



Envisioning the future of virtual production in filmmaking: A remote co-design study

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Abstract

Virtual Production is a new process in the audiovisual industry, taking advantage of emerging technologies and attracting a significant degree of interest in academic and industrial research. This article documents a research process focusing on co-design of innovative solutions for Virtual Production relying on immersive technologies. Two remote collaborative workshops were organized involving audiovisual professionals covering different roles in different phases of the making process of audiovisual production. A range of innovative design concepts was generated as part of the research following group-based iterative discussion and evaluation. The study has contributed a set of innovative design solutions in relation to applications of immersive technologies in the audiovisual industry. The authors argue that the methods adopted have the potential to serve as a blueprint for design and implementation of future remote collaborative co-design processes in relation to audiovisual studies and, more generally, across disciplinary boundaries.

Keywords Co-design · Remote workshop · Audiovisual production · Virtual reality · Augmented reality

1 Introduction

Since its conception, filmmaking has had a strong bond with the technology of the time. Today, we are witnessing a new wave of innovation due to the advancements of virtual reality (VR), augmented reality (AR), extended reality (XR), artificial intelligence (AI), digital twins (DTs), and real-time game engines, among others and the convergence of these technologies in Virtual Production (VP). Large-scale commercial organizations have paved the way to VP, a new technology-enhanced approach to filmmaking that has already brought creative and business benefits to stakeholders involved in high-end audiovisual (AV) productions [5].

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The present study is a contribution to this line of research, with an emphasis on remote co-design of innovative VP concepts enabled by immersive technologies.

Two workshops, conducted remotely, brought together a diverse group of AV professionals working on small and medium-budget productions (SMPs). The first workshop led to the identification of pain points in existing filmmaking workflows, and the second generated a range of innovative concepts for workflows with a potential for further development and testing in operational settings. The contribution of the article is 1) initial scenarios on how the current AV workflows can be enhanced using immersive technologies and 2) using creative tools to enable remote co-design workshops to bring meaningful collaborative design.

The successful implementation of remote online co-design strategies documented in this article, reflecting approaches developed in response to the COVID-19 pandemic, has the potential to serve as a blueprint for other researchers in search of suitable remote online co-design methods in relation to AV production as well as more broadly.

2 Literature review

2.1 Virtual production

An exact definition of VP is still a subject of debate. Sebastian Sylwan, former Chief Technology Officer at Weta Digital and member of the VES Founding Board, has stated that *“there’s no checklist of things you can go through and say, if you have all of these, this is virtual production”* [45], and has further explained that the industry is still in the process of learning and exploration. Netflix, one of today’s industry leaders in the field, defines VP as an umbrella term that covers a range of techniques across the production process [29]. VP has been increasingly attracting research interest among academics in recent years, and one notably-clear definition of it can be found in Helzlsouer et al. [19] in terms of a concept combining *“key aspects of media production in a real-time, or close to real-time, environment where creative decisions can be taken in direct consultation with other members of the team”* (page 347). Based on these definitions, VP is not a technology itself but rather an alternative making process to the established one currently employed in AV productions. A process having at the core real-time game engines to which can be added and combined several other software and hardware technologies to produce an audiovisual result.

Integrating the VP process with immersive technologies such as VR and AR enable activities and tasks not possible in traditional AV production process. For instance, the Directors wearing a VR headset could be immersed and navigate freely in the virtual scene as if they were in a real location shooting a live-action scene, a process with which they are very familiar. As a result, he can ask their collaborators to make changes about the camera position, lighting, set design (and so on) to recreate their vision quicker and better, being able to shoot multiple takes with great ease.

The VP process has the potential to bring i) economic and ii) creative benefits for all the stakeholders involved in the making of an AV production. Other academic researchers [13, 22, 26, 40, 49] have investigated VP from a different perspective on high-end AV productions in light of the different skill sets and resources available to them. They have researched, prototyped, and tested new VP design solutions using affordable consumer devices. These research efforts have the potential to enable the adoption of VP workflows

by AV professionals operating within strict budgetary constraints and with limited access to specialized skill sets.

2.2 Remote co-design

Conducting in-person (as opposed to remote online) co-design workshops has advantages in terms of depth of the input generally received from participants, also in light of an enhanced sense of cohesion within each participant group, and thanks to the availability of a richer set of communication channels, including non-verbal ones. This often results in more spontaneous reactions and more genuine answers to questions [9].

However, the COVID-19 pandemic has placed unprecedented constraints on fieldwork activities, which has prompted researchers to identify new ways of collecting data from participants [1, 4, 40]. A useful online document, crowdsourced and manually curated, details remote fieldwork methods employed during the COVID-19 pandemic by social researchers worldwide [23]. The document covers a range of communication channels, including online discussion platforms, and has proven useful during the design of this study.

The execution of remote online (as opposed to in-person) co-design workshops can increase participant access by lowering potential barriers associated with travel time and cost [49]. This can result in more effective engagement of worldwide audiences [6] and, potentially, of traditionally under-represented groups [7]. The literature review has highlighted two knowledge gaps, namely (i) a need to involve AV professionals in the design process when designing new VP processes and (ii) a lack of remote co-design studies applied to VP.

3 The study: collaborative creative engagement

The aim of this study was to prompt participants to generate collaborative ideas, building on immersive technologies, with a potential to improve their existing AV production workflows. The identification of an effective research approach and design methods was central to fostering this creative process, with a view to facilitating the generation of innovative ideas around immersive technologies for VP. Co-design was deemed appropriate to facilitate the generation of innovative and useful solutions responding to stakeholders needs, as highlighted in [43], and to convey a sense of ownership and empowerment in the participants, as documented in [48].

Whereas generation of creative output from co-design workshops is driven by the participants, the facilitator plays an important role in terms of providing the correct tools and methods to help non-designers generate and express their ideas [37]. For the purpose of this study, two design thinking workshops were run to facilitate participant exploration of innovative use cases of immersive technologies in the context of VP.

Design workshops are well suited for idea generation, as discussed in [2], in that they allow participants to express more effectively aspects of their working habits that are often tacit and implicit [37], and they provide an opportunity for participants to share anecdotal experiences with each other. The co-design workshops designed and executed in the context of this study relied on use of online collaborative software boards. The boards were set up to help participants express their opinions and ideas freely, yet consistently with a pre-determined sequence of steps that helped maintain focus in the discussions. In particular, sequential activities were designed and implemented to guide participants in transitioning

from each activity to the next (Fig. 1). According to [36], this sequential aspect is critical to successful execution of co-design workshops.

Suitable digital tools, platforms, and services were identified. The Zoom platform [51] proved useful for video-based participant activities in the context of this study in light of its intuitive interface and the availability of recording functionalities. Participants were already familiar with Zoom, which reduced friction and helped towards a smooth execution of the online activities. Audio recordings were processed using the browser version of Trint [46], a service to automatically converts audio files to written text. In addition to the Zoom video call service, other collaborative online platforms (Miro, Mural, and Klaxoon) were tested by the team in preparation for the workshops, with a view of identifying the most suitable for replicating the functionality of whiteboards commonly used for in-person activities. All three software applications proved capable of enabling effective interaction among participants during the online workshops by replicating common actions such as placement of Post-it notes, writing, and drawing. The browser version of Mural [43] was ultimately selected in light of its ease of use.

