Welcome to the Jungle: Using ARTV to Balance Media Immersion and Reality Awareness for Passengers on Public Transport

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Figure 1: Images show how ARTV can be applied to passenger contexts. The plant models and textures were environmental augmentations matching the nature documentary being viewed, intended to enhance media immersion while supporting passenger awareness of the surrounding train environment. *Top Left:* AR Baseline *Top Right:* High FOV - Low ARTV Ornamentation *Bottom Left:* High FOV - Medium ARTV Ornamentation *Bottom Right:* High FOV - High ARTV Ornamentation.

ABSTRACT

Head-mounted displays (HMDs) offer new possibilities for reclaiming and improving passenger travel time. Common Virtual Reality (VR) HMDs provide an immersive mobile media viewing experience, overcoming the screen size constraints of mobile and seat-back displays. However, they also reduce environmental awareness as they completely occlude reality. Conversely, Augmented Reality (AR) glasses afford environmental awareness by default, allowing unrestricted presentation of media through large virtual planar displays, but without the same immersion as VR. Our work transposes the immersive benefits of VR to AR, whilst preserving awareness of the environment. We present results from a user study (N=24) exploring the addition of plants and textures as augmentations of a simulated VR train environment to enhance passenger media immersion when watching a nature documentary. We evaluated two different fields of view (50°, 104°) and three different levels of ARTV ornamentation (from none to a fully textured jungle environment in the train). We found that on high FOV devices, ARTV ornamentation results in levels of media immersion that are not significantly lower than those achieved with full VR whilst retaining environmental awareness not possible with typical VR solutions. On low FOV devices, ARTV ornamentation loses effectiveness and distract users. Our results show that the immersiveness of AR can be significantly increased while still allowing the awareness of the environment that travellers need to manage their journeys.

IMX '24, June 12–14, 2024, Stockholm, Sweden

ACM ISBN 979-8-4007-0503-8/24/06
https://doi.org/10.1145/3639701.3656321

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; **Virtual reality**.

KEYWORDS

AR, VR, XR, MR, Immersive Video, ARTV, Ornamentation, Train, Public Transport, Public Transit

ACM Reference Format:
Iain Christie, Mark McGill, and Stephen Brewster. 2024. Welcome to the Jungle: Using ARTV to Balance Media Immersion and Reality Awareness for Passengers on Public Transport. In *ACM International Conference on Interactive Media Experiences (IMX '24), June 12–14, 2024, Stockholm, Sweden.* ACM, New York, NY, USA, 12 pages. https://doi.org/10.1145/3639701.3656321

1 INTRODUCTION

Commuting is a daily occurrence for many people, for example the average person in England makes 110 commuting journeys each year [6] averaging 27 minutes long [6]. Commuters often perceive travel time as "dead" or wasted and there is a strong desire to engage in tasks to fill the time [28]. Singleton surveyed 650 commuters and found that some would not opt to teleport straight to their destination, if given the chance [28]. This reinforces the idea of the positive utility of travel time and the concept of worthwhile travel time [4, 29]. Lyons [11] looked at three instances of the British Rail National Passenger Survey: 2004, 2010, and 2014, (which [28] based many of their questions upon) and found that, with the advancement of digital devices such as laptops, etc., more commuters were reporting their travel time as worthwhile (24.4% in 2004 vs 30.6% in 2014). Extended Reality (XR, a combination of virtual and augmented reality) technologies could increase this further.

Virtual Reality (VR) allows passengers to overcome the constraints of physical mobile devices and their limited screen size to render unbounded virtual and immersive content around the user. This does, however, have disadvantages: when using a VR headset the user can be immersed in the content and may lose awareness of their surroundings. When we consider passenger contexts, reality awareness is particularly important - it underpins safety (e.g. other passengers posing a hazard to the user), security (e.g. protecting ones belongings) and is necessary for managing journeys, supporting the user to get off at the correct stop [3]. VR occludes reality by default forcing VR-using passengers to trade safety/security for immersion.

Conversely, Augmented Reality (AR) and pass-through VR overcome the issues posed by occlusive VR by allowing in a view of the outside world while rendering video content on top. However, this is at the cost of immersion in the content. Devices such as the XReal Air[1] or Apple Vision Pro[2] are marketed for this purpose. Although they leverage AR's benefits to increase the screen size beyond that of a laptop, they fail to fully utilize the abilities of AR to immerse the user in the content. For example, they do not employ environmental ornamentations or augmentations that might enhance the content being experienced Figure 1. Research has previously examined the concept of ARTV [23] where AR augmentations accompany 2D video media to enhance immersion, engagement and enjoyment. However, ARTV has yet to be explored outside the living room.

Our work investigates combining the benefits of VR (immersive environments and presence in the VR experience) with those of AR (reality awareness) for passenger consumption of 2D video media. We do this through immersive ARTV augmentations of reality based on the media being consumed. For example, a nature documentary might lead to leafy augmentations of the passenger environment, much as suggested for ARTV applications in the home [24]. *ARTV ornamentations* aesthetically match the on-screen content to extend the experience into the real world. These augmentations differ from those that provide information to users or divert attention from the content on ARTV screen (e.g. an AR panel with details about characters in a TV show or an alternate camera angle of the sports game being displayed on an AR screen). For passengers, ARTV ornamentation could balance the immersion/awareness trade-off and support more enjoyable viewing while travelling.

In this paper, we simulate a 2D ARTV experience in a commuter train environment using VR, evaluating the impact that aesthetically matching AR ornamentations have on the balance between media immersion and reality awareness. We used a Meta Quest 2 headset to simulate AR in VR [3, 14]. We compared media immersion and environmental awareness at increasing levels of ARTV ornamentation (see Figure 1) to understand how they trade off against each other. We also looked at the effect field of view (FOV) had on immersion by repeating the experimental conditions for a low AR FOV (representative of the Hololens 2) and a higher FOV (representative pass-through AR from the Quest Pro).

This paper contributes insights into the use of ARTV in passenger transit for the first time, exploring the impact that display ornamentations have on passenger awareness and the efficacy of ARTV across low and high FoV AR devices. We highlight that a) on high FoV devices, ARTV ornamentations can increase media immersion without affecting environmental awareness; b) on low FoV devices ARTV ornamentations are distracting and jarring. Our findings have implications for the growing number of AR consumer devices (e.g. XReal Air, Apple Vision Pro) targeting immersive media consumption when mobile.

2 RELATED WORK

2.1 The Problem with VR for Reality Awareness

The majority of passenger XR experiences have concentrated on a VR-centric approach where immersion is achieved in VR, and reality awareness is selectively incorporated. For example, Bajorunaite *et al.* looked at introducing elements of the real world ("Reality Anchors") into virtual reality to keep the user aware of their surroundings [3]. Allowing users to know where other passengers were increased their perceived level of safety. However, this exposes a potential trade-off between improving perceived safety, versus the ability to attend to, and be immersed in, the content that they view.

Bajorunaite *et al.* [3] conducted two studies, first looking at how Reality Anchors could alleviate concerns around safety, social acceptability, and comfort. The findings illustrated the trade off between immersion and the acceptance of the use of these technologies on public transport. Awareness of the environment was not as useful as awareness of personal belongings or location of other passengers. The second study [3] allowed participants to toggle on and off the reality anchors that they wished to be aware throughout the journey. The study found that the most important factor was awareness of other passengers when it came to participant comfort, social acceptability and feelings of safety. Participants either used the anchors continuously or toggled them on and off regularly to check in on the real world, since having the anchors continually present was distracting and reduced immersion. This is similar to [18] whose findings were that participants wanted

[1] https://www.xreal.com/air/, Last visited 04/10/2023.
[2] https://www.apple.com/apple-vision-pro/, Last visited 04/10/2023.

awareness of nearby bystanders. Bajorunaite also found that the reality anchors that participants wanted to be visible varied based on the content being consumed, the type of journey. It was also suggested that these reality anchors be themed to avoid a stark contrast between them and the content. This was thought to lead to a loss of awareness so wasn't looked at in the paper.

Similarly, Williamson *et al.*[33] looked at the usability and social acceptability of VR devices on a plane. The biggest issue identified in their survey was the loss of awareness of the environment and the concerns surrounding that. The ability to have reality awareness within the context of the VR experience was also identified in [3, 18].

