User Experience Study of 360° Music Videos on Computer Monitor and Virtual Reality Goggles

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***Abstract*—360° videos are increasingly used for media and entertainment, but the best practices for editing them are not yet well established. In this paper, we present a study in which we investigated the user experience of 360° music videos viewed on computer monitor and VR goggles. The research was conducted in the form of a laboratory experiment with 20 test participants. During the within-subject study, participants watched and evaluated four versions of the same 360° music video with a different cutting rate. Based on the results, an average cutting rate of 26 seconds delivered the highest-quality user experience both for computer monitor and VR goggles. The cutting rate matched with participants' mental models, and there was enough time to explore the environment without getting bored. Faster cutting rates made the users nervous, and a video consisting of a single shot was considered to be too static and boring.**

Keywords-user experience; 360° video; music video; cutting rate; VR; virtual reality goggles; HMD

I. INTRODUCTION

Virtual Reality (VR) technology offers an attractive medium for providing high-level, multisensory experiences that are suitable for people of all ages. VR has already been used for a variety of purposes, including travel, education, industrial applications, healthcare, and of course entertainment (games, music, 360° videos, etc.).

With VR getting into the music industry, the need for different types of video and audio-related projects (incl. commercial R&D, academic, and experimental research) has also increased dramatically. During 2016-2017, the first author of this paper worked for Nokia Technologies doing user experience design for the OZO Live (currently Imeve Live [1]) product. In collaboration with a group of students from Tampere University of Applied Sciences (TAMK), we attended several live concerts, conducted live broadcasts, and edited several multi-camera 360° videos in post-production.

To develop workflows for editing the videos, we pushed ourselves to the limits, participated in stressful real-life events, and experimented with different types of tools and techniques. To test if our solutions were equally efficient for working with different types of music, we worked with various Finnish bands (e.g., Steve 'N' Seagulls, Nightwish, Amorphis, Hurriganes, Helsinki Philharmonic Orchestra, Santa Cruz, and UTU) from different genres including rock, pop, jazz, bluegrass, and orchestral music.

In this paper, we present the results of a study in which we investigated the user experience of 360° music videos viewed on computer monitor and VR goggles, with the emphasis being on finding guidelines for the cutting rate of multi-camera videos. In addition to cutting rate, we also give a short summary on the current state of 360° music videos, describe what kind of experiences people had while watching our 360° music videos, and elaborate on the differences between consuming content on a head-mounted display (HMD), i.e., "VR goggles", and a computer monitor.

II. VR AND 360° VIDEOS

According to the Oxford dictionary [2], Virtual Reality (VR) is "The computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors". In practice, the equipment used for viewing VR content is called a VR headset or VR goggles, and they are available for several manufacturers including Oculus, Samsung, and HTC.

VR technology offers an attractive medium for providing high-level, multisensory experiences that are suitable for people of all ages. Therefore, VR has already been used for a variety of purposes including travel [3], education [4], industrial applications, healthcare [5], and of course entertainment (games, 360° videos, etc.).

360° videos are special video recordings, where a view in every direction is recorded at the same time, capturing the entire sphere around the camera. The videos are typically recorded using a dedicated omnidirectional camera (e.g., Nokia OZO or Insta360 Pro) or a rig of multiple cameras. After recording, the overlapping angles are "stitched" together, i.e., merged into one spherical video, either by the camera itself or using dedicated video editing software. [6]

360° videos can be consumed using various devices including computers, mobile devices, and head-mounted displays (HMD), i.e., "VR goggles". During the playback, the user can control the viewing direction by, e.g., moving his head, moving the device, or clicking and dragging on the screen. In addition to web browsers, YouTube, Facebook,

and Vimeo, various applications from smaller companies now support the playback of 360° videos.

While not interactive as many other VR applications, 360° videos - especially when viewed using VR goggles - can deliver extremely immersive experiences that trigger users' sense of presence [4], allowing them to focus on the content of the video while feeling to be physically present in the shown environment. In the case of multi-camera 360° videos, the users can enjoy the scene from different positions as specified by the cutting rate of the video.