With reference to remote online co-design, our experience of the design process is in line with published studies [1, 4, 6, 9–11, 17, 21, 23, 40, 49]. The specificity of the problem investigated, namely the design of new VP processes enabled by immersive technologies, has required involvement in co-design of AV professionals with considerable VP expert knowledge but with limited or no familiarity with immersive technologies. For this reason, our approach has built on studies focusing on integration of expert knowledge in co-design processes. One notable example of this type of integration is discussed in [20], where the value of abductive approaches for generating new insights has been highlighted. Abductive reasoning, which enables logical inference based on limited information available, can facilitate re-contextualising and re-thinking of existing concepts.

We speculate that abductive reasoning may have played a role in the generation of innovative design concepts by AV professionals during the workshops conducted during this study. AV professionals were faced with the task of generating new design concepts for future VP processes augmented by immersive technologies, while at the same time having limited or no experience with immersive technologies and – to compound things further

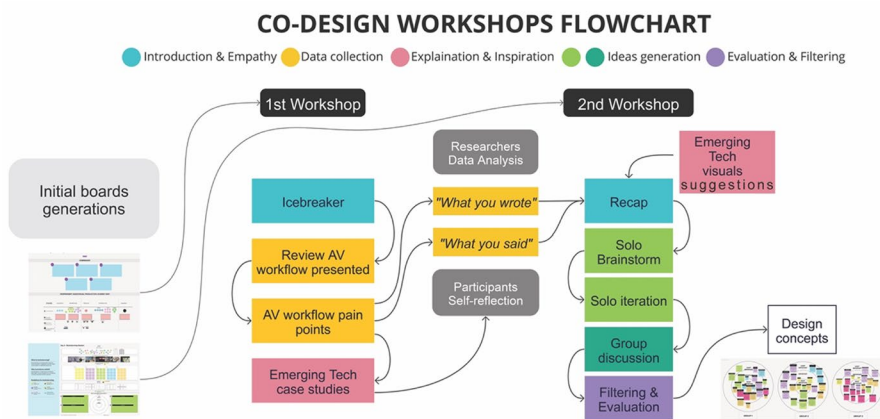


Fig. 1 Design process flowchart

– without hands-on experience of physical prototypes given the remote online nature of the workshops. The success of the remote online co-design workshops conducted during this study can be contextualised through the lens of Social Cognitive Theory [3] (SCT) and abductive reasoning.

3.1 Participants

In order to co-design effective and innovative concepts, the involvement of professionals working in the AV industry, including Directors, Cinematographers, Producers, and Editors, was essential (Table 1).

Thanks to the involvement of a range of professional across roles in the AV sector, a diverse set of knowledge, perspectives, and skills could be brought together, which created favorable conditions for identifying solutions to complex problems [23].

Three groups, each composed of five participants, were recruited for the workshops. This choice of group size is in line with recommendations reported that can be found in the literature in relation to remote collaborative workshops and aims to reduce the risk of technical issues interfering with the creative processes [10, 16].

Attention was paid to whether or not prior professional relationships were in place among participants, with a view to achieving a balance between groups in which participants were not familiar with each other and those consisting of participants with prior shared professional experience. Two groups included participants who had already collaborated with each other on previous projects. This was meant to facilitate more effective and honest communication compared to groups consisting of participants unfamiliar with each other, e.g. due to a reduced risk of individuals feeling embarrassed or judged by others during the activities. There was also an expectation that the group dynamic could be favourably impacted by participants being in a position to recall common experiences on previous projects, which could in turn encourage them to share different viewpoints. This is in line with what was observed during the implementation of the workshops. As documented in [28], stories can be effective in triggering conversations, as they often encode details about user habits, needs, pain points, expectations, desires, and additional contextual information that can be particularly meaningful when tackling a design problem.

3.2 First workshop – board framework

The first workshop, for which the Mural board displayed in Fig. 2 was adopted, was implemented in order to achieve the following objectives: (a) introduce participants to each other, thereby facilitating the creation of an open and friendly environment; (b) discuss pain points across their AV projects; (c) introduce participants to emerging technologies (VR, AR, AI, DTs), using existing case studies to illustrate the potential of these technologies for augmenting AV production workflows. To achieve the first objective and create an environment where every participant could feel empowered to express themselves without feeling judged, an ‘ice breaker’ activity was employed (Appendix 1, Fig. 9). ‘Ice breaker’ activities are commonly used for overcoming initial participant reticence and insecurity. The first block of the board in Fig. 2 reflects this phase of the workshop. Participants were asked to consider a science fiction object, emblematic of a movie or TV series, and sketch it in the box assigned on the Mural board. In addition to building a feeling of mutual empathy, this activity helped participants become familiar with the functionalities provided by the online collaborative platform, including navigation, selection, and drawing tools.

Table 1 A summary table of the participant pool

PARTICIPANT	GROUP	ROLE	DESCRIPTION
P01	GROUP 1	Cinematographer	Operating cameras and lighting on set, working closely with Directors
P02		Cinematographer	Operating cameras and lighting on set, working closely with Directors
P03		Editor	Working mainly on documentaries
P04		Producer	Overseeing the entire making process of fictions and documentaries
P05	GROUP 2	Sound Designer	Working closely with Directors in the making of the audio component for documentaries
P06		Producer	Overseeing the entire making process of fashion commercials
P07		Producer	Overseeing the entire making process of fashion commercials
P08		Producer	Overseeing the entire making process of fashion commercials
P09		Director	Directing commercials, music videos and fictions
P10	GROUP 3	Editor	Working mainly on commercials and TV series
P11		Archive Producer	Overseeing the production and post-production of documentaries
P12		Producer	Involved during the development phase of a project and actively looking for funding
P13		Animator	Working as Animator on fictions and indie games
P14		Director	Directing short-films, art installations and actively looking for funding
P15	Producer	Working on the business side of Film/TV projects	