Since there was such variance in the reality anchors users wanted and as there was a desire expressed to make the visualisation of the reality anchors match the content being consumed [3], it makes sense to approach this problem from an Augmented Reality perspective where the necessary reality anchors are included naturally by virtue of the experience being grounded in AR. The way that we provide the user with reality awareness differs drastically between the VR and AR experience. VR relies on sensing and reintroducing elements of reality, which entails the problem of identifying items such as personal belongings and subway information signs to represent them in VR. AR reality awareness on the other hand is the extent to which we can occlude the user's perception of reality before we diminish their awareness past a comfortable threshold. If the virtual content is not rendered over objects that the user needs to be aware of, then users will maintain awareness.

By utilising AR instead of VR, the problem of having to tailor this reality awareness to each individual experience and having to recognise passengers, signage, and belongings, can be avoided. Instead, AR content can be introduced into the environment in locations that will not obfuscate passengers and as a result maintain the user's awareness of the real world to the desired extent. If virtual content is rendered over something important, we can give the user the ability to easily remove it. Another benefit of AR is the natural inclusion of motion cues which may help mitigate motion sickness, as detailed in [7, 12, 13, 19].

2.2 Desire for More Immersive Passenger Entertainment

Li *et al.* [10] investigated Virtual Reality usage for productivity in cars and found participants were reticent to use it and thought it better suited to watching videos, not the reading and writing tasks that they would usually do on commutes. It was not just the in-car use case that entertainment is preferred over productivity. In [2], two surveys were administered (N=60, N=108), the first concerned the use of VR on aeroplanes. There was strong interest on using this technology (65% somewhat or very interested). Respondents ranked their interest across the three use cases of entertainment, communication, and work, with entertainment ranking the highest. Reasons for this included the perceived set-up cost associated with using a VR headset and that the system did not replace traditional devices for work. Participants across these studies identified the potential of VR for viewing videos but without ways to support environmental awareness, it is unlikely to find widespread use in passenger contexts. If the application is simply a large screen VR cinema experience then it fails to take advantage of the potential of XR.

Wilson *et al.* [34] used an online survey (n=1378) and in-depth interviews (n=18) to understand the tasks that people wanted to perform in an AV and the motivations for private AV ownership. 88% of the 566 that answered this question agreed or strongly agreed that they would undertake leisure activities when the vehicle was driving autonomously. This was the highest of all the activity groups questioned. The remaining being *rest and sleep*, *socialise*, *be productive*, *remain in the driving position*, *morning routine*, *work with a colleague* (ordered in descending order of agreement).

2.3 Supporting Media Immersion through ARTV

Augmented Reality Television is the idea that we can enhance the experience of watching TV using Augmented Reality [8, 9, 31]. This can include contextual information about what is being viewed being displayed outwith the bounds of the television or utilising AR to render, in the room around the user, 3D models related to the content being displayed on screen. For example, a turtle swimming through the air in the living room whilst a nature documentary is playing. ARTV is not restricted to AR glasses. As laid out in Vatavu *et al.* [32], there is an ARTV continuum that encompasses both physical and virtual TVs, second screens such as phones, projector-based augmentations in the room and around the TV, AR HMD augmentations, and watching TV in VR. Using their ARTV Continuum our proposal would be in position 7 - *Augmented World / Virtual TV*.

Popovici and Vatavu [20] conducted an exploratory study with the aim of understanding user preferences and prioritisation of ARTV as a concept and of 20 distinct ARTV scenarios; such as virtual objects coming out of the screen, watching different perspectives of the same movie scene on different displays, and having additional content such as character names displayed next to the TV screen. The third, fourth and fifth highest rated concepts in terms of perceived value centred around increasing the field of view of content beyond the display of the TV and having objects come out of the TV. This inspired the concept we used in this paper of having a jungle-like series of ARTV ornamentations placed in the user's vicinity.

Saeghe *et al.* [24] conducted a user study looking at the effects of adding AR artefacts to an existing TV programme using a Microsoft Hololens. The findings suggested that augmenting the TV can result in increased engagement. A follow up study [25] then looked at the impact that changing the starting point for a sea turtle hologram swimming near the TV had on user experience. The role of the hologram was mixed, with participants raising concern that the more engaging the hologram was, the less attention that was paid to the TV. Participants felt that they would be missing out on something by dividing their attention. Participants were also asked about watching TV in VR and the response was overwhelmingly positive to the concept.

As ARTV content can distract from the intended viewing experience, it is necessary to balance the degree of ARTV related content. For this reason, we explored three different levels of ARTV ornamentation within our study to understand the immersion - awareness trade-off.

2.4 The Consumer Reality of AR in 2024

Current AR devices such as the Xreal Air (2022), Xreal Air 2 Ultra (2024), and Microsoft Hololens 2 (2019) have a limited FOV (46° Horizontal, 52° Horizontal, and 43° Horizontal respectively)[3]. VR headsets have larger FOVs, e.g. the Meta Quest 2 has a Horizontal FOV of 104°, but still far less than human vision. One method to experience higher FOV AR HMDs is to use pass-through AR. That is, augmented reality that uses a VR headset's cameras (and wider FOV) to capture the real world and display it to the wearer, such as the Meta Quest Pro. This allows for a FOV within which the ARTV ornamentations can be rendered but does come with lower visual quality as the real world can only be captured and displayed at the quality of the device's cameras and screens.

In time, AR headsets may be able to match the FOV of current VR HMDs without requiring solutions such as pass-through AR. Recent papers propose new AR display solutions that allow for FOVs higher than that of current devices [36–39]. It is not clear the impact this increase in FOV will have on the experience of viewing media, especially not the impact of immersive ARTV for media viewing. However, at present the limited FOV of these devices restrict the types of experiences they can provide. For example, with ARTV the television itself (be it physical or a virtual screen) would take up the vast majority of the central viewing area leaving little room for ornamentations to be rendered within the available FOV.

2.5 Summary

Entertainment is desired by passengers and there is an appetite to use VR for this purpose. However, there are drawbacks insofar as VR inhibits the user from being aware of their travel environment, which is necessary for safety, security and journey management. Instead, we propose to use Augmented Reality to support passenger entertainment. AR affords environmental awareness by default, whilst supporting ARTV ornamentations that can enhance media immersion through augmenting the surrounding transportation environment in keeping with the video content being viewed.

3 EXPERIMENT

We apply the concept of ARTV to a passenger train context. This is undertaken to determine if we are able to improve the experience of watching ARTV video while retaining the environmental awareness needed for a journey. The study addresses three research questions:

- RQ1 **FOV:** Does device Field of View (FoV) impact perceived media immersion of the user consuming ARTV content?
- RQ2 **AR vs VR:** How does ARTV Ornamentation compare to immersive VR in terms of enjoyment, engagement, immersion?
- RQ3 **Degree of ARTV:** How does increasing the *Degree of ARTV Ornamentation* impact the trade off between immersion and environmental awareness?

[3]https://www.xreal.com/air/, https://www.microsoft.com/en-us/hololens/, Last visited 04/10/2023.

3.1 Design

We used a within-subjects design. Participants experienced 8 conditions total, two of which were controls. The VR Baseline was a full VR jungle environment with a large 2D screen (150 inch diagonal, 4.5m from the user as recommended for home cinema configuration [5]) showing the documentary. This was inspired by the viewing experience seen in the Apple Vison Pro keynote presentation[4]. There was no view of the train carriage. The AR Baseline was an AR environment showing a smaller 2D screen overlaid on the train carriage 0.5m from the participant, with no ornamentations (see Figure 1, top left). This floating panel is similar to the solution employed by the Xreal Air AR glasses[5]. Through these two controls, we captured the two parts of the reality-virtuality continuum [15, 16] that we are interested in to understand the immersion - awareness trade-off involved.

For the remaining experimental conditions, we manipulated two factors: *Degree of ARTV Ornamentation* (3 levels) and *Field of View (FOV)* (2 levels). Figure 1 shows some examples. For Degree of ARTV Ornamentation, at the Low Ornamentation level we had a sparse selection of 12 plants models on the table in front of the participant, the table across the other side of the train and hanging down from the overhead bins. At the Medium Ornamentation level this increased to 55 models. A mixture between plants, rocks, and various foliage debris spread around the carriage. At the High Ornamentation level (bottom right of Figure 1), we also modified the textures of the train carriage (see video figure) to match the jungle theme. The plant models were obtained from the Jungle - Tropical Vegetation asset pack from Seedmesh Studio [30].