In the case of music, several interesting single and multi-camera 360° music videos have already been created. For example, the Swiss musician Seven stitched together three different scenes where he is performing the same song in a different setting. In "Saturnz Barz" by Gorillaz, the animated scene jumps from a train to a haunted house, then to space, and finally back to the train. The 360° video of School of Rock uses only one camera, but there is a lot of scripted action around it. OneRepublic, in collaboration with Nokia, took the concept even further by moving a single OZO camera between two buildings, and shooting everything on one take. [7] [8]

In the case of live music, the situation is slightly different. While artists such as Metallica [9] and Quincy Jones [10] have experimented with live 360° videos, the quality of such videos has often been surprisingly low. For example, the cameras may have been placed too far away from the performers, or the videos may use only one camera – even when the stage is large. One good example of using a single camera in a small setting is "It's a long way to the top" by the Finnish band Steve 'N' Seagulls [11].

III. Multi-Camera Case Studies

To develop workflows for shooting and editing 360° videos, we have attended the live concerts of several popular Finnish artists, shot their entire concerts, and then edited 360° videos for selected songs. The bands have been from different genres including rock, pop, jazz, bluegrass, and orchestral music. At the time of writing this paper, the total number of edited music videos was approx. 20, and the list of bands included, e.g., Nightwish, Steve 'N' Seagulls, Amorphis, 69 Eyes, Reckless Love, Jussi Syren & The Groundbreakers, Tampere Philharmonics, and Popeda.

To record the videos, we used Nokia's state-of-the-art OZO camera, which can record 3D 360° video at 30 fps. OZO also contains eight built-in microphones for recording spatial audio [12]; however, in most cases we have relied on external microphones to have more flexibility in the mixing phase. The camera can be controlled and monitored wirelessly using the OZO Remote application, and the recorded footage can then be processed and edited using, e.g., OZO Creator and Adobe Premiere.

Most of the concerts have been recorded using more than one synchronized OZO camera; in the case of the Hurriganes farewell concert at Helsinki Ice Hall, we used as many as five. In the case of every concert, we have focused on different aspects of the workflow such as planning, camera locations, live streaming, spatial audio mixing, or transitions from one camera to another. Instead of working in a sterile office environment, we have attended stressful real-life situations, always pushed ourselves to the limits, and experimented with different types of tools and techniques.

For example, in the case of The 69 Eyes [13], we tested different camera locations (according to limitations set by the band) and developed the core of our current workflow for mixing spatial audio [14]. During the Tampere Philharmonics concert [15], we also streamed the main camera to YouTube and Facebook as 360° video, and experimented with Dolby Atmos miking. For the Timo Rautiainen & Trio Niskalaukaus concert [16], we decided to use two moving cameras. The main camera was moving slowly on a dolly placed in front of the stage, and the drum camera was mounted on a camera crane (jib).

Figure 1. Screenshot from the Timo Rautiainen & Trio Niskalaukaus 360° video [16].

In the case of Popeda [17], we had to take a more conservative approach to making 360° videos. The concert took place in Pakkahuone, Tampere in December 2017, and it was the band's 40th anniversary concert. As we were not allowed to place the front camera directly in front of the lead singer, we decided to place two cameras in front of the stage. There were also two other cameras on the stage: between the drums and the keyboards, and between the drums and the brass section. Due to the popularity of the band, the venue was sold out for two days in a row, and we were not allowed to use moving cameras so that the security personnel and the photographers would have enough space in front of the stage.

On the positive side, the recorded content enabled us to start our research on the user experience of watching 360° live music videos, and especially to study the effects of different cutting rates [18].

IV. Study on User Experience of 360° Live Music Videos

When editing the multi-camera 360° live music videos, we always struggled with the same type of problems: How to cut the video for YouTube and for the VR goggles? Should the cutting rates be the same, or should we make two different versions, which could potentially result in a better user experience but cost us more money?

