User perception of camera movement in VR video

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Abstract

The metaverse age is beginning. Virtual Reality (VR) content will become the language of new media communication. 360 video is used in many VR applications. As the viewer is now in the middle of the camera shot and there is no framing, the new film language grammar rules need to be defined.

Camera movement is one of the techniques of classical film-making. It causes a change in frame or perspective through the movement of the camera and allows cinematographers and directors to shift the audience's view without cutting. In this paper we are evaluating how the users perceive it in 360 video. Through the User eXperience (UX) evaluation study we will check whether it adds to the immersion in the virtual environment or causes unbearable motion sickness. The results of this evaluation will contribute to the VR film grammar development and offer directions for creation of future VR applications.

Keywords: VR video, Virtual Reality, User eXperience, immersion, VR sickness

1 Introduction

The term "Virtual Reality" or its shortened form "VR", can no longer be called new in terms of their existence. There are a lot of people who still never tried using a VR headset, and from those who actually have, many tried it just once or twice. Since VR applications have mostly 3D generated environments, most of them are programmed in different game engines like Unreal Engine or Unity. If we add the fact that the gaming industry has a larger revenue than both the film and music industry, it is only natural that the biggest usage of VR, can actually be found in gaming. Slow adoption of VR in the modern world can be attributed to the following:

- VR applications require dedicated hardware for usage which must be purchased separately and can only be used for VR content.
- VR hardware is still not cheap.
- Limited VR content is available.
- Many users feel uncomfortable while using VR and experience nausea if there is lot of movement.

After a decline in VR device sales in the years after first commercial devices became available [1], the start of the pandemic brought a surge to the entirety of IT sector sales, and VR was a part of it. Much more content started appearing, such as Valve's "Half Life: Alyx", as it was a major advancement in virtual gaming. Valve introduced their own headset along "Half Life: Alyx", which was another step ahead in the adoption of VR.

Alongside VR applications there was a large-scale rise in popularity of new video formats which are filmed in 360 degrees. Even though not fully innovative, the rise in popularity of VR headsets brought new 360 degrees cameras to the market which made filming in this format considerably easier. People always strived to be a part of their videos [2]. Directors are learning new rules and ways to tell a story, and many new issues now affect storytelling differently, such as camera placement [3]. What is completely different in filming of 360 video is the fact that there cannot be any crew or equipment in the vicinity of the camera, since everything is now showed within the frame. That includes the cameraman himself, meaning the camera must be operated remotely.

"Film directors have adopted several means by which they can control audience attention" [4] and one of the most important tools for telling a story for every director is framing. To properly frame the action, the cameraman can pan, tilt and move camera. In order to do it, the cameraman moves the tripod head in different directions from the stationary position. However, to move the camera, the camera operator can carry it or mount it on a dolly which is moved by a dolly operator. In films, camera movement is regularly used to emphasise the story.

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In the case of 360 video, everything is inside a frame. [5] That makes panning and tilting unusable, but camera movement is still theoretically possible. To move the camera in 360 video we must hide the camera operator or the dolly on which the camera is mounted. The usage of 360 videos in VR applications [6, 7] greatly enhances user immersion. It allows users to dive into the video and explore places which are unavailable to them in real life, from the warmth of their own home. Viewing 360 videos on VR headsets represents a completely new level of cinematic enjoyment and therefore deserves to be further explored and have new rules made for it.

In light of these circumstances we found motivation for this research. As mentioned, every director strives to have the ability to control what they are showing to their audience. Many directors we worked with expressed a desire to move 360 camera around the location of shooting while keeping the action going. Many would just try to figure out how to move the camera without exposing the camera operator, but considering the slow adoption of VR, nausea that users sometimes might experience while using headsets must be carefully examined and weighted before filming moving shots. Therefore, we decided to stage a project dedicated only to study how people actually react to the movement inside 360 video while using a VR headset and standing in one place without actually moving in real life.