To simulate overlaying a texture over an object in AR, we retextured the surfaces of the train carriage utilising transparency in the High Ornamentation conditions so that the original textures could still be seen (jungle textures were 15% transparent). Similarly, all the 3D models were 5% transparent. These values were chosen to mimic the appearance of the visuals in current AR devices and also to make the ARTV ornamentations noticeably distinct from the train interior.

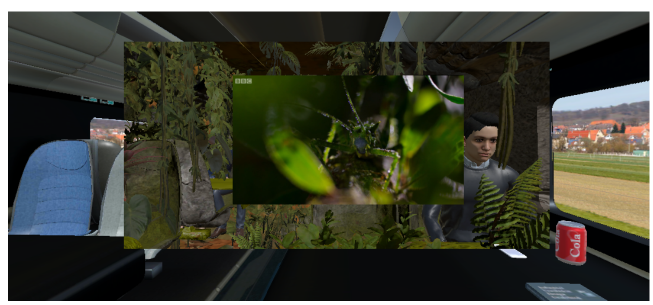

Figure 2: Mock up showing the view of the Low FOV - High ARTV Ornamentation condition as FOV restriction was applied per eye.

For FOV, our two levels were that of the Quest 2 (104° Horizontal, 98° Vertical) which we used to represent current pass-through AR

[4]https://www.youtube.com/watch?v=TX9qSaGXFyg Last visited 04/10/2023.
[5]https://www.xreal.com/air/, Last visited 04/10/2023.

Condition	FOV (Hor Ver)	Augmentation
Baseline	104, 98	None
Low FOV - Low ARTV Ornamentation	50, 40	12 Models
Low FOV - Medium ARTV Ornamentation	50, 40	55 Models
Low FOV - High ARTV Ornamentation	50, 40	55 Models & Textures
High FOV - Low ARTV Ornamentation	104, 98	12 Models
High FOV - Medium ARTV Ornamentation	104, 98	55 Models
High FOV - High ARTV Ornamentation	104, 98	55 Models & Textures
VR Baseline	104, 98	No train - VR

Table 1: Table showing the fields of view within which the ARTV ornamentations were rendered and the number of augmentations utilised for each experimental condition.

FOV. This FOV constrained all conditions as it was the maximum FOV of the device itself. The other FOV was that of a near future AR device (50° Horizontal, 40° Vertical) (see video figure). For the FOV of this hypothetical device, we took the FOV increase from Hololens 1 (30° Horizontal, 17.5° Vertical) to Hololens 2 (43° Horizontal, 29° Vertical) and applied this percentage increase to the Hololens 2's current FOV. The ARTV Ornamentations would only be rendered within the field of view as specified (see Figure 2) whilst the train would be rendered up to the FOV limit of the Quest 2 itself.

We only had a single AR Baseline, which used the larger FOV, rather than having another within which the video screen would be rendered only within the lower AR FOV. The video screen for Low FOV - Low ARTV Ornamentation, Low FOV - Medium ARTV Ornamentation, and Low FOV - High ARTV Ornamentation was wholly contained within the bounds of the Low FOV and would only be cut off if the participant looked away. As there was little incentive for the participant to look around in the baseline, the Low and High FOV baselines would be effectively the same. By using the High FOV baseline instead of Low FOV we allow for comparisons with pass-through AR which has higher FOV than see through AR (like the Hololens).

3.2 Environment and Content

A train environment was chosen as it is a very common method of travel and one where users are most comfortable watching videos [28]. We chose to simulate a long-distance train journey, simlar to Medeiros *et al.* [14]. On this type of journey, there is a need for awareness of other passengers for a feeling of comfort and safety, as established in [3]. A series of nature documentary clips set in jungle environments was chosen, with the ARTV ornamentations themed in a similar way to [25]. The models used to augment the train carriage were paid assets from an asset package on the Unity store[6]. We used VR to simulate a passenger train environment and the participant was in VR for all conditions in this study. Simulating AR in VR has been used successfully in prior studies [14, 33]. This approach enabled us to conduct a controlled experiment with a repeatable scenario prior to a more costly and challenging *in situ* evaluation.

[6]https://assetstore.unity.com/packages/3d/environments/jungle-tropical-vegetation-178966, Last visited 04/10/2023.

3.3 Measures

The questions participants answered after experiencing each condition were a combination of several pre-existing questionnaires and two of our own questions. This was comprised of the full *Film Immersive Experience Questionnaire* (Film-IEQ) [21] and the short versions of both the *User Experience Questionnaire* (UEQ) [27] and *User Experience Survey* (UES) [17] as these questionnaires were utilised in a previous assessment of ARTV [24]. We decided to utilise the UEQ-S instead of the full UEQ to reduce demands on participants. Our own questions were 2 statements asking participants to indicate how much they agreed with on a 5 point Likert scale from Strongly Agree to Strongly Disagree: "*I was aware of other passengers whilst watching the video*" and "*I was aware of the virtual modifications (trees and plants) whilst watching the video*".

After having experienced all conditions, participants were then asked two questions as part of an exit questionnaire. Participants were asked to rank all conditions in order of preference. Participants were also asked, for each condition, if they were interested in watching media on a train using that condition instead of using a phone or laptop. At the end of the study, a short interview was conducted to understand perceptions of the ARTV ornamentations and desires to use any of the conditions to watch media. Recordings were transcribed using WhisperX [1] and anonymised. The transcripts were analysed using a thematic analysis approach as detailed in [26]. The original audio files were deleted after transcription was completed.

3.4 Participants

Participants were recruited from the university's participant recruitment mailing list and from flyers posted on campus. The 24 participants ranged in ages from 20 to 60 with 12 males and 12 females. Participants were given a £10 Amazon voucher for compensation after the 75 minute study was completed.

3.5 Procedure

Participants were given an information sheet at the beginning of the experiment and gave consent for the experiment and interview logs to be recorded. After this, they answered demographic questions. Participants were seated on a chair and wore an Quest 2 headset which was plugged into a computer which ran the study via Quest Link. The experiment took approximately 75 minutes to complete. The conditions experienced and the documentary clips seen were counterbalanced between participants using a latin square design to reduce order effect. The experiment was approved by our University Ethics committee.

3.6 Analysis

For the Film-IEQ, UES-SF, UEQ-S, and each of their subscales, a Shapiro-Wilk test for normality and Mauchly's test for Sphericity was conducted. In the case that normality was violated, we used the Aligned Rank Transform (ART) [35] for analysis. Once these tests were complete and any necessary transformations conducted, we conducted a two-factor repeated measures ANOVA with FOV and Degree of ARTV Ornamentation as factors. We excluded the two control conditions from this to have an orthogonal matrix of conditions as required for the test. For significant ANOVA results *post hoc* pairwise comparisons were conducted. To compare the conditions to the controls we reduced our two factors to a single combined factor and conducted a one-way ANOVA to confirm a significant effect and then completed a *post hoc* Dunnett's test for each control.

4 RESULTS

4.1 Quantitative Results

Figure 3 shows three notched box plots showing the scores for each of the questionnaires administered broken down by *Degree of ARTV Ornamentation.*

Scores for the overall scales and subscales of each questionnaire used were calculated following the procedure laid out in their respective papers [17, 21, 27]. When *post hoc* pairwise t-tests were conducted the Bonferroni correction was applied. Results and statistical analysis can be found in Table 2. For brevity, only tests for overall scores are reported in the body of the paper for Film-IEQ, UES-S and UES SF; tests for subscales for each of the measures used can be found in the Appendix (Table 2).

4.2 Impact of FOV

Media Immersion. Media immersion was measured by the overall Film-IEQ. As seen in Table 2, FOV had a significant effect on the Film-IEQ score (see Appendix Table 2for full statistical testing for each questionnaire's subscales). The high field of view led to significantly higher levels of immersion when compared to the low FOV conditions.

Experience. FOV also had significant impact upon the UEQ-S and with higher FOV resulting in higher scores. FOV affected scores for the UES-SF in a similar manner.

Engagement. Engagement was measured by the Focused Attention subscale of the UES-SF. As above, the high FOV conditions had significantly higher engagement scores ($p<0.01$).