As VR goggles are now becoming more and more accessible to the public, and 360° videos are produced along with regular videos to deliver more realistic experiences to

the users, it is also crucial for the 360° video producers to know how the users perceive (multi-camera) 360° videos through regular displays and VR goggles. In other words, what is the user experience of viewing 360° videos?

The user experience (UX) of a technology or a product refers to "a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service" [20]. UX involves both pragmatic and hedonic quality aspects of the product, and it is highly personal.

To study the UX of watching 360° live music videos, and especially the effects of different cutting rates in multi-camera videos, the two first authors of this paper supervised the M.Sc. thesis of the third author [18]. The research questions of the thesis were:

- What kind of experience do people have while watching 360° music videos?
- How do users experience 360° music videos on a computer monitor and VR goggles?
- How do users experience the different cutting rates of the 360° music videos?
- What are the optimal cutting rates for both computer display and VR goggles?

To conduct the tests, four different versions of the song "Helvetin pitkä perjantai" by a popular Finnish rock band called Popeda were edited. Each version was a 4K (3840 x 2160 pixels), 3D and 360° video running on YouTube (computer monitor) or a memory card (VR goggles). The content of the four videos was created from same stage performance. However, each video had a different number of cuts, and therefore also a different number of shots with varying lengths (Table 1). To minimize the effects of audio, each video used the same stereo soundtrack.

Version A used only one of the front cameras (see Section III), so it did not have any cuts, and version D had the most cuts. Video C was also the "official" Popeda release that one can now find from YouTube [17]. All videos had the same intro (approx. 5 seconds) and outro texts.

TABLE I. SPECIFICATIONS FOR VIDEOS USED IN THE STUDY.

Video	Cameras	Cuts	Shots	Length of shots	Avg. cutting rate
A	1	(no cuts)	1	3.25	3.25
B	4	1:12, 1:43, 2:46, 2:58, 3.11	6	1:07, 0:31, 1:03, 0:12, 0:13, 0:19	0:34
C	4	0:35, 0:43, 1:12, 1:28, 1:48, 2:00, 2:44	8	0:30, 0:08, 0:29, 0:16, 0:20, 0:12, 0:44, 0:46	0:26
D	4	0:35, 0:43, 0:48, 0:58, 1:03, 1:12, 1:22, 1:29, 1:48, 2:02, 2:12, 2:30, 3:37, 3:44, 2:54, 3:06, 3:12	18	0:30, 0:08, 0:05, 0:10, 0:05, 0:09, 0:10, 0:07, 0:19, 0:14, 0:10, 0:18, 0:07, 0:07, 0:10, 0:12, 0:06, 0:18	0:11

Figure 2. Snapshots from the "Helvetin pitkä perjantai" 360° video before (top) and after (bottom) a cut. [17]

The empirical research was conducted in the form of a laboratory experiment with 20 test users. During the study, the participants first watched all four videos on a computer monitor, and then all four videos using VR goggles. The order of the four videos was randomized. After watching each video, the users were given a short questionnaire to evaluate that video. Short semi-structured interviews were conducted after watching all videos on the computer monitor and after using the VR goggles. The think-aloud method was used to extract users' thoughts and feelings. In the end of the session, the users also filled in a background questionnaire. The average experiment of one experiment was roughly one hour.

All the participants were recruited from Tampere, Finland. 75% had a college or university degree, and 25% had a high school or other educational qualification. The participants were 19-33 years old, with a mean of 25.1 and standard deviation of SD=4.2.

When asked how much the participants had used VR devices previously (7-point Likert scale, where 1=never and 7=regularly), the mean was 2.5 (SD=1.5), meaning that the participants did not have much experience in VR. In the case of 360° music videos, the experience was also low (mean 2.1, SD=1.2). However, most participants watched music videos quite often (mean 5.2, SD=1.8) and listened to music (mean 6.3, SD=1.4). The participants did not have much experience in playing a musical instrument (mean 2.25, SD=0.78).