2 Related work

360 videos are often an integral part of the VR experiences. Both VR and 360 videos deliver a high level of immersion and presence to the viewer in the virtual world [6]. Interactive visualisation and immersive storytelling provided by the use of these VR environments are also becoming imperative to cultural heritage presentation and preservation. [8, 9]

This argument is shared by authors in [10], expanding their research to 3D 360 videos, however employing only static view points. It is stated that exactly this resulted in a "low level of dropouts and low cyber sickness experienced". It is also suggested that the lack of the participants' experience with VR contributed to their opinion that there is no difference between the user's sense of presence in 2D and 3D 360 video.

In [5] the author argues the general notion that the interactive and immersive component of 360 video, and VR in general, does not adhere to the conventional norms of narrative, pointing out limitations, such as a fixed perspective. It has been pointed out that a repeatable narrative is imperative, and that a successful storyteller will employ all possible elements to bring the narrative forward.

When developing an application which is to be used as a virtual experience, one must consider the device used for running the application. Even though VR platforms such as Head Mounted Displays (HMD) enable true stereoscopic VR playback of 360 media, such content can also be viewed through desktop browsers and mobile apps [11]. So, when posing the question of which type of device is most suitable for VR applications containing 360 video content, bringing the most immersion to the user experience, the authors in [12] state that a HMD brought a high level of immersion to the experience, however, with the side effects of "higher cognitive burden, motion sickness and physical discomfort".

Genuine 360 films are still rare, and many of them cannot be found online. One example is a film by "RTVE: El Ministerio del Tiempo" [13] filmed with a static camera. There are also a few films with a moving camera like: "Bear Heist" [14] or horror film "Catatonic" [15]. "Catatonic" has a slower moving camera with an even pace and is seen in a seated position, which might reduce nausea for viewers. While exploring the cinematic VR [16], the author noted the opinion of the director of photography for the VR film Static about camera movement: "Move it, as much as possible." This appeared controversial, because of the nausea caused by movement in 360 video, but it shows the desire of film professionals to move the camera, and a need to find a way to do it smoothly.

3 Case study

Our case study was recorded in the Sarajevo Tunnel Museum, the memorial of a tunnel which saved Sarajevo citizens during the siege 1992-1996. Even though we might have gained similar results with more neutral videos, this was a great opportunity to make educational videos which could have wider use outside this research. The purpose of our experiment was to test the movement of the camera in a 360 environment. The impact of movement was tested by actually gradually increasing the amount of movement in 360 videos. To achieve that, three sets of videos were recorded, each set with different amounts of movement. We chose three important spots in the museum in three different rooms and our actor prepared a short description of things we can see there. The idea was to replicate a real visit to the museum. People usually follow guides who talk about exhibits, but also have the freedom to look around the museum.

In the first set of videos named "Option 1", we placed the 360 camera on a tripod in the middle of each room while our actor was standing on a fixed spot, talking about surrounding exhibits. This first set of videos was filmed from a static position which already proved as a good way to observe 360 videos from our past experience [8] and also experiences of others [3]. This option was also used to show the users what they are looking for and to make them familiar with the surroundings. After the presentation in one room, a button appears to allow the user to move on to the next room. When all three rooms are explored, the user is returned to the main menu to choose the next option.

In the second set of videos named "Option 2" we introduce the camera movement. At first we wanted to mount the camera to some sort of dolly, but we later decided to attach it directly on to the cameraman's head. Using GoPro straps, a VIRB 360 camera was attached to the head of our camera operator. He had to follow the actor around the museum but he also had to crouch-walk so the camera would not be too high. This proved quite demanding, but it ensured that video will be shaking due to walking, introducing more realism in the movement, but also making videos more demanding to watch. In this set of videos, the user follows the actor around the museum but stops in the middle of each room and stands still while the actor talks about exhibits. After the presentation is finished, the button appears again. This time it does not teleport the user to the next room, but starts the next video which includes the actual movement to the next room. In the third video we introduced a part where users descend the stairs to increase immersion. At the end, the user is returned to the menu for the third option.

Third set of videos named "Option 3" is actually just one video without any pause. The camera is constantly moving together with the actor around the scene. Since we filmed this option last, fatigue was catching our operator which introduced a welcomed side-effect – the camera was shaking even more. Users must watch almost 4 minutes of 360 video moving all the time without taking a second of break. At the end, the user is returned to the main menu.