Awareness. The highest FOV condition led to decreased awareness of other passengers. *FOV* had a significant effect for our first self-defined question with a significant pairwise comparison for the low and high levels. Similarly for our second question there was also a significant low and high level pairwise comparison with increased awareness of the augmentations at the higher FOV level.

Interaction effects for all variables were analysed with interaction plots and no effect was found.

4.3 Impact of Degree of ARTV Ornamentation

4.3.1 Trade-off between Immersion and Awareness. Increasing *Degree of ARTV Ornamentation* led to an increase in immersion. This can be seen in the significant effect the *Degree of ARTV Ornamentation* had on our first self-defined question with a significant pairwise comparison for the low and high levels. Our Dunnett's test against the AR Baseline condition found significant decreases in self-reported awareness for the High FOV - High ARTV Ornamentation ($p<0.01$) and High FOV - Medium ARTV Ornamentation ($p = 0.001$)conditions. All of the conditions had significantly more awareness than VR Baseline ($p<0.01$ for each).

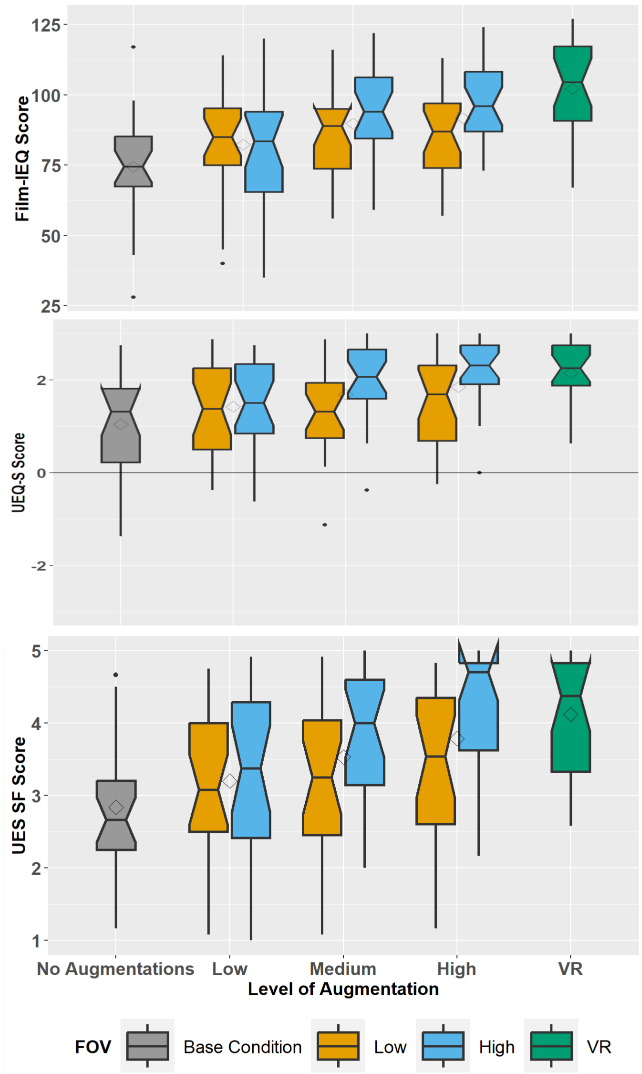

Figure 3: Notched Box Plot showing Distribution of Film-IEQ, UES-S, and UES SF Scores by Degree of ARTV Ornamentation and by FOV. All three graphs show increasing scores as Level of ARTV Ornamentation increases. VR Baseline has the highest scores for all scales.

Our second self defined question had a significant pairwise comparison for the low and high levels of *FOV* with participants being significantly more aware of the ARTV ornamentation at the higher *FOV*. This suggests that when using immersive AR with a limited FOV participants focus more on the content than the ARTV ornamentation. This combined with the results for the Low *Degree of ARTV Ornamentation* conditions (no significant Dunnett's for

		Two Factor ANOVA			Significant *post hoc* Comparisons		One Factor ANOVA	Significant *post hoc* Dunnett's			
								Baseline		VR	
Questionnaire	**Factor**	DoF	F	p	Comparison	p	p	Comparison	p	Comparison	p
	FOV	1, 23	13.18	<0.01	Low-High	0.032	<0.01	High FOV - High DoA	<0.01	Baseline	<0.01
Film-IEQ								High FOV - Med DoA	<0.01	High FOV - Low DoA	<0.01
	DoA	1.42, 32.58	7.49	<0.01	Low-High	0.023		VR	<0.01	Low FOV - High DoA	<0.01
										Low FOV - Low DoA	<0.01
	Interaction	2, 46	4.30	0.02						Low FOV Med DoA	<0.01
	FOV	1, 115	20.78	<0.01	Low - High	<0.01	<0.01	High FOV - High DoA	<0.01	Baseline	<0.01
UEQ-S								High FOV Med DoA	<0.01	Low FOV - Low DoA	<0.01
	DoA	2, 115	4.73	0.01	-	-		VR	<0.01	Low FOV - Med DoA	<0.01
	Interaction	2, 115	2.81	0.06							
	FOV	1, 115	20.88	<0.01	Low-High	<0.01	<0.01	High FOV - High DoA	<0.01	Baseline	<0.01
UES SF								High FOV - Med DoA	<0.01	High FOV - Low DoA	0.02
	DoA	2, 115	8.8	<0.01	Low-High	0.02		VR	<0.01	Low FOV - High DoA	0.05
										Low FOV - Low DoA	<0.01
	Interaction	2, 115	2.77	0.07						Low FOV - Med DoA	<0.01
I was **aware**	FOV	1, 115	11.82	<0.01	Low-High	<0.01	<0.01	High FOV - High DoA	<0.01	Baseline	<0.01
of other								High FOV - Med DoA	0.001	High FOV - High DoA	<0.01
passengers	DoA	2, 115	8.95	<0.01	Low-High	0.04		VR	<0.01	High FOV - Low DoA	<0.01
whilst										High FOV - Med DoA	<0.01
watching	Interaction	2, 115	4.32	0.02						Low FOV - High DoA	<0.01
the video										Low FOV - Low DoA	<0.01
										Low FOV - Med DoA	<0.01
I was	FOV	1, 115	20.42	<0.01	Low-High	<0.01	<0.01	High FOV - High DoA	<0.01	Baseline	<0.01
aware of the								High FOV - Low DoA	<0.01	High FOV - Low DoA	0.05
augmentations	DoA	2, 115	7.67	<0.01	Low-Medium	0.03		High FOV - Med DoA	<0.01	Low FOV - Low DoA	<0.01
					Low-High	<0.01		Low FOV - High DoA	<0.01		
	Interaction	2, 115	0.33	0.72				Low FOV - Low DoA	<0.01		
								Low FOV - Med DoA	<0.01		
								VR	<0.01		

Table 2: Statistical testing for questionnaires including *post hoc* tests. For the effect of FOV against Degree of ARTV ornamentation (DoA), a two-factor repeated measures ANOVA was conducted, with *post hoc* pairwise t-tests with the Bonferroni correction applied. For comparisons including our AR and VR baseline conditions, a one factor repeated measures ANOVA was conducted, followed by *post hoc* Dunnett's tests for comparing all conditions combining FOV/Degree of ARTV Ornamentation against the AR and VR baselines.

AR Baseline for Film-IEQ, UEQ-S, or UES-SF) also suggests that the lowest *Degree of ARTV Ornamentation* is not captivating or attention grabbing. When comparing our proposed immersive AR conditions (High FOV - High ARTV Ornamentation and High FOV - Medium ARTV Ornamentation) to the immersive VR condition (VR Baseline) we can look at the results of the Dunnett's test for the various scales and subscales. The only significant differences between High FOV - High ARTV Ornamentation and VR Baseline were found in our self-defined questions with passengers being significantly more aware of passengers and significantly less aware of the ARTV ornamentation in the High FOV - High ARTV Ornamentation condition. In VR, participants would have no awareness of the train interior and hence less awareness of passengers and more of the jungle environment. It suggests that our immersive AR High FOV - High ARTV Ornamentation condition significantly improves awareness without significantly reducing immersion in the media being watched.