For the computer monitor condition, a 27-inch Lenovo Ultra HD 4K monitor was used along with a 100 mbps network connection. For the VR goggles condition, two

pieces (the 2nd one as a backup) of Samsung Gear VR were used with Samsung Galaxy S7 edge and Samsung Galaxy S8 mobile phones. For audio, we used a Bose SoundLink Speaker III instead of headphones. This enabled us to communicate with the participants; also, the focus of the study was not in audio.

V. Results

In this section, we discuss the results and findings of the aforementioned questionnaires and interviews. The user evaluation questionnaires focused on participants' immediate experiences after watching each video, and resulted in a collection of quantitative data. The short semi-structured interview was conducted immediately after watching all eight versions of the video, and it focused mostly on collecting qualitative data.

A. Questionnaires

When designing the study, we realized that while Popeda has been (and still is) one of the most popular bands in Finland, it may not that important to younger people or especially to some foreign students taking part in the study. Thus, after showing each video to the participants, we also asked them how pleasant the music was using a 7-point Likert scale (7= very pleasant, 1= very unpleasant).

In the case of computer monitor condition, Popeda A (i.e., the version using only one camera, see Table 1) got a mean of 4.15 (SD=1.75), Popeda B 4.50 (SD=1.35), Popeda C 4.55 (SD=1.46), and Popeda D 4.15 (SD=1.46). Therefore, on average the test participants found Popeda C to be more pleasant than the other music videos.

In the case of VR goggles, Popeda A got a mean of 4.25 (SD=1.65), Popeda B 4.75 (SD=1.41), Popeda C 4.95 (SD=1.23), and Popeda D 4.05 (SD=1.73). Again, the participants found Popeda C to be slightly most pleasant, despite the fact the song and the mix were always the same.

Next, we asked the participants to give an overall rating for the video they had just seen (1=very bad, 7=very good). Figures 3 and 4 visualize these results using boxplots. In the case of computer monitor (Fig. 3), Popeda A received a mean of 3.85 (SD=1.34), Popeda B 4.30 (SD=1.12), Popeda C 4.40 (SD=1.18), and Popeda D 3.90 (SD=1.37). Thus, the participants rated Popeda C and Popeda B roughly as good, with the other two videos performing worse.

In the case VR goggles (Fig. 4), Popeda A got a mean of 4.20 (SD=1.43), Popeda B 4.75 (SD=1.25), Popeda C 4.60 (SD=0.82), and Popeda D 3.90 (SD=1.44). Thus, the results resembled those of the computer monitor condition.

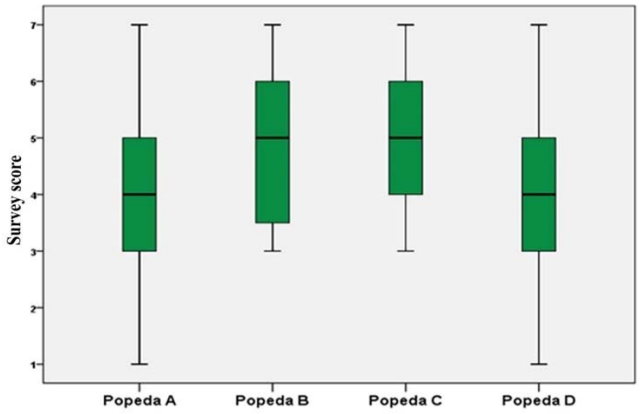

Figure 3. Overall ratings for the videos in the case of computer monitor.