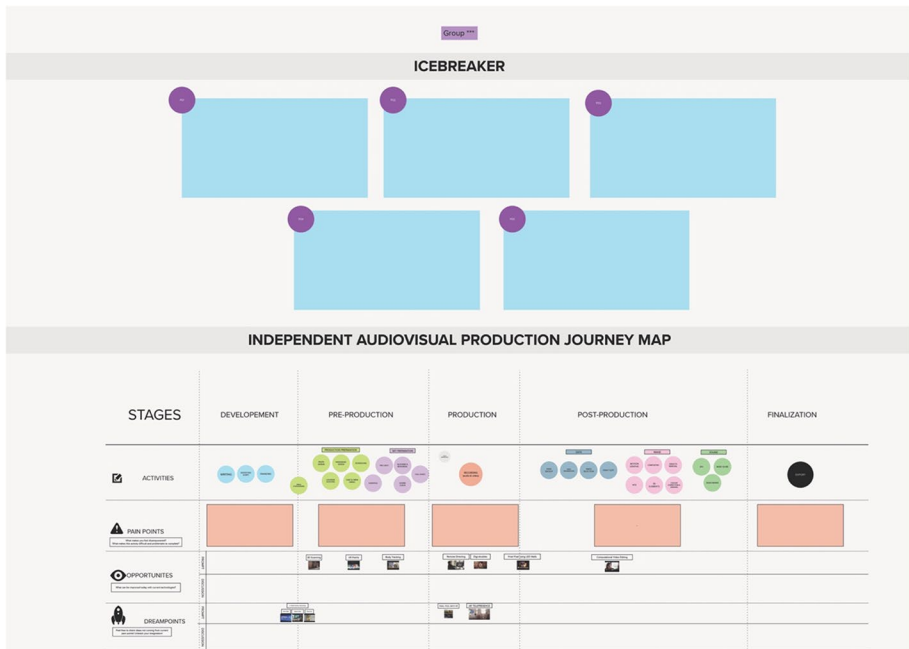


Fig. 2 Mural board designed for the first workshop

Asking participants to focus on an emblematic science fiction object was also meant to help them enter a ‘futuristic’ mindset, to distance themselves from limitations associated with existing technologies, and to consider innovative ideas. The positive impact of playful tasks on creative workshop activities has been documented in Ehn [15] and Muller [27].

Following the ‘ice breaker’ activity, participants were asked to express their opinions on the follow-on section of the Mural board focusing on the existing linear AV production process. Such process is mainstream in the AV industry and consists of a sequence of stages including development, pre-production, production, post-production, and finalisation (Appendix 1, Fig. 10). Participants were shown the results of a study on immersive technologies for VP based on one-to-one exploratory interviews with a different group of AV professionals [8]. This was done for the purpose of evaluating the outcomes from the previous study and gathering additional opinions and thoughts in relation to potential applications of immersive technologies for AV production. Afterward, participants were asked to reflect on the obstacles they encountered throughout the AV production process (Appendix 1, Fig. 11). This resulted in an open discussion where participants elaborated on their current pain points and shared relevant anecdotes from previous projects. The final activity of the first workshop focused on presentation and discussion of case studies in relation to high-end VPs such as ‘The Lion King’ (2019) [18] and ‘The Mandalorian’ (2019) [38]. The emphasis was on the role played by immersive technologies (VR, AR, XR), real-time game engines, and a broader range of emerging technologies such as those enabling automated image generation based on descriptive text. AI Algorithm such as DALL-E [33], its iteration DALL-E 2 [32], and Imagen [35], which have attracted attention in recent years as potentially disruptive in the media industry [30], were a topic of discussion in addition to immersive technologies.

To inspire participants further, recent developments to the concept of DT applied to human beings were also mentioned and explored with the participants. This included a discussion of MetaHuman [47], a freely-available Cloud-based application from Unreal Engine that facilitates the creation of realistic virtual human agents for use in media production. This phase of the workshop was designed to prompt participants and help them envision future scenarios (Appendix 1, Fig. 12). Keeping participants focused throughout the workshops was not straightforward. Unveiling parts of the Mural board in a stepwise fashion, thereby prompting participants to focus on one aspect of it at a time instead of presenting the board in its entirety, proved particularly useful. In the context of a follow-up discussion, one participant considered stepwise unveiling of the Mural board beneficial in that it helped participants understand the board better and reduced the risk of cognitive overload.

3.3 Self-reflection task in between workshops

A break was introduced between the first and second workshops in line with [14], where it was shown that self-reflection following a learning activity could improve learning outcomes. Participants were invited to reflect on what had been previously discussed, to explore further the materials that were made available to them (videos and articles on the emerging technologies presented to them during the first workshop), and to come back to the Mural board for refinement in their own time over the following days.

3.4 Second workshop – board framework

The objective of the second workshop was to generate a set of innovative ideas relying on emerging technologies discussed during the first workshop (Fig. 3). A range of activities was implemented: (i) recap, (ii) visual prompting, (iii) independent brainstorming, (iv) building on others' ideas, (v) group discussion, and (vi) filtering and evaluation.

- i) Firstly, the output from the first workshop was summarised in order to refresh the participants' memories about the pain points previously identified (right-hand side in Appendix 1, Fig. 13: “*What you wrote*” and “*What you said*”). In addition, the main phases of the filmmaking process were reported in the “*Area of interest*” box (left-hand side in Appendix 1, Fig. 13), with a view to prompting participants to consider relevant key works from which they could take inspiration during the following brainstorming activity.
- ii) *Visual prompting*
Similarly, a set of images providing examples of emerging technologies were displayed in order to stimulate participants' imagination further and inspire them during the execution of the follow-on core activity (Appendix 1, Fig. 14). Participants were encouraged to request any clarifications and enquire about the technologies considered during the self-reflection task.
- iii) *Independent brainstorming*

After this introduction to the workshop by the facilitator, participants were given ten minutes to start brainstorming ideas independently (Appendix 1, Fig. 15). The Zoom' breakout room' feature was used to isolate individual participants for the duration of the activity. The facilitator was able to join each breakout room to ensure correct understanding of the task. The facilitator was also provided with a real-time view of the ideas

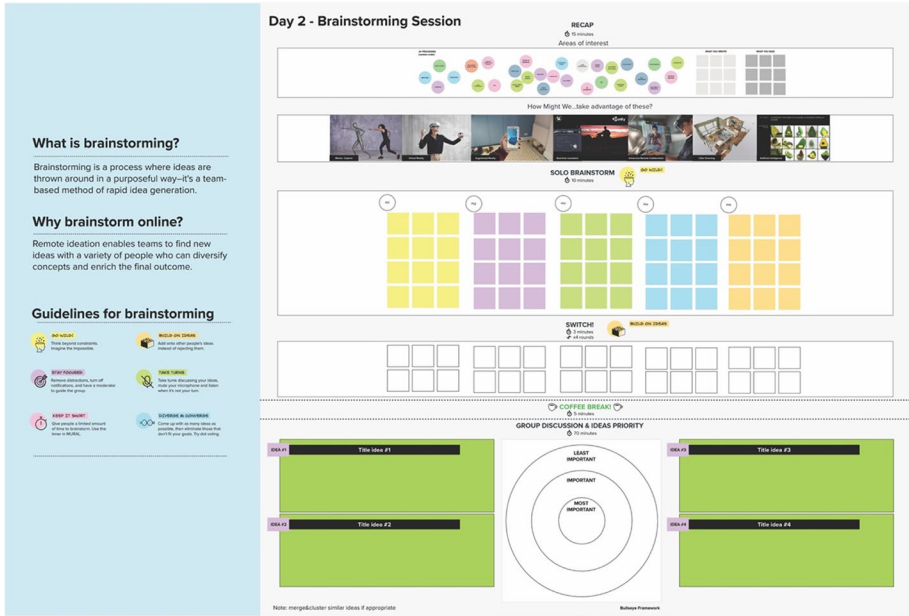


Fig. 3 Mural board designed for the second workshop

generated by the participants on the Mural board and was able to keep track of time using the ‘stopwatch’ feature.