The main purpose of this research is to see how well users could withstand camera movement in a 360 environment. When watching those videos on a flat screen there are no problems, however watching them on VR headset introduces confusion to our brain which can easily cause nausea and motion sickness.

The VR application was created in order to present the mentioned sets of videos in three different presentation versions to the user in a cohesive way, and test the user's presence and immersion, as well as the motion sickness experience levels in relation to each presentation version. In terms of story, each video is inherently identical, only the presentation method is different. Some of the presentations include "story points", represented by buttons labelled "Continue", which, when pointed on, lead the user to the next video. At the end, we obtained the following story versions:

- static with "story points" - the user is presented several static videos, each filmed in a different spot, without camera movement;
- moving with "story points" - the user is presented a single video with camera movement, divided by "story points"
- moving without "story points" - here the user is presented a single video with camera movement.

In order to view these presentations, a menu containing buttons, each leading to one of the presentations, was placed in a virtual room. Here, the user can select the preferred language, presentation, or exit the application. Upon the end of each presentation the viewer is taken back to the menu room. The application structure can be seen in Figure 1.

The application was developed using Unity, since it is cross-platform and offers VR integration. Furthermore, Unity's XR Interaction Toolkit package was used for VR-related functionalities, such as VR camera rig and input support. This package offers cross-platform XR controller input, meaning that the application can be used with a variety of VR controllers, and therefore does not restrict the application to the device it was built with.

4 User experience evaluation

The research question of our user experience evaluation was the following:

"Does the increase in camera movement increase the unwanted side effect experiences, and whether this would decrease immersion?"

The sequence of options 1, 2 and 3 relates to the presentation versions described above, these are: static with "story points", moving with "story points" and moving without "story" points, respectively.

The experiment included 21 participants engaged by invitation. Subjects were invited with balanced demographic features in mind, regarding gender, age and level of VR experience. Each participant used the same type of VR headset and watched the presentation versions of the application - options 1, 2 and 3, in the same order. Immediately after viewing each application presentation version, the participant was invited to fill out the questionnaire. The questionnaire was organized in three sections:

- Introduction, containing questions related to demographic data
- Section dedicated to measuring (1) the presence and immersion, (2) experience and (3) behavioural intention.
- Open questions, additional comments and critiques regarding their experience.

The measurement of the variables of interests was performed using a 5-point Likert scale with the following structure: 5 items for the presence and immersion, 6 items for experience and one item for behavioural intention.

The results of the evaluation are presented in Table 1, with average value and standard deviation per each question for each VR application option:

- Mean values for Presence and Immersion for the Option 1 ranged (3.87-4.61), for the Option 2 (3.73 - 4.5), and for the Option 3 (2.82-4.09).

