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Lee, Sueyoon; Viola, Irene; Singla, Ashutosh; Cesar, Pablo

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Sueyoon Lee
Centrum Wiskunde & Informatica (CWI)
Amsterdam, The Netherlands
sueyoon@cwi.nl

Irene Viola
Centrum Wiskunde & Informatica (CWI)
Amsterdam, The Netherlands
irene@cwi.nl

Ashutosh Singla
Centrum Wiskunde & Informatica (CWI)
Amsterdam, The Netherlands
ashutosh.singla@cwi.nl

Pablo Cesar
Centrum Wiskunde & Informatica (CWI)
Delft University of Technology (TU Delft)
Amsterdam, The Netherlands
p.s.cesar@cwi.nl

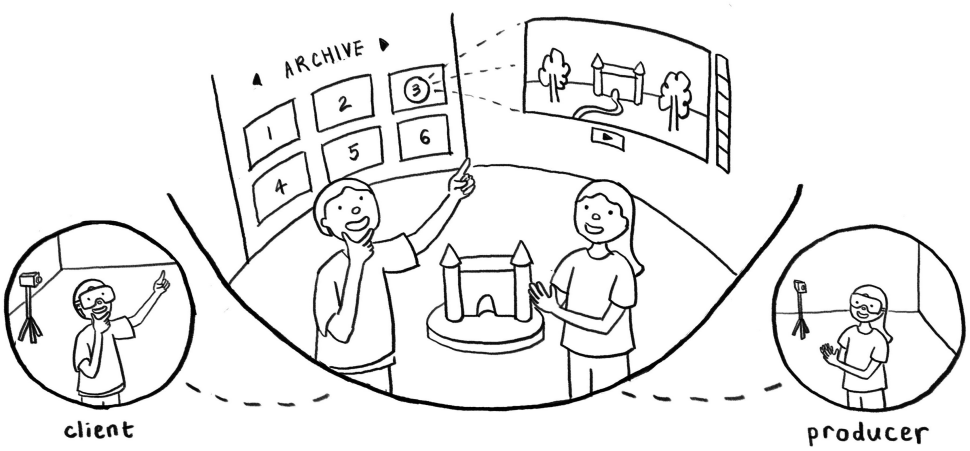

Figure 1: A conceptual social XR tool solution for clients and producers to communicate and showcase prototypes clearly during the pre-production phase.

ABSTRACT

Extended Reality (XR) has emerged as a transformative and immersive technology with versatile applications in content creation and consumption. As XR gains popularity, companies eager to adopt it often possess a surface-level understanding, investing significant resources without effectively addressing the genuine needs of end-users. This study explores the current workflows of XR production companies, and the potential of social XR in mitigating challenges throughout the XR production workflow. We present the outcomes of three respective focus group workshops conducted with three XR production companies and their experts (N=17). The results indicate that at every stage of the production, namely pre-production, production, post-production, and post-release, there are communication challenges between producers and clients, as well as different production and post-production specialists. We discuss various aspects of XR concerning the problem and propose novel opportunities offered by social XR to ameliorate those challenges, improving communication and making development more agile.

CCS CONCEPTS

• **Human-centered computing** → *Empirical studies in HCI*; **Virtual reality**; • **Applied computing** → **Media arts**.

KEYWORDS

Social XR, production workflow, communication

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1 INTRODUCTION

Immersive multimedia experiences have witnessed a surge in popularity in the last years, thanks to the availability of consumer-grade tools to capture, distribute, and consume such content through eXtended Reality (XR) devices. Immersive experiences promise a higher level of engagement, enhanced sense of presence, and better quality of experience for the end-users while offering new venues for interactive and immersive storytelling. Thus, immersive contents have been recently integrated into media production pipelines, as virtual production [2, 27], immersive storytelling [20], enhanced museum experiences [10], and cultural heritage [22]. However, several challenges arise in the production of XR media experiences, from content placement in XR environments to guide attention while curbing cybersickness [17], to integrating sensory cues such as haptics and smell [3]. More critically, issues have been identified with experience gaps in learning to use XR authoring tools for designers with low technical skills [16, 22, 36], marginalized groups who do not have access to the technology [23], and performers that need to learn to interact with"XR that is invisible to them, but visible to the audience" [8].

