Immersive Video Sketching: Low-Fidelity Extended Reality Prototyping for Everyone

Oğuz ‘Oz’ Buruk
Gamification Group, Tampere University
Tampere, Finland
oguz.buruk@tuni.fi

Juho Hamari
Gamification Group, Tampere University
Tampere, Finland
juho.hamari@tuni.fi

Figure 1: A scene from an Immersive Video Sketch

ABSTRACT

As the extended reality (XR) field advance, the need for tools assisting designers in the early-design phases for these immersive environments also increases. Although several tools exist, we still need a method that allows non-experts to engage in designing for XR, especially for collaborative contexts such as participatory design (PD) workshops. In this paper, we introduce Immersive Video Sketching (IVS), a low-cost prototyping method for early-phase XR design that can be easily employed by novice and non-expert designers. IVS combines body storming, paper prototyping and video sketching for XR environments. We tested IVS with 23 participants in a PD session focusing on XR game wearables. Our results showed that IVS can help non-experts to grasp the immersive nature of XR environments easily. On the other hand, a 4-hour design session might not be enough for iterations on design ideas and different design skills might create discrepancies in the outcomes.

CCS CONCEPTS

• **Human-centered computing → User interface design**; **Interface design prototyping**; *User centered design.*

KEYWORDS

virtual reality, augmented reality, bodystorming, paper prototyping, video sketching

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1 INTRODUCTION

Rapid developments of the extended reality (XR) [1] hardware and software brought ample amount of tools that can be used in the design and development process of applications for these immersive environments. Nowadays, with plug-and-play “software developer kits,” developing interactive environments for extended reality (XR) does not require extensive time or expertise when it comes to creating basic applications that seamlessly work with XR hardware.

Still, design methods for the early sketching and prototyping phase for XR environments are underexplored. Although creating an interactive XR environment through relatively user-friendly software such as Unity Game Engine is not too demanding, while designing the fundamentals of an interactive system, the sketching and low fidelity prototyping phase is critical for exploring the design space in depth. For the early stages of the interactive systems design, designers frequently use methods such as paper prototyping (making prototypes out of paper), body storming (enacting user scenarios for creating ideas) or video sketching (creating storylines with sequential still images). Compared to more traditional design methods like 2D sketching on a paper, these design methods are more inclusive as they do not require expertise in design [44, p.56] or in a specific field [41, 52] and can be employed by everyone. Thus, these methods are also commonly used in collaborative design contexts such as participatory design or co-design workshops [4, 11, 38, 46, 49].

These early design methods, however, fall short in capturing the immersive environment of head-mounted extended reality (HMXR) environments and many practitioners need to employ tools and processes which were aimed for 2-dimensional or physical product design [3]. Therefore, several studies developed various tools and procedures for the early design process of applications that will

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[1] Extended Reality is a term that encapsulates a wide variety of real-virtual technologies such as Virtual Reality (VR), Augmented Reality (AR) or Mixed Reality (MR) [10]

be run on HMXR environments [24, 27, 29, 35, 51]. However, solutions presented in these studies either require specifically designed software or require expertise such as sketching on photosphere templates [24] [2]. Apart from these studies, several participatory design studies focus on designing applications for virtual reality by using methods such as 360° video prototyping that includes shooting a 360° video by using omnidirectional cameras and editing to demonstrate interactions in HMXR [16, 45]. Although video prototyping methods allow involving embodied methods or paper prototyping in the design process of XR and can be used for engaging users, they still require expensive equipment such as 360° cameras and expertise in video editing which is also time-consuming. Therefore, sketching methods that support more embodied ways of exploration in HMXR environments while also grasping the immersive nature of the medium are quite limited, especially in settings where non-expert users and other stakeholders participate as designers. Therefore, we need a method that would allow 1) utilization of paper prototypes in XR environments, 2) allow embodied exploration, 3) accessible to everyone through off-the-shelf tools, 4) can be understood and employed quickly, and 5) introduce the immersive experiences, opportunities and the limitations of extended reality environments.

To fill this gap, we developed a method called Immersive Video Sketching (IVS) (**Figure 1**) that combines paper prototyping, bodystorming and video sketching to be incorporated for HMXR environments. IVS requires several tools that are easily accessible: 1) a smartphone, 2) a 360° camera app, 3) a cardboard VR headset, 4) an online platform for creating 360° tours, 5) a photo editing software (e.g., MS Paint, MS Powerpoint, Adobe Photoshop) 6) prototyping materials (e.g., cardboard, scissors, tape). The process includes a) making paper prototypes, b) creating a story-line, c) taking 360° photos for this story-line, d) making minor visual edits (e.g., adding speech bubbles, interface elements), e) adding hot-points to skip between photos in a 360° tour platform and f) experiencing the video sketch in XR through cardboard VR headsets. As in the video sketching method designed to be shown in conventional displays, *IVS is also not for creating videos* but storylines with *still images*. In this paper, we explain the overall structure of the IVS method and present the participants' feedback on IVS from a participatory design workshop session with 23 participants. We also give in-depth instructions about how to employ this method by explicating the tools we have used in the process, however, the IVS method and our specific process should be considered separately, since IVS demonstrates an overall structure in which different tools can be employed and with the development of available tools, the whole process can be improved.

2 BACKGROUND AND RELATED WORK

To understand why IVS might be useful for the design of XR environments we need to understand the place of paper prototyping, embodied design methods, video sketching in the early interface design. In this section, we elaborate on these concepts and then introduce existing prototyping and sketching methods for XR environments by demonstrating their relations to these concepts, as well as their differences from the IVS method.

