Augmenting a Nature Documentary with a Lifelike Hologram in Virtual Reality

Pejman Saeghe
Department of Computer Science
The University of Manchester
Manchester, United Kingdom
pejman.saeghe@manchester.ac.uk

Bruce Weir
Research and Development
The British Broadcasting Corporation
Salford, United Kingdom
bruce.weir@bbc.co.uk

Mark McGill
School of Computing Science
University of Glasgow
Glasgow, United Kingdom
mark.mcgill@glasgow.ac.uk

Sarah Clinch
Department of Computer Science
The University of Manchester
Manchester, United Kingdom
sarah.clinch@manchester.ac.uk

Robert Stevens
Department of Computer Science
The University of Manchester
Manchester, United Kingdom
robert.stevens@manchester.ac.uk

ABSTRACT

While augmented reality television (ARTV) is being investigated in research labs, the high cost of AR headsets makes it difficult for audiences to benefit from the research. However, the relative affordability of virtual reality (VR) headsets provides ARTV researchers with opportunities to test their prototypes in VR. Additionally, as VR becomes an acceptable medium for watching conventional TV, augmenting such viewing experiences in VR creates new opportunities. We prototype a nature documentary ARTV experience in VR and conduct a remote user study ($n = 10$) to investigate six points on the visual display design dimension of presenting a lifelike programme-related hologram. We manipulated the *starting point* and the *movement behaviour* of the hologram to gain insight into viewer preferences. Our findings highlight the importance of personal preferences and that of the perceived role of a hologram in relation to the underlying TV content; suggesting there may not be a single way to augment a TV programme. Instead, creators may need to provide the audiences with capabilities to customise ARTV content.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

augmented reality; television; design space; virtual reality

ACM Reference Format:
Pejman Saeghe, Bruce Weir, Mark McGill, Sarah Clinch, and Robert Stevens. 2022. Augmenting a Nature Documentary with a Lifelike Hologram in Virtual Reality. In *ACM International Conference on Interactive Media Experiences (IMX '22), June 22–24, 2022, Aveiro, JB, Portugal.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3505284.3532974

IMX '22, June 22–24, 2022, Aveiro, JB, Portugal

1 INTRODUCTION

While augmented reality television (ARTV) is being investigated by researchers, the current high cost of augmented reality (AR) headsets and glasses impedes mass deployment and adoption of ARTV—since for a typical ARTV experience a consumer would have to have an AR-enabled device (e.g., an AR headset) in addition to a TV set. However, virtual reality (VR) headsets are currently more affordable, and are even being used for watching conventional TV in an immersive environment.

In the context of ARTV, the opportunities provided by VR headsets are twofold; first, researchers can use VR as a test-bed to prototype novel ARTV experiences [3]; second, as more people use VR to watch conventional TV, VR-based ARTV experiences will likely emerge. The latter was predicted by Vatavu et al.'s [14] conceptualisation of ARTV, in a scenario where both TV and living room are virtual (see [14] 6.2, item 9).

In this paper, we prototype a nature documentary ARTV experience in VR to investigate six points on a *visual display* dimension of a lifelike programme-related hologram.

Our findings highlight the importance of personal preferences and that of the perceived role of the hologram in relation to the underlying TV content and narrative. We found that there may not be a single suitable way to augment a nature documentary; instead, audiences may want the ability to customise their experience based on individual needs and preferences. Our contributions in this paper are:

1) the first ARTV user study in VR to investigate the impact of changing two specific design decisions regarding the visual presentation of a lifelike hologram;
2) a refinement of Saeghe et al.'s [7] display dimension, by introducing three visual regions in the context of an ARTV experience for the living room;
3) a three-tier framework to classify a hologram's movement in the viewing environment.

2 RELATED WORK

We overview prior ARTV research and expand on Saeghe et al.'s [7] *display* dimension, which provides the basis for the six points of the ARTV design space that we investigated in this paper.

2.1 Augmented Reality Television

Over the past couple of decades, researchers and broadcasters have been investigating the ways in which AR can be used in the context of TV broadcasting (e.g., [6, 9–12, 15]). Enhancing a conventional TV viewing experience was reported by Saeghe et al. [7] as the most widely addressed theme in ARTV research, with use-cases including the provision of novel interaction techniques (e.g., [1]), extending the real estate of a TV screen (e.g., [2]), delivering programme-related additional holograms in the viewing environment (e.g., [8]), delivering virtual TV screens around a TV set (e.g., [13]), or even replacing a TV set entirely (e.g., [16]).

