A Comparison of Immersive and Non-immersive VR for the Education of Filmmaking

Zhejun Liu
(Tongji University, Shanghai, P.R. China
wingeddreamer@tongji.edu.cn)

Yunshui Jin
(Tongji University, Shanghai, P.R. China
jinyunshui@tongji.edu.cn)

Minhua Ma
(Falmouth University, Penryn, United Kingdom
m.ma@falmouth.ac.uk)

Jiachen Li
(Tongji University, Shanghai, P.R. China
1733462@tongji.edu.cn)

Abstract: Nowadays, both IVR (Immersive VR) and NIVR (Non-immersive VR) have already been adopted by filmmakers and used in the education of filmmaking, but few studies have shown their differences in supporting learning. This article aims to compare these two forms of technology as educational tools for learning filmmaking and give suggestions on how to choose between them. Two applications with the same purpose and content were developed using IVR and NIVR technologies respectively. An experiment of within subject design was implemented using these two versions as experimental material. 39 subjects participated in experiment and the quantitative measures include presence, motivation and usability. SPSS was used for data analysis and the statistical results, together with interview reports showed that both technologies led to positive learning experience while IVR had better performance in the presence (especially in the "sensory & realism" and "involvement" subscales) and intrinsic motivation (especially in the "enjoyment" subscale) while NIVR was more accessible to the public and may provide more complex and powerful functions with sophisticated GUI. In conclusion, both technologies are capable of supporting the learning of filmmaking effectively when chosen for proper educational missions.

Keywords: Immersive VR, Non-immersive VR, Virtual Reality Learning Environment (VRLE), Head Mounted Display (HMD), Education of Filmmaking

1 Introduction

Film has long been recognized as the potentially most powerful art of the century with subversive power. (Vogel 1974) Nowadays, people or so-called digital natives are born into a media-rich world where they are being recorded, and often they are recording (Prensky, 2001). The film industry today is undoubtedly among the most important culture industries that make great contributions to economy and society. As a result, learning to make a film is important because it can raise our consciousness and awareness of life (Anderson et al., 2020).

The total global box office revenue of year 2019 amounts to $ 42.2 billion, almost the sum of Jordan's GDP or half of Cuba's GDP in the same year, and it offers nearly half of a million job opportunities in the US alone (Statista, 2020; World Bank, 2020). The knowledge-intensive and talent-intensive film industry is also highly competitive, which places high demands on the expertise of her employees. As future filmmakers, students in relevant majors need not only explicit knowledge from theories but also tacit knowledge from practice. However, compared with in-class lectures, practice is far from enough in most film schools, hindering students from being prepared and qualified for the industry on graduation. Usually, this happens because of the formidable cost of practicing filmmaking at a professional level. Possible expense involves purchasing equipment, renting filming sites, hiring cast members and so forth by industry standards, which may quickly go beyond what most schools or students can afford. This dilemma forces us to explore new ways to practice filmmaking.

Technology is an expression of the ability to dream and imagine (Lopreiato, 2014). The rise of the film industry is undoubtedly a successful example. However, it was not until the emergence of a series of Virtual Reality (abbr. VR) technologies that full multi-sensory immersion in virtual worlds became so achievable (Gutierrez et al., 2008; Berntsen et al., 2016).

It's commonly believed that the Sensorama Simulator invented by Morton Heilig in 1962 was the earliest form of VR (Jones et al., 2018). Various types of VR technologies emerged thereafter can be mainly categorized as non-immersive VR (abbr. NIVR) and immersive VR (abbr. IVR). The former places users in a 3D environment, which the users interact with via a conventional desktop monitor display, keyboard and mouse (Robertson et al., 1993; Shahrbanian et al., 2012). The latter gives the users a psychophysical experience of being surrounded by a virtual environment (Dam et al., 2000), usually with a Head-Mounted Display (HMD) or multiscreen stereoscopic projection surrounding displays (Bowman & McMahan, 2007). The HMD category includes HMD for PC which provides stereoscopic vision and spatial sound through a digital helmet connected to a computer, and mobile HMD which integrates mobile CPU and GPU inside the helmet. Surrounding display refers to stereoscopic projection on embracing screens with various shapes including cube (CAVE), hemisphere (Dome Screen) and open cylinder (Cylindrical Screen) (See Figure 1).

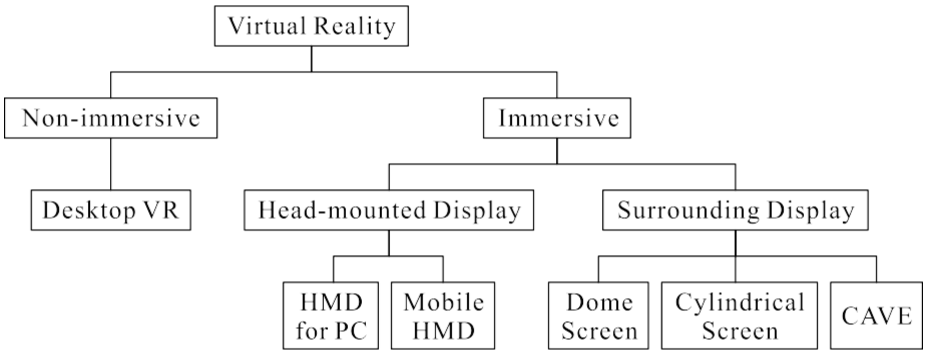

Figure 1: Types of virtual reality technologies

Early surrounding displays and HMDs were formidably heavy, expensive, and complicated to use (Sutherland, 1968; Cruz-Neira et al., 1993). A radical change occurred in 2013 when a new HMD product was introduced: Oculus Rift DK1 (Parkins, 2014) which made decent VR HMDs affordable for ordinary people. After DK1, Rift DK2, CV1 and other similar products like HTC Vive and Sony PS VR followed, each with improvements over their early versions. While there are still some technological challenges before HMDs may be widely accepted by every household, their ability to create an immersive and interactive environment has already made them popular in scientific and social research, education, design and many other professional fields.

The rapid development of hardware and software technologies for both NIVR and IVR has brought exciting new possibilities to the film industry as a powerful tool for faster iterative modification and lower production cost. *Unreal*, one of the most popular engines for game and VR software development, began to rise prominently in the film industry. It has been used to create previz videos, digital backdrops or even final shots for many famous titles like *Westworld*, *Game of Thrones*, *Avengers: Age of Ultron* and etc. (Unreal, 2020). Though this is not strictly NIVR, the techniques and workflow are similar. Moreover, the possibility of using IVR to enhance filming has also been explored lately. For instance, *Disney Animation Studios* tried to use IVR tools for storyboards, painted keys, character poses and so forth in the production of "*Cycle*", a short animated film (Gipson et al., 2018). There were also pilot studies trying to use IVR for quick movie prototyping (Galvane et al., 2018). This trend of development naturally made us wonder whether VR technologies would also be a solution to the problems in filmmaking education.

There are already many attempts to use VR technology, both IVR and NIVR, in education. For instance, the i-LabX online platform (http://www.ilab-x.com/) was established in 2017 by the Ministry of Education of the People's Republic of China to make up for regional economic differences and to improve fairness in education by providing VR learning experience free of charge. There are already 3250+ projects of a variety of subjects available online (investigated in December 2021). 41 of them are related to filmmaking, among which 38 uses only NIVR, 1 uses only IVR and 2 uses both. (i-LabX, 2021) Another example comes from the Rift Store operated by Oculus. It was among the earliest and most influential online store dedicated to IVR software and had an extraordinarily rich collection of various applications. Though IVR games occupied the largest proportion, IVR tools for learning and creation do exist and the famous ones for learning filmmaking include *AnimVR*, *Tvori*, *Quill* and *Ollie*. Typically, they provided users with toolsets to create and manipulate scenes, lights, props and characters to make films virtually. However, these applications targeting at professional users were too demanding and complicated for beginners to use as learning resources. (Rift Store, 2021) These two examples reveal the fact that the value of using VR technology to aid the learning of filmmaking has been recognized by educators and software developers worldwide, but the practice in this direction is still far from enough. Moreover, because either IVR or NIVR has its own pros and cons, different software developers may choose to use different VR technologies and therefore more needs to be known about the actual efficacy in education practice.