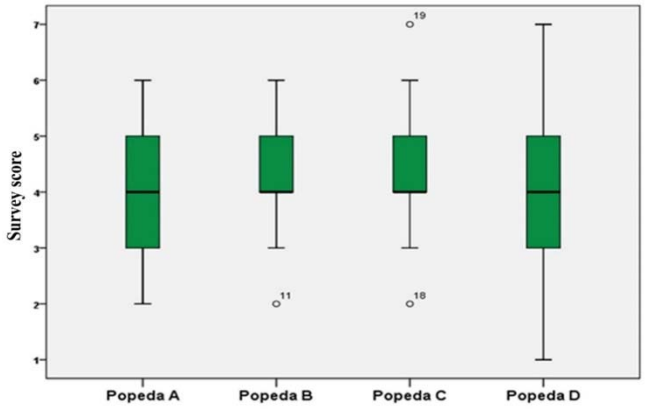

Figure 4. Overall ratings for the videos in the case of VR goggles.

Next, we studied how the participants perceived the cutting rate of the video they had just watched. In the case of computer monitor (Fig. 5, left), 55% of participants reported that for Popeda D, the camera changed too frequently, while in Popeda C and B the numbers were only 20% and 15%, respectively. In the case of VR (Fig. 5, right), the corresponding numbers were 75%, 20% and 5%.

In the case of both computer monitor and VR goggles, 65% of the participants reported that they had lost their concentration because of the frequent camera changes of Popeda D (Fig. 6). For Popeda C, the numbers were 30% (monitor) and 15% (goggles), and for Popeda B, 20% (monitor) and 20% (goggles). On the other hand, most participants reported that the camera changes of Popeda C enhanced the flow of the video (75% computer monitor, 70% goggles, see Fig. 7). For Popeda B, the corresponding numbers were 70% and 80%, and for Popeda D 60% and 50%.

In general, the cutting rates of Popeda B and C did not reduce the feeling of being present in the environment (Fig. 8). For Popeda D, the results were worse, especially in the case of VR goggles. In the case of all videos, the majority of participants felt that they were able to actively explore the environment (Fig. 9). However, in the case of VR goggles, Popeda A and Popeda D seemed to have some limitations due to too few (=zero) or too many cuts.

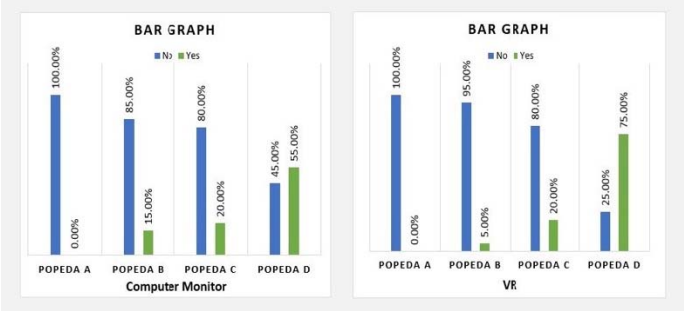

Figure 5. Answers to question "Did the cameras change too frequently ?"

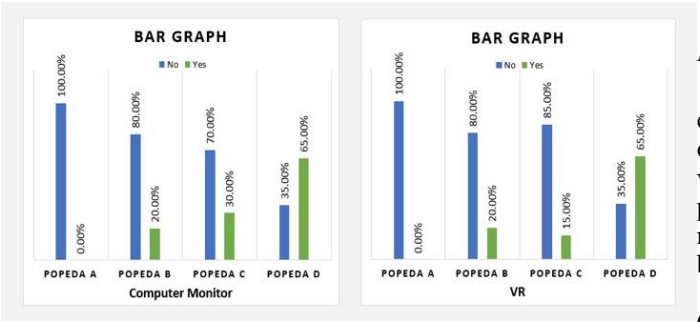

Figure 6. Answers to question "Did you lose your concentration because of camera changes?".

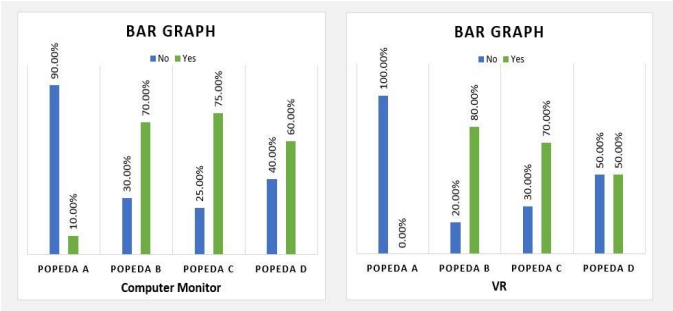

Figure 7. Answers to question "Did the camera changes enhance the flow of video?".