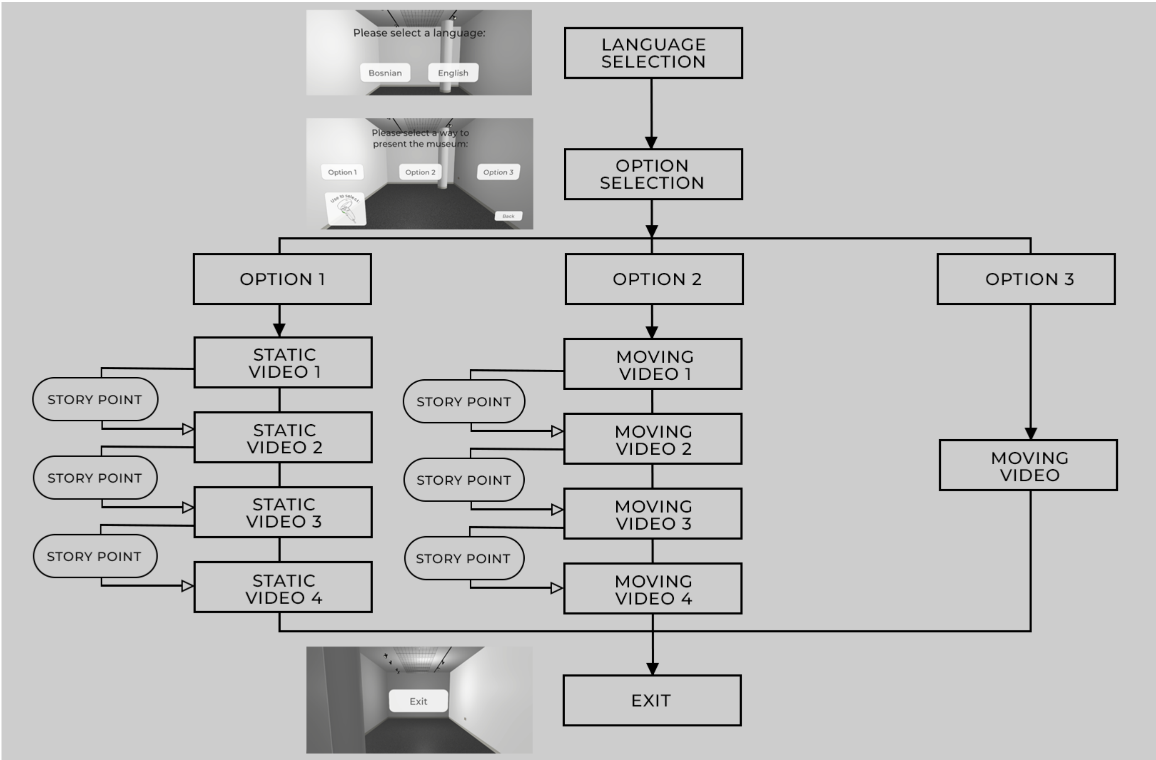

Figure 1: Application structure schema

- Mean values for Experience for the Option 1 ranged (1.26-1.65), for the Option 2 (2.14-2.89) and for the Option 3 (2.64-3.14).

- Mean value for Behavioural Intention for the Option 1 was 3.43, for the Option 2 was 2.41, and for the Option 3 was 1.46.

Regarding user experience, which was our ultimate goal to measure, we hypothesised that users would experience a high level of presence and immersion, a low level of negative effects related to the physical experience and an intention to continue the use of virtual environments in this manner. Therefore, expected outcomes were high values for Presence and Immersion, low values for Experience and higher values for Behavioural Intention.

The results strongly indicate that Presence Immersion are decreasing with Experience, as well as Behavioural Intention, suggesting that strong negative physical experiences will diminish the level of presence and immersion of the virtual environment.

A visualisation of users' feedback regarding Experience, and Presence and Immersion is presented in Figure 2. Distribution of the answers confirms the increase for Experience and decrease for Presence and Immersion through the sequence of VR application options as we indicated with mean values before.

The analyses we performed indicate that the side-effect Experience of the VR technology has a negative effect on both Presence and Immersion and on the Behavioural Intention.

Besides poll results, we discussed with each user about their experience while watching the videos. Observing them also provided some interesting information. As our poll showed, a number of users experienced high levels of nausea and could not watch the videos until the end, however others had no problems going through all three sets feeling quite relaxed. While observing the users who were watching "Option 2" and "Option 3" we noticed that they were shaking and weaving a bit. It is an interesting side effect of the brain trying to compensate for the virtual movement. What is even more interesting is a report of two users who stated that by walking in place they match the pace of camera movement and nullify nausea. This is something that could be further researched.

Many users reported that the crooked camera angle bothers them, something that is easily fixed, and was not even planned. A loose screw contributed to camera moving out of its place sometimes. Many users found turning of camera to be troubling especially if they were turning their head in the other way from the camera. Lastly, videos had no stabilisation applied to them, which caused a bit of blurriness and some users found it unsatisfactory.