While the production workflow for traditional media is well understood by both clients and producers, honed through years of expertise [26], producing XR experiences presents an additional challenge in how to manage communication and expectations between technology enablers, experience designers, and end customers [16]. A plethora of factors are responsible for this knowledge gap between XR providers and clients: the relative infancy of the field so that the possibilities and added values of the medium are not implicitly understood [31]; the entry cost of purchasing devices to access the XR experiences [14, 15]; the lack of a common vocabulary to effectively communicate what can be offered and their limitations [1, 18]. Moreover, time and budget constraints limit the amount of face-to-face meetings that producers have with clients, hindering communication. Similarly, internal communication during the production process suffers from a lack of standardized tools for collaboratively designing XR experiences, sharing assets, and simultaneously accessing and modifying XR contents between remote users. In this context, social XR has been recently gaining momentum as a way to remotely collaborate and share workloads [25].

In this paper, we aim to explore what possibilities and opportunities lie in enabling social XR in various stages of the production workflow. Specifically, we aim to address two research questions:

- **RQ1:** What are the communication challenges and pain points at each stage of the XR production workflow?
- **RQ2:** How can social XR contribute to addressing the challenges faced during XR production?

To do so, we conducted three focus group workshops to better understand the challenges faced by XR production companies. We then drew some possibilities for social XR to alleviate some of those challenges.

2 RELATED WORK

2.1 Workflow for XR Production

As described in different studies [6, 11, 29] and industry resources (ImageKit[1], Unity[2], and Lucidchart[3]), the traditional video production workflow is often broken down into distinct phases: pre-production, production, post-production, and post-release/distribution (see Figure 2).

A review of the existing literature reveals that the production workflow for XR experiences roughly follows the same steps. For example, the production of immersive experiences for TV and film industries [1] involves a pre-production step involving the design and research of a suitable concept related to a particular XR technology; after securing funding, the concept is refined and goes into production, post-production, and release, similarly to traditional film production. The creation of XR experiences for cultural heritage follows similar steps in sourcing historical documentation, 3D surveys, and assets as a pre-production step, which is then followed by the production of 3D scenes, assets, and experiences, which are deployed to the public [7, 28]. The literature highlights several challenges related to the production of XR experiences as opposed to traditional workflows: smaller budgets and team sizes; technology limitations in terms of acquisition, reconstruction, and interaction capabilities; clients' and consumers' expectations; design and storytelling challenges for immersive content where users can look anywhere, anytime; scarcity of skilled professionals [1, 7, 16, 28]. These challenges provide the starting point for the exploration conducted in this work, in identifying pain points for XR producers, and seeing how social XR can ameliorate them.

2.2 Communication and Collaboration between Producers and Clients

Communication challenges have been observed in other production processes such as the automotive industry [30], video editing [24], and construction [5]. In the case of XR production, such challenges are compounded by the difficulties of communicating with technical partners and clients who are often geographically distant [1]. Remote communication and collaboration can be conducted through conventional platforms like Zoom or Teams. However, these platforms offer limited interaction with the environment and provide almost no sense of presence [9, 32]. Thus, Social XR has been used by several researchers to facilitate communication and collaboration in solving different tasks [12, 13], and specifically to ameliorate communication challenges between clients and providers [21, 33–35]. For example, Wu et al [34] used VR to help clients understand their design and provide feedback. Yamamoto et al. [35] developed a VR application that allowed designers, owners, and engineers to work collaboratively and discuss design changes. Mei et al. [21] created an application for clients and chefs to co-design cakes in VR, highlighting how the solution improved communication.