2.1 Paper Prototyping

Paper prototyping is a method to create the earliest mock-ups of an interface by using paper and other similar low-fidelity materials [44]. Commonly, it is used for creating interaction sequences and user scenarios for screen-based interfaces [44]. In practice, different screens of an interface are drawn on paper, cardboard or post-its and designers switch between these different parts of the interface as the user pretends to interact with the elements drawn. Paper prototyping is also used for designing interaction beyond screens, for contexts such as wearables, augmented reality environments or tactile interfaces [18, 25, 26, 33]. In the design process, paper prototyping is one of the critical parts to have a preliminary understanding of the intended user experience before starting to invest time and resources in actual development [44]. It is also very common to use this method in participatory and collaborative design settings for testing the possible experience of an idea because it is easy and quick to realize [14, 42, 47]. Previous studies do not propose a method that would integrate paper prototyping into HMXR design in a way that captures the immersive experiences provided by these environments and is easily employed by participants without any expertise in design or development.

2.2 Embodied Design

Another significant part of designing for extended reality environments is the design of the embodied interaction. Since interaction in HMXR environments is mostly realized through the movement of bodies, it is important to understand the role of the body in the design process. In interaction design, designing for and around the body is a well-studied area and there are plenty of ideation methods that would help to understand how the body of the user is situated in the interaction space. For example, embodied sketching is one of the noteworthy concepts that is developed to understand the socio-spatial relationships around the body [30]. In their previous work, Segura et al. identified ways of using the body for ideation and sensitization during the design activity. Among the methods that can be used for embodied sketching, Bodystorming is a common method that allows designers to enact different user scenarios by using prototypes including paper prototypes [39]. This method can be used for most simple interfaces such as interactive kiosks [50] or more complicated products such as smart furniture [40]. Without using these methods and involving the body in the soma-based design, it is quite challenging to grasp the nature of embodied interaction that has many dimensions including user, artifact, body, bodies of others and spatiality [20].

Embodied design methods allow designers to experience all these aspects in the early design phase and a similar approach is also required for designing for HMXR. In this direction, a previous study by Boletsis et al. explored bodystorming in virtual reality by integrating a 3D environment in which designers can manipulate different 3D models [6]. The method is found to be immersive enough by experts but needed more development in terms of freedom to manipulate the environment. Experts also suggested that it can be used in collaborative and crowded settings given the infrastructure is sufficiently robust. Lee et al. also proposed a method for including Embodied Design Improvisation for augmented and

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[2] Photospheres are canvases to create 2D sketches that can be turned into 360°images.

virtual reality environments to reveal unexpected embodied interaction [28]. They found that this method might benefit designers to come up with unexplored body movements by observing users' improvisation through video recordings. Another approach related to embodied design is Immersive Design Fiction which envisions virtual reality environments as potential spaces where fictional prototypes and experiences can be created [31]. The authors reported that they created experience prototypes [7] before implementing the working virtual prototypes. In that sense, IVS can help also in the Immersive Design Fiction context by allowing designers to easily demonstrate experience prototypes in the virtual setting.

All these embodied design methods show that embodied exploration is a vital procedure in body-based interaction and previous studies tried to incorporate these methods in virtual environments. Still, these studies require the involvement of expert designers in the process and not available to average users without designer skills. Therefore, they do not provide a method that allows users without design expertise to ideate, design, implement and experience their concepts in an XR environment in situ.

2.3 Video Sketching

Video sketching is a tool for ideation, documentation and presentation. It uses a series of photos (not videos, contrary to its name) to be shot and organized in a way that tells a story [52]. It is especially appropriate for non-expert designers, since taking photos and ordering them does not require technical expertise such as video editing skills [52]. Video sketching also partially encapsulates embodied exploration and paper prototyping because the production of the storyline is done through enacting the use-cases through the utilization of paper prototypes. Similar to paper prototyping and body storming, it is also commonly used in collaborative and participatory design settings [8, 13, 19] because it is considerably quicker to depict ideas and requires less effort and expertise compared to the methods such as hand drawing storyboards or detailed product sketches. Video Sketching partly resembles Video Prototyping, however, there is a fundamental difference between the two methods. In Video Prototyping, videos are shot, manipulated, edited and tested through Wizard of Oz [12] method. In the Video Sketching method, still images are used instead of videos. This difference makes video sketching appropriate for designers with novice skills and quicker in terms of implementation because organizing, editing and post-processing photos is far easier than doing the same for videos. Video Prototyping for virtual reality environments has been used by previous work [1, 32] and proved to be effective for simulating the immersiveness and authenticity of HMXR. However, these prototypes were developed by designer teams and the effectiveness of a method that centralizes around Video Sketching (and not video prototyping) was not tested in collaborative or participatory design settings for HMXR.

2.4 Prototyping and Sketching Tools for XR

The word "Sketching" encapsulates all kinds of activities that are conducted to generate rough and preliminary ideas [9, 48]. Although traditional 2D sketching is the first form that comes to mind, sketching also takes forms such as embodied sketching which uses the movement of the body and acting [30] or as mentioned in the previous chapter video sketching which uses photos [52]. Tools that allow making 3D visual drawings [15] or turning 2D traditional sketches into 3D models that can be interacted in the virtual environment such as SymbiosisSketch [2] are common. However, they are out of the scope of this study, because similar to embodied and video sketching, we aim to facilitate the creation of preliminary interactive concepts through methods such as bodystorming and paper prototyping.