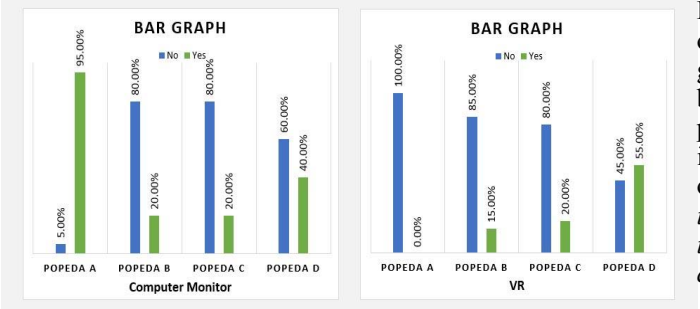

Figure 8. Answers to question "Did the camera changes reduce the feeling of being present in the environment?"

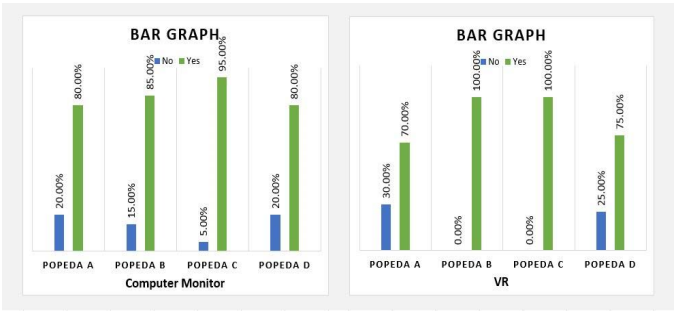

Figure 9. Answers to question "Were you able to actively explore or search the environment?"

B. *Interviews*

After watching all eight versions of the video, we also conducted a short semi-structured interview. In the beginning of the interview, the participants were asked to rank the videos from best to worst. As illustrated in Fig. 10, Popeda C performed best clearly both in the case of both computer monitor and VR goggles. Popeda B was most often ranked to be the second best (Fig. 11).

Many participants reported that the cutting rate of Popeda C was neither too fast nor too slow, so there was enough time to explore each shot. For example, one of the participants stated [sic]: *"Popeda C was pleasant and immersive because it gives proper time to explore and the changes came when I felt a need."* Another participant reported that *"C was easy to perceive from different positions, and the camera changes matched my expectations."*

In the case of the VR goggles condition of Popeda B, one participant stated: *"I felt I am present at the concert and Popeda B gave me enough time to enjoy everything happening there."* Another participant mentioned that *"Popeda B was suitable to explore as it gave enough time to explore all the viewpoints including the audience viewpoint and the band members on stage."*

When asked about the worst video, the "winners" were Popeda A (55% computer monitor, 55% goggles) and Popeda D (40% computer monitor, 45% goggles). In the case of Popeda A, 55% (computer monitor) and 60% (VR goggles) of the participants reported that they felt bored because the video was so static. In the case of Popeda D, the problem was the too fast cutting rate. The participants found it hard to explore within the video environment; for example, one participant reported that *"A sudden camera change teleported me to another position then I had to use some time to adopt with the environment at that time again the camera changed to another position, it was annoying."*

Other negative comments included, e.g., *"Popeda D was more like TV video because the camera changed too frequently"* and *"I was so uncomfortable and tensed while watching Popeda D about when the camera is changing again."* One of the participants even reported motion sickness: *"In Popeda D, the camera changed several times, and I felt motion sickness, though I had never faced it before."*