In summary, apprentice filmmakers require a great deal of practice beyond what can be provided by traditional school education. The rise of VR technologies, IVR in special, has suggested new possibilities of solving this problem of insufficient training. Our research aims to explore these possibilities for students and apprentice filmmakers to enhance their learning of filmmaking so as to help them adapt to the requirements of the future film industry.

2 Literature Review

Encouraged by the recent advances in hardware (GPUs in particular) and software, the film industry began to use game engines in their production pipeline, especially in the process of previsualization (de Goussencourt et al., 2015, Muender et al., 2018). The latest trend in filmmaking is to be real-time, interactive and non-linear (Bąk et al., 2019). The technology known as non-immersive VR has already been used for the final production in several projects, such as *Fortnite* teaser (Pohl, 2018), *Adam* (Krasimir, 2016),*The Book of Death*, *Wind Up* (Unity Technologies, 2021).

On the other hand, Spielmann et al. (2016) once tried to use HMD-VR for virtual filmmaking, but they finally abandoned the initial idea because the input system was too limited at that time. However, this technology was still valuable as a review tool for panoramic videos. (Nguyen et al., 2017a) After several years of hardware and software development, researchers again started to explore the possibility of using HMD-VR technology in film production, including editing and previz (Galvane et al., 2019; Galvane et al., 2018; Nguyen et al., 2017b). Galvane et al. developed an IVR authoring system using HTC Vive and they assessed the system with two experiments. The result demonstrated positive feedback from both novices and professional users because it enabled rapid prototyping of filmic sequences. However, one limitation of their study was that they didn't compare their system with any other software. (Galvane et al., 2019)

The participants in Galvane's study, who were teachers and experts working in the field of film and animation, mentioned the potential of HMD VR as an educational tool for filmmaking. In fact, due to the capacity of high-level interaction and immersion (Lu, 2008), VR has been used for educational purposes for a while. It was proven to have not only the ability to enhance perception and memorization (Chu, 2019) but also the potential to facilitate the acquisition of higher-order thinking and problem-solving skills (Araiza-Alba et al., 2021; Chen et al., 2016). As learning filmmaking involves many problem-solving tasks, it is reasonable to estimate that VR has potential in this field. Several articles further compared the efficacy of IVR and NIVR used for learning purposes. Harman (2017) and Krokos et al. (2019) both found that IVR had an advantage over NIVR in spatial recognition and information recall; Greenwald et al. (2018) suggested that HMD VR was better for learning complex spatial topics. However, Makransky et al. (2019) reported that both media were equivalent for immediate retention tests, and Moreno et al. (2002) also found no difference on measures of retention, transfer, or program ratings between the two VR forms. Freina et al. (2015) argued that HMD VR could increase the cognitive load and distract users' attention from the main task. In short, mixed results and opinions are found in the literature, but it is generally believed that IVR performed better in spatial-related tasks than NIVR. Because filmmaking is largely a spatial-related task, we hypothesized that IVR could potentially offer better experience of presence and lead to better learning outcome.

The User Experience (UX) of an educational system is also important for learning experience and outcome. UX is defined as "a person's perceptions and responses that result from the use or anticipated use of a product, the system of service" (ISO, 2010), and usability is a part of the broader term "user experience" and refers to the ease to access and/or use of a product (ISO, 2001). Enhancing UX has positive implications for users, including increased enjoyment, satisfaction, and productivity (ISO, 2010). Several articles have investigated the UX and usability of VR. Silva et al. (2017) concluded with descriptive statistics that IVR did better in "attention" and "relevance", while NIVR did better in "confidence"; Santos et al. (2009) found that NIVR had better global user performance than IVR; (Pallavicini et al., 2019) also claimed that IVR was more immersive and elicit more positive emotions than NIVR. However, Schroeder et al. (2017), Tcha-Tokey et al. (2017) and Makransky et al. (2019) concluded that there was no significant difference of usability between these two types. According to these studies, it is difficult to conclude which type of VR provides better usability but evidence showed that IVR was more enjoyable in terms of UX.

In summary, as film industry is starting to embrace VR technologies, it is urgent to investigate the potentials of IVR and NIVR as well as their differences when they are used for the training and learning of filmmaking. From the existing literatures, we are positive that VR technologies may contribute to higher-order thinking and problem-solving tasks including filmmaking. In addition, IVR could hopefully perform better in terms of presence and enjoyment than NIVR. However, their differences in UX are hard to predict. In order to obtain solid evidence to support the usage of IVR and/or NIVR in the education of filmmaking, we planned to compare IVR with NIVR for the learning of filmmaking via a controlled experiment.

3 Design of the Learning Environments

3.1 Learning Theme

When discussing the learning of filmmaking, we are actually talking about a great many learning themes. However, it is not possible to cover all of them in one experiment. As a result, we must decide on one theme that is not only significant but also representative.

According to Anderson et al. (2020), the two pillars of filmmaking education are making and appreciating, which are intricately and irrevocably linked concepts. (Anderson et al., 2020) By giving students the tools of creation and guiding them in developing their work, they understand the aesthetic of film by being active participants within it. Filmmaking comprises three parts: pre-production, production and post-production (Oumano, 2010). Pre-production includes narrative script, directorial vision and layout development. Production involves the skill of framing the action and using the production device like camera angles, focus, shot length, movement, lighting, acting, and sound capture. Post-production is mainly about editing, music, and sound to adjust the film's tension, pace, and mood. Film language is the unique feature of the art of film and is used throughout the three parts of making (Giannetti, 1999). It conveys the narrative in pre-production and guides the camera shooting, movement, and editing in production and post-production, and therefore, it is one of the cores of teaching and learning filmmaking.

There are several traditional ways of low-cost film language training: storyboard, camera plan views, miniature models and live-action using low-cost devices like DV or mobile phone (Higgins, 1994). One of the problems of these training methods is that they are either abstract and less intuitive or lack controllability and richness by industry standards. Besides, in traditional pedagogy, practice sessions are often separated from theoretical teaching sessions, which commonly happens in the form of in-classroom lectures, while students usually have to rely on themselves to solve problems without teachers' guidance in the practice sessions after class. Using VR technologies for film language training can be more convenient, flexible and accessible. Especially, virtual acting is less expensive, dangerous or physically restricted than live-action (Wikipedia, 2021). In addition, VR technology also makes it possible to integrate theoretical learning and practical training together in one virtual environment, which may hopefully result in more effective and efficient learning.

Considering the importance of film language learning and the possibility of improving it with VR technology, it was chosen as the learning theme in our experiment.

3.2 Principles of Experimental Material Design

The experimental material includes two virtual reality learning environments in the form of IVR and NIVR respectively. They are instructional tools that provide users with opportunities to deepen their understanding of film language by practicing filmmaking virtually. The main target users are students in relevant majors such as filmmaking, directing and animation. Considering the fact that most people have their own personal video recorders like mobile phones and SLR cameras today, the target users also include amateur filmmakers from various backgrounds.

To make sure that the results are comparable, we developed our own experimental material based on the following principles:

- Both shall use the same plot, set and cast;
- Both shall deliver the same amount of information in similar ways;
- Both shall provide similar, if not identical, visual quality;
- Both shall provide similar, if not identical, functions;
- Both shall require the same task to be accomplished.

3.3 Content and Technology

The plot used in both VR applications originated from *Afandi's Stories*, a series of stop-motion TV animations produced by *Shanghai Animation Film Studio* in 1980s. Because of its high aesthetic quality, this animation series is still very famous today. These fictional stories were passed down orally by people in Xinjiang province in early 1900s when the territory was still reigned by greedy and stingy landlords. Afandi, the main character in this animation series, was a tenant peasant oppressed and exploited by them. The stories were about how he rose against them bravely and embarrassed them many times with his wisdom.