From the above, we can see that social XR tools could enhance understanding and collaborative decision-making between clients and service providers. However, there is a significant gap in understanding how these tools meet the specific needs of XR production

[1] https://imagekit.io/blog/video-production-workflow/
[2] https://learn.unity.com/tutorial/the-real-time-production-cycle?uv=2021.3#
[3] https://www.lucidchart.com/blog/how-to-develop-a-video-production-workflow

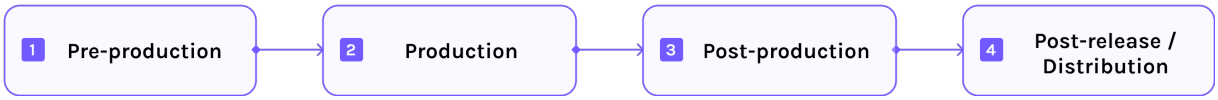

Figure 2: Traditional Video Production Workflow.

workflows. To address these research gaps, we conducted a focus group workshop with various XR production companies to understand the practical challenges they face in their production workflows and how social XR tools could help in their production processes.

3 FOCUS GROUP

We conducted three on-site focus group workshops with XR production companies to understand their internal XR production workflows.

3.1 Participants and setup

From May 24th to June 6th, 2023, three focus group workshops with experts (N=17) were conducted at XR production companies in Copenhagen (C1), Vilnius (C2), and Bordeaux (C3) (Table 1).

C1, established in 2015, specializes in XR production and learning, offering nearly 500 immersive experiences across philosophy, techno-anthropology, design, and business with a team of about 40. C2, founded in 2014, focuses on education, culture, and exhibitions. Their portfolio comprises 80% content and 20% hardware (i.e., physical installations), with a team of around 20 and partnerships with freelancers. C3, established in 1994, creates immersive workspaces globally, with over 800 solutions installed. They operate in innovation, production, marketing, training, and maintenance, with a team of 40 and 4 offices in France and Singapore.

Within the companies, expert participants were selectively recruited by each company's project manager to ensure a diverse representation of roles for sharing their expertise.

Table 1: XR production companies and participant details

No.	Date	Location	No. of Participants (Roles)
C1	May 24, 2023	Copenhagen, Denmark	**8** (CTO/Co-founder, CG artist, Lead programmer, Project managers, Film producer, Business developer, Programme manager)
C2	Jun 2, 2023	Vilnius, Lithuania	**5** (Sales managers, Creative, Project manager, CEO (theatre))
C3	Jun 6, 2023	Bordeaux, France	**4** (R&D director, R&D engineer, Designer, Human factor engineer)

Each session lasted 2-3 hours and took place in a closed room with a table, where participants were seated facing each other to evoke an active discussion (Fig. 3 (left)). The materials used include 8-10 pages of printed activity sheets (Fig. 3 (center)) where participants could draw and write down their ideas, along with accompanying slides displayed on a monitor screen (Fig. 3 (right)). A single moderator led the session with the support of one assistant, responsible for tasks such as voice recording, taking photos, organizing the activity materials, and taking notes.

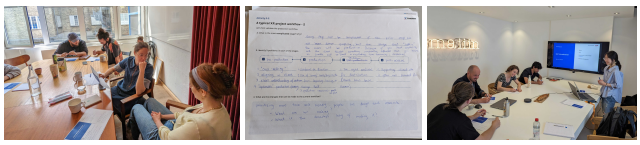

Figure 3: Participants are actively discussing their ideas at C1 (left); an example result of the activity sheet filled by one participant (center); a moderator giving an introduction and participants filling in the activity sheets at C3 (right)

3.2 Procedure

We followed the procedure outlined below, and Table 2 provides a list of questions asked at each step. In each step, participants first individually recorded their answers on the activity sheet and then shared them with the group:

Introduction and warm-up. The introduction by the moderator outlined the workshop's goals and structure and guided usage of the activity sheets, to establish a relatively relaxed environment, making participants more at ease expressing themselves before transitioning to the main discussion.