Inspired by Milgram and Kishino's *reality-virtuality continuum* [5], Vatavu et al. [14] conceptualised ARTV for the living room, where the TV set and the living room were each placed, and free to move, on their own reality-virtuality continua (see [14], Fig 4). Vatavu et al. [14] used this design space to generate nine types of ARTV experiences, one of which consisted of viewing a virtual TV screen in a virtual living room—a category that was highlighted as an area where further research is required. In this context, this paper can be viewed both as testing a conventional ARTV experience in VR, and as testing an ARTV experience where both the TV and the living room are virtual.

2.2 Entry point and movement behaviour

Saeghe et al. defined *display* as an ARTV design dimension that affords various possibilities regarding the visual presentation of AR content in relation to TV content, from the perspective of a TV viewer [7]. In the context of a single viewer positioned in front of a TV display, we refine this dimension by considering three broad regions where a hologram can be positioned in relation to a TV screen and the field of view of the viewer: 1) superimposed on the TV screen, 2) around the TV screen, and 3) outside the field of view. Furthermore, since a hologram can potentially move in 3-D space, we dissect its movement position into three components: 1) starting point, 2) travel path, and 3) destination.

While a non-moving hologram can be described as one with no *travel path* with its *starting* and *destination* points coinciding, at least two versions of a moving hologram can be envisaged, by changing the destination parameter. For instance, a hologram can start at a point, travel a path, and then *settle* on a destination, or it can move *continuously* in the viewing environment, without an apparent destination.

3 METHOD

We conducted a remote repeated-measures user study ($n = 10$) in VR to investigate the impact of changing the hologram's starting point and movement behaviour in the viewing environment on viewers' ARTV experience. The study was approved by the departmental ethics committee at The University of Manchester (Reference: 2021-11427-19154).

3.1 Experimental conditions

The study had a 3x2 design, consisting of three conditions for the hologram's starting point: 1) the TV screen, 2) adjacent to the TV screen, and 3) outside the field of view; and two conditions for hologram movement behaviour: 1) settling below the TV screen on a coffee table, within the field of view, and 2) continuously moving in the viewing environment. Table 1 presents our six experimental conditions.

Table 1: Six experimental conditions.

Condition	Starting Point	Movement Behaviour
1	The TV screen	Settle on the coffee table
2	The TV screen	Continuous movement
3	Adjacent to the TV screen (wall)	Settle on the coffee table
4	Adjacent to the TV screen (wall)	Continuous movement
5	Outside the field of view (ceiling)	Settle on the coffee table
6	Outside the field of view (ceiling)	Continuous movement

3.2 The ARTV experience

The ARTV experience consisted of a video clip (TV content) and a hologram (AR content), where the TV show's main character—a sea turtle—appeared outside the TV screen as a life-sized hologram.

The video clip (3.6 minutes in duration) was a segment from the Coral Reefs episode of the BBC's Blue Planet II programme[1]. It told a story revolving around the daily activities of a sea turtle, such as searching for food and competing for a spot on a rock at the bottom of the sea to get its shell cleaned by small fish.

The hologram was a life-size 3-D sea turtle asset acquired from the Unity Asset Store[2]. We used the Unity game engine to build the experience and deployed it to the Oculus Quest 2 VR headset.

The original video clip was split into six shorter clips (each about 36 seconds in duration), enabling us to create six short ARTV episodes corresponding to our six experimental conditions (see Table 1). The order of the video clips remained unaltered between participants, to keep the narrative flow intact. The experimental conditions were counterbalanced according to a Latin square.

3.3 The VR environment

We simulated a conventional living room in VR. Figure 1 illustrates the virtual living room with TV content being displayed on the virtual TV set and a holographic sea turtle, when settled on the coffee table (1a) and when entering the viewing environment from three different points: the TV screen (1b), next to the TV screen (1c), and the ceiling (1d).

3.4 Procedure

Participants received the information sheet, and returned completed consent forms and a basic demographic questionnaire. They received the experimental software in the form of an .apk file, a day before their scheduled session.

During the session, participants joined a researcher on a one-to-one Zoom call. They first received a verbal introduction to the study, then were asked to wear their VR headset. For each of the six ARTV episodes that they watched during their session, they would view the ARTV episode, remove their headset and respond to a set of questionnaire items on a web browser.

[1] https://en.wikipedia.org/wiki/Blue_Planet_II
[2] https://assetstore.unity.com/packages/3d/characters/animals/reptiles/sea-turtles-57461

(a) Hologram settled on the coffee table.

(b) The TV screen starting point.

(c) The TV-adjacent starting point.

(d) The ceiling starting point.

Figure 1: The virtual living room. Also depicted are the hologram settled on the coffee table, and the three starting points.