iv) Building on others’ ideas

At the end of the activity, all participants re-joined the Zoom group call and received instructions about the follow-on task. They were asked to consider others’ ideas and provide any thoughts, comments, and critiques to others’ notes on the board, with a view to expanding on the concepts (Appendix 1, Fig. 16). Each participant was allocated up to three minutes for adding notes to each idea proposed by others in the group, corresponding to a total of twelve minutes for the other four participants’ ideas.

v) Group Discussion

Following a short break, a group discussion took place for the remaining duration of the workshop. Each participant was asked to elaborate verbally on the most relevant ideas they generated.

vi) Filtering & Evaluation

Finally, participants were asked to position individual ideas within a Bullseye Framework consisting of three concentric circles on the Mural board labelled ‘most important’, ‘important’, and ‘least important’ (Appendix 1, Fig. 17). The more central the positioning, the higher the perceived relevance and value of the idea. Previous studies have documented the usefulness of the Bullseye Framework for organizing and prioritizing ideas [24, 34]. The Bullseye Framework was originally introduced by Mares and Weinberg [24] to support commercial organizations in identifying the most promising marketing channels towards business development. In the context of this study, the Framework was used as a visual representation reflecting an underlying scoring system, as detailed in the following. On the sides of the Bullseye Framework were placed some green boxes to be

used by the research team to edit and summarise participant input, including signposting of the most promising ideas and elimination of redundant concepts.

4 Results and discussion

After completing the workshops, the data generated (audio recordings and Mural boards) was analyzed using Nvivo version 12 [31] using a MacBook Pro Retina 15-inch 2013 (2 GHz Quad-Core Intel Core i7, 8 GB 1600 MHz DDR3, Intel Iris Pro 1536 MB).

4.1 First workshop

During the ‘ice breaker’ activity (Fig. 4), participants had a chance to understand the nature of the study and familiarise themselves with the workshop agenda. The ‘ice breaker’ activity also gave them time to become comfortable with the Mural tools and allowed the Group 3 members to introduce themselves to each other. During the first workshop, participants were mostly receptive of concepts presented by the facilitator and didn’t contribute much content to the Mural board, at a stage where the focus was on the established AV production process. Participants added the following to the board:

- A note about ‘*Legal paperwork*’ (e.g. permission to shoot in a specific location and film individuals);
- Clarifications about the difference between ‘*Offline Editing*’ (transcoding of the original high-quality footage to lower resolution to reduce the computational resources

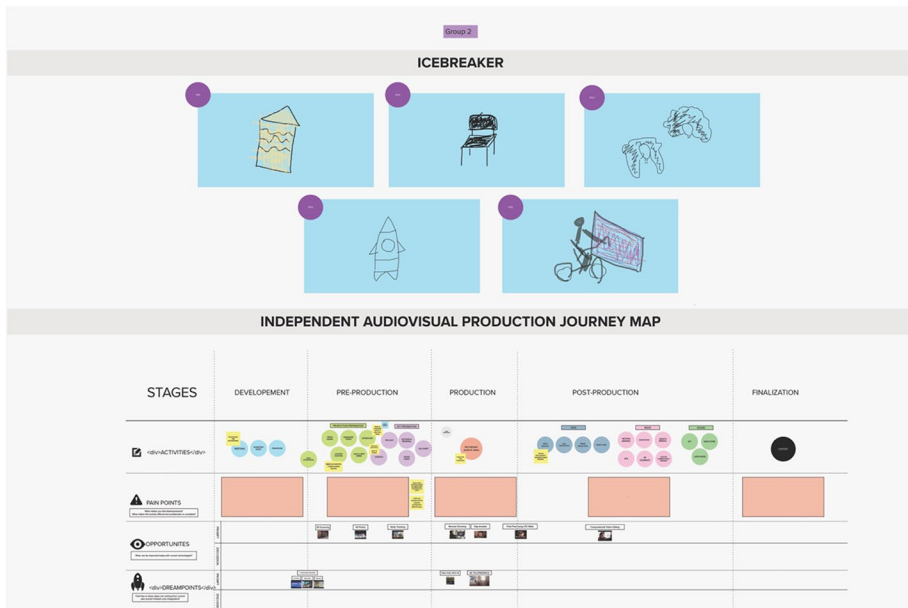


Fig. 4 Mural board after the first workshop with Group 2

required for editing) and ‘*Online Editing*’ (the concluding stage where low-resolution files are re-linked to the original high-quality footage and the final edit is made available for exporting);

- Clarifications about the so-called ‘Treatment’, i.e. a document used by Directors to express their ideas about the visual style they want to achieve and how they intend to manage the project happen from a production standpoint. If an AV project is requested by a client, which is often the case in the advertising AV segment, Directors are asked to compete with each other by proposing and presenting a ‘Treatment’. If Directors develop a project independently, they normally rely on their ‘Treatment’ for ‘selling’ their project idea and for securing funding. This is often the case for feature films, shorts films and documentaries.

Participants pointed out that different segments of the industry may adopt workflows consisting of slightly different stages, sometimes arranged in a different order, but they agreed that the established AV production workflow as illustrated to them during the workshop is a faithful description of their professional experience. The findings from this study are therefore consistent with the outcomes from a previous investigation by Bodini et al., [8]. Regarding pain points, a range of opinions was expressed. One participant (P04, Producer) highlighted a need to “*fulfill and combine all the requests coming from different departments*”, which can be complicated by unforeseen problems during production, thereby resulting in a need to “*micro re-schedule based on daily micro issues*”. A theme that clearly emerged in relation to pain points with established AV production workflows is a need for effective communication across departments when dealing with unexpected issues, both before and during the production stage. Those participants working in post-productions roles such as Editor (P03 and P10) and Archive Producer (P11) drew attention to the challenges arising from processing and managing large volumes of data.

Attention was also paid to challenges associated with shooting in real-world locations. Examples were provided in relation to the importance of reliable weather forecasts, to ensure that weather conditions during the shooting are in line with the expectations. This can make the difference between progressing, postponing or even wasting an entire shooting day. In particular, the ability to gain prior understanding of how different weather conditions can influence the shooting outcome was considered critical for the decision-making process. Part of the first workshop was devoted to presenting relevant VP case studies to the participants. For this reason, the facilitator was the only one talking and there was not much space left for participants to intervene except for asking questions or providing clarifications. As anticipated, groups in which participants already knew each other were those in which the discussions were more open, often building on shared anecdotes from previous projects to highlight pain points and issues encountered.

4.2 Second workshop

The second workshop started with a ‘recap’ activity aimed at refreshing the participants’ memory and prompting their imagination (Fig. 5). The facilitator recapitulated participant notes previously placed on the Mural board (“*What you wrote*” section), and outlined the key points verbally discussed during the first workshop after listening and transcribing the conversation (“*What you said*” section).