There are several tools for aiding designers to sketch preliminary ideas for interaction concepts in XR environments. One of the suggested methods follows a workflow where designers first sketch their ideas on a photosphere template and then transfer it to the VR environment [24]. This method provides a way to quickly design environments for VR, however drawing on photospheres requires a learning process and sketching skills. The pARnorama is another project, which has similarities to IVS, however tries to leverage 360° videos, instead of still images, and requires video editing skills and 360° cameras that are not available to all.

360proto uses a different approach and lets designers place paper cutout layers to a virtual immersive environment, through using a specially developed user interface [35]. This tool allows novice AR/VR designers to develop prototypes for XR, and reported to have a fairly quick learning process. Still, 360proto requires specific software and the design process does not focus on embodied exploration. XRDirector takes this further by also enabling collaborative and embodied design methods by creating an environment where designers can have different roles such as directors, actors or viewers to create animated scenes and interactive prototypes [34]. Compared to our method, 360proto and XRDirector are capable of producing higher fidelity prototypes and can be used also as part of Wizard-of-Oz studies. Yet, we aim to integrate participants without expertise into the design process in the least challenging and straightforward way and our focus is not on the fidelity of prototypes but the accessibility and free-form embodied exploration. Similar to 360proto, ProtoAR is another tool that proposes solutions for Augmented Reality environments by letting users place paper and low-fidelity objects in a mobile AR environment through a dedicated interface [36]. Another recent tool, Pronto, allows designers to walk around the physical environment and place seemingly interactive objects as an overlay to video for AR environments [29]. Pronto is an effective tool for developing mobile device-based Augmented Reality applications with a dedicated tool, however, it does not target HMXR. These solutions are all targeted to fill the gap of low-fidelity prototyping and sketching for XR environments, and they all provide valuable tools. However, these solutions still rely on exclusive software which is research projects and not easily accessible as off-the-shelf tools, do not incorporate methods that are targeted to embodied exploration which are critical for XR environments.

XR environments introduced a new paradigm for interaction design and we are still in the process of understanding the best practices for designing improved user experiences. As seen from the developed sketching and prototyping tools, we need different approaches especially for early design phases which take embodied interaction and immersive experiences into the center. In the development of such interfaces, methods that will help ideation such as paper prototyping, embodied sketching, body storming or video sketching is critical. Especially in the context of participatory design and collaborative hands-on experiences in designing, tools and processes that will help non-expert participants to engage with the design is needed. Current tools for sketching and low-fi prototyping require specifically designed interfaces which are mostly research projects and not immediately available without a special request from authors and need further setup to run on a variety of systems. In this paper, we fill this gap by introducing a method that incorporates paper prototyping, body storming and video sketching in HMXR environments by allowing users to produce scenarios in a short frame of time that can be experienced in the head-mounted cardboard XR headsets and with easily accessible, low-cost and off-the-shelf tools. Therefore, contrary to previous approaches, we are introducing a set of steps that might be realized by a variety of readily available and exchangeable tools. Our aim is not to replace the existing tools created by previous studies, but to form a complementary method that can be widely accessible by different audiences such as users without expertise in design and development for XR or who do not have access to expensive VR/AR equipment or the software developed in research projects.

3 IMMERSIVE VIDEO SKETCHING METHOD

The basic concept of IVS method relies on creating an interactive storyline with 360° photos (Figure 2). Although this sounds pretty straightforward, discovering tools that can work across different mobile phones and cardboard VR goggles is a challenging process because they require different settings. Therefore, for increasing the accessibility of the system, we need to use a set of applications that can work across devices, screen sizes and cardboard goggles. In this section, we will describe the steps of the IVS method for preparing immersive video sketches. The order of steps and the different types of software and tools proposed in each step worked well in our context and we are confident that researchers who want to employ IVS can follow the steps as proposed here. However, it is also open to interpretation for each particular project. For example, we used the photo editing step for adding speech bubbles or other interface elements. Other researchers may want to prefer this step and use speech bubbles as cardboard cutouts or design all interface elements with paper prototypes without the need for digital photo editing. Thus, although our experience showed that the process introduced here can be considered as the ideal workflow, minor modifications and reordering can be made. The steps and the tools introduced here were used by us in a participatory design setting and freely available to researchers who want to employ this method.

1 - Preparation: The first step of IVS, is to build paper prototypes and a draft storyline around these prototypes. Neither the paper prototypes nor the storyline needs to be carefully thought because the storyline can be easily modified by adding or removing 360° photos in IVS. Therefore, participants can easily add scenes by modifying their paper prototypes or enacting an extra scene.

2 - Bodystorming and 360° Photo Shooting: After the draft storyline and paper prototypes are ready, participants can start to shoot 360° photos of their bodystorming performances. In this part, while one person in the team is shooting 360° photos, other team members can enact the scenarios and modify the physical environment in each sequence to demonstrate the interaction with the interface. In this phase, for photo shooting, we have used the Google Cardboard Camera App which could have been downloaded for free to both Android and iOS phones at the time of the workshop. With this app, without needing any external camera extension, users can take 360° photos that can be viewed in cardboard XR headsets. Taking one photo takes about 30 seconds. Therefore, the photoshoot of 20 photos can technically be finished in 10 minutes. This step can be realized by any camera application that is capable of taking panoramic photos. Apart from Google Cardboard Camera App, we also tested panorama photos with Samsung Stock Camera App and Panorama Camera App[3] which is available in Android and iOS platforms. All these apps allow users to take 360° panoramas and freely available. One detail that needs to be taken into account in 360° photo taking is that seams occur in the starting point of the 360° photo. Therefore, the main object (e.g. interface sketches, paper prototypes) should remain outside the starting point of the 360° photo.