There was a whole group of users who felt no discomfort watching videos. They could look around and explore even when the camera was moving and turning. This is very interesting for medical research because it is probably connected to how our brain and vestibular system in our ears work. It is interesting to point out that most of

		Option 1		Option 2		Option 3	
	Item	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.
P&I 1	I felt that my interactions with the virtual environment were natural.	3.87	1.06	3.73	1.35	3.36	1.53
P&I 2	I actively visually explored the virtual environment around me.	4.61	0.72	4.23	1.15	3.55	1.68
P&I 3	I correctly located the sounds in the virtual environment.	4.35	1.03	4.5	0.8	4.09	1.15
P&I 4	I felt physically present in the virtual environment.	4.13	1.29	4.27	1.16	3.95	1.21
P&I 5	I think using a virtual environment in this manner is practical.	4.35	0.88	3.73	1.32	2.82	1.59
E 1	I think using a virtual environment is confusing.	1.65	0.88	2.14	1.39	2.73	1.75

Table 1: Questionnaire structure and overview of statistical measures. Questions related to the Presence and immersion are marked by PIx, whereas questions related to side effect Experience are marked by Ex and questions related to Behavioural Intentions were labelled with BI. The responses were conveyed based on a 5-point Likert scale ranging from strongly negative to strongly positive.

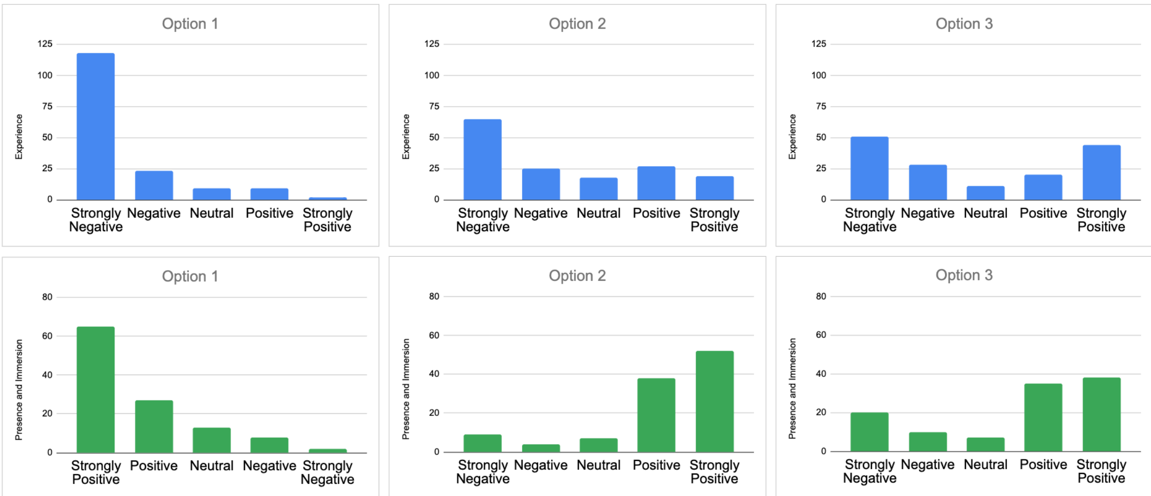

Figure 2: Distribution of responses relative to variables of (a) Experience and (b) Presence and Immersion.

the users that reported nausea still went on and watched "Option 2" but gave up while watching "Option 3" immediately after. It means that they still watched 5-6 minutes of video which was moving constantly.

The experiment confirmed that camera movement producing unwanted side effects decreased significantly the quality of user experience for all participants. The future evaluations should offer videos in random order, and should include larger number of participants to provide for more strict statistical analysis of the results.

5 Conclusions

In this paper, we designed a UX study to evaluate immersion, motion sickness and user experience in 360 videos with moving cameras. UX evaluation results showed that the increase in movement increased the side effect experience, and also decreased immersion. We concluded that the enhancement of presence and immersion is linked to minimising side effects experience, and consequently camera movements.

From our user evaluation we have seen that we must approach movement of the camera in 360 videos with great care. Even though we had some very positive reactions, others were very unpleasant. However, the fact that almost all users went on and viewed "Option 2" until the end, gives ground for additional research. Stabilising videos, correcting angle of the camera, and minimising camera turning could greatly enhance the experience. Furthermore, usage of camera movement should be carefully planned and used occasionally and less dramatically.

We feel this research will also contribute to VR film language grammar development, giving opportunity to the directors to use 360 space even better. It is one step closer to making the list of "do" and "don't" for the VR film, and a good guide for 360 camera manufacturers. There are companies that are already making 360 cameras with internal stabilisation, but additional equipment for cameras could play a key role in standardising camera movement in 360 videos.

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