As expected, prompting participants with the ‘recap’ activity led to the generation of a richer dataset during the second workshop compared to the first. All participants executed

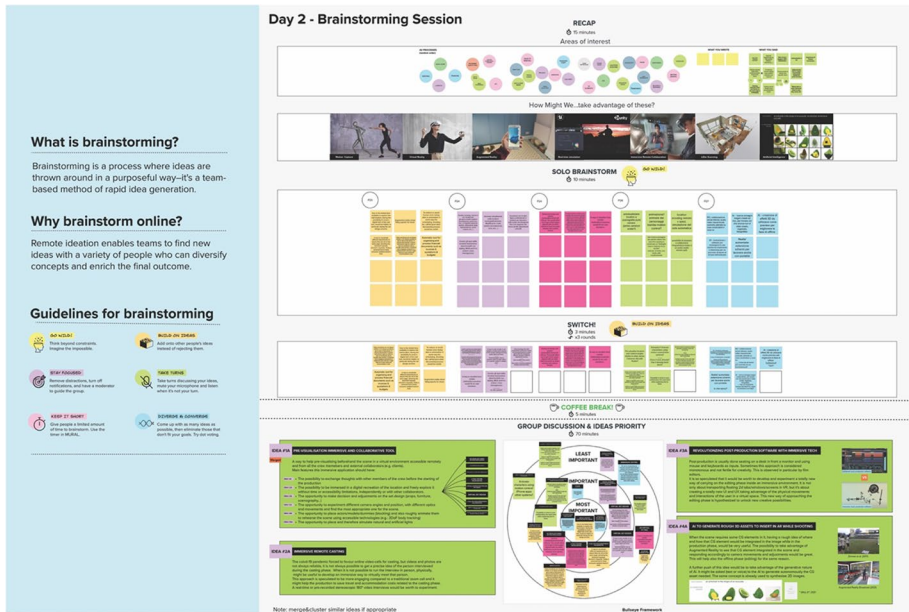


Fig. 5 An overview to the Mural board after the second workshop with Group 1

the independent brainstorming exercise in line with the instructions received. Interaction with the Mural board was frictionless, which we argue was facilitated by prior familiarisation of the participants with the online tools during the first workshop. Moreover, the possibility for the facilitator to enter and exit individual Zoom breakout rooms to check whether participants needed assistance in executing the task, proved particularly useful. Similarly, keeping track of time using the Mural stopwatch function was useful throughout all activities. At the end of the ten minutes allocated to execution of the ‘independent brainstorming’ activity, the number of ideas generated by individual participants ranged from three (P05, Sound Designer) to nine (P14, Director).

The follow-on activity in which each participant was asked to expand on others’ ideas was particularly useful for strengthening and extending the concepts initially proposed. Inviting participants to read about ideas put forward by others, either new or similar to theirs but expressed with different words as reflecting a different perspective, provided participants with additional sources of inspiration and boosted the creative process. This ultimately resulted in fresh input to the original ideas generated during the workshops.

Following this activity, most of ideas attracted additional notes by others. This included expressions of appreciation (“Agree!”, “Cool!”, “Very useful!”), questions (“Does it exist already?”, “What do you mean?”), and in most cases additional input to the initial ideas (“not only from the point of view of a creative such as the Director, but also for those involved in the production dpt.”). In some instances, comments were meant to initiate a more structured debate (“some of these aspects of production need real-life evaluation.. don’t you think some parts of the process will always need non-virtual dynamics?”).

During the group discussion, participants often built on others’ comments to add constructive input to the concept being discussed, thereby promoting the representation of different viewpoints. This dynamic facilitated the exchange of ideas, enhanced the collective

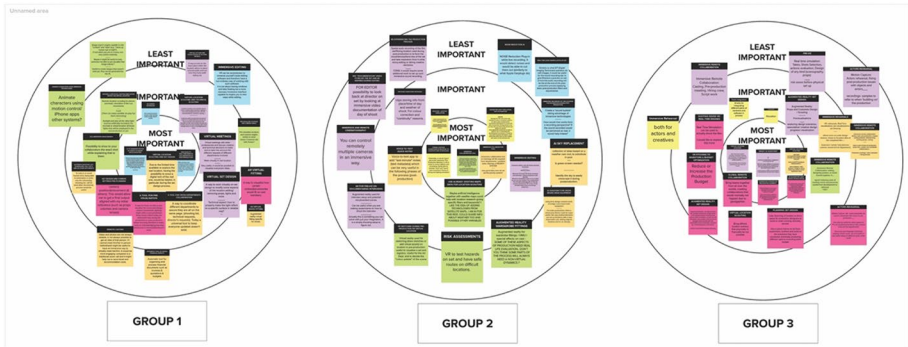


Fig. 6 Ideas generated and placed within the Bullseye Framework by participants

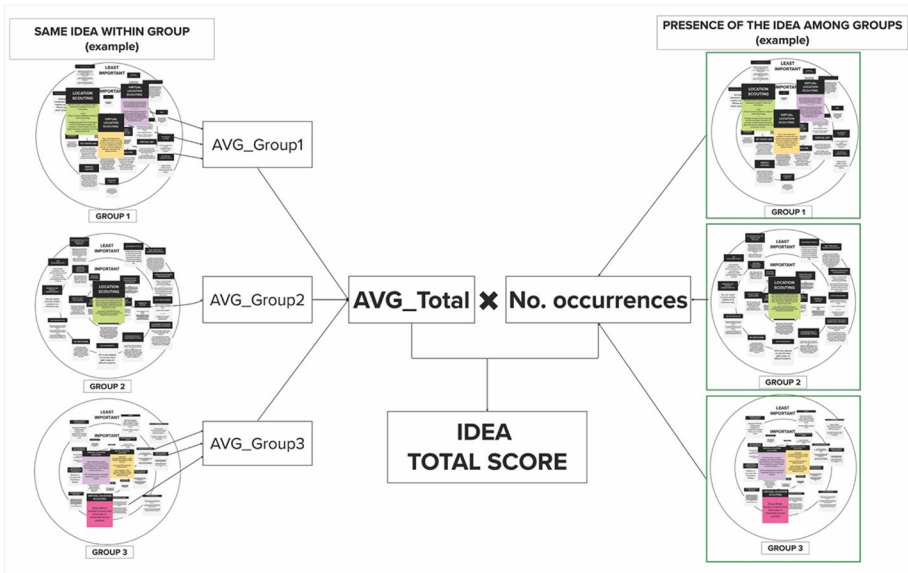


Fig. 7 Visual representation of the idea scoring system

thinking process, and led to a richer understanding of the anticipated benefit in relation to future adoption of the design solutions. Whenever only few participants were involved in a conversation, the facilitator played an important role in inviting others to join, with a view to broadening the scope of the discussion. Some concepts were presented and barely commented on, while others were reviewed by several participants, thereby resulting in a more intense exchange.

Finally, participants were asked to identify a subset of ideas worthy of further development by positioning the corresponding iterated ideas within the Bullseye Framework (Fig. 6). A few concepts were merged or excluded from this list because deemed not relevant to the aim of the study.

As shown in Fig. 7, each idea was assigned a score reflecting its potential usefulness as perceived by the participants. Ideas placed within the ‘most important’ circle of the

Bullseye Framework were assigned a score of 3, those within the ‘important’ circle a score of 2, and those in the ‘least important’ circle a score of 1. If an idea was generated by more than one participant within a group, the corresponding scores were averaged (AVG_Group). If multiple groups generated the same idea, the corresponding group-level averages were averaged to produce a total score (AVG_Tot).