Sensitizing Activity: My experience with XR projects. We began with a sensitizing activity with a slightly broader subject [4], to immerse participants and enhance the chances of uncovering new perspectives.

Activity 1: A typical XR project workflow. Activity 1 aimed to validate the general production workflow utilized by XR production companies. We presented the participants with the production workflow diagram (Figure 2) depicting the four stages and asked the questions (Table 2). With their answers, participants discussed whether the given workflow could be generalized, citing examples from their previous projects, and explored whether the criteria for delineating each step were consistent. Eventually, they reached an agreement on the internal workflow and the terms.

Activity 2: XR project workflow stage. Activity 2 aimed to concretize the production workflow, distilling detailed information and understanding the current challenges for each stage. As of Activity 2, participants shared and discussed the results, reaching a general agreement.

3.3 Data Analysis

We documented the answers from the activity sheet into an Excel spreadsheet and transcribed the audio recordings of the entire focus

Table 2: A list of questions asked at each step during the focus group

Procedure	Questions
Warm-up	A brief 30-second self-introduction, covering: name, professional role, years of experience, favorite XR project(s)
Sensitizing Activity	Recall the latest or most memorable / complicated XR project you worked on. a) What was the project, and how long did it take to complete? b) Which tools did you use? c) Who did you directly work with? d) Why do you consider it as most memorable or complicated? e) What is the one thing that could have been improved?
Activity 1	1) Do you think the diagram (Figure 2) represents the current production workflow well? a) If not, how would you change it? 2) What is the most complicated stage and why? 3) Identify three problems in each stage. 4) What changes can be made to the current workflow?
Activity 2	For each stage (pre-production, production, post-production, post-release): a) What are the types of outputs? b) List the type of tools you use. c) Do you have any communication issues while developing XR applications? d) Current Limitations?

group sessions using *Dovetail*[4] (Fig. 4). We conducted a thematic analysis [19] of the collected data. A researcher first reviewed and labeled the text, and organized the labels under each production workflow stage as a high-level category. Labels were turned into various themes, which underwent several rounds of review by researchers to reach an agreement through label cross-checking. The coded texts and themes were sorted into two main sections: (1) the four stages of XR production: activities, outputs, and used tools, and (2) communication issues and challenges of the current production. Results are presented in Section 4. Participants are labeled P1-P17.

4 RESULTS

All three companies (C1, C2, C3) agreed on the four-phase XR production workflow: pre-production, production, post-production, and post-release.

4.1 Four stages of XR production: activities, outputs, and used tools

4.1.1 Pre-production. The project may commence with clients approaching with new ideas, the company applying for projects, or sometimes organizing internal idea workshop events by inviting potential clients. During initial discussions, the company shares its portfolio, budget, and estimated hours with clients to establish a mutual understanding among stakeholders. Research and development (R&D) is then conducted, followed by concept development in the form of mood boards, storyboards, and scripts. A more detailed plan is created after rapid prototyping and requirement specification, forming a (preliminary) production plan and wireframes. Once an agreement is reached with clients, the contract is signed, and the internal team's roles and budgets are confirmed.

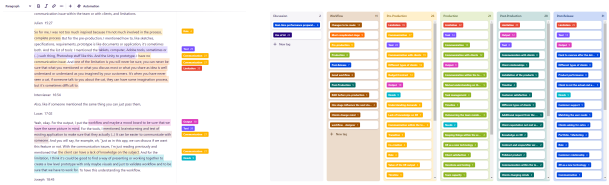

Figure 4: An example of the transcript of the focus group session and labeled texts (left); tags from all three sessions (right)

The tools they use fall under three categories: *communication* (e.g., Google Suites, Airtable, MS Office), *prototyping* (e.g., Miro, Sketch, Figma, Adobe Suites, Unity, pen and paper), and *R&D* (e.g., observation, interviews, surveys).