The High FOV - Medium ARTV Ornamentation condition, which did not change the textures of the train interior, had similar results as participants were also more aware of passengers and less aware of the ARTV ornamentation. When compared to the VR Baseline control it was also not significantly less immersive as no difference was found for the overall Film-IEQ. This indicates that even the High FOV - Medium ARTV Ornamentation condition comes close to the media immersion of VR with the advantage of better environmental awareness.

4.3.2 Increased Immersion with High Ornamentation. Significant effects were found for the degree of ARTV ornamentation for the Film-IEQ and the *Real World Dissociation* ($p<0.01$) and *Transportation* ($p<0.01$) subscales. There were also significant pairwise comparisons between the low and high levels for *Degree of ARTV Ornamentation* for both the overall score and the *Transportation* subscale ($p = 0.015$). Looking at the Dunnett's test against the baseline condition, we see significant differences for the AR Baseline against the High FOV - High ARTV Ornamentation and High FOV - Medium ARTV Ornamentation conditions for the same scale (see Table 2) and subscale ($p<0.01$ for both conditions). This suggests that the higher degree of ARTV ornamentation significantly increases immersion.

A significant difference was found for the overall UES-SF. This suggests increasing the extent of ARTV ornamentation led to feeling more absorbed in the interaction and losing track of time (*Focused Attention* subscale), more visual appeal (*Aesthetics* subscale), increased desire to recommend the experience / use again in future, sense of novelty and interest, and feeling of being drawn in and

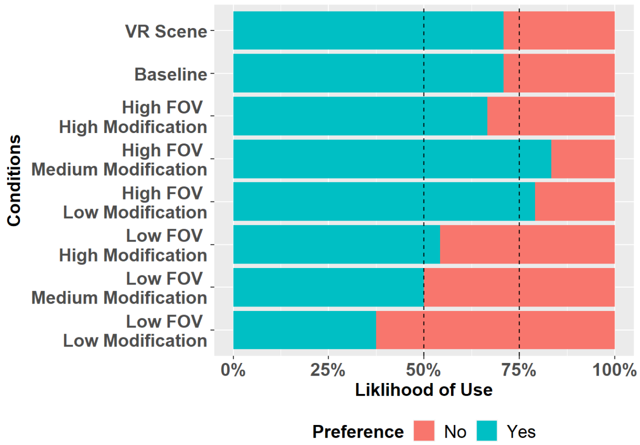

Figure 4: Participant's response to the question "Would you be interested in using this condition instead of a phone / laptop when watching a video on the train?". Dotted lines are shown for 50% and 75% thresholds.

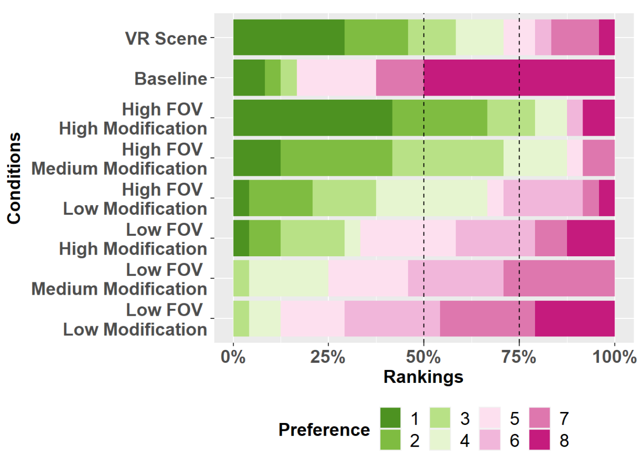

Figure 5: Participant ranking of conditions in order of preference. 1 - Most Preferred, 8 - Least Preferred. Dotted lines are shown for 50% and 75% thresholds.

enjoyment (*Reward* subscale). We can attribute these qualities as the results for these subscales were significant (p<0.01) and the *Perceived Usability* subscale results were not significant (p = 0.14).

Significant differences were also found for overall UEQ-S and the *Hedonic* subscale (p<0.01) when increasing *Degree of ARTV Ornamentation*. There was a significant increase in scores for the *Hedonic* subscale for medium and high levels of ARTV ornamentation across both levels of FOV when compared to the AR Baseline condition (p<0.01 for both). This suggest the increase in ARTV ornamentation led to more fun and enjoyment when watching the video.

4.4 Condition Preferences

As can be seen in Figure 5, participants ranked all Low FOV conditions the lowest. High FOV - High ARTV Ornamentation and High FOV - Medium ARTV Ornamentation had the same number of top 4 preferences beating High FOV - Low ARTV Ornamentation and VR Baseline in this regard. High FOV - High ARTV Ornamentation was given rank 1 by the most participants followed by VR Baseline.

More than 75% of participants said they would be interested in using either High FOV - Medium ARTV Ornamentation or High FOV - Low ARTV Ornamentation instead of a phone or laptop to watch a video on a train (Figure 4). The same number of people said they would use the AR Baseline as those that said VR Baseline. High FOV - High ARTV Ornamentation ranked behind the aforementioned four.

4.5 Qualitative Results

A single coder thematic analysis was performed identifying the themes from the post experiment interviews.

4.5.1 *Low FOV Conditions.*

Users found the limited FOV distracting (n=7). The Low FOV condition necessitated only rendering the ARTV ornamentations within a smaller portion of the Quest 2 headset's field of view (see Figure 2). 7 of the 24 participants complained that the rendering of the ARTV ornamentation only within this rectangle was distracting. P11 said *"I felt kind of distracted by the square. I'm not going to lie."* and P14 echoing this *"I like the idea of the low one, but I felt as if it was kind of distracting sometimes. When you moved, the trees would disappear"*.

No peripheral awareness of the ARTV ornamentation (n=7). Again 7 of the 24 participants noted that the low field of view meant many of the modifications were not visible when watching the movie. P2 said *"When I was watching the TV, I didn't really see anything else. I wasn't really seeing the plants around it."* P11 held the same concern *sometimes I wanted to see the plants, like, to get more, like, feeling I was in there, but it was like, I have to move my head and then I lose the sight of what I'm watching."*.

Too much contrast (n=4). P1, P17, P19 and P20 discussed the concept of the border between the video and ARTV ornamentation, and the ARTV ornamentation and the train interior being distracting and confusing. As P1 put it *"I think the low field of view was just a bit distracting. contrast between the train and the field of view. And then there's three separation barriers, you know, for the movie and the field of view and the train"*.

Awareness Trade-Off (n=6). Six participants remarked on the benefit of limiting the rendering of the ARTV ornamentations to within the small field of view as it increases the user's awareness of the environment compared to the High FOV conditions. As P2 explained it: *"I have more of an understanding of who's around me and what's happening, which is super important to me if I'm on a train. But I still have all the the benefits of being in VR, seeing my world augmented in such a way"*. P3 had similar views *"So I put the low FOV and the high modification first [in my ranking] because I felt like I could still see like if the door was opening or like a stop was* *coming up on the train or people were there ... but I could also still see all the cool flora around So that was pretty cool."*

4.5.2 High FOV Conditions.

Immersion (n=4). Four of the participants made it clear that the increased FOV improved their feeling of immersion. P2 explained the improvement *" I felt a lot more immersed. Because even when I wasn't looking to the left, I could still see there were plants to the left."*.

Increase in immersion worth the decrease in awareness (n=4). Four participants expanded upon this idea, explaining that they were happy to be less aware of their environment as they were much more engaged in the video clips. P23 explained it as such *"The high FOV high modification was top [in my ranking] because it was the best balance of having a more immersive experience but also still staying aware of my surroundings. I think if I was on a train I might need to keep track of people coming and going and where the train is and so on. So I wouldn't necessarily want to be entirely immersed [like] in the VR scene. So I think I went for the best of both worlds."*

4.5.3 High Modification.

Distraction (n=5). Five of the participants mentioned that the highest level of modification was distracting. P2, P7, and P20 all had similar concerns. P2 said *"It's a lot more distracting, and it took me a second to get into what was happening"*.

Reduced Awareness of Environment (n=4). Four participants raised the issue of the modifications affecting their awareness of the train environment. P19 said*"personally I wouldn't prefer this because it obscures the real world and I still want to be involved in the real world"*.