Each complete episode lasts for 15 to 20 minutes, which is too long for educational purposes or a comfortable IVR experience. Therefore, we chose a 3- minute-long segment from the second episode and turned it into a 3D animation (See Figure 2). It is a short yet self-contained plot happening between Afandi and his master, which contains not only dialogues and cinematic performance but also a solo dance. This richness in the forms of performance makes it very suitable for learners to explore how different types of shots can be used properly according to the film language theories.

Figure 2: Original Stop-motion Animation (left) and Recreated 3D Animation (right)

Both versions were developed using the *Unity* engine v2018.4. In order to keep their visual quality consistent, both used *standard rendering pipeline* and *PBR* materials created in *Substance Painter*. The character models were created in *3ds Max* and animations were captured using the optical motion capture technology from *Vicon* and were then finetuned in *Motion Builder*. The sound was a mixture of the original music track and the new vocals from professional voice actors. All the contents were made as close to the original animation as possible.

The IVR version was exported as a standalone executable using *OpenVR* as the VR SDK because of its compatibility with most common HMDs including Oculus Rift and HTC Vive. The NIVR was exported as a WebGL program accessible via www.ilab-x.com/details/v5?id=4989.

3.4 Functionality and Interface

The main principle of functionality plan and interface design was that the applications should be feature-rich and easy to use. Modern cameras, especially professional ones, offer lots of features to allow manual control over all the aspects of filming. Different physical appearances of these cameras made this situation so complicated and challenging that even a professional cameraman needs some time to get used to a new device. In order to avoid confusion and frustration so that users may focus on film language rather than camera operation, the following functions were identified as necessary in both versions:

- Free camera movement: users may move and rotate a camera freely so that most common types of shots are possible;
- Zoom lens: users may play with focal length and understand how it affects perspective, depth of field and etc.;
- Exposure control: users may adjust parameters, i.e. aperture size, shutter speed and iso value, to change exposure;
- Time control: users may utilize common time control functions such as play, pause, fast forward, fast rewind and jump to the beginning/end;
- Non-linear editing: users may review finished parts and revise them as they wish.

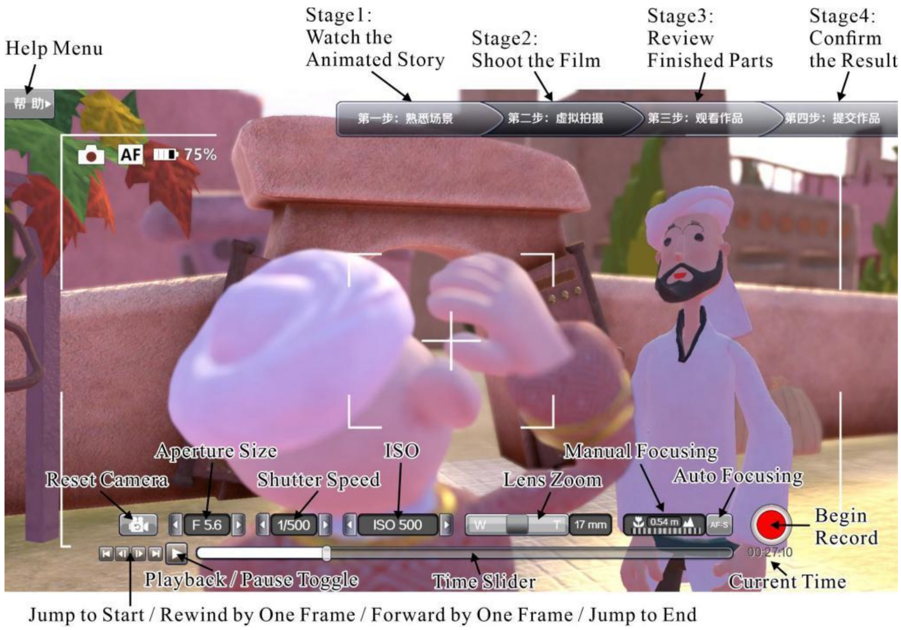

Figure 3: User Interface of the NIVR Version (Stage 2)

The NIVR version organizes the whole learning process into 4-stages according to the task objectives. They all use the same GUI design scheme but certain GUI elements will be greyedout or hidden when they become irrelevant to the current task. (See Figure 3) In stage 1, a user may watch the complete animation from different angles and plan the shots. Then he/she may switch between stage 2 and 3 to change camera parameters, make new shots and review the finished parts. The procedures of revision are simply going back to a previous point on the time line and then shooting to overwrite the existing content. When a user is satisfied with the result, he/she may go to stage 4 to end the session.

The virtual camera is controlled with mouse and keyboard in a manner similar to a First-Person Shooter (FPS) game. Time begins to elapse and the characters begin to act only when the record button is pressed. The virtual world freezes again when the recording is paused, which makes multiple shots possible in an easy way.

However, it's not wise to copy this interface design scheme into the immersion HMD version, because a consumer-grade HMD has a much lower perceptual resolution than a common PC screen, making GUI text and graphics difficult to read or recognize at normal size. Moreover, a 2D GUI is also clumsy and exhausting to use with the hand-held controllers. In order to make the IVR version as easy to use as the NIVR version, we followed the principles of the minimalist design theory and created a very different interface so as to adapt to the characteristics of HMD devices.

Similar to the NIVR version, there are also 4 stages in this version. However, when a user finishes stage 1, he/she can switch between shooting mode (stage 2) and editing mode (stage 3) by pressing the left-hand trigger. The functions of the controller buttons change automatically according to the current mode as shown in Figure 4.

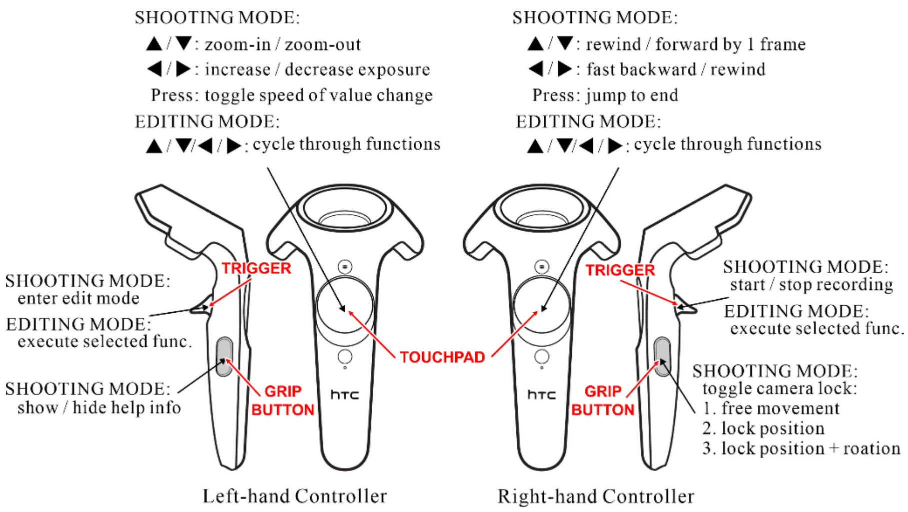

Figure 4: Hardware Interface of the IVR Version, Controller Functions

In shooting mode (see Figure 5), a virtual camera is directly controlled by the right-hand controller, moving and rotating with it. In the real world, most cameras have viewfinders attached to them. If we mimic this physical structure in IVR, however, it means that a user must keep his/her head close to the right-hand controller while shooting, which will make overhead shots, ground level shots and many other types of shots difficult. So we decided to keep the viewfinder in the upper left corner of the view for the sake of convenience. All other interactive functions are assigned to the buttons as shown in Figure 4. Tosimplify the interface, we made the exposure automatic with a compensation adjustable by ±10ev at 1ev intervals. Furthermore, to make it easy to keep the handheld virtual camera stable, we added *position lock* and *position+rotation lock* to make perfect static shots possible.

Figure 5: Shooting Mode in the IVR version

In editing mode (see Figure 6), a user presses direction buttons on a touchpad to cycle through functions and uses the trigger button to execute them. He/she may move the current time indicator using the time control buttons to where he/she wants, press the left-hand trigger again to return to shooting mode and begin shooting from that moment, overwriting what is already on the timeline. When he/she is satisfiedwith the result, he/she may go to editing mode again and use the last "Finish" button to end this session and go to stage 4.

