating preferences were in line with prior work [49], showing that aisle spaces were seen as more exposed, risking more opportunities to encroach into other passengers' space.

In contrast to studies focused on VR awareness in controlled indoor environments, like homes and offices, we observe several key differences in transit settings. Work by Harley and MacArthur [27] shows that changes within these indoor environments, such as room or furniture rearrangements, are typically more predictable. Concerns in these settings often relate to the presence of familiar passersby, pets, or the necessity of maintaining visual access to specific elements of reality, which may include workplace essentials or personal items [33, 55]. While prior research by Eghbali et al. [13] indicates that broader public spaces lead to similar concerns about physical obstacles, the safety of personal belongings, and avoiding collisions with passersby, our work shows that transit environments intensify these challenges. In transit settings, passengers experience constant changes in both the internal and external environment. More than merely displaying specific elements of reality, transit settings require dynamic communication about changes in the environment. For instance, passengers need to be aware not only of others entering their immediate space but also of broader environmental changes like new passengers boarding or leaving. This requirement extends externally as well, such as tracking the journey's progress to ensure alighting at the correct stop.

In addition, our work shows that having control is an essential part of reality awareness systems in transit. Many pre-implemented awareness systems, such as 'Passthrough' or 'Guardian', offer limited customisation options. However, the dynamic nature of the environment means that awareness needs can fluctuate, sometimes requiring more or less engagement depending on the situation, such as when a train suddenly becomes busy. Participants responded positively to the ability to adjust portal coverage and create custom shapes, giving them greater control over their interaction with the real world. Some, however, appreciated starting with pre-set portals, noting that setup takes time and skill. Future research should explore integrating these extended awareness needs into customisable reality-awareness systems across transit settings, to further enhance passenger safety, awareness, and alleviate social fears.

5.3 Between Isolation and Interaction with VR on Public Transport

Our study highlights the distinct advantages of VR use in transit settings, as participants appreciated the opportunity to use their time productively (P3), finding it preferable to the limitations of traditional devices with their "really small screens" (P2), resonating with prior research [47]. Furthermore, we find that the transit environment is perceived as less socially active than other public spaces where spectatorship and shared experiences are more common [13, 60], enabling VR users to 'shield' themselves from other passengers and enjoy the "privacy" (P5) that VR provides.

However, not all passengers wish to disengage from their surroundings. Some, like P14, cherish the spontaneous interactions that occur on public transport, which can be restricted by VR use. The communication barriers posed by VR are particularly challenging when travelling with companions, where social interaction is expected. The difficulty in conveying crucial social cues like eye gaze [8] remains unresolved. Previous attempts to address these issues included gestures, virtual 'doorbells' [70] and displays showing the user's face and eyes [39]. Recently, commercial innovations such as the Apple Vision Pro headset have also utilised simulated eye gaze as a solution. However, these efforts have elicited some early reactions, with the technology described as 'creepy' or 'uncanny' [78] raising questions about its suitability.

The communication challenge in VR is more pressing in transit settings, where the constant turnover of passengers can lead to unexpected interactions, often with safety implications. These challenges extend beyond simply attracting the attention of VR users. Those who opt to shield or disengage from their surroundings may not be ready or willing to communicate. Current solutions often address the needs of non-HMD users (e.g., helping to get a VR user's attention) but rarely consider the VR user's desire to signal disinterest in engagement. This gap highlights an ongoing challenge that invites novel solutions, complementing existing technologies like gaze simulation, requiring further research.

6 Limitations

There are certain study design limitations in our research that must be acknowledged when interpreting our findings. First, while our in-the-wild study allowed us to gather ecologically valid insights from users in real transit settings, it also meant that each participant's experience was not necessarily controlled or identical. Time constraints of adhering to train schedules also limited the time available to test multiple reality awareness solutions. Second, the 15-minute route minimized participant fatigue but may have restricted our understanding of awareness needs during longer journeys, which could be explored in future studies. Third, the experimenter was present during the study sessions. This was necessary for safety in a public, uncontrolled environment. The experimenter's role included handling the equipment and ensuring participants' well-being, especially when using pre-set portals. Stewarded evaluations like these are standard in HCI studies conducted in the wild [10, 71]. However, we need to acknowledge that the experimenter's presence may have impacted the level of control and independence participants had during the study. Finally, we utilised passthrough portals, allowing passengers to explore where and what they chose to attend to in reality by adjusting the portal size and position. While useful, this method is not definitive. Additionally, the study's content was designed for constrained transit spaces, and participants primarily focused on a single virtual screen within a 360-degree virtual environment. Engaging with different types of content or interacting more fully with the 360-degree space could uncover additional issues and should be explored in future research. Exploring other types of reality awareness visualisations could provide further insights into the most effective ways of supporting user awareness needs.

7 Conclusion

We present the first 'in-the-wild' study on VR headset use during real train journeys, offering genuine insights that extend beyond controlled research settings. Our study enabled users to explore passthrough style 'portals' to reality – a customisable example of potential reality-awareness tools – investigating the impact these portals have on users' perceived safety, awareness, and social fears when using a headset in transit. Our use of 'in-the-wild' methods marks our first contribution (1). The findings demonstrate how VR portals enhance safety and awareness, and reduce social concerns in transit settings, marking our second contribution (2). Finally, we uncover unique challenges in adopting VR in transit. These include navigating real/virtual environments that create a sense of being neither here nor there, experiencing 'information wormholes' where information unexpectedly slips past the portals, and a preference for passive monitoring of the real environment over actively checking the portals, marking our third contribution (3). Our work advances understanding of VR adoption challenges in real-world settings and offers insights for future reality-aware systems.

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A APPENDIX

Interview Questions (Excluding Probes)

- (During the break between train rides): Could you share your first impressions of what you have just experienced?
- (During the break between train rides): How did you decide where to sit?
- In retrospect, how did you feel about using a virtual reality headset on the train?
- How did the experience of using a virtual reality headset on a train compare with your expectations? Were there any surprises?
- Did you feel more present in the train, the virtual environment, or the mix? Please explain.
- How comfortable or uncomfortable did the mix of real and virtual content make you feel during the experience? Why?
- Did you have any concerns during the journey? If yes, how did you deal with these concerns?
- How comfortable or uncomfortable did you feel about using the VR headset?
- Considering the social context during the journey, what did you think other people were thinking about you? Was this on your mind?
- Did the virtual reality experience impact your sense of social connection with other passengers? If yes, how?
- What are your overall thoughts on the portals?
- Reflecting on the portals you drew; what influenced your choice to draw a portal?
- On the journey back, there were three pre-set portals. How did that compare to your setup on the way out?