Awareness of Train (n=6). Several participants highlighted the benefits of still being aware of the train whilst being immersed in the video. As P16 put it *"I can still keep an eye on like what's happening out in the world, but I still have that experience of like being immersed of it"*. P23 commented *"High FOV high modification was top because it was the best balance of having a more immersive experience but also still staying aware of my surroundings. I think if I was on a train I might need to keep track of people coming and going and where the train is and so on. So I wouldn't necessarily want to be entirely immersed in the scene. So I think I went [for] the best in both worlds"*.

Increased Immersion (n=11). Eleven participants mentioned the impact the High level of modification had on their immersion. P12 explained *"I could still see what's happening around me, but it felt more like you're in the scene. So I really liked that"*. P16 similarly said *" when you had a lot I felt like it was really kind of dragging you into it"*. P21 went on to elaborate *"I'm not sure how, but it didn't distract me at all. I'd say it definitely enhanced it. And it was only when, perhaps because I saw the high condition first and I was like, oh, this is amazing"*. P22 captured the intention of this condition in their comments *"I really like that because it is very aesthetically pleasing and it really gave more sense of what was in the video, what was being discussed, especially because it was more connected to the environment. So I think I like that"*.

Texture Change Improved Experience (n=12). By contrast, 12 of the 24 participants remarked that changing the texture of the interior of the train resulted in a notable increase in their immersion. P3 and P5 mentioned how "cool" it was *"I think it made things a lot more worth it, it was very cool."* and *"because the table was green and the chairs were too it genuinely was so cool"*.

P12, P21, P23, and P24 mentioned the effect it had on the chairs. *"So because the seats, I think they were bluish, so that is very much a colour that you don't really see in the jungle. So that's very much different from that. So I think really changing that [texture] did make a difference."* and *"I didn't realise how much making the chairs blend in made a difference. I was like, oh god, they're blue."*

P14, P16, and P21 explained the impact the texturing had on their experience. *"I felt it did add to the experience a lot"* and *"it looks like kind of like almost like a zombie apocalypse kind of like if this was a jungle and this train had derailed yeah this is what it would look like"* and *"it's interesting how much it then added to it, just having the different sort of concordant colors there. I was like, okay, the tables are green as well. It's like they just fit, that fits in"*.

Occluding Passengers (n=10). Ten participants explained that having the modifications occlude other passengers in the vehicle was a positive rather than a negative.

Participants 6, and 24 had similar opinions *"If someone was next to me or around me and was moving vividly then It would be nice if there were some plants around so it would feel more immersed"* and *"If I'm like, you know what? I don't want to see you. It's nice to have a leaf in front of [them]. I liked that there was a leaf covering him a little bit"*. Interestingly participant 16 touched on how they thought it helped them with their ADHD *"I felt like ... especially with having ADHD, all of these, I felt like I saw everybody and I would watch them, whereas these, the plants kind of covered them up a bit. So that was a good thing"*.

4.5.4 Low Modification.

Awareness (n=3). P2, P4, and P23 all touched on the benefits to their awareness of the train and other passengers. As P23 explained *"I'd maybe rather just have a slight modification to keep good awareness of everything, while just watching a movie with a little bit of ornamentation"*.

Unconvincing Immersion (n=6). Six participants highlighted the lack of immersion they felt with the low modification conditions. P14 and P16 had similar feedback. *"Yeah, so the low one was a bit too low, in my opinion. Okay, I felt like, what was the point in [it] being there?"*, and *"it was giving you a little bit of ambience whereas like when you had a lot [of plants] I felt like it was really kind of dragging you into it and when it was just a little bit you're like what's going on? It's kind of like somebody that buys like one house plant and puts it in the living room"*.

4.5.5 Attitudes towards the VR Baseline.

Awareness (n=6). Six participants raised the issue of awareness of their environment whilst watching something in VR. As P2 explained *" I have no idea of what's happening around me, who's around me."*.

Immersive (n=5). Five of the participants mentioned how immersive the VR scene was. P10 summarises it *"The VR scene, that was more or less, you were wrapped in cotton wool. The only distraction was what was happening in and on the outside of the scene. On the train one, you had your plants and that. But I would definitely say that the VR was more immersive"*.

4.6 Limitations

4.6.1 Lab Setting. As this study was conducted in a lab environment and used an AR in VR design, it is possible that results may differ in a real passenger train environment. The passenger models we included had idle animations which made them more realistic than static models. However, it is possible that these animations did not generate a strong enough sense of realism to be convincing. Our animations did not have passengers leave their seat or walk around the carriage. This does not properly mimic the dynamic nature of reality. It is likely that the interaction between passengers and ARTV ornamentations would impact the user's level of media immersion. Future work is required to understand the effect this would have. However, our findings make a strong case for the utility of immersive AR to maintain awareness of the user's environment while enhancing the media viewing experience beyond that of traditional devices and current AR solutions such as the Xreal Air, motivating further *in situ* study in real trains in the future.

4.6.2 Limited Duration. The study had participants watch short clips taken from a full documentary. It is possible that the results would be different if the participants had watched a full documentary under these conditions. With the short duration of the clips the experience remains novel and the effects of participant's attention spans did not have an impact.

4.6.3 Media Content Genre. Our study considered a single genre of video clips: nature documentaries. The increased levels of immersion that we achieved may not be possible across all genres. It is also not clear which ARTV ornamentations should be used for every type of media. For example; which ARTV ornamentations should be included when watching a romantic film set in the current day? It is worthwhile for future studies to examine the impact genre has on immersive AR and ornatmentations.

4.6.4 Types of ARTV Ornamentation. The ARTV ornamentations we chose were basic 3D models with some movement to mimic swaying in the wind. It is possible that results may differ if more sophisticated ornamentations were used. For example, inhabiting a more detailed world based on the content or having active ARTV ornamentations similar to the turtle in [25].

4.6.5 No Comparison Against Other Reality Awareness Solutions. We did not evaluate our ARTV ornamentation solution against other VR and reality awareness solutions e.g. *Reality Anchors* or the environment awareness dial from the Apple Vision Pro. Future work will need to consider if there are effective VR reality awareness techniques that remove the need for a passthrough-style awareness of reality for passengers.

4.6.6 Journey Type. We only considered a long externally managed journey as defined in [3] and did not consider alternatives such as short self-managed journey which would demand much more awareness of the user's environment. In this case, the higher levels of ARTV ornamentations could make it more difficult to maintain awareness of stops, so lower levels might be more useful.

4.6.7 No Comparison Between ARTV Ornamentation and 3D TV. With Apple supporting 3D video on the Apple Vision Pro it is worthwhile to investigate the the effects ARTV Ornamentation have compared with both 3D TV provided by a headset and autostereoscopic 3D TV. The latter, which necessitates a physical screen, will encounter the same problems that other physical displays have compared to AR glasses. Such as display size, ergonomics, and set-up time. Nonetheless, it is worthwhile for future work to investigate the difference in immersion between these solutions.

5 DISCUSSION

Our results broadly affirm the benefits of ARTV ornamentations for supporting media immersion while retaining environmental awareness. The inclusion of ornamentations led to a significant increase in the score for the Film IEQ. This suggests it does not affect the ability to watch the content but does improve the enjoyment and immersion when doing so. This can also be seen in the interview quotes with participants appreciating the feeling that they are within the content that they are watching. The fact that High FOV - High ARTV Ornamentation and High FOV - Medium ARTV Ornamentation outranked both controls and participants said High FOV - High ARTV Ornamentation was more likely to be used instead of a traditional device on a train, reinforces this idea.

5.1 ARTV Ornamentation More Hindrance Than Help for Low FOV AR Devices

As seen from the interview transcripts the inclusion of ARTV Ornamentations that are cut off by the limited FOV was a distraction and caused annoyance to many participants. Participants wanted to concentrate on the media itself. It follows that the Low FOV conditions were not significantly more immersive than the AR Baseline condition, as was seen from questionnaire response data. This explains the poor rankings of these conditions and participant's reticence to use them instead of a phone / laptop.

From this we can answer **RQ1**. There is a significant impact upon immersion for different levels of field of view. As such, immersive AR as we have described here is less effective on the current generation of devices such as the Xreal Air and Microsoft Hololens 2. It is more effective on devices with FOV similar to, or higher than, current VR devices, such as VR devices that offer passthrough AR (e.g. Quest Pro, Pico 4) or the next generation of AR displays.