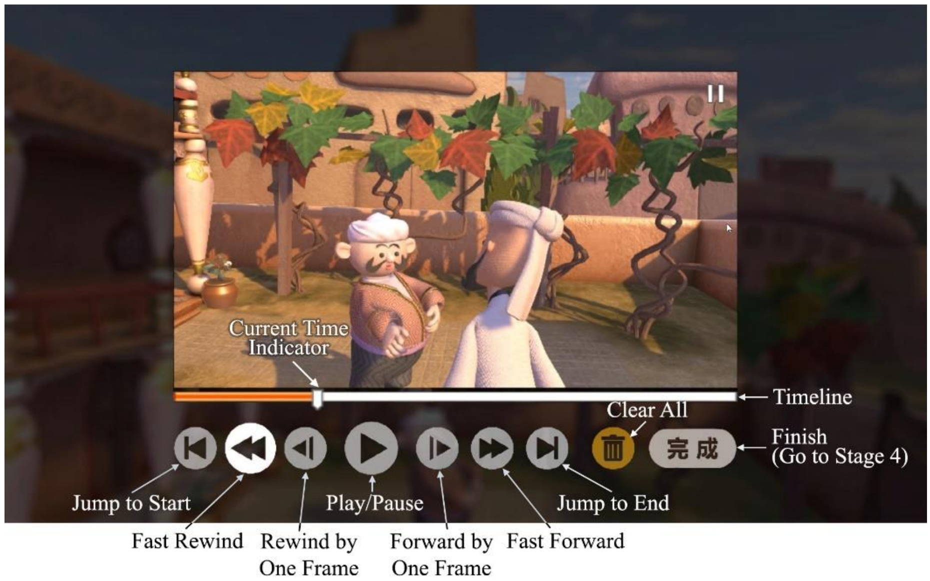

Figure 6: Editing Mode in the IVR version

4 Experiment

To answer the research questions in a systematic and reliable way, an experiment was conducted to compare the two program versions mentioned above. Since the most important superiority of VR technology relies in its capacity of bringing close to real life experience via interactable virtual environments, this experiment tried to answer whether IVR or NIVR was more appealing, motivative and usable for target users.

Considering the fact that subjective evaluation of self-experience might vary greatly among individuals, within-subject design was chosen and counterbalancing was employed to minimize possible bias.

4.1 Hypotheses

Hypothesis 1: the presence level from the IVR experience was expected to be higher than that from the NIVR experience, because of IVR's ability to provide a totally immersive virtual environment.

Hypothesis 2: the motivation level from the IVR experience was expected to be higher than that from the NIVR experience, because IVR allowed a user to interact with the system in a more natural and intuitive way, making it more friendly and appealing.

Hypothesis 3: As far as usability was concerned, however, NIVR was expected to yield better results because of its ability to deliver more visual information simultaneously through the use of a GUI system, which was very difficult for HMD devices due to their limited perceptual resolution and operation mode.

4.2 Measures

Three instruments were used to evaluate the experimental results from different perspectives, namely *presence*, *motivation* and *usability* scales. They were translated into Chinese to cater for the participants.

Witmer and Singer's *Presence Questionnaire (PQ)* (a=0.88) (Witmer et al., 1998), specifically aiming at virtual environments, was selected to measure *presence*. It contains 10 *Likert Scale* affirmations whose answers ranged from 1 (totally disagree) to 7 (totally agree). Four subscales of PQ are *control*, *involvement, Sensory & Realism* and *perceived distraction*.

The *Intrinsic Motivation Inventory (IMI)* (McAuley et al., 1989; Deci et al., 1994) was used to assess participants' subjective experience and to predict, hopefully, their future learning interest and motivation. There are five subscales in the IMI: *interest/enjoyment*, *perceived competence*, *perceived choice*, *pressure/tension*, *value/usefulness.* As our activity is a short-term filming training session, participants won't have issues of pressure or choice. Thus, the subscale of *perceived choice* and *pressure/tension* are excluded. 20 items were selected from 3 subscales, i.e. *enjoyment*, *value* and *perceived competence*. Some questions were rephrased for better understanding in the context of this experiment. For instance, the word "activity" was replaced with "virtual filmmaking" for clarity.

IBM's *Computer System Usability Questionnaire (CSUQ)* (a=0.95) (Lewis, 1995; Albert et al., 2013) was used to evaluate participants' satisfaction with system usability. This questionnaire contains 3 components: *system usefulness, information quality* and *interface quality*. Questions not suitable for this experiment, like "The system gives error messages that clearly tell me how to fix problems", were removed and 7 *Likert Scale* affirmations remained in the final questionnaire.

4.3 Participants

41 students from Tongji University in Shanghai, P.R. China participated in the experiment. All of them volunteered to participate and there was no grading associated with it but a compensation of 10 dollars approximately for each.

During the experiment 2 students reported that they felt strongly uncomfortable due to the simulator sickness caused by VR exposure: one with IVR and the other with NIVR. Finally, data from 39 participants was considered valid and their information is shown in Table 1.

Gender		Age			Educational Background	
male	female	min	max	avg.	Filmmaking	Other
17	22	19	26	21.44	19	20

Table 1: Demographic data and educational background of the participants

4.4 Experimental Material and Apparatus

The two versions of the VR software described in section 3 were used as the experimental material. Both ran on high-performance workstations (See Table 2). HTC Vive Pro, offering an FOV of 110˚ and a single-eye resolution of 1440 × 1600, was used as the HMD equipment. This configuration guaranteed that user experience, especially the experience from HMD VR, would not be jeopardized by low framerate or poor visual quality.

CPU	Intel Xeon E5-1660V4	Grapic Card	nVidia Geforce 1070
Memory	16GB	Harddrive	1TB SSD

Display	24 inch LCD display @ 1920 x 1080 (for NIVR) HTC Vive Pro (for IVR)		
Operation System	Windows 10 64bit	WebGL Browser (for NIVR)	Firefox

Table 2: Configuration of apparatus

4.5 Procedures

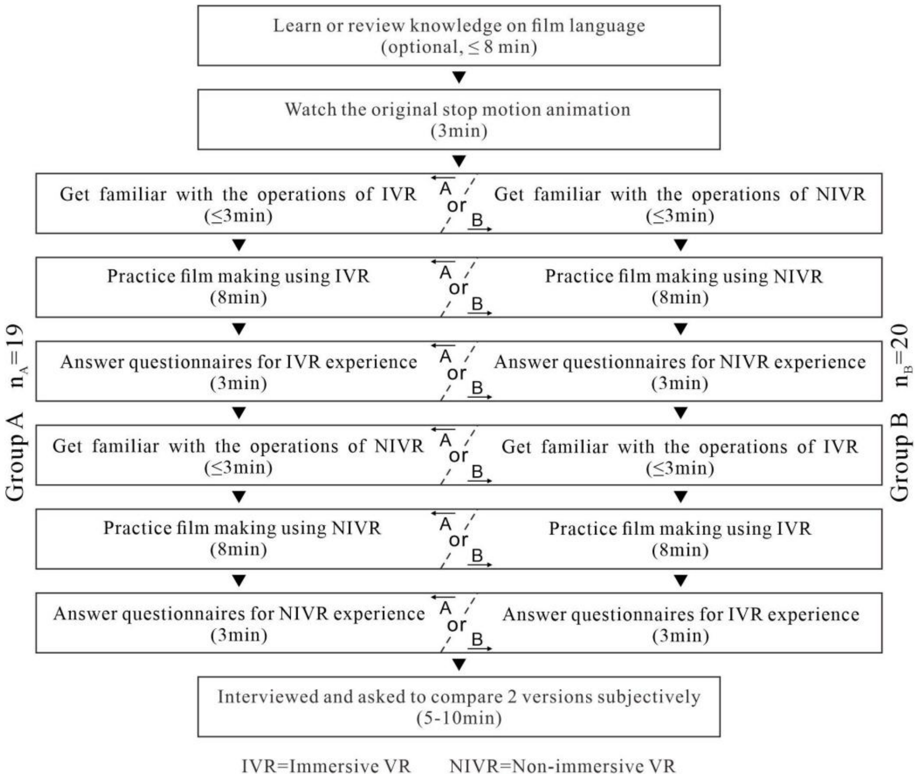

Figure 7: Experimental Procedures

The experiment was carried out in the *Non-planar Screen Lab* in the *College of Arts and Media*, *Tongji University* following the procedures described in Figure 7. Participants were asked to enter the lab one by one and go through the experimental procedure individually. At the beginning of the experiment, a subject was given a maximum of 8 minutes to review the knowledge of film language by learning from a set of instructive webpages. This step was optional and might be skipped by the participant. Next, the 3-minute-long version of the original stop motion animation was shown to the subject as a reference and an inspiration. After that, participants were randomly assigned to Group A (n_A=19) or Group B (n_B=20). In Group A, they used the IVR version first and the NIVR version next. In Group B this order was reversed to serve as a means of counterbalancing to minimize possible bias from *practice effect.* After each experience, participants were immediately asked to appraise it with questionnaires. Finally, the experiment ended with a short interview in which open questions were used to understand how the participants felt about these 2 versions.