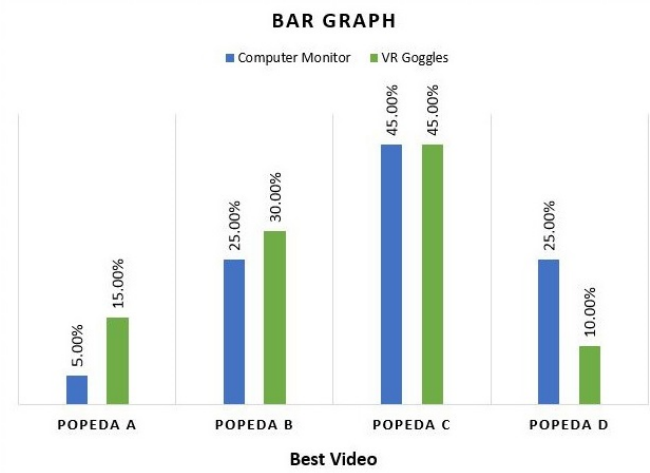

Figure 10. Ratings for the best video.

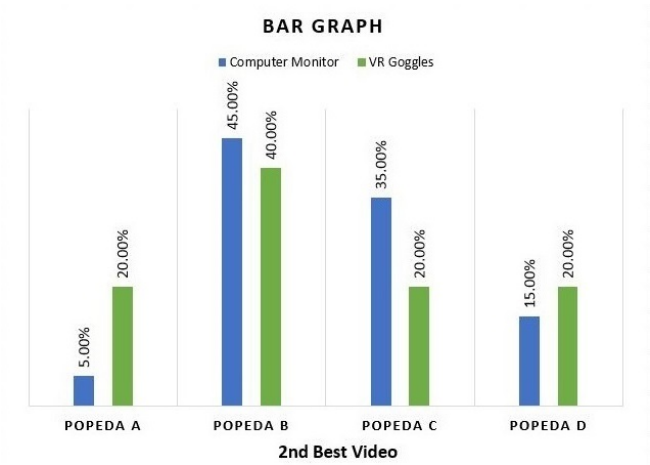

Figure 11. Ratings for the 2nd best video.

Only 30% of the test participants mentioned that they enjoyed the 360° music videos on a computer monitor, and these participants found the videos to be interesting, pleasant, and enjoyable. One mentioned that *"Watching 360° videos from monitor seems useful for me since I do not want to move or turn around."* However, 35% reported they did not enjoy the videos that much. The reasons included, e.g., that the framerate and the video quality seemed bad, the interaction was too slow, and moving the mouse was considered annoying. One participant mentioned that the videos did not match his expectations, and that they were less immersive on computer monitor than on VR goggles.

When watched using VR goggles, 85% of the participants reported that the 360° music videos were more enjoying and exciting, and that the visual experience was more realistic than on the computer monitor. Participants also mentioned that the video quality appeared to be better in VR, while in theory it was more like the opposite. One of the participants mentioned that *"I just felt being in the concert and closer to the band members!"* Another participant stated that *"The visual experience in VR goggles was highly realistic, and I think if people get a chance to enjoy the 360° records of concerts or live events that they missed, they will never miss it."*

Two participants had problems with the camera positioning. The first one mentioned: *"One camera was placed in the edge of the stage, and I was feeling scared, it feels I am going to fall from the stage."* The other participant commented that *"While watching through the camera which was placed in the edge of stage and audience, I felt confused about whether I belong to the band or belong to the crowd."*

Some participants reported having problems with the cuts in general. For example, *"I was exploring the stage, and suddenly it changed my perspective, then I identified myself facing at the back of stage heading towards the wall."*

VI. Discussion

In the conducted study, "Popeda C", i.e., the official YouTube release, delivered highest-quality user experiences for both computer monitor and VR goggles. The selected length of shots (on the average 26 seconds) seemed optimal for this type of music performance, and it matched well with the viewers' expectations. Also, the length of each shot was long enough for the users to actively explore the environment. As most of our other videos have also had roughly the same cutting rate, we were naturally pleased to find out that we have already been on the right track.