5.2 AR Level of Immersion Approaches that of VR

Considering just the high FOV conditions, for reasons outlined in the previous section; there were no significant Dunnett's tests between VR Baseline and High FOV - Medium ARTV Ornamentation or High FOV - High ARTV Ornamentation. This means our conditions were not significantly worse than VR Baseline. From our interviews we found participants enjoyed the High FOV - High ARTV Ornamentation and High FOV - Medium ARTV Ornamentation conditions with many of them remarking about the immersion they felt during the High FOV - High ARTV Ornamentation condition. This suggests that immersive AR is able to provide an immersive experience similar to viewing media in a fully virtual environment without the awareness drawbacks of having reality be entirely occluded by the device. This answers **RQ2**, ARTV ornamentation is similar to immersive VR in terms of enjoyment, engagement, and immersion.

5.3 Balancing Reality Awareness against Media Immersion

Increasing the extent of the ARTV ornamentation did result in increased immersion scores and enjoyment but this came at the detriment of awareness of the environment and other passengers. Although four of the participants explicitly said in the interviews that the highest degree of ARTV ornamentation was worth this trade-off, it was High FOV - Medium ARTV Ornamentation that the highest number of participants said they would be interested in using instead of a traditional device on a train. Similarly, although High FOV - High ARTV Ornamentation was ranked 1st the most number of time, it was tied with High FOV - Medium ARTV Ornamentation for top 4 rankings.

As different participants preferred different levels of ARTV ornamentation, citing lowered awareness and distraction as the negative aspects of High FOV - High ARTV Ornamentation, it would be prudent to allow the user to adjust the extent of ARTV ornamentation to their preference so that they are able to enjoy as much increased immersion as they are comfortable with. In Apple's Vision Pro trailer, they showed a reality awareness dial which controls the field of view of reality mixed with virtuality[7]. Instead, it might be more beneficial to use this dial to control the degree of ARTV ornamentation applied to the environment as this is likely to strike a better balance between immersion and awareness.

Regarding **RQ3**, ARTV Ornamentations significantly improved the viewing experience with increased levels of immersion but this comes with reduced environmental awareness. Arguably, High FOV - Medium ARTV Ornamentation strikes the best balance as it tied High FOV - High ARTV Ornamentation as the condition with the highest number of top 4 rankings and was the condition that the most participants said they would be interested in using to watch media instead of a phone / laptop on a train. Given this, the question for further research is how to make such ARTV ornamentation a feasible reality. There would be a significant implementation overhead if custom content must be tailor-made for each television programme / video clip. But by utilising generative AI similar to Stable Diffusion [22], it may be possible to generate appropriately themed ARTV ornamentation from video metadata or knowledge of the video content itself - unlocking the benefits for ARTV ornamentation for any content in any space.

5.4 ARTV Ornamentations Applicable to Other Activtities

This work examined the use of ARTV Ornamentations when watching 2D planar video content but there is no reason to constrain their use of to just this scenario. When a passenger is reading while wearing AR glasses (either a physical book or on an AR panel), the use of augmentations themed to the book's content might similarly improve the experience as the use ARTV Ornamentations does to watching a video.

A passenger who is trying to relax or simply pass the time during a journey might benefit from the use of calming or relaxing augmentations which improve the appearance of their environment. A babbling brook down the centre aisle or koi pond on the table in front of them might make a Monday morning commute a more calming experience than it otherwise would be.

[7]https://www.youtube.com/watch?v=TX9qSaGXFyg, Last visited 04/10/2023.

5.5 Recommendations

Rec. 1 Use ARTV Ornamentation instead of Virtual Reality to achieve a high degree of media immersion while retaining reality awareness of the travel context.
Rec. 2 Provide at least 2 levels of ARTV Ornamentation to allow users to choose the setting that matches their personal immersion - awareness threshold.
Rec. 3 Do not use ARTV Ornamentations on devices with limited FOV (<50°) as it becomes a distraction and does not improve the viewing experience or immersion.

6 CONCLUSION

In this paper, we investigated the impact augmented reality ornamentations had on the passenger viewing experience when watching 2D ARTV nature documentary clips. Our results demonstrate that ARTV ornamentations and likely immersive AR as a concept are more effective with larger FOV devices. For low FOV conditions, ARTV Ornamentations did not significantly increase immersion nor enjoyment and participants found the limited FOV distracting. However, for larger FOVs, ornamenting the environment around a 2D ARTV display significantly improved immersion and viewing enjoyment. The AR ornamentations made the TV content more immersive while allowing the traveller to maintain enough awareness of their surrounding environment to be comfortable using them while travelling. The immersive AR solutions were perceived as more likely than either AR Baseline or VR Baseline to be used to watch videos on a train instead of using a phone or laptop. Our work demonstrates the potential for ARTV to improve media viewing on public transport, by affording passengers greater levels of media immersion but retaining reality awareness - exemplifying the benefits of ARTV beyond the living room for the first time.

ACKNOWLEDGMENTS

This research was funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (#835197, ViAjeRo).

REFERENCES

[1] Max Bain, Jaesung Huh, Tengda Han, and Andrew Zisserman. 2023. WhisperX: Time-accurate speech transcription of long-form audio. *INTERSPEECH 2023* (2023). https://doi.org/10.21437/interspeech.2023-78
[2] Laura Bajorunaite, Stephen Brewster, and Julie R. Williamson. 2021. Virtual reality in transit: How acceptable is VR use on public transport? *2021 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)* (2021). https://doi.org/10.1109/vrw52623.2021.00098
[3] Laura Bajorunaite, Stephen Brewster, and Julie R. Williamson. 2023. Reality anchors: Bringing cues from reality to increase acceptance of immersive technologies in transit. *Proceedings of the ACM on Human-Computer Interaction* 7,