3 - Photo Editing: The next step after the photoshoot is to edit those photos for adding details such as interface elements or speech bubbles to render the storyline more understandable. The additions to 360° photos can be done in any photo editing software including free tools such as MS Paint[4] or Paintbrush[5]. In the workshop, participants used several different software including Adobe Photoshop[6], MS Powerpoint[7] or MS Paint[5]. Editing 360° photos is not different than editing any photo as they are plain images with a wide ratio. This phase aims to design more in-depth details in terms of interactions (e.g., selecting menu items, designing preliminary effects, notifications etc.) and also clarifying the context by adding thoughts, conversations or reactions of users.

4 - Immersive Sequencing: After photo editing, the final step is to create the interaction sequence. For creating such sequences, online 360° tour creation tools such as Kuula[8], 3DVista[9], Theasys.io[10] or Lapentor[11] can be used. Originally, these platforms are designed for creating virtual tours of specific places (e.g., historic sites, rental houses). However, they also work very well with forming interactive scenarios since it is possible to assign hot spots to specific places in the photos to progress to the next photo. Therefore, it is possible to form branched storylines in which interacting with the specific parts of the picture can reveal different photos. For the sake of accessibility and scalability, the platform that will be used should support the WebVR plugin that allows adjusting the view to different screen sizes and lens configurations for different types of cardboard goggles. The most ideal candidate to be used in such a scenario was the Lapentor platform. Because it can adapt to different types of cardboard headsets, it is free to use, allowing the addition of unlimited photos, compatible with cylindrical panoramas, and operates completely online. The biggest shortcoming was that it was not possible to view the created projects in iOS devices since iOS does not support HTML5 API. Still, in our

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[3] https://bit.ly/panoramacam
[4] https://support.microsoft.com/en-us/help/4027344/windows-10-get-microsoft-paint
[5] https://paintbrush.sourceforge.io
[6] https://www.adobe.com/products/photoshop.html
[7] https://www.microsoft.com/en-us/microsoft-365/powerpoint
[8] https://kuula.co
[9] https://www.3dvista.com/en/products/virtualtour
[10] https://www.theasys.io
[11] https://lapentor.com

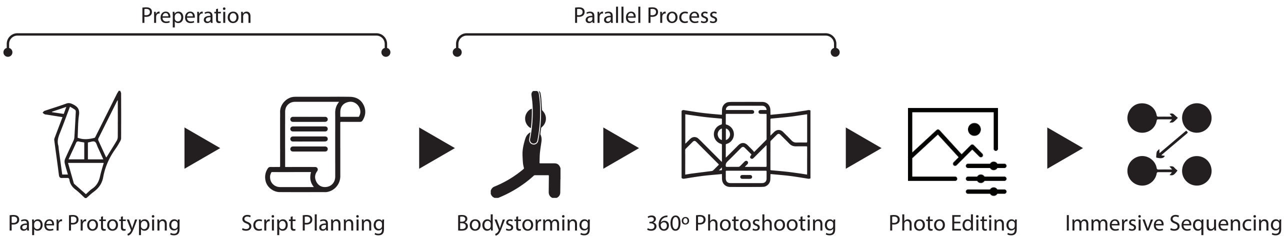

Figure 2: Workflow of Immersive Video Sketching

workshop, participants were able to run it on a variety of Android devices with the cardboard headsets we provided. In collaborative settings with many participants such as our participatory design workshops, for providing as many cardboard goggles as possible with a limited budget, flexibility of the WebVR plugin is needed for adapting to unbranded and even custom cardboard goggles. That said, other 360° tour platforms can work well with more common cardboard headsets such as Google Cardboard. However, Google Cardboard VR is considerably more expensive (15€) than the Spectra VR Goggles we provided (2€) which can make a difference in crowded design activities.

4 METHOD

4.1 Procedure

We organized a participatory design workshop that aims at designing wearable devices for extended reality games. Although this was a 3-day workshop that includes exploration and ideation phases, the last day of the workshop was for creating prototypes and presenting them in the IVS format. In this paper, we will focus on the last day in which we employed the IVS method. The workshop started with a presentation that communicated the practicalities of IVS. After the presentation, groups (which includes 5-6 participants) started working on refining the ideas they developed in the previous days and started to produce the paper prototypes. Following the paper prototyping, they started to enact their user scenarios and documented them by using the IVS method. Although paper prototyping and preparation of the video sketch were separate sequential phases, we encouraged participants to start video sketching early on so that they can have time for revisions in case they realize flaws in their design when viewed in the cardboard headset. When each group completed their IVS, they presented their concepts to other participants. Meanwhile, participants also had a chance to try out these interactive video sketches through their cardboard headsets. In total, participants engaged with the IVS method for four hours. The workshop concluded with a questionnaire inquiring participants' opinions about IVS experience. The questionnaire included open-ended questions which asked users to express their opinions about the IVS method, if their concept changed during sketching and how, if the sketching in XR revealed any unnoticed points and their recommendations for improvement. Moreover, we wanted to rate them the usefulness and the difficulty of this method along with the rationale behind the difficulty rating.