A final metric reflecting the perceived usefulness of each idea was obtained by multiplying the total score (AVG_Tot) by the number of participant groups in which each idea was generated (No. occurrences). In Table 2 are listed and summarised the most innovative and valuable concepts according to what was generated, iterated and evaluated by the stakeholders.

5 Conclusions

Conducting fieldwork research subject to practical constraints arising from the COVID-19 pandemic has been a complex endeavor, and identifying effective strategies to work around the associated limitations has been a worthwhile effort that holds significant potential for future design research. Furthermore the current literature lacks a study where the involvement of AV professionals started from the beginning of the design process for generating alternative VP ideas. This approach led to the generation of several innovative concepts evaluated as valuable to further develop.

As consequence it was possible to draw benefits and limitations of the study.

5.1 Benefits and limitations

This study has validated some of the findings documented in Boland et. al., [9] when they review strengths and limitations of videoconferencing tools as a means to facilitate qualitative research. Specifically, remote online workshops have proved to be a cost-effective method of collecting data in light of a lack of additional hardware and software equipment requirements. Moreover, the implementation of remote workshops using existing digital tools and services, as opposed to in-person events in physical venues, has the advantage of potentially lowering barriers to participation, associated with travel time and cost [17].

The adoption of a remote online approach facilitated participation of AV professionals who were willing to engage in the research in the absence of financial compensation arrangements. This online approach also holds potential for increasing the speed of data collection as also pointed out by other researchers [21]. The only potential obstacle is the participants’ availability. A significant challenge in relation to this study was selecting a date and time suitable for everyone, given that all participants were AV professionals who opted to take part in this research without financial compensation and despite concurrent demands arising from their professional duties. This proved particularly hard at a stage when the AV industry was returning to operational levels closer to a pre-pandemic regime. In order to address this issue, workshops sometimes needed to be rescheduled. As a recommendation to other researchers wishing to engage professionals in similar research in the future, it is recommended that suitable incentives ought to be identified with a view to increasing participation and facilitating workshop planning. One participant, approached again following the workshops, commented favorably on the idea of organizing future in-person workshops on this theme, and considered an opportunity to experience immersive technologies first-hand a good investment of their time.

Table 2 List of concepts generated, filtered, and prioritized during the second workshop

#	Concept	Brief description	Bullseye's priority (avg.)	No. occurrences among groups	Idea Total Score
#1	Virtual Pre-production meeting	Exchange thoughts with other crew members before the starting of the production	2.33	3/3	6.99
#2	Virtual Location Scouting	Be immersed in a digital recreation of the shooting location and freely explore it without time or accessibility constraints, independently or with other collaborators	2.33	3/3	6.99
#3	Virtual Set Design	The opportunity to make decisions and adjustments on the set design (props, furniture, scenography...)	1.5	3/3	4.5
#4	Virtual Drone Flight Path Simulation	Immersive planning and simulation of drone flight path and later import in the piloting software to replicate the same movement autonomously	2	1/3	2
#5	Virtual Cinematography	Cinematography planning of camera angle, optics, and light simulation (both artificial and natural...also according to weather conditions). Immersive cinematography remote control in real-time	2	3/3	6
#6	Actors Blocking & Rehearsal	The opportunity to place actors/models/dummies (blocking) and also roughly animate them to rehearse the scene using accessible technologies (e.g.: 3DoF body tracking)	1.25	2/3	2.5
#7	Virtual Pitching	The opportunity to better pitch some ideas to investors	2	1/3	2
#8	Immersive Remote Casting	The possibility to interview and run casting remotely but in an immersive way, taking advantage of immersive stereoscopic videos	1	1/3	1
#9	New interactions with post-production software	An innovative way of using post-production software commonly employed in the av production	1	1/3	1
#10	AI to Generate rough 3D assets and AR integration when shooting	The possibility to implement in real-time, while on set shooting, a low poly version of the objects that will be added in post-production	3	1/3	3
#11	Immersive Editing	An innovative way for editing av projects, using gestures and visualizing footage clips in an immersive environment	2	1/3	2

Table 2 (continued)

#	Concept	Brief description	Bullseye's priority (avg.)	No. occurrences among groups	Idea Total Score
#12	Re-experiencing the production process	The possibility to re-experience the filming set thanks to a pre-recorded 360° video	1	1/3	1
#13	Augmented Reality for Set Design	The possibility to visualize beforehand how certain objects would look like in the scene thanks to Augmented Reality	2	1/3	2
#14	Generative AI scenarios	AI to predict the economic performance at the box office when casting certain actors	3	1/3	3

The implementation of remote online co-design workshops presented challenges that, if not uniquely associated with reliance on an online medium, were compounded by it. In particular, keeping participants continuously engaged online in the face of potential distractions in their domestic settings was a priority for the facilitator and proved critical to a successful implementation of the co-design activities. The remote workshops documented in this article were valuable in generating a set of initial design concepts with a potential to enhance future filmmaking workflows and tackle some of the pain points currently faced by professionals. Without the adoption of a co-design approach aimed at empowering participants and generating a sense of ownership within the design process, it would not have been possible to decode and take advantage of AV professionals' tacit knowledge to produce, iterate, and evaluate ideas as effectively as achieved in this study. Compared to previous studies [13, 22, 26, 41, 50], where other researchers involved AV professionals only in the evaluation phase of the VP process they developed, in this study, AV professionals were involved since the early stage of the design process contributing to the final outputs of the workshops.

The collaborative nature of the activities carried out and the broad range of AV skillsets involved proved to be key enablers of a shared process of ideation and critical assessment of innovative ideas around the potential of immersive technologies for VP.

Reliance on data collection methods potentially less participatory in nature, such as focus groups, would most likely have resulted in the facilitator having to play a more prominent role in the activities, thereby potentially reducing the scope of the group discussions and limiting the creative output from the workshops. Instead, thanks to the co-design process implemented, the discussions were primarily participant-led, which created ideal conditions for the generation of a range of innovative design concepts.

In the context of the first workshop, additional time could have been allocated by the facilitator to illustrating how immersive technologies can augment existing AV production workflows for SMPs. This could have increased participant understanding, with a positive impact on the follow-on discussions, and will be considered for further research. For the same reason, the inclusion of additional in-person activities between the first and second workshops could have been beneficial. As mentioned in Ssozi-Mugarura, Blake and Rivett [42] co-design “*is challenging when users have little understanding of technology*”. In this study, despite the fact that the final activity of the first workshop aimed to explain the potential arising from immersive technologies and despite at the beginning of the second workshop the facilitator summarized what was discussed in the previous session, some participants required more clarifications and felt insecure in regard of what ideas to generate. This uncertainty is likely to be due to their moderate experience and understanding of such experiential technologies.

It is argued that the main drawback of running remote (as opposed to in-person) co-design workshops is the lack of a ‘familiarisation’ phase during which participants – guided by a facilitator – can appreciate hands-on the potential of emerging technologies.