MHCI (2023), 1–28. https://doi.org/10.1145/3604266
[4] Yannick Cornet, Giuseppe Lugano, Christina Georgouli, and Dimitris Milakis. 2021. Worthwhile travel time: A conceptual framework of the perceived value of enjoyment, productivity and fitness while travelling. *Transport Reviews* 42, 5 (2021), 580–603. https://doi.org/10.1080/01441647.2021.1983067
[5] Scott Davies. 2022. Calculating the ideal screen size from your seating position. https://www.customht.com.au/blogs/ht-hifi/calculating-the-ideal-screen-size-from-your-seating-position
[6] Office for National Statistics (ONS). 2023. Office for National Statistics: Travel Survey 2022. https://www.gov.uk/government/statistics/national-travel-survey-2022
[7] Philipp Hock, Sebastian Benedikter, Jan Gugenheimer, and Enrico Rukzio. 2017. CARVR: Enabling In-Car Virtual Reality Entertainment. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (2017). https://doi.org/10.1145/3025453.3025665
[8] Brett Jones, Rajinder Sodhi, Michael Murdock, Ravish Mehra, Hrvoje Benko, Andrew Wilson, Eyal Ofek, Blair MacIntyre, Nikunj Raghuvanshi, and Lior Shapira. 2014. RoomAlive: Magical Experiences Enabled by Scalable, Adaptive Projector-Camera Units. In *Proceedings of the 27th Annual ACM Symposium on User Interface Software and Technology* (Honolulu, Hawaii, USA) *(UIST '14)*. Association for Computing Machinery, New York, NY, USA, 637–644. https://doi.org/10.1145/2642918.2647383
[9] Brett Jones, Rajinder Sodhi, Michael Murdock, Ravish Mehra, Hrvoje Benko, Andrew Wilson, Eyal Ofek, Blair MacIntyre, Nikunj Raghuvanshi, and Lior Shapira. 2014. RoomAlive: Magical Experiences Enabled by Scalable, Adaptive Projector-Camera Units. In *Proceedings of the 27th Annual ACM Symposium on User Interface Software and Technology* (Honolulu, Hawaii, USA) *(UIST '14)*. Association for Computing Machinery, New York, NY, USA, 637–644. https://doi.org/10.1145/2642918.2647383
[10] Jingyi Li, Ceenu George, Andrea Ngao, Kai Holländer, Stefan Mayer, and Andreas Butz. 2020. An exploration of users' thoughts on rear-seat productivity in virtual reality. *12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (2020). https://doi.org/10.1145/3409251.3411732
[11] Glenn Lyons, Juliet Jain, and Iain Weir. 2016. Changing Times – a decade of empirical insight into the experience of rail passengers in Great Britain. *Journal of Transport Geography* 57 (2016), 94–104. https://doi.org/10.1016/j.jtrangeo.2016.10.003
[12] Mark McGill and Stephen A. Brewster. 2017. I am the passenger: Challenges in Supporting AR/VR HMDs In-Motion. *Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications Adjunct* (2017). https://doi.org/10.1145/3131726.3131876
[13] Mark McGill, Julie Williamson, Alexander Ng, Frank Pollick, and Stephen Brewster. 2019. Challenges in passenger use of mixed reality headsets in cars and other transportation. *Virtual Reality* 24, 4 (2019), 583–603. https://doi.org/10.1007/s10055-019-00420-x
[14] Daniel Medeiros, Mark McGill, Alexander Ng, Robert McDermid, Nadia Pantidi, Julie Williamson, and Stephen Brewster. 2022. From shielding to avoidance: Passenger augmented reality and the layout of virtual displays for productivity in shared transit. *IEEE Transactions on Visualization and Computer Graphics* 28, 11 (2022), 3640–3650. https://doi.org/10.1109/tvcg.2022.3203002
[15] Paul Milgram and Herman Colquhoun. 1999. A taxonomy of real and virtual world display integration. *Mixed Reality* (1999), 5–30. https://doi.org/10.1007/978-3-642-87512-0_1
[16] Paul Milgram, Haruo Takemura, Akira Utsumi, and Fumio Kishino. 1995. Augmented reality: a class of displays on the reality-virtuality continuum. *SPIE Proceedings* (1995). https://doi.org/10.1117/12.197321
[17] Heather L. O'Brien, Paul Cairns, and Mark Hall. 2018. A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form. *International Journal of Human-Computer Studies* 112 (2018), 28–39. https://doi.org/10.1016/j.ijhcs.2018.01.004
[18] Joseph O'Hagan, Mohamed Khamis, Mark McGill, and Julie R. Williamson. 2022. Exploring attitudes towards increasing user awareness of reality from within virtual reality. *ACM International Conference on Interactive Media Experiences* (2022). https://doi.org/10.1145/3505284.3529971
[19] Pablo E. Paredes, Stephanie Balters, Kyle Qian, Elizabeth L. Murnane, Francisco Ordóñez, Wendy Ju, and James A. Landay. 2018. Driving with the fishes: Towards Calming and Mindful Virtual Reality Experiences for the Car. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 2, 4 (2018), 1–21. https://doi.org/10.1145/3287062
[20] Irina Popovici and Radu-Daniel Vatavu. 2019. Understanding users' preferences for augmented reality television. *2019 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)* (2019). https://doi.org/10.1109/ismar.2019.00024
[21] Jacob M. Rigby, Duncan P Brumby, Sandy J. Gould, and Anna L Cox. 2019. Development of a questionnaire to measure immersion in video media. *Proceedings of the 2019 ACM International Conference on Interactive Experiences for TV and Online Video* (2019). https://doi.org/10.1145/3317697.3323361
[22] Robin Rombach, Andreas Blattmann, Dominik Lorenz, Patrick Esser, and Bjorn Ommer. 2022. High-resolution image synthesis with Latent Diffusion Models. *2022 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)* (2022). https://doi.org/10.1109/cvpr52688.2022.01042
[23] Pejman Saeghe, Gavin Abercrombie, Bruce Weir, Sarah Clinch, Stephen Pettifer, and Robert Stevens. 2020. Augmented reality and television: Dimensions and themes. *ACM International Conference on Interactive Media Experiences* (2020). https://doi.org/10.1145/3391614.3393649
[24] Pejman Saeghe, Sarah Clinch, Bruce Weir, Maxine Glancy, Vinoba Vinayagamoorthy, Ollie Pattinson, Stephen Robert Pettifer, and Robert Stevens. 2019. Augmenting television with augmented reality. *Proceedings of the 2019 ACM International Conference on Interactive Experiences for TV and Online Video* (2019). https://doi.org/10.1145/3317697.3325129
[25] Pejman Saeghe, Bruce Weir, Mark McGill, Sarah Clinch, and Robert Stevens. 2022. Augmenting a nature documentary with a lifelike hologram in virtual reality. *ACM International Conference on Interactive Media Experiences* (2022). https://doi.org/10.1145/3505284.3532974
[26] Johnny Saldaña. 2022. *The coding manual for qualitative researchers*. Langara College.
[27] Martin Schrepp, Andreas Hinderks, and Jorg Thomaschewski. 2017. Design and evaluation of a short version of the User Experience Questionnaire (UEQ-S). *International Journal of Interactive Multimedia and Artificial Intelligence* 4, 6 (2017), 103. https://doi.org/10.9781/ijimai.2017.09.001
[28] Patrick A. Singleton. 2019. Multimodal travel-based multitasking during the commute: Who does what? *International Journal of Sustainable Transportation* 14, 2 (2019), 150–162. https://doi.org/10.1080/15568318.2018.1536237
[29] Patrick A. Singleton. 2020. Exploring the positive utility of travel and Mode Choice. *Mapping the Travel Behavior Genome* (2020), 259–277. https://doi.org/10.1016/b978-0-12-817340-4.00014-0
[30] SeedMesh Studio. [n. d.]. https://assetstore.unity.com/packages/3d/environments/jungle-tropical-vegetation-178966
[31] Radu-Daniel Vatavu. 2013. There's a World Outside Your TV: Exploring Interactions beyond the Physical TV Screen. In *Proceedings of the 11th European Conference on Interactive TV and Video* (Como, Italy) *(EuroITV '13)*. Association for Computing Machinery, New York, NY, USA, 143–152. https://doi.org/10.1145/2465958.2465972
[32] Radu-Daniel Vatavu, Pejman Saeghe, Teresa Chambel, Vinoba Vinayagamoorthy, and Marian F Ursu. 2020. Conceptualizing Augmented Reality Television for the Living Room. In *Proceedings of the 2020 ACM International Conference on Interactive Media Experiences* (Cornella, Barcelona, Spain) *(IMX '20)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3391614.3393660
[33] Julie R. Williamson, Mark McGill, and Khari Outram. 2019. PLANEVR: Social Acceptability of Virtual Reality for Aeroplane Passengers. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (2019). https://doi.org/10.1145/3290605.3300310
[34] Christopher Wilson, Diane Gyi, Andrew Morris, Robert Bateman, and Hiroyuki Tanaka. 2022. Non-driving related tasks and journey types for future autonomous vehicle owners. *Transportation Research Part F: Traffic Psychology and Behaviour* 85 (2022), 150–160. https://doi.org/10.1016/j.trf.2022.01.004
[35] Jacob O. Wobbrock, Leah Findlater, Darren Gergle, and James J. Higgins. 2011. The aligned rank transform for nonparametric factorial analyses using only ANOVA procedures. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (2011). https://doi.org/10.1145/1978942.1978963
[36] Yuanjun Wu, Chang Pan, Changtai Lu, Yinxin Zhang, Lin Zhang, and Zhanhua Huang. 2023. Hybrid waveguide based augmented reality display system with extra large field of view and 2D exit pupil expansion. *Opt. Express* 31, 20 (Sep 2023), 32799–32812. https://doi.org/10.1364/OE.499177
[37] Jianghao Xiong, En-Lin Hsiang, Ziqian He, Tao Zhan, and Shin-Tson Wu. 2021. Augmented reality and virtual reality displays: Emerging technologies and future perspectives. *Light: Science & Applications* 10, 1 (2021). https://doi.org/10.1038/s41377-021-00658-8
[38] Jianghao Xiong, Guanjun Tan, Tao Zhan, and Shin-Tson Wu. 2020. Breaking the field-of-view limit in augmented reality with a scanning waveguide display. *OSA Continuum* 3, 10 (Oct 2020), 2730–2740. https://doi.org/10.1364/OSAC.400900
[39] Kun Yin, En-Lin Hsiang, Junyu Zou, Yannanqi Li, Zhiyong Yang, Qian Yang, Po-Cheng Lai, Chih-Lung Lin, and Shin-Tson Wu. 2022. Advanced Liquid Crystal Devices for augmented reality and virtual reality displays: Principles and applications. *Light: Science & Applications* 11, 1 (2022). https://doi.org/10.1038/s41377-022-00851-3