4.2 Participants

Twenty-three participants took part in the workshop which was part of the Design Thinking for Wearables, Games and Extended Reality course. Twenty-two of them were grad and undergrad students from Tampere University while one participant was a non-student expert from the gaming industry. Graduate and non-student participants had various backgrounds including game design (5), business administration (1), bioengineering (1), interaction design (2), and electronic engineering (4). Other than that 12 participants assumed the role of the players/consumers of the XR games since they do not have a related background to workshop topics. During the workshop, participants were divided into 5 groups to work on their projects and each group had members with different backgrounds. Every group included at least one participant who had a gameplay experience in virtual reality. However, none of the groups were developer or designer teams of XR applications. Only one participant had a prior experience of VR development.

4.3 Analysis

We analyzed the answers of the participants by using directed content analysis [21]. In the beginning, the first author read through all the answers submitted by participants as the open-ended answers to the questionnaire. Afterward, these answers were categorized under related questions and transferred to MaxQDA[12] software for coding. As required by the directed content analysis, before starting to code the text, primary tags were specified. These tags were created to understand if IVS method 1) was easy to use, 2) helped participants to understand how concepts would work in the immersive environment of XR, 3) grant participants awareness about the spatial area that can be used in XR and 4) make them realize flaws in the design and do iterations. Codes were as follows: 1) Easy to use, 2) Spatiality, 3) Iterative Design Process, 4) Immersiveness and 5) Practicality of the Concept. Other than that, three meta codes were also created with the names Positive, Negative and Neutral to understand participants' attitudes towards the above concepts. In line with the directed content analysis, new codes were also formed during the coding process if the previously created codes did not cover the extent of the comments made by participants. The first author who has conducted the workshops and familiarized himself with the answers coded the data. For the questions that ask participants to rate the difficulty and the usefulness of the IVS method

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[12] https://www.maxqda.com

Figure 3: Top and middle figures represent effective use of spatial area while the bottom figure uses only a small part of the available area

with a 7-point Likert Scale, we calculated Median and Interquartile Range (IQR).

Moreover, to understand how effective the spatial area was used, we analyzed the 360° photos shot by participants. We checked each image and examined the effective utilized area. In Figure 3, rectangles with red dashed lines (will be referred to as "red boxes" from now on) represent the field of view when these images are viewed in the cardboard headset and are added to each image by authors during the analysis. In the top and the middle image, the effective interaction area is spread around almost half of the available area and covered by two red boxes. Therefore, a user who looks at this video sketch needs to rotate their head and look around to fully engage with the image. On the contrary, in the bottom photo, the interactive objects (hand, paper goggles and slippers) remain strictly in the center of the field of view. In the bottom example, experiencing the sketch is not very different than viewing it on screen because it does not prompt the viewer to engage with the environment. Therefore, we considered that the projects which have focus objects that spread across at least two red boxes used the spatial area of the extended reality environment effectively. We counted the red boxes each picture had and reported them in the results section. Readers can see each image in the supplementary material.

5 RESULTS

Our workshop yielded five immersive video sketches. The project of the Group1[13] focused on the virtual representations of physical wearables and the transfer of tangible parts between users. Group2[14] implemented a location-based and secretive augmented reality game in which the users try to spot the players by their auras and fight them to dominate imaginary areas. Group3[15] designed a game in which the players can wear virtual costumes to gain different powers for their virtual selves. Group4[16] implemented a remote football game in which bodily data such as high stress or anger also part of the game. In this game, wearable slippers were used as haptic-feedback devices and gloves can convey gesture messages and bodily data such as heart rate. Group5[17] implemented an adventure game, however, its relation to wearables remained vague. The immersive video sketches of the projects can be reached through the links in the footnotes. It can be shown through web browsers but also can be viewed with cardboard headsets through the Android operating system (VR button appearing at the bottom of the screen needs to be tapped for switching to WebVR view). In the remainder of this section, we present the results of the questionnaire.

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[13] https://360.goterest.com/sphere/group-1-cyber-bracelet

[14] https://360.goterest.com/sphere/group-2-secret-world

[15] https://360.goterest.com/sphere/group3-mira-culus-world

[16] https://360.goterest.com/sphere/group-4-football-fever

[17] https://360.goterest.com/sphere/group-5-ghostly-adventure

5.1 Ease of Use

One of our aims in the workshop was to see if participants could easily understand how to use the method and create an immersive video sketch in the given time frame. All groups could create full scenario loops and some of them even implemented branched storylines. Fourteen participants rated 3 and below (indicating low difficulty) for the question "Please rate the difficulty of using XR Video Sketching. Three participants rated 4 and 6 participants rated 5 and above indicating high difficulty. Median was 3 and IQR was 2.5 for this question (Figure 4).

When it comes to open-ended answers, 4 participants expressed that they could use the method without any difficulties (P17 - *"Everything worked quite easily"*), 13 participants stated that it was applicable while pointing out some challenges (P22 - *"It required some tutorial type explanation but once it was clear what to do and how to do it then it was a breeze."*), and 5 participants indicated that it was hard to use without indicating any positive aspects (P13 - *"It's somewhat time-consuming and to be effective and not look "stupid" needs people who know they way around graphical software and can take good photos. Luckily we had both, but still, time-consuming."*)

One of the challenges raised by participants was about the time constraints. Seven participants indicated that the process was time-consuming and the time spared for this activity was not enough. P14 indicated, *"The whole thing was new so it felt slow to do and then surprisingly the day was already almost over."* Moreover, 7 participants also expressed that the Lapentor platform caused slowness especially while uploading the photos.