4.1.2 Production. The production phase is where the majority of prototyping and production takes place, resulting in a project that is 70 – 90% complete. Development involves numerous iterations, primarily with internal team members, and modifications are made based on feedback. The output encompasses materials such as images, scenes, video clips, 3D models, and functionality, along with low/high-fidelity prototypes (e.g., XR/Unity/C++).

The main tools used are either for *XR prototyping* (e.g., 3D software, C#, Unity, Unreal, Maya, GitHub, Visual Studio, JetBrains) or for *communication* (e.g., Asana, Google Drive, email, Slack, Docs).

4.1.3 Post-production. Finalizing the UI, sound, and XR experiences, as well as deploying the finished product after the client's confirmation, constitutes the post-production phase. This phase involves extensive testing for quality assurance, and, in most cases, clients come to the office to test the final prototype. The prototype or app undergoes evaluation, and the release includes the app license and documentation, such as a quick start guide. This phase is often neglected in short-spanned projects.

Similarly to the production phase, they use tools for *XR prototyping* and *communication*. Additional tools are included for *editing* (e.g., sound, Premiere, After Effects), *testing* (e.g., hardware such as Oculus, Pico, user testing and design tools), and *releasing* (e.g., Android/iOS store).

4.1.4 Post-release. After releasing the product, the company is responsible for maintaining the software, fixing bugs, and implementing new features. C2 provides a 2-year support period, while C1 and C3 mention that the support duration varies from case to case, depending on the clients and the type of project. User satisfaction, audience, and client feedback are outputs they are looking for

[4]Dovetail: https://dovetailapp.com/

beyond the released VR apps or experiences. Often, impact evaluations are conducted, and download metrics or on-site visits to the installed product (e.g., in the case of museum installations) are used. Additionally, companies internally document and archive projects, and have debrief sessions to learn takeaways. This documentation becomes part of their portfolio, including visuals, social media, and their platform, and is used for marketing purposes. The new features developed during the project often lead to the initiation of the next project (pre-production of the next project).

The tools used include: *evaluation* (e.g., Google Analytics, debrief meetings, marketing tools, long-term UX evaluation), *app launch* (e.g., MDM systems, pushing updates, hardware such as Vive, iPhone/Android), and *communication* (e.g., emails, calls).

4.2 Communication issues and challenges of the current production

4.2.1 Pre-production. The pre-production phase is where most communication issues arise and is also considered the most complicated phase in the entire workflow, as voted by the participants (9 out of 17). A critical issue is the difficulty of establishing a 'mutual understanding' between the client and the company regarding their concept and direction. This difficulty primarily stems from a lack of understanding and education in XR. Clients often have highly optimistic expectations about budget, timeline, possibilities, and the value of XR outputs due to its status as a relatively new technology (*P3: "because VR/AR is still new for clients, ... they don't always know what to expect, or what is possible and what is not possible."*). An additional layer of the issue arises as most of the time, communication regarding the contract occurs between the salesperson or project manager, who has limited sketching skills and technical understandings to present potential XR outcomes to clients, not the actual development team. Both parties (client and the company representative) struggle to discuss intangible 'XR objects' without proper tools, such as XR headsets (*P14: "... I think each person has a different representation in their minds because we don't have real objects to discuss."*). Furthermore, some clients are willing to actively participate in the ideation or prototyping process using tools in the market, like *ShapesXR*[5]; however, such tools still have high barriers for non-designers (clients) to quickly learn the tool, showcase their creativity, and efficiently deliver and present ideas in a limited time (*P5: "...it takes a little deeper knowledge before we can truly utilize [XR prototyping tool]..., it would just end up with a bunch of boxes in a room."*). As pre-production is the initial phase, and the decisions made here will have consequences for the later stages, overall, an extra level of clarity in communication is required.