In the absence of restrictions to in-person interaction moving forward, follow-on activities are envisaged with a view to validating the findings from this study in the context of in-person co-design workshops. This will enable participants to gain hands-on experience of immersive technologies, thereby enriching exchanges of opinions and discussions. We submit that a combination of remote online and physical in-person co-design activities has a potential to result in better participant understanding of immersive technologies, which can in turn facilitate the generation of innovative ideas, while at the same time improving access to the co-design activities. The adoption of a remote online co-design strategy to facilitate the generation of creative ideas by AV professionals around applications of emerging technologies underlines the innovative character of this study. It is anticipated that this investigation will prove useful to other design researchers seeking evidence of

successful strategies for running remote online co-design workshops, with an emphasis on collecting data about stakeholder needs, expectations, and perspectives, and on facilitating collective brainstorming.

5.2 Outlook

A similar study that used remote co-design approach to conceptualize innovative ideas on potential VR applications, is given by Bryant et al., [11]. However, apart from investigating in a different area such as the medical field, they did not involve the end-users in the co-design process (individuals with communication disabilities) of the prototype developed (named DISCOVER). Instead, the practical contribution generated by this study, represented by the concepts listed in Table 2, was obtained by directly involving the end-users of these alternative VP processes (Fig. 8).

The design concepts generated and evaluated as part of this study will serve as a starting point for further research around the role that immersive technologies applied to VP can play in enhancing AV workflows. This is a particularly worthwhile endeavour in relation to SMPs, where creative processes often take place with reduced access to specialized technical expertise and within stricter budgetary constraints. Finally, this study contributed by highlighting the limitations when co-designing remotely applications and processes about immersive technologies and VP. From the findings it emerged how the creative output generated by participants is also influenced by the degree of hands-on experience participants had in the past with these experiential technologies. Therefore, before running a remote co-design workshop having at the center these topics, we argue that an additional in-person and hands-on stage should be introduced in the co-design process.

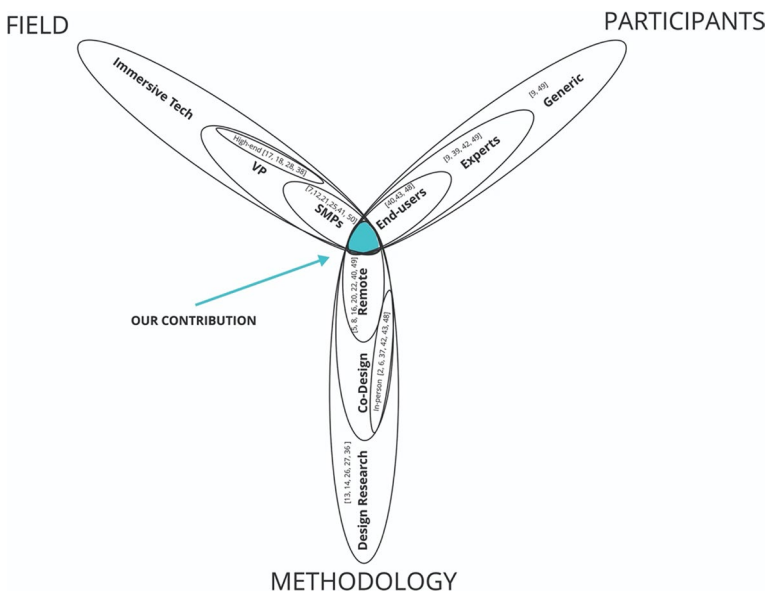


Fig. 8 Contribution of this work compared to previous studies

Appendix 1

First workshop

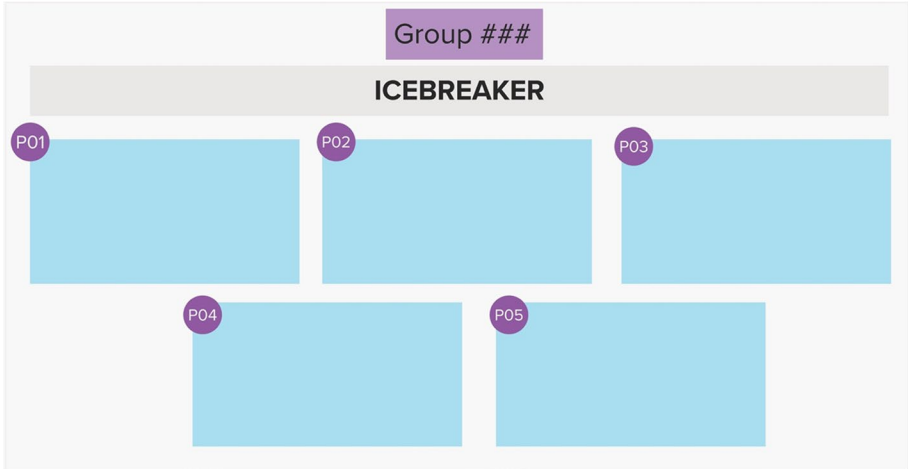


Fig. 9 Board used for the 'icebreaker' activity

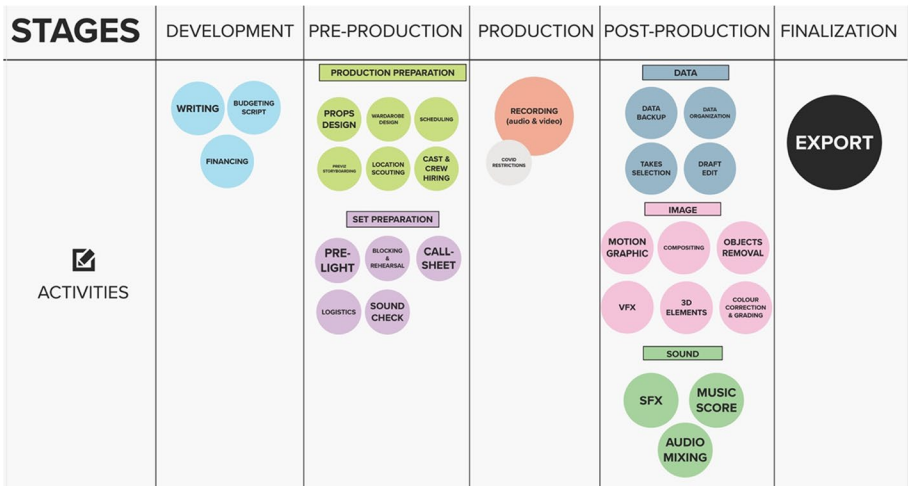


Fig. 10 Stages of the AV filmmaking process as identified in [7]

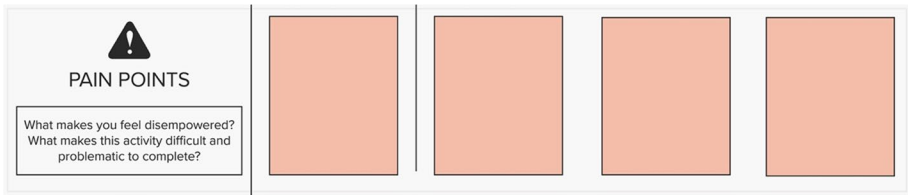


Fig. 11 Boxes in which participants expressed their challenges in existing AV production workflows