Another common point raised by 5 participants was the requirement of a clearer tutorial about the steps of the IVS method and the workflow in 360° tour software. We already had given a tutorial presented at the beginning of the workshop but it might be worth accompanying it with a more detailed and easy to reach written or recorded tutorial. As P23 put it, *"Maybe a Powerpoint to see the steps in case during the explanation somebody forgets one of them?"* Still, we did not face a serious problem during the workshop as the moderator attended the questions and problems quickly, yet a written document could cover the problems better. Connected to this, 3 participants indicated that a prior preparation before the workshop might help them to use the time more effectively. Therefore, with a written tutorial, participants might practice before the workshop or at least familiarize themselves with the process and with the immersive sequencing software where they add the interactive features to their sketches. It might especially be useful for participants to discover different features such as adding sounds or GIFs to their sketches and also make them remember details such as activating plug-ins needed for playing the sketches in a cardboard VR headset.

Lastly, 5 participants raised concerns about required expertise especially when it comes to photo editing (P10 - *"...but also limited creativity if the groups didn't have photo editing software."*). At the beginning of the workshop, we showed participants editing techniques using MS PowerPoint[8] since this software was available to all participants in the workshop and it was a tool with which most participants were familiar. The techniques we showed were limited to adding shapes, speech bubbles and text that can be used for conveying the narrative and for simulating some basic interaction sequences. However, in some groups, some participants were more capable in photo editing and had a reach to photo editing software such as Adobe Photoshop[7]. As a result, the interfaces and interactions designed by those groups were more detailed and looked more impressive compared to other projects. Although the point of the IVS method is to create quick and dirty prototypes that can help participants to understand the extent of their design in the XR environment as well as communicating the idea to the audience, these types of discrepancies might affect the motivation of participants towards their projects.

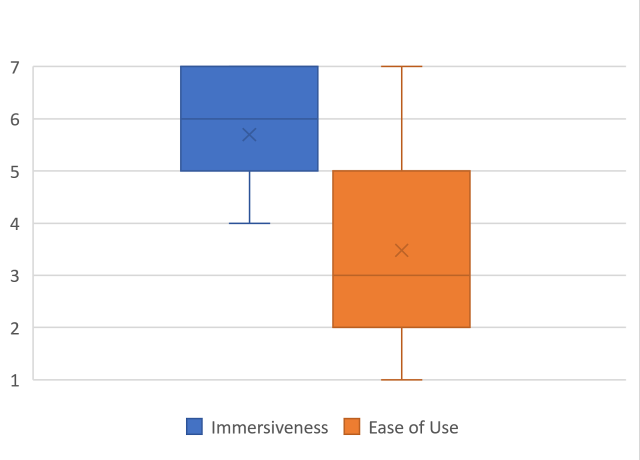

Figure 4: The boxplot of participants' ratings regarding the difficulty and the immersive nature of the IVS method

In the workshop, all groups successfully implemented their video sketches and the majority of participants found it reasonably easy to use in our participatory design context. Thus, IVS can be used in contexts such as participatory design workshops where users' and other stakeholders' contributions and input are important. Still, a 4-hour time span that also includes paper prototyping may be perceived as limited by participants. We believe that a similar period that is dedicated only to bodystorming, photo shooting, editing, and immersive sequencing might work better for utilizing the full potential of the method. Other than that, sensitizing participants with the method beforehand might help them to use the time effectively.

5.2 Immersive Experience and Practicality

Another thing that we want to understand was if the IVS allowed participants to envision how their ideas would play out in the immersive environment of HMXR. The immersive environment here means the surrounding nature of XR where participants are enveloped by the media, and XR environments are frequently referred to as the immersive interfaces by the related literature [5, 17, 23]. Immersive experiences can encapsulate many other psychological constructs such as cognitive absorption, flow, or presence [22]. However, in our study, it simply refers to the surrounding nature of XR interfaces. Twenty participants rated 5 and above (indicating high usefulness) for the question of "Please rate the usefulness of XR Video Sketching in terms of grasping the immersive nature of your concept." while 3 participants rated 4 (neutral). None of the participants rated the usefulness below 4. The median of the answers is 6 while the IQR is 1.5 (Figure 4).

Apart from the ratings, 7 participants specifically indicated that IVS provided them the opportunity to understand the experience of what their concept would feel like in an extended reality environment. As indicated by 6 participants, experiencing their concept in the XR environment was surprising, exciting and transferring the concepts to the XR environment made the ideas looked better (P13 - *"Most memorable was the moment when we fired up the presentation through the cardboard goggles and found out that it looked a lot cooler than on a flat-screen"*). Furthermore, 6 participants expressed their interest to engage in the immersive video sketching activity in the future for purposes such as using it in other projects, showing the results to family and friends or just feeling of encouragement about designing their own applications for VR environments (P2 - *"The VR presentation was really cool, it showcased that I can do a VR based game concept myself and demo it like that if I want to."*)

Seeing the projects in an immersive environment, motivated users but also helped them to understand how their ideas can play out in the XR environment. Twelve participants indicated that this method helped them to realize the ways their idea would work when it is run in an XR-Headset. For example, P22 explained it as follows: *"I liked it very much as it allows our concepts to be seen in the flesh and explained more clearly, so we can have a much better idea of how it will be like in real life. Even though it is not a complete game that can be played, from there it is not too much of a stretch to imagine what the game will be like."*

According to these results, we can confidently assert that the IVS method is an effective way to introduce XR concepts that are close to the real experience of using XR headsets.