5 Results

5.1 Quantitative Results

Participants rated the statements on the questionnaires using seven-point Likert Scales where 7 meant total agreement. The final score of a scale/subscale was the total of all the ratings in it.

We used statistical methods to analyze data collected in the experiment. *Shapiro-Wilk test* and *Levene's test* were used to check normality and homogeneity of variance. According to the result, *usability* and *presence* data was well-modelled by normal distribution and had the same variance. The *intrinsic motivation* data was also normally distributed on the Q-Q plot. Therefore, *paired-samples t-test* was chosen to compare *presence*, *usability* and *intrinsic motivation*.

Hypothesis 1:

The presence scale was composed of four subscales: *control*, *involvement*, *sensory & realism* and *distraction*. Paired samples t-tests revealed significant differences in *overall presence* (M_{IVR}=96.82, SD_{IVR}=12.38; M_{NIVR}=89.10, SD_{NIVR}=13.48; t(38)=-.384; p=.002), *involvement* (M_{IVR}=52.10, SD_{IVR}=6.74; M_{NIVR}=47.69, SD_{NIVR}=6.56); t(38)=-3.869; p<.001) and *sensory & realism* (M_{IVR}=51.48, SD_{IVR}=6.33; M_{NIVR}=46.18, SD_{NIVR}=8.1; t(38)=-4.106; p<.001). No significant differences were found in *control* (M_{IVR}=39.05, SD_{IVR}=5.73; M_{NIVR}=37.92,SD_{NIVR}=5.77; t(38)=-1.22; p=.23) or *distraction factor* (MIVR=10.77, SDIVR=2.15; MNIVR=10.49, SDNIVR=2.76; t(38)=-.536; p=.595) (See Table 3). The result showed that IVR can lead to better presence than NIVR, as participants perceived higher degree of realism and stronger involvement provided in the IVR environment. In summary, hypothesis 1 is partially supported.

	Overall Presence	Control	Involvement	Sensory & Realism	Distraction Factor
IVR	M = 96.82 SD = 12.38	M = 39.05 SD = 5.73	M = 52.10 SD = 6.74	M = 51.48 SD = 6.33	M = 10.77 SD = 2.15
NIVR	M = 89.10 SD = 13.48	M = 37.92 SD = 5.77	M = 47.69 SD = 6.56	M = 46.18 SD = 8.1	M = 10.49 SD = 2.76
T-test Results	t(38)= -3.384 p = .002	t(38)= -1.22 p = .23	t(38)= -3.869 p < .001	t(38) = -4.106 p <.001	t(38) = -.536 p = .595

Table 3: Comparison of Presence

Hypothesis 2:

The intrinsic motivation scale, commonly used to predict potential learning interest and motivation, was composed of 3 subscales: *interest/enjoyment*, *value/usefulness* and *perceived competence*. Significant differences were found in *intrinsic motivation* (M_{IVR}=88.23, SD_{IVR}=16.71; M_{NIVR}=81.13, SD_{NIVR}=19.29; t(38)=2.869; p=.007) and *enjoyment* (M_{IVR}=27.21, SD_{IVR}=5.74; M_{NIVR}=22.82, SD_{NIVR}=7.98; t(38)=3.808; p<.001). No significant differences were found in *usefulness* (M_{IVR}=42.10, SD_{IVR}=6.65; M_{NIVR}=40.90, SD_{NIVR}=6.94; t(38)=1.437; p=.149) or *perceived competence* (M_{IVR}=18.92, SD_{IVR}=6.05; M_{NIVR}=17.41,SD_{NIVR}=6.24; t(38)=1.51; p=.139). (See Table 4.) In other words, participants perceived more enjoyment and intrinsic motivation in the IVR environment. In summary, hypothesis 2 is partially supported.

	Overall Intrinsic Motivation	Interest /Enjoyment	Value /Usefulness	Perceived Competence
IVR	M =88.23 SD=16.71	M = 27.21 SD = 5.74	M = 42.10 SD = 6.65	M = 18.92 SD = 6.05
NIVR	M = 81.13 SD = 19.29	M = 22.82 SD = 7.98	M = 40.90 SD = 6.94	M = 17.41 SD = 6.24

T-test Results	t(38)= 2.869 p = .007	t(38)= 3.808 p < .001	t(38)= 1.437 p = .149	t(38)= 1.51 p = .139

Table 4: Comparison of Intrinsic Motivation

Hypothesis 3:

The usability scale was composed of two subscales: *system usability* and *interface satisfaction*. The mean and standard deviation values were close in terms of *overall usability*, *system usability*, *information quality* and *interface quality*. However, no statistically significant difference was found in *overall usability* (M_{IVR}=98.54, SD_{IVR}=14.45; M_{NIVR}=97.72, SD_{NIVR}=14.11; t(38)=-.354; p=.725), *system usability* (M_{IVR}=46.1, SD_{IVR}=7.18; M_{NIVR}=45.46, SD_{NIVR}=7.02; t(38) =-.575; p=.569), *information quality* (M_{IVR}=29.67, SD_{IVR}=4.29; M_{NIVR}=29.97, SD_{NIVR}=4.03; t(38) =-.468, p=.642), or *interface quality* (M_{IVR}=16.85, SD_{IVR}=3.20; M_{NIVR}=16.44, SD_{NIVR}=3.44; t(38) =.633, p=.531). (See Table 5.) Hypothesis 3 is not supported.

	Overall Usability	System Usability	Information Quality	Interface Quality
IVR	M=98.54 SD=14.45	M=46.1 SD =7.18	M=29.67 SD=4.29	M=16.85 SD =3.20
NIVR	M=97.72 SD=14.11	M=45.46 SD=7.02	M=29.97 SD=4.03	M=16.44 SD=3.44
T-test Results	t(38) = -.354 p = .725	t(38) = -.575 p = .569	t(38) = -.468 p = .642	t(38) = .633 p = .531

Table 5: Comparison of Usability

Finally, one-way ANOVA was used to find out whether there was a difference of *usability*, *presence* or *intrinsic motivation* between different gender or different majors. The result showed that *major* as a variable had a significant impact on the *control* factor of *presence* in HMD VR at the p<.05 level [F(1, 37) = 4.7, p = .037]. The participants majoring in filmmaking (M=37.11, SD=5.96) had less sense of *control* than those from other majors (M=40.9, SD=4.95). The effect size estimate showed a medium effect ($\eta 2$=.113).

5.2 Interview Results

This section offers a brief descriptive analysis of the interview results, which is also expected to serve as the basis for later discussion. Interview questions were as follow:

Q1: Do you think your knowledge of film language improved after the VR experience? If so, please rate how much knowledge you think to have obtained from each application respectively, from 0 (none) to 6 (a lot).

Q2: In general, do you think one system is better than the other? If so, why?