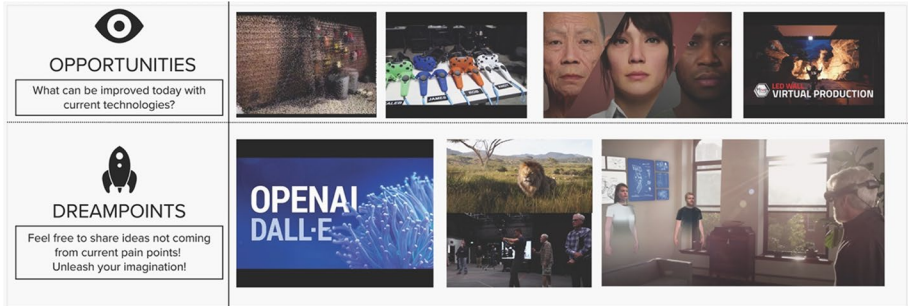


Fig. 12 Pictures and videos on emerging technologies and applications to inspire participants

Second Workshop



Fig. 13 Recapitulation of the topics discussed during the first workshop

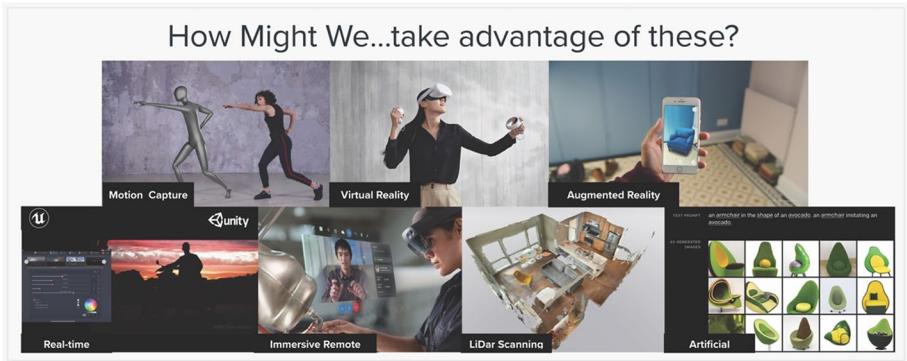


Fig. 14 A visual recapitulation of the emerging technologies introduced during the first workshop



Fig. 15 Boxes for the 'solo brainstorming' activity



Fig. 16 Boxes used for the 'switch' activity

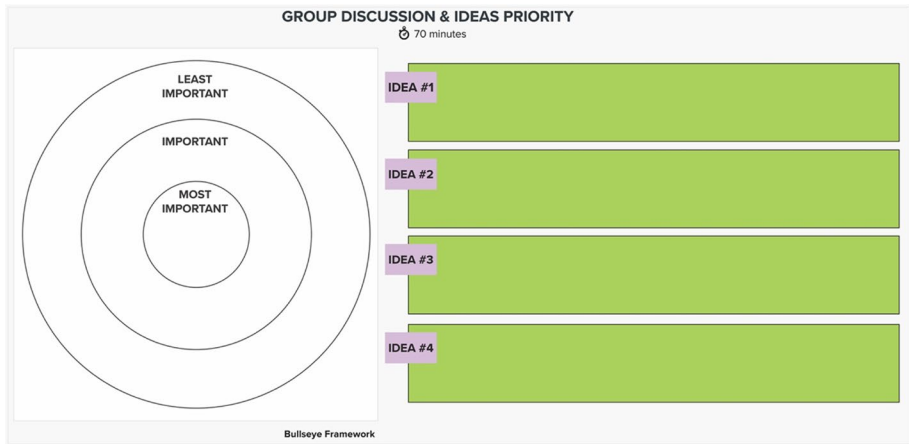


Fig. 17 Bullseye Framework (left-hand side) and green boxes for summarizing ideas (right-hand side)

Abbreviations AI: Artificial Intelligence; In the context of this research, it was referred to AI when describing those algorithms capable of generating new media content such as images or texts.; AR: Augmented Reality; Real-time viewing of virtual elements in a real environment.; AV: Audiovisual; A media product resulting from the combination of a visual and audio component.; AV industry: Audiovisual Industry; The totality of all the different Audiovisual sectors and products.; AV sector: Audiovisual Sector; A specific category of the Audiovisual industry characterized by its final output, production process and distribution dynamics.; AV production: Audiovisual Production; The entirety of professionals working towards the completion of all the processes necessary to produce an AV product; AV product: Audiovisual Product; The final output generated at the of the AV production process; DTs: Digital Twins; A Digital simulation of a physical object or system mutually exchanging data in real-time.; XR: Extended Reality; An Umbrella term describing the range of technologies or approaches that are used to supplement or merge the real and virtual environments.; /: Real-time rendering; It refers to the process of rendering images at a rapid enough rate that the viewer does not see individual images enabling a smooth interaction with the machine.; SMPs: Small and Medium Productions; Includes single AV productions with medium budget (less than \$100.000), small budget (\$20.000), and micro-budget (less than \$4.000); /: Stakeholders; It refers to those involved in the making process of an Audiovisual production. The term is used to broadly include Directors, Cinematographers, Producers and all the different professional figures taking part in the projects; VP: Virtual Production; An umbrella term to define a process having at the core real-time game engines combined with several other technologies; VR: Virtual Reality; A simulated experience of an artificial or virtual environment that is commonly computer-generated in real-time; /: Workflow; In the context of the AV industry, the term workflow refers to the series of stages an AV product passes through from conception to completion. In this work, it is used interchangeably with “making process”

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All the diagrams were created by the authors

Data availability All the outcomes from the co-design studies have been made publicly available in the form of Mural boards.

Mural Boards.

Day 1 – Group 1: <https://app.mural.co/invitation/mural/journeymap4695/1678464689359?sender=u6856f66193d05621354f3891&key=ced1b798-734d-4381-81b9-4d65ca0f9010>

Day 1 – Group 2: <https://app.mural.co/invitation/mural/journeymap4695/1678464729866?sender=u6856f66193d05621354f3891&key=e8f18672-3a1d-4cf3-a68d-3ff117355089>

Day 1 – Group 3: <https://app.mural.co/invitation/mural/journeymap4695/1678464745092?sender=u6856f66193d05621354f3891&key=b9792658-7dc2-416a-8231-deaa6c3186b5>

Day 2 – Group 1: <https://app.mural.co/invitation/mural/journeymap4695/1678464985583?sender=u6856f66193d05621354f3891&key=c61080a1-da68-4cca-bafa-c24c0d9d0a1d>

Day 2 – Group 2: <https://app.mural.co/invitation/mural/journeymap4695/1678464974634?sender=u6856f66193d05621354f3891&key=ba1628a7-6a29-4e2c-8ebe-edc5250c29b8>

Day 2 – Group 3: <https://app.mural.co/invitation/mural/journeymap4695/1678464959669?sender=u6856f66193d05621354f3891&key=0cd7572a-e849-4212-bfd1-ef5404c33de5>

Workshop Agenda: <https://docs.google.com/document/d/1efUQqiEOtrc15US8IBSflcB5R8rpytDACYkH48h2IA/edit?usp=sharing>

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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