5.3 Spatial Awareness

We also analyzed the photos of every project to understand if this method allowed users to realize the periphery in HMXR environments. In traditional video sketches, since the image is restricted to the borders of the frame, it is hard to visualize and understand the available interaction area in XR environments. Therefore, we were curious if IVS differed from the conventional video sketching method in this dimension.

Our examination of photos revealed that 22 out of 52 photos and images used in the video sketches had more than two red boxes (see Figure 3 - top and bottom) and used an effective area not restricted to the only one focus point. All groups had included at least one image that had more than two red boxes. This indicates, IVS helped participants to realize the available interaction area when their projects are converted for HMXR. In line with this, P1 asserted, *"I realized that in a single 360-degree photo, there could be many many alternatives/options available for selection. A VR game would not be very immersive if only limited interactions/choices/decisions are possible since it would deprive users of having the freedom of choice."* Still, groups also varied in their utilization of the effective area. Group 1 had 5, Group 2 had 6, Group 3 had 8, Group 4 had 2 and Group 5 had only 1 image that had more than two red boxes. Thus, the effectiveness of IVS in terms of allowing participants to realize the available space in HMXR may not be the same for everyone and thereby, moderators of workshops may weigh-in for more effective use.

Other than that, among these 22 images, we evaluated 8 as having two red boxes unintentionally. We came to this conclusion by drawing on participants' reports and the visual composition. In three of the photos, objects in the focus overflew to the second red box incrementally. We believe that participants' intention here was not to use the area for creating different focus points. Other than that, some of the object placements were reported as accidental by participants. For example, P6 mentioned that their text was too large and required unnecessary head movement to read the whole. Their group could not realize that the text they placed would cover almost a 360° area. Therefore, we also evaluated the 5 images from this video sketch as unintentional. While these instances indicate that the spatial awareness and utilization might be accidental in some of the projects, we think that this might be one of the advantages of IVS especially for participants unfamiliar with XR environments. During 360° photo-shooting, some items may be incidentally positioned in a larger span of the 360°photo, just to be realized when the photos are transferred to cardboard goggles. Contrary to existing methods that would need prior knowledge of such interaction availability, we believe that the spontaneous and accidental placement of in-game objects outside of the immediate periphery may help participants to realize the wide interaction area that they can use. Still, our results also suggest that workshop moderators might emphasize the utilization of the periphery more frequently if they aim to get more versatile utilization of spatial area.

5.4 Iterative Design

We also asked participants if they made changes during video sketching to see whether IVS is an effective prototyping process for realizing the possible flaws in the design. Eleven participants mentioned that they made changes and modifications to their design during the sketching process. Four participants mentioned that they made minor modifications in terms of game mechanics and interface elements. Two participants indicated that they found technical issues such as the text they placed was too large to view in the XR environment. Other than that, 4 participants needed to simplify their ideas due to the time constraints or being unable to fit some photos into their storyline.

Reiterations indicated by participants were quite minimal or changes were due to the restrictions imposed by the IVS method. The time spared for the sketching was enough to explore scenarios in the XR environment and explain the ideas to the audience. Yet, in the given time frame, it was not possible to reiterate the concepts effectively. Therefore, although several participants were indicating that the process helped them to concretize design decisions or make modifications, it would be ideal to leave more time for participants to experiment with their ideas.

6 DISCUSSION

Previous studies providing tools for low-fi prototyping for XR such as 360Proto [35] and ProtoAR [36] also aim at providing solutions for designers in the early phases of design. They provide impressive modules such as 360° capturing of an object for AR environments or placement of cutouts in layers in VR environments. Moreover, they are also aimed at assisting design methods such as Wizard-of-Oz.

We believe that these tools are invaluable solutions for early-phase XR design. Immersive Video Sketching, however, is situated in an earlier phase than prototyping, namely sketching. Therefore, it is not capable of simulating interactions such as real-time manipulation of 3D objects as in ProtoAR, but it is more accessible, not restricted to specific software and less dependent on digital tools as objects in an Immersive Video Sketch can be manufactured out of physical objects. Moreover, as indicated by the results, it can simulate the immersive experience of XR, similar to video prototyping methods [6, 32] and is reasonably easy to apply. In that sense, it can be one of the ways to fill the gap which is also identified by Ashtari et al. [3], indicating that designers, experts or hobbyists were either restricted to design and prototyping methods belonging to 2D interfaces or they skip this phase completely. Moreover, the IVS approach also brings us closer to the envisioned tools which are as simple as Microsoft PowerPoint for XR environments [37] and hints at a workflow that might be incorporated for such future tools. Thus, IVS is a valuable complementary method that can be used during sketching and might be an effective ideation process before switching to tools such as 360Proto which can reproduce higher fidelity interactions.

Still, results also indicate that iterative design through reflection in/on action [43] was not quite possible during our workshops. As expressed by participants, the allocated time was not enough for leaving room for iterative design activity. However, similar to traditional video sketching [52], tools and methods introduced by us provide the capability of adding, removing, or changing sequences of 360° photos. With enough time, IVS can provide early insights about what can be modified and improved in a design for XR. As shown in the investigation on the spatial design opportunities, IVS can help realize flawed placements or missed interaction opportunities in the 360° environment of XR. This aspect was visible to only a small minority of participants, and thereby, further studies are needed to understand how it can afford iterations in design. Therefore, with the current results, we can indicate that the IVS can be used in participatory design settings where participants can engage in designing for HMXR, but its utilization in the longer term to see how it can be employed in iterative design needs further investigation.