The faster cutting rate of Popeda D delivered unpleasant user experiences. It distracted the participants, and they found it difficult to concentrate on the content. Viewers felt lost, and many of them did not have enough time to explore the environment. Interestingly, some of our colleagues have been pushing us to increase the cutting rate of our 360° videos, and the results of the study will now help us to prove our point of using longer cuts.

Popeda A, which consisted of a single shot, was considered to be too static, it bored the users, and it narrowed their viewpoint. However, here we would like point the importance of a good, energetic performance: In 2017, Nokia, Finnish teleoperator Elisa and TAMK did a 360° live stream from the concert of a Finnish metal band Amorphis [19]. While there was only one camera on the stage, the band performed so well to the camera that the feedback we received was overwhelmingly positive. Still, while it may sometimes be a good decision to use longer shots than the 26 seconds of Popeda C, using shorter shots will definitely be a problem for most viewers.

Not so surprisingly, 360° music videos appear to be much more enjoying and exciting when viewed using VR goggles instead of a flat screen, and they also deliver a more realistic and immersive visual experience. Interestingly, the participants also felt that the video quality appeared better in VR goggles, despite not being so in theory.

When editing the videos, one should pay attention to how to prepare the cuts. One good approach is to use crossfades, as it gives some extra time to the viewer to adjust to the new position. This technique has already been used in all our videos, and it received positive feedback in the study as well.

Yet another important component of the UX of 360° videos is the camera placement. In general, the closer the better, but unfortunately this is not always possible due the

restrictions of the venue, security issues, and/or the band members themselves. Some viewers may also get scared if the camera is placed too close to the edge of the stage.

VII. Conclusions and Future Work

The process of shooting, editing and mixing 360°/VR videos is still not that well documented, and it is hard to find any standardized solutions or workflows. Fortunately, there has already been some progress on the audio side (see, e.g., [14]), and this study tries to bring some new guidelines to the video side as well.

In this paper, we studied the user experience of 360° live music videos viewed on computer monitor and VR goggles, with the emphasis being on finding guidelines for the cutting rate of multi-camera videos. The results of this study indicate that for the given content (a Finnish rock band shot with four high-quality 360° cameras), an average cutting rate of 26 seconds delivered the highest-quality user experience for both computer monitor and VR goggles. The cutting rate matched with participants' mental models, and there was enough time to explore the environment without getting bored. The cuts should be based on the theme, concept, performance, or music, instead of just changing randomly or according to strict rules (e.g., every 26 seconds).

In the study, a 360° video consisting of a single shot was considered static and boring. However, in the case of a more energetic band with lots of action on the stage, longer shots could also be acceptable. However, with faster cutting rates, the users start losing their concentration, they get stressed, and all users do not have enough time to explore the video.

When watched using VR goggles, 85% of the participants reported that the 360° music videos were more enjoying, exciting, and more realistic than when watched using a computer monitor. Some participants also mentioned that the video quality appeared to be better in VR, while in theory it was more like the opposite.

While we are already editing most of our 360° videos according to the findings of the study, and are planning to do that in our future productions as well, there are also some cases where we may want to make an exception. We are currently experimenting with so-called "overcapture videos", which have a cutting rate resembling almost that of traditional music videos. In these cases, we use 360° cameras to capture everything that happens on the stage, then edit and release the video as 360°, but we are not expecting most viewers to explore or rotate the video that much. One example of such a video can be found from [21], should it still exist at the time of publishing this paper.

While most browsers, YouTube, etc. already play 360° content, the field is still evolving. What works today, may not work anymore tomorrow, and thus it is necessary to study and practice as many types of video production techniques as possible. We have to be prepared for the next steps of the VR industry (whatever they may end up to be), and thus gather practical experience in all aspects of 360° videos. For example, we are already conducting a user study focusing on the user experience of stereo vs. spatial audio, and investigating the different aspects of overcapture videos.

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