Because it’s usually difficult to define objective criteria to assess artistic skills or artworks, participants were asked to make a subjective judgment on their knowledge improvements (Q1). Over half of the participants (n=23) reported positive results from either or both interventions but the rest (n=16) reported no improvements. (See Table 6.) The numbers of positive reports from both conditions were similar (n_{IVR}=16, n_{NIVR} =17). Participants reported higher average score for knowledge improvement in NIVR (M=1.61, SD=1.36) than in IVR (M=1.46, SD=1.29). Since the duration of the intervention was relatively short, it was understandable that the average knowledge improvement reported by users was not high.

Q1 Answer	IVR	NIVR	Both	Either	Neither
Knowledge Improvement	17	16	10	13	16

No Change	22	23	

Table 6: Answers to Q1 for subjective knowledge acquisition

In Q2, we asked the participants to reflect on the general experiential differences between IVR and NIVR and point out which one they preferred. 24 participants (61.5%) advocated IVR, 9 participants (23%) advocated NIVR, and the other 6 participants (15.38%) expressed mixed attitudes that each version had its own advantages and disadvantages. This result was in accordance with the quantitative result that IVR was significantly more enjoyable. The interview answers were classified and coded from 1 to 6 (see Figure 8).

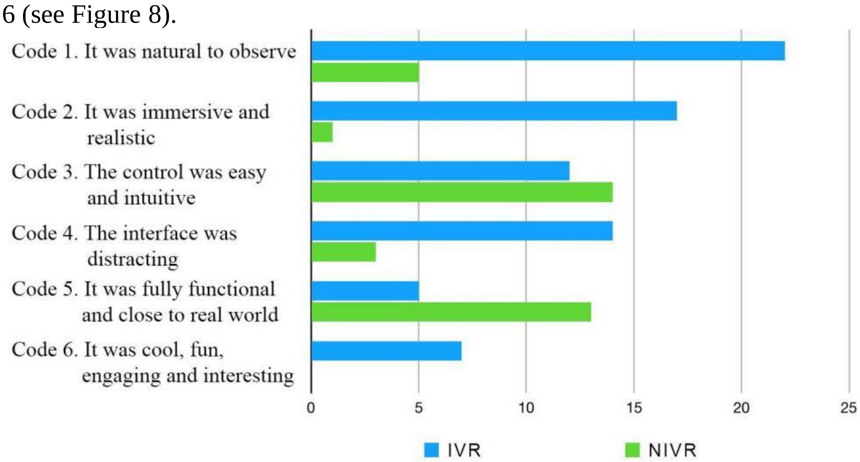

Figure 8: Answers to Q2, subjective evaluation

In terms of Code 1 (natural observation), Code 2 (immersion), and Code 6 (engaging factors), IVR had an edge over NIVR. In the interview, 17 participants emphasized their feeling of immersion and the convenience of freely observing the virtual environment using the HMD while only one subject reported feeling more immersion in the NIVR condition. Besides, 7 participants mentioned that IVR was more engaging. Some comments were:

"…It was very immersive to experience the HMD VR program. I felt as if I was transferred to another world, a world with remarkable vividness…"

"…It was a lot of fun for me to use the IVR version. Those puppets looked so cute. Besides, I could try some crazy shots impossible in the real world…"

"…It was very easy for me to walk and observe in the virtual world using an HMD. I could easily understand the relationship between the characters and the environment. Camera movement control was also simple and intuitive...",

These interview results aligned with the quantitative result that IVR was superior to NIVR in *presence* and *enjoyment*, which reinforced the conclusion.

Code 3 indicated a mixed result. 12 and 14 participants preferred the control scheme in IVR and NIVR respectively. Those fond of NIVR claimed that its manipulation was more familiar and convenient. The contradictory statements included:

"…The NIVR version was easier to use because the control was very similar to PC games, which I am used to. Therefore, it was quick to learn and led to higher efficiency…"

"…It was difficult to manipulate the camera in the NIVR version. The IVR was easier to learn and more comfortable to use..."

"…Camera control was easier in NIVR experience, very easy for camera dolly…"

"…It was very hard for me to learn to use the camera in the NIVR version. I could hardly accomplish the shooting task because I found it counterintuitive…"

"…I didn't like filming using the IVR version because I had to move and crouch a lot. It made me feel exhausted very quickly. The NIVR was much easier..."

These answers also aligned with the quantitative results which revealed similar scores of *control* and *usability* in both conditions. In addition, the result indicated that the control scheme of the IVR version was intuitive but sometimes physically exhausting, while that of the NIVR version was easy and efficient for participants with good gaming skills but might be unfriendly for those non-gamers.

As for Code 4 and Code 5, many participants reported that the NIVR version offered an interface similar to a real-world camera, resulting in less interface distraction. Some statements were:

"…I felt as if I was using a real-world camera in the NIVR experience as it offered easy controls of all the necessary features including aperture, shutter, ISO…"

"…I found it much easier to replay and reshoot in the NIVR version. The interface was more friendly and similar to professional video editing software..."

"…It's easier to shoot with a moving camera using the NIVR application. The movement was neat and smooth as if it was shot with a real-world camera car…"

"…I would like to have a virtual camera car in the IVR version. Camera panning or tracking is popular nowadays…"

"…The virtual viewfinder in the IVR version was too small for me and it couldn't be resized. To film with such a small viewfinder was not common…"

"…Presence from the IVR experience was impressive, but it was still no match for the real world. Movement of the hand-held virtual camera was not accurate enough…"

"…The virtual viewfinder blocked my vision from the environment…"

"…The headset was too heavy to wear. As time went by, it got worse and worse…"

These messages were inconsistent with the quantitative results where the *usability* and *distraction* scores were close in both conditions. Although we presumed that the IVR version would be generally more popular, the interview revealed a slightly different result and helped us to understand the characteristics of IVR and NIVR better. For instance, the NIVR provided more accurate virtual camera manipulation and its user interface was more comprehensive and easier to use because of its similarity to existing software. Besides, the disadvantages of IVR are also worth our attention: the equipment was heavy and distracting, the accuracy of its controllers was not satisfactory for professional purposes and the unfamiliar user interface could sometimes frustrate users. As a result, even though IVR offered a more immersive and realistic virtual environment, many participants thought the usability of the IVR version, including *system usability* and *interface satisfaction*, was not as good as that of the NIVR version.

6 Discussion

According to the results above, hypothesis 1 and 2 are both partially supported, which means that IVR is very likely to have better performance than NIVR in *presence* and *intrinsic motivation*. This finding is consistent with previous studies (Santos et al., 2009; Pallavicini et al., 2019). Hypothesis 3 is not supported. The overall usability scores of both versions were close but no significance was found. Many other researchers drew similar conclusions. They claimed that there was no significant difference in usability among VRs of different immersion levels (Schroeder et al., 2017; Tcha-Tokey et al., 2017; Makransky et al., 2019). But some claimed that IVR led to better usability than NIVR (Paes et al., 2018; Schnack et al., 2019). Taking the interview results into consideration, a possible cause is that presently the user interface of IVR, especially the input devices, was not well designed for precise control, which made common GUI items like buttons, sliders clumsy or even impossible. This implies that it is necessary to redesign both hardware and software user interface if IVR is intended for some serious tasks. For example, to allow voice interaction to mimic real world film production where a user can use verbal commands such as "action", "cut", "roll camera" to control the filming process could be more intuitive and convenient than relying only on GUI elements like buttons and sliders.

Interestingly, we found that students majoring in filmmaking gave obviously lower scores ($M=37.11$, $SD=5.96$) in the *control* subscale of IVR than those from other backgrounds ($M=40.9$, $SD=4.95$), and the difference was significant ($F(1,37)=4.7$, $p=.037$). The interview results lead to a reasonable guess that the professional students were more familiar with real-world cameras and more sensitive to any mismatch between the virtual camera and a real one, which could then cause them to feel the loss of control. Another evidence to support this reasoning is that almost every participant complaining about the camera's lack of certain functions in IVR were students majoring in filmmaking, and this same group of participants praised NIVR for its accurate camera movement control and close-to-real-world GUI design. In contrast, none of the participants from other majors reported similar issues in the interview. Going further, it is reasonable to infer that professional or experienced users have less tolerance of the inaccuracy or incompleteness of a virtual environment while beginners are more likely to accept a simplified version.