Time constraints were one of the major complaints about the IVS method. It is hard to compare it with previous studies in terms of the time needed because the applied methods for assessing the tool were different. In our study, a 4-hour span included ideation, prototyping and the preparation of the immersive video sketch. Contrary to this, previous studies tested the ease of use through design challenges or detailed reviews focusing on the tool [29, 35, 36]. The reason for employing a method that does not exclude preparing the video sketch from the rest of the design process is that our study focused on introducing a method that can blend into the design process. In that sense, although results showed that IVS can be used alongside early design processes and non-expert participants can easily engage with it to show their concepts in an immersive way, application of the method might need to be modified to allow for iterative sketching. More detailed tutorials, familiarization with the process beforehand, or prompting the early finalization of the first version of the sketch might be among these methods that might help for more reflective sketching practice. Therefore, further studies can focus on rearranging the structure by aiming at effective iteration that can also help with understanding the spatial availability in XR environments.

7 LIMITATIONS AND FURTHER WORK

Instead of comparing IVS to another baseline state, we chose an in-depth qualitative analysis of the participants' opinions. The main reason behind this is that, in creative processes, it is quite challenging to set baseline measurements and all other methods mentioned in this paper aimed at different audiences or design phases compared to IVS. Previous research such as 360Proto [35] or Pronto [29] also followed a similar approach and focused on the qualitative outcomes rather than a comparison to a baseline method. In that sense, although we acknowledge this as a limitation of the studies focusing on design activities, the method we chose is in line with the similar previous work. Further work can encapsulate a systematic examination of IVS that can compare it to previous tools especially in terms of usability and user experience through empirical quantitative methods, that can also help to identify possible improvements and shortcomings compared to the existing prototyping tools for XR environments in a more granular manner.

Another limitation of this work is that its scope encompasses the experiences of novice designers and non-expert users. The audience we included in our workshops fit this aim, however, as future work, it is also important to understand the benefits and the shortcomings of the IVS method for the expert users. Different user experience tests aiming at various types of audiences and shorter or longer engagement times can reveal other advantages or drawbacks of the IVS method.

Finally, although IVS relies on off-the-shelf tools which are available to anyone, the availability, service capacity or the pricing of the tools recommended in this paper may also change in the future. However, we introduced the IVS method in a broader framework that is independent of the specific tools. Although the apps and web-based tools explained in this paper provided the most seamless experience after our trials with many different tools, they are not non-exchangeable. Thus, if any of the apps and software recommended in this paper stops working in the future, researchers who want to employ IVS can substitute it with another software in line with the required features described in Section 3.

As indicated, IVS can inform the design of simple sketching tools that would be needed for XR environments [37]. Although the aim of introducing this method is to free designers and researchers to be limited to specific tools, the elements used by different projects might be useful for the development of future tools that can be incorporated into the IVS process. First of all, four of the projects used interface elements such as progress bars, buttons, text windows, texts or labels. Other than that, three projects used speech bubbles to depict scenarios with the actors (users or in-game characters). Three projects used environmental effects or objects such as the tornado in the project of Group 2 or the fire effects in Group 3. Two groups made manipulations on the actors, additions of costumes (in Group3) or body auras (in Group2). To come up with a formal result that suggests that these elements are the most needed, we need further evaluations with more projects, however, tools that can be used both in the screen-based interfaces and in XR environments seamlessly and allow the addition of mentioned elements would ease the process by decreasing the amount of the tools needed (e.g., combining 360°Photoshooting, Photo Editing and Immersive Sequencing).

8 CONCLUSION

In this paper, we described the IVS method which is a low-cost sketching method for head-mounted extended reality environments. IVS method can especially be effective in collaborative, participatory and co-design settings as it is easily accessible incorporates design methods such as paper prototyping, body storming, and video sketching which are appropriate for non-experts and allows them to grasp the immersive nature of XR quickly. To understand the effectiveness of IVS, we organized a participatory design workshop with 23 participants from different backgrounds and analyzed their remarks about the method by using directed content analysis.

Our study revealed that the IVS method is clear and easy enough to be learned and implemented in a short participatory design setting and it was effective in conveying the immersive nature of XR. On the other hand, we observed that the time allocated for IVS activity should be more than four hours to allow more iteration on the design scenarios. Other than that, the differences in the expertise level in topics such as photo editing resulted in discrepancies in the outcomes of the workshop and demotivated some of the participants. The IVS affords exploration of spatial interactive properties of the 360° environment, yet this exploration is partially unintentional and more clear directions and a more relaxed timeline can help the exploration of spatial properties.

We believe that IVS fills an important gap in the extended reality field because extant methods for low-fidelity XR prototyping require tools that are not easily accessible and are usually targeted for designers with skills such as drawing or video editing. IVS is an employable method for design activities with non-designer users and even a couple of hours are enough for a basic implementation. Researchers and designers who seek appropriate prototyping and sketching methods for XR-related participatory design activities including courses and workshops can employ this method. We also believe that it is also worthy as a tool for expert and individual designers to quickly realize and test their ideas in XR environments.

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