4.2.2 Production. While the issue during pre-production mainly concerns scoping the project between clients and the production company, the critical aspect of the production phase is the performance of the internal team, including development and management. The development team takes a highly iterative approach, constantly updating and sharing interim results, conducting tests, and discussing the prototype internally. A communication issue arises here as discussions often take place through 2D monitor screens due to a lack of gadgets (e.g., XR headsets) for all team members. The hiring of third-party contract workers for projects also complicates communications. Regarding project management, delays in the schedule and inefficient task management also occur due to a lack of communication between teams (development, design, management, etc) (*P4: "...we sometimes end up having to wait for each other. The programmer needs to wait for a huge amount of 3D that needs to be ready, and vice versa."*). Late feedback from clients, especially overseas clients, and deciding how often to share progress updates with clients are struggles that project managers face in optimizing cost efficiency. Some clients attempt to introduce new concepts or ideas after reviewing the developed prototype that do not meet their expectations; however, this is due to misunderstandings from the pre-production stage (*P11: "... in pre-production, client expectation wasn't handled quite good, and he didn't understand what he will get in the end. [This is] where the problem starts...."*).

4.2.3 Post-production. As production nears release, efficiently managing limited resources —money, time, and human capacity—poses a constant challenge, often leading to delays beyond the planned schedule. The delayed production leads to insufficient iterations and testing, resulting in a failure to meet the company's own quality standards (*P13: "Sometimes, we [think], 'we have extra time, let's try something new,' but then the product concept isn't tested yet."*). The participants identified these challenges as stemming from a lack of XR state-of-the-art knowledge (learning-by-doing) and management issues (insufficient communication within development teams). Some mentioned that having proper briefing sessions for previous projects would have helped all the developers stay up to date with the technology and approaches, reducing trial and errors (*P4: "...if the app is ready, and now we have to jump to the next one,... So, some information may be lost until we do the debrief."*). Additionally, the issue of delayed feedback or the introduction of new ideas from clients, along with the discovery of UX issues too late for integration into the software, was raised (*P16: "We never share anything before the end. But we invite them if they want to experience the application or stuff... because if we share plan, we share pictures, screenshot that is never [ending]..."*). Participants noted that a clearer definition of the project scope during pre-production could have prevented most of these problems.

4.2.4 Post-release. Managing maintenance with clients and measuring the actual impact on the end-user pose significant issues in the post-release phase. The frequent deprecation of released XR software and the constant system updates or new version releases are unavoidable due to the rapidly evolving XR ecosystem and its high dependency on other platforms, APIs, and software (*P8: "... API is deprecated and they contact us and, 'It doesn't work! It worked yesterday!' They'll have to buy a new headset, or you have to update this..."*). Communicating with clients through a phone call and remotely guiding them on which updates to implement proves challenging, even if it's a minor fix. Additionally, clients may request 'quick changes' in functionality after release as part of maintenance. Despite appearing straightforward, these requests often involve structural changes, demanding significant effort. Determining the company's support for software maintenance and establishing clear boundaries is also a complication (*P2: "it's really hard where do we draw the line... We don't want to scare people away by having a gigantic legal contract... But then again, we need to protect ourselves."*).

[5]ShapesXR: https://www.shapesxr.com/

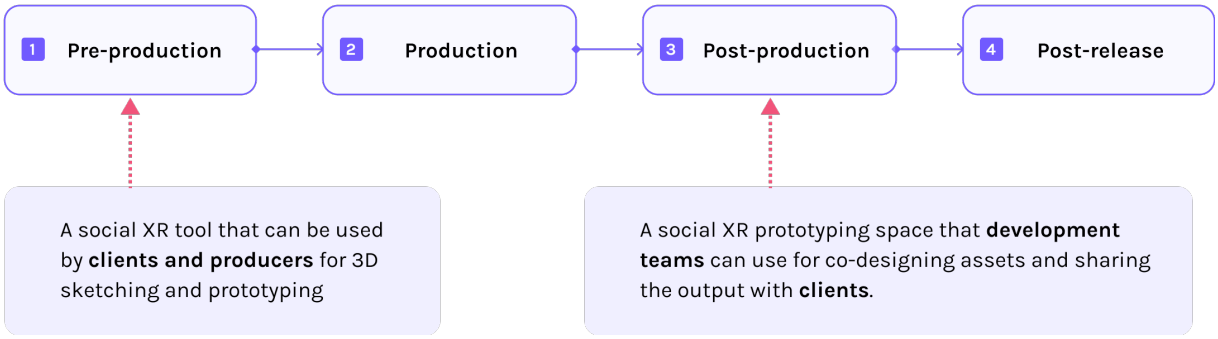

Figure 5: A production workflow diagram with suggested Social XR solutions.