Regarding learning outcomes, more than half of the participants (n=23) reported that their knowledge and skills of filmmaking improved using either IVR or NIVR version. It was beyond our expectation because the intervention lasted only a few minutes. One possible explanation is that the implementation of VR technology itself brought a whole new learning experience to its users when compared with traditional ways of teaching. As pointed out by Collins, it is the instructional implementation of technology, and not technology itself, that determines learning outcomes (Collis,1991). Though it's not reliable to draw any conclusion on how much knowledge the participants factually acquired in this experiment, it's reasonable to say that the novel, interesting and rewarding experience itself resulted in more confidence and positive attitudes toward the learning subject and a higher subjective evaluation. Although these benefits are mainly in the "affective domain" instead of "cognitive domain" according to Bloom's taxonomy (Hoque, 2016), they are still significant and valuable because self-efficacy has been proven to keep students motivated, creative and may lead to better performance and academic success (Dogan, 2015; Puozzo Capron et al., 2021; Schunk, 1995).

Finally, the hardware limitations of the HMD device were mentioned many times in the interview. Several participants complained that the helmet was heavy and the hand controllers were not precise. In fact, these problems are big obstacles for IVR to be used extensively in everyday education. Even HMD manufacturers remind users to take a 10–15 minutes break once every 30 minutes. On the other hand, though NIVR is less immersive and enjoyable, many participants (n=17) still gave positive feedback to its intervention as an instructional tool. Considering its low cost and great accessibility, NIVR has more potential for frequent and long-term usage.

7 Conclusion

This research made several contributions to the theory and practice of the education of filmmaking with VR technology. We found that both IVR and NIVR led to positive learning experience and suggested a possible teaching approach of higher efficiency that integrates theoretical and practical learning better. IVR shows better performance in the *presence* (especially in *sensory & realism* and *involvement*) and *intrinsic motivation* (especially in *enjoyment*), while its disadvantages mainly lie in uncomfortable wearing and limitations on user interface. In contrast, NIVR is more accessible and may be more easily distributed to individuals and organizations. It also has more freedom in GUI design, which ensures better usability in general. The major disadvantages of NIVR include the lack of presence, less appealing graphics and less intuitive camera movement in 3D space. In summary, both VR technologies have their own characteristics and it's difficult to give a clear-cut answer regarding which one is absolutely and completely superior than the other. Their potential values will be fully displayed when they are exploited to serve suitable people in appropriate scenarios: IVR as an educational tool for film language is more suitable for beginners and amateurs when available, because they are often indecisive learners and have relatively short periods of learning time. In this situation, IVR is more attractive and immersive and may help to keep them delighted and focused. NIVR, though less sensorially appealing, is more suitable for professional learner who is capable of extracting the essential qualities of shots and film language without relying on vivid visuals. For them, complete and precise control over all the details in film shooting is more important and NIVR with much less constraints on GUI design is a better choice in this case. Moreover, because they tend to use the software for a longer period of time to create more complex content, the uncomfortableness of wearing an HMD may become increasingly unbearable in this process.

This research has several limitations worth mentioning though. Firstly, the study was based on a short-term learning experience in a lab environment, instead of a real-world school scenario. This 16-minute-long initial experience of NIVR and IVR should not be considered as a support for precise predictions about students' real-life reaction and performance. Secondly, the learning outcomes were evaluated based on subjective self-reports, which might be augmented with carefully devised objective assessment in the future. Lastly, the participants in this research were all university students and the total number of participants was limited to a small number. More studies are needed to validate the conclusions in a wider range of population with larger sample sizes.

In conclusion, we hope this paper may serve as an initial attempt to enhance the education of filmmaking using VR technology. Further explorations in this direction to expand understanding, to recognize influential factors or to develop design guidelines are bound to be attractive and rewarding in the future.

Acknowledgements

This work was funded partially by the National Key Research and Development Program of China (2018YFB1004903). We would also like to acknowledge the support from the College of Arts and Media and the College of Design and Innovationduring this study.

References

Albert, B., & Tullis, T. (2013). *Measuring the user experience: collecting, analyzing, and presenting usability metrics*. Newnes.

Anderson, M., & Jefferson, M. (2020). Teaching the screen: Film education for generation next. Routledge.

Araiza-Alba, P., Keane, T., Chen, W. S., & Kaufman, J. (2021). Immersive virtual reality as a tool to learn problem-solving skills. *Computers & Education*, 164, 104121.

Bąk, A., & Wojciechowska, M. (2019). Using the game engine in the animation production process. In *Asian Conference on Intelligent Information and Database Systems* (pp. 209-220). Springer, Cham.

Berntsen, K., Palacios, R. C., & Herranz, E. (2016, November). Virtual reality and its uses: a systematic literature review. *Proceedings of the Fourth International Conference on Technological Ecosystems for Enhancing Multiculturality* (pp. 435-439).

Bowman, D. A., & McMahan, R. P. (2007). Virtual reality: how much immersion is enough?. *Computer*, 40(7), 36-43.

Chen, Y. L. (2016). The effects of virtual reality learning environment on student cognitive and linguistic development. *The Asia-Pacific Education Researcher*, 25(4), 637-646.

Chu, E. S., Payne, A., Seo, J. H., Chakravorty, D., & McMullen, D. (2019, July). Data Center Physical Security Training VR to Support Procedural Memory Tasks. In International *Conference on Human-Computer Interaction* (pp. 353-358). Springer, Cham.

Cinema Today (pp. 92-147). Rutgers University Press.

Collis, B. (1991). Anticipating the impact of multimedia in education: Lessons from literature. *International Journal of Computers in Adult Education and Training*, 2(2), 136-149.

Cruz-Neira, C., Sandin, D. J., & DeFanti, T. A. (1993, September). Surround-screen projection- based virtual reality: the design and implementation of the CAVE. *Proceedings of the 20th Annual Conference on Computer Graphics and Interactive Techniques* (pp. 135-142).

Dam Van, A., Forsberg, A. S., Laidlaw, D. H., LaViola, J. J., & Simpson, R. M. (2000). Immersive VR for scientific visualization: A progress report. *IEEE Computer Graphics and Applications*, 20(6), 26-52.

de Goussencourt, T., Dellac, J., & Bertolino, P. (2015) A game engine as a generic platform for real-time previz-on-set in cinema visual effects. Vol. 9386. *Lecture Notes in* Computer *Science* (pp. 883-894).

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: The self-determination theory perspective. *Journal of Personality*, 62(1), 119-142.

Dogan U.(2015). Student engagement, academic self-efficacy, and academic motivation as predictors of academic performance. *The Anthropologist*, 20(3), 553-561.

Freina, L., & Canessa, A. (2015, October). Immersive vs desktop virtual reality in game based learning. In *European Conference on Games Based Learning* (p. 195). Academic Conferences International Limited.

Galvane, Q., Lin, I. S., Christie, M., & Li, T. Y. (2018). Immersive previz: Vr authoring forfilm previsualisation. In *ACM SIGGRAPH 2018 Studio* (pp. 1-2).

Galvane, Q., Lin, I.-S., Argelaguet, F., Li, T.-Y., & Christie, M. (2019). VR as a Content Creation Tool for Movie Previsualisation. In *IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*

Gipson, J., Brown, L., Robbins, E., Gomez, J., Anderson, M., Velasquez, J., ... & Cooper, D. (2018). VR story production on Disney animation's "cycles". In *ACM SIGGRAPH 2018 Talks* (pp. 1-2).

Giannetti, L. D., & Leach, J. (1999). Understanding movies. Englewood Cliffs, NJ: Prentice Hall.

Greenwald, S. W., Corning, W., Funk, M., & Maes, P. (2018). Comparing Learning in VirtualReality with Learning on a 2D Screen Using Electrostatics Activities. *J. UCS*, 24(2), 220-245.

Gutierrez, M., Vexo, F., & Thalmann, D. (2008). *Stepping into virtual reality*. Springer Science & Business Media.