After watching all six episodes, the moderator conducted a semi-structured interview. The interviews were recorded and subsequently transcribed. At the end of the session, participants were briefed and given the opportunity to ask questions. They received a £10 Amazon gift voucher, on completion of the session.

3.5 Participants

Adult participants were recruited using social media (LinkedIn and Twitter) and electronic mailing lists. Ten individuals (8 male, 2 female) opted to participate (M=36.4, SD=12.3). There was one participant in each of the $18-24$, $35-39$, and $40-44$ age groups. There were four and three participants in the $25-29$ and the $50-54$ age groups, respectively.

4 RESULTS

In this paper we present the results of our qualitative analysis of participant interviews. We used a *deductive content analysis* technique [4] to analyse interview transcripts. Initially, a codebook with fourteen codes was generated from the semi-structured interview protocol. Through an iterative process, the codes were subsequently grouped into the following categories:

1) suitable entry points,
2) hologram's behaviour,
3) the role of the hologram,
4) interaction,
5) presentation of story-related holograms outside the TV screen,
6) watching TV content in VR, and
7) the virtual living room.

4.1 Suitable entry points

Overall, the responses highlight that the "right" entry point may depend entirely on the role of the hologram in the story. For instance: "it really depends on …the context of the story you're trying to tell" [P6] and "I would prefer [the hologram] to come out of the actual story." [P7]

We group the responses in three sub-categories:

1) **Coming out from the TV screen:** Five participants reported coming out of the TV screen as their favourite entry point. However, the success of this condition appears to "very much depend on what you're showing on the TV screen" [P8] at the time when the hologram enters the viewing environment (or exits the TV display). In cases where the hologram came through the TV screen when there was a sea turtle displayed on the TV screen, two participants thought it "felt right" [P2], and "felt more real and amusing" [P1], whereas P5 found it distracting and jarring, due to the hologram occluding the TV screen. P10 suggested that this entry point would be suitable only when the 2D turtle in the TV

programme is itself perceived to be entering the viewers' environment in holographic form.
2) **Emerging from the environment:** Three participants reported the wall and two reported the ceiling, as their favourite entry points. All participants reported both these conditions to be less distracting, however, P1 reported that the wall adjacent to the TV screen and the ceiling "felt unnatural" and "like a glitch".
3) **Other methods to introduce a hologram:** As opposed to entering the environment dynamically from a designated entry point, P4 suggested either fading it in or having the hologram present before the TV programme starts. This highlights a distinction between using a realistic behaviour (e.g., a swimming sea turtle) and one that defies expected realism (e.g., a sea turtle that cloaks and uncloaks itself), when presenting a lifelike hologram.

4.2 Hologram's behaviour

Similar to *hologram's entry point* (Section 4.1), the responses here also suggest that the "right" behaviour "really depends on the context." [P1]

We group the responses into five sub-categories:

1) **Landing on the coffee table:** Five participants preferred having the sea turtle land on the coffee table. It tended to "invite inspection ... my instinct was ... to interact and find out more" [P3]. It was also perceived to "give you a lot of options to watch it more closely" [P1] and to "provide the least amount of disruption." [P2]
2) **Continuous motion across the living room:** Three participants preferred the continuous motion of the hologram. The main reason for disliking the continuous motion was distraction from the TV screen. For instance, by causing the viewer "to pay the least amount of attention to the clip and wondering what I missed." [P2] However, P10 "perceived [the continuous animation] as more pleasant".
3) **Hologram as part of the story:** Three participants suggested that the hologram's behaviour should be either similar to the behaviour of its counterpart on the TV screen, or it should be driven by the needs of the narrative.
4) **Reactive to the environment:** Two participants highlighted that the hologram needs to react to the viewer and the elements in the viewing environment: e.g., "I prefer the holographic sea turtle to interact with the physical entities within my surroundings." [P9]
5) **Controllable by the viewer:** P4 suggested that the hologram "needs to be controllable by the [viewer]".

4.3 The role of the hologram

The comments point to an apparent trade-off between distraction (from the underlying TV content) and viewer engagement and immersion (due to the presence of holographic content). For instance, P2 suggested that "there's a spectrum where the more engagement you get with the hologram, the more distraction from the clip you get also."

While the negative comments can all be grouped under the umbrella of distraction, the positive comments highlight three main points:

1) **An increased sense of immersion and engagement:** Four participants reported an increase in their sense of engagement with the story. For instance, P10 said they "felt more immersed into the environment." Furthermore, P6 reported that the addition of a hologram would encourage them to re-watch the previously seen TV content.
2) **A bridge to the story-world:** P2 articulated the role of the hologram as connecting the viewer to the story-world, by creating a bridge between the TV display and the viewer.
3) **Learning about the animal:** Getting a sense of size, proportions, and how the actual animal swims was pointed out by P1 as the main positive aspect of having a holographic sea turtle.