Meanwhile, all companies have expressed a strong desire to assess the actual impact of the released software on the end-user, beyond satisfying the clients who made requests. However, due to limited methods for collecting end-user data and the absence of agreements with clients, the companies have a limited chance to measure, oversee the real impact they made, and receive feedback from the end-users (*P1: "'Okay, how many people did we affect?'... And we don't know, because we never incorporated the metrics or evaluation into the experience."*). Another internal issue within the company was the absence of post-project debrief sessions. This was due to time constraints and the immediate transition to the next project, leading to deprioritization despite the perceived necessity.

5 SUGGESTED SOLUTIONS AND TOOLS USING SOCIAL XR

Our findings highlighted that communication challenges occur in the entire production workflow, from pre-production to release. Such challenges stem from accurately conveying to clients the possibilities offered by XR while indicating how different budgets and timelines impact the final result; how to match the client's expectations on a medium that is still little understood; how to effectively handle production and post-production with geographically distant operators; and how to offer support and gather feedback in post-release. Compounding the problem are the monetary and time resources needed to carry on the communication. In this regard, social XR represents a viable medium for improving communication challenges and fostering better collaboration [21, 25]. In the following, we detail how such a tool could be used in the various stages of the workflow.

5.1 Pre-production

One of the issues identified in our focus groups is the difficulty of presenting a concept to the clients and communicating what the XR product can offer within a specified timeframe and budget. Being able to showcase previous work clearly and modify it on the fly to show fast prototypes to potential clients based on their needs and expectations, is a valuable tool for improving communication. Thus, the effectiveness of social XR to improve communications and manage expectations has been shown in some client-producer use cases [21]. A social XR tool (Figure 1) for clients and producers to do 3D sketching and prototyping could facilitate the initial negotiation process, and help understand what is available and possible in the medium, while directly showcasing previous advances in XR production. The tool should be easy to use and accessible to people with low to no technical or design background in XR (see Section 4.2.1) and should allow for real-time manipulation and simultaneous handling of 3D objects. Moreover, the tool could showcase what a given budget and timeframe can realistically offer, and how different price points might lead to different experiences, to better manage client expectations and facilitate the communication process during production.

5.2 Post-production

The main challenge in the (post) production phase was sharing a clear vision and progress on the prototype among the production team members and when receiving confirmation on the prototype from clients. Having a centralized social XR prototyping space for sharing and modifying assets together and co-designing them would help production teams efficiently communicate the vision, managing the assets even with third-party contract workers. The tool could provide two modes: prototyping and showcasing/feedback, allowing producers to selectively share the prototype with clients. The tool should provide real-time communication and easy feedback, such as accurately highlighting specific parts with a marker in a three-dimensional manner. Simultaneously, it should be able to save different versions, allow for leaving comments, and enable checking them later, even between remote participants, as one of the challenges was synchronizing all stakeholders' timelines. These capabilities would alleviate delays related to feedback issues, especially from overseas clients, while saving time and budget normally spent on on-site visits.

6 CONCLUSION

This paper presents the production workflow of immersive media producers, emphasizing their communication challenges at each stage, and proposes preliminary solutions utilizing social XR. We conducted three on-site focus group workshops with 17 professionals to comprehend the current activities, outputs, and tools utilized at each stage, discovering underlying pain points through thematic analysis. We suggest social XR tools with functions and sketches that could most benefit producers in pre and post-production stages. Future work will include developing a social XR communication

tool for producers and clients during pre or post-production stages and testing the user experience.

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