Harman, J., Brown, R., & Johnson, D. (2017, September). Improved memory elicitation in virtual reality: new experimental results and insights. In *IFIP Conference on Human-Computer Interaction* (pp. 128-146). Springer, Cham.

Higgins, S. C. (1994). The moviemaker's workspace: towards a 3D environment for pre-visualization [Doctoral dissertation, Massachusetts Institute of Technology]. https://mf.media.mit.edu/pubs/thesis/scottMS.pdf

Hoque, M. E. (2016). Three domains of learning: Cognitive, affective and psychomotor. *The Journal of EFL Education and Research*, 2(2), 45-52.

iLab-X National Sharing Platform of Virtual Experiments, 2019, http://www.ilab-x.com/

ISO. International Organization for Standardization, & International Electrotechnical Commission. (2001). *Software Engineering-Product Quality* (Vol. 9126).

ISO. International Organization for Standardization. (2010). Ergonomics of Human-systemInteraction: *Part 210: Human-centred Design for Interactive Systems*.

Jones, S., & Dawkins, S. (2018). The sensorama revisited: evaluating the application of multi- sensory input on the sense of presence in 360-degree immersive film in virtual reality. In *Augmented Reality and Virtual Reality* (pp. 183-197). Springer, Cham.

Krasimir Nechevski (2016). Adam - Animation for the real-time short film. Unity *Blog*. https://blog.unity.com/games/adam-animation-for-the-real-time-short-film

Krokos, E., Plaisant, C., & Varshney, A. (2019). Virtual memory palaces: immersion aids recall. *Virtual Reality*, 23(1), 1-15.

Lewis, J. R. (1995). IBM computer usability satisfaction questionnaires: psychometric evaluation and instructions for use. *International Journal of Human -Computer Interaction*, 7(1), 57-78.

Lopreiato, P. (2014). Reflections on art, nature and technology: the role of technology, algorithm, nature, psyche and imagination in the aspiration of an aesthetic experience. *Technoetic Arts*, 12(2-3), 423-428.

Lu, L. (2008). A Art Café: A 3D Virtual Learning Environment for Art Education. Art *Education*, 61(6), 48-54.

Makransky, G., & Petersen, G. B. (2019). Investigating the process of learning with desktop virtual reality: A structural equation modeling approach. *Computers & Education*, 134, 15-30.

McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. *Research Quarterly for Exercise and Sport*, 60(1), 48-58.

Moreno, R., & Mayer, R. E. (2002). Learning science in virtual reality multimedia environments: Role of methods and media. *Journal of Educational Psychology*, 94(3), 598.

Muender, T., Fröhlich, T., & Malaka, R. (2018). Empowering creative people: Virtual realityfor previsualization. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (pp. 1-6).

Nguyen, C., DiVerdi, S., Hertzmann, A., & Liu, F. (2017, October). CollaVR: collaborative in-headset review for VR video. In *Proceedings of the 30th Annual ACM Symposium on User Interface Software and Technology* (pp. 267-277).

Nguyen, C., DiVerdi, S., Hertzmann, A., & Liu, F. (2017). Vremiere: In-headset virtual reality video editing. In *Proceedings of the 2017 CHI Conference on Human Factors in* Computing *Systems* (pp. 5428-5438).

Oumano, E. (2010). 5. The Process: Pre-Production, Production, and Post-Production.

Paes, D., & Irizarry, J. (2018). A usability study of an immersive virtual reality platform for building design review: Considerations on human factors and user interface. In Construction*Research Congress* (Vol. 2018).

Pallavicini, F., & Pepe, A. (2019, October). Comparing Player Experience in Video Games Played in Virtual Reality or on Desktop Displays: Immersion, Flow, and Positive Emotions. In*Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts* (pp. 195-210).

Parkin, S. (2014). Oculus rift. *Technology* Review, 117(3), 50-52.

Pohl, B., Brakensiek, T., Lombardo, S. (2018). Fortnite Trailer: Developing a Next Genpipeline for a faster workflow. *Unreal Engine*. https://www.unrealengine.com/en-US/tech-blog

Prensky, M. (2001). Digital natives, digital immigrants part 1. On the horizon.

Puozzo Capron, I., & Audrin, C. (2021). Improving self-efficacy and creative self-efficacy to foster creativity and learning in schools, *Thinking Skills and Creativity*, 42, 100966.

Rift Store, 2019, https://www.oculus.com/experiences/rift

Schunk, D. H. (1995). Self-efficacy, motivation, and performance. *Journal of Applied Sport Psychology*, 7(2), 112-137.

Robertson, G. G., Card, S. K., & Mackinlay, J. D. (1993). Three views of virtual reality: non-immersive virtual reality. *Computer*, 26(2), 81.

Santos, B. S., Dias, P., Pimentel, A., Baggerman, J. W., Ferreira, C., Silva, S., & Madeira, J. (2009). Head-mounted display versus desktop for 3D navigation in virtual reality: a user study. *Multimedia Tools and Applications*, 41(1), 161.

Schnack, A., Wright, M. J., & Holdershaw, J. L. (2019). Immersive virtual reality technology ina three-dimensional virtual simulated store: Investigating telepresence and usability. *Food Research International*, 117, 40-49.

Schroeder, B. L., Bailey, S. K., Johnson, C. I., & Gonzalez-Holland, E. (2017, July). Presence and usability do not directly predict procedural recall in virtual reality training. In *International Conference on Human-Computer Interaction* (pp. 54-61). Springer, Cham.

Shahrbanian, S., Ma, X., Aghaei, N., Korner-Bitensky, N., Moshiri, K., & Simmonds, M. J. (2012). Use of virtual reality (immersive vs. non-immersive) for pain management in children and adults: A systematic review of evidence from randomized controlled trials. *Eur J Exp Biol*,2(5), 1408-22.

Silva de Souza, T., Marinho, E. C. R., Cabral, G. R. E., & da Gama, K. S. (2017, November). Motivational impact of virtual reality on game-based learning: Comparative study of immersiveand non-immersive approaches. In *19th Symposium on Virtual and Augmented Reality (SVR)* (pp. 155-158). IEEE.

Spielmann, S., Schuster, A., Götz, K., & Helzle, V. (2016). VPET: a toolset for collaborativevirtual filmmaking, In *SIGGRAPH ASIA 2016 Technical Briefs* (pp. 1-4)

Statista statistics (2020), https://www.statista.com/statistics/264429/global-box-office-revenue-by- region/

Sutherland, I. E. (1968, December). A head-mounted three dimensional display. In *Proceedingsof the December 9-11, 1968, Fall Joint Computer Conference, Part I* (pp. 757-764).

Tcha-Tokey, K., Loup-Escande, E., Christmann, O., & Richir, S. (2017, September). Effects on user experience in an edutainment virtual environment: comparison between CAVE and HMD. In

Proceedings of the European Conference on Cognitive Ergonomics 2017 (pp. 1-8).

Unity Technologies (2021). *Unity3D Demos*. https://unity.com/demos

Unreal (2020). *Unreal Virtual Production Hub*. https://www.unrealengine.com/en-US/virtual-production

Vogel, A., & MacDonald, S. (1974). *Film as a subversive art*. New York: Random House.

Wikipedia (2021). Machinima. https://en.wikipedia.org/wiki/Machinima

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence*, 7(3), 225-240.

Bibliography

Zhejun Liu works as an associate professor in the College of Design and Innovation in Tongji University. He is also the founder and head of the Digital Animation and Entertainment Lab and the Immersive Simulation Lab in Tongji University. His fields of research and creation include electronic games, serious games, VR/AR experience and immersive simulations.

Yunshui Jin is the deputy director of Arts and Media Lab and a lecturer in animation department at Tongji University. He is specialized in 3D animation and real-time rendering technologies. He has been advancing the development of VR, AR application and serious games for museum and education.

Minhua Eunice Ma is the professor of Falmouth University in the UK. She has published widely in the fields of serious games for education, medicine and healthcare, VR and AR, and has received grants from RCUK, EU, NHS, NESTA, UK government and charities for her research on serious games.

Jiachen Li is an assistant researcher in Arts and Media Lab at Tongji University. His research field include serious games, 3D animation and augmented reality.