4.4 Interaction

While two participants preferred to consume content in a passive mode, the rest of the participants ($n = 8$) reported a willingness to interact. The three themes that emerged from the responses were:

1) **Interaction for the sake of interaction:** Three participants reported a desire to interact with the hologram, as if it was a *real* creature. For instance, P6 "was very tempted to go out and try and touch it" and P3 reported that "as soon as it landed in front of [them], all [they] wanted to do was [to] pick it up."
2) **Having an interactive mode triggered by the viewer:** P5 reported that they would expect to interact with the hologram either when the TV programme is paused, or when "the TV show had some space" such that while they were interacting they would not miss out on the story. P4 reported that as soon as they start their interaction, they expect the programme to transform from a *"directed experience"* to one where the viewer can manipulate the objects; and back to the original "directed experience" once the viewer is finished interacting.
3) **Interaction to get more information:** P1 suggested to use the hologram as a way to deliver extra information about the real animal: "when I click on it [I want to see] where they live, how endangered they are, is there a place near me where I can go and watch the real animal ... whatever helps me to learn more about the turtle."

4.5 Presentation of story-related holograms outside the TV screen

Participants were asked to generalise from what they saw during the experiment and share their thoughts regarding the possibilities provided by combining story-related holograms with a TV show.

We present the comments in three categories:

1) **Enriching a conventional TV programme:** Five participants reported that story-related holograms would be suitable for enriching a conventional TV viewing experience. For instance, P9 reported that "it can encourage people to watch TV more and to engage in TV content more" and P6

suggested that holograms "bring people into the experience . . . by bringing the experience out to them."

2) **A new form of storytelling:** Two participants suggested that they "could easily see the technology being used to add components to enhance the narrative" [P2], and that "it creates new opportunities for storytelling." [P8]
3) **Eliminating the TV display:** P1 suggested that a mechanism should be provided for the viewer to select how much of the narrative's components they want to view in holographic mode. They suggested that when all the relevant components are presented outside the TV screen, the viewer can ignore the TV screen and follow the story mid-air in holographic mode and get much more from the experience.

4.6 Watching TV in VR

Eight participants only made positive comments, characterising watching TV in VR either comparable or better than the traditional way of watching TV. For instance, P1 said "you feel much more immersed. It's like experiencing the video in a theater"; P2 said "[it's] less distracting than watching [TV] in the physical world"; P4 said that watching TV is "basically one of the reasons why I bought a VR headset." Two participants pointed out that wearing prescription glasses while wearing a VR headset and the weight of the VR headset were the main barriers for them to watch TV in VR over long periods.

Based on the increasing popularity of watching TV content in VR, we suggest that the term ARTV may be overly restrictive; given that TV content can be consumed in both reality and virtuality with AR-type augmentations applied in both cases. Furthermore, an AR headset can render augmentations, while TV content is rendered either by a physical TV or by the same headset; or a VR headset can render both the TV content and the augmentations. We suggest Augmented TV (ATV) may be more appropriate nomenclature to capture these use-cases.

4.7 The virtual living room

Seven participants made only positive comments, two of which reported preferring the virtual living room to their own physical space, because it was "more spacious" [P3] than their own living room and because the sofa was "nice, comfortable, more comfortable than the chair I'm sat on." [P6]

Two participants highlighted that the living room wasn't real enough to look completely real. For instance, P10 said that it looked "like a typical lab environment . . . it is too clean to be fully realistic."

5 CONCLUSION

We prototyped a nature documentary ARTV programme in VR, where a lifelike sea turtle was presented as a hologram in the viewing environment. In a repeated-measures user study ($n = 10$), we investigated the impact of changing the starting point and the movement behaviour of the holographic sea turtle on the viewers' experience. Our findings suggest the relevance of empowering the viewers to customise their ARTV experiences. This raises challenges regarding the ways in which audience preferences can be elicited. Furthermore, as ARTV experiences—whether in VR or in physical living rooms—become more popular, it is likely that they follow the footsteps of conventional TV, e.g., by becoming a centre of focus in a household; in such scenarios, be it in the context of collocated viewers or viewers at-a-distance, the ways in which different individuals' preferences are prioritised raises further challenges.

ACKNOWLEDGMENTS

Research reported in this paper was funded by the UK EPSRC under grant number EP/R512394/1.

REFERENCES

[1] Caroline Baillard, Matthieu Fradet, Vincent Alleaume, Pierrick Jouet, and Anthony Laurent. 2017. Multi-device Mixed Reality TV: A Collaborative Experience with Joint Use of a Tablet and a Headset. In *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology* (Gothenburg, Sweden) *(VRST '17)*. ACM, New York, NY, USA, Article 67, 2 pages. https://doi.org/10.1145/3139131.3141196

[2] Naoki Kimura and Jun Rekimoto. 2018. ExtVision: Augmentation of Visual Experiences with Generation of Context Images for a Peripheral Vision Using Deep Neural Network. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. ACM, New York, NY, USA, Article 427, 10 pages. https://doi.org/10.1145/3173574.3174001

[3] Florian Mathis, Xuesong Zhang, Joseph O'Hagan, Daniel Medeiros, Pejman Saeghe, Mark McGill, Stephen Brewster, and Mohamed Khamis. 2021. Remote XR Studies: The Golden Future of HCI Research? (2021).

[4] Philipp Mayring. 2014. Qualitative content analysis: theoretical foundation, basic procedures and software solution. (2014).

[5] Paul Milgram and Fumio Kishino. 1994. A Taxonomy of Mixed Reality Visual Displays. *IEICE Transactions on Information and Systems* E77-D, 12 (December 1994), 1321–1329. https://search.ieice.org/bin/summary.php?id=e77-d_12_1321

[6] Veronica Pialorsi and Pejman Saeghe. 2020. Designing Intergenerational Media Experiences: A Participatory Design Approach. In *Toys and the TV: Serious Play. Workshop at the ACM International Conference on Interactive Media Experiences.*

[7] Pejman Saeghe, Gavin Abercrombie, Bruce Weir, Sarah Clinch, Stephen Pettifer, and Robert Stevens. 2020. Augmented Reality and Television: Dimensions and Themes. In *ACM International Conference on Interactive Media Experiences* (Cornella, Barcelona, Spain) *(IMX '20)*. Association for Computing Machinery, New York, NY, USA, 13–23. https://doi.org/10.1145/3391614.3393649

[8] Pejman Saeghe, Sarah Clinch, Bruce Weir, Maxine Glancy, Vinoba Vinayagamoorthy, Ollie Pattinson, Stephen Robert Pettifer, and Robert Stevens. 2019. Augmenting Television With Augmented Reality. In *Proceedings of the 2019 ACM International Conference on Interactive Experiences for TV and Online Video* (Salford (Manchester), United Kingdom) *(TVX '19)*. ACM, New York, NY, USA, 255–261. https://doi.org/10.1145/3317697.3325129

[9] Pejman Saeghe, Sarah Clinch, Bruce Weir, Steve Pettifer, and Robert Stevens. 2019. Augmented Reality Broadcasting: Challenges and Opportunities. In *Challenges Using Head-Mounted Displays in Shared and Social Spaces. Workshop at The ACM CHI Conference on Human Factors in Computing Systems (CHI 2019).*

[10] Pejman Saeghe, Mark McGill, Bruce Weir, Sarah Clinch, and Robert Stevens. 2022. Evaluating and Updating a Design Space for Augmented Reality Television. In *ACM International Conference on Interactive Media Experiences* (Aveiro, JB, Portugal) *(IMX '22)*. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3505284.3529965

[11] Jürgen Stauder and Philippe Robert. 2002. Let the sunshine on your screen: introducing augmented reality into interactive television. In *Proceedings. IEEE International Conference on Multimedia and Expo*, Vol. 1. IEEE, 837–840.

[12] Radu-Daniel Vatavu. 2012. Point & click mediated interactions for large home entertainment displays. *Multimedia Tools and Applications* 59, 1 (2012), 113–128.

[13] 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)*. ACM, New York, NY, USA, 143–152. https://doi.org/10.1145/2465958.2465972

[14] Radu-Daniel Vatavu, Pejman Saeghe, Teresa Chambel, Vinoba Vinayagamoorthy, and Marian F Ursu. 2020. Conceptualizing Augmented Reality Television for the Living Room. In *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

[15] Simon von der Au, Leon Giering, Christina Schneegass, and Markus Ludwig. 2020. The SpaceStation App: Design and Evaluation of an AR Application for Educational Television. In *ACM International Conference on Interactive Media Experiences*. 24–33.

[16] Christian Zimmer, Nanette Ratz, Michael Bertram, and Christian Geiger. 2018. War Children: Using AR in a Documentary Context. In *2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*. IEEE, 390–394.