Virtual Reality Rehearsals for Acting with Visual Effects

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Figure 1: The use of VR for acting rehearsal enables actors to rehearse immersed in the virtual scenery before being shot on a green and empty set.

Abstract

This paper presents the use of Virtual Reality (VR) for movie actors rehearsal of VFX-enhanced scenes. The impediment behind VFX scenes is that actors must be filmed in front of monochromatic green or blue screens with hardly any cue to the digital scenery that is supposed to surround them. The problem is worsens when the scene includes interaction with digital partners. The actors must pretend they are sharing the set with imaginary creatures when they are, in fact, on their own on an empty set. To support actors in this complicated task, we introduce the use of VR for acting rehearsals not only to immerse actors in the digital scenery but to provide them with advanced features for rehearsing their play. Indeed, our approach combines a fully interactive environment with a dynamic scenario feature to allow actors to become familiar with the virtual elements while rehearsing dialogue and action at their own speed. The interactive and creative rehearsals enabled by the system can be either single-user or multi-user. Moreover, thanks to the wide range of supported platforms, VR rehearsals can take place either on-set or off-set. We conducted a preliminary study to assess whether VR training can replace classical training. The results show that VR-trained actors deliver a performance just as good as ordinarily trained actors. Moreover, all the subjects in our experiment preferred VR training to classic training.

Index Terms: K.6.1 [Management of Computing and Information Systems]: Project and People Management—Life Cycle; K.7.m [The Computing Profession]: Miscellaneous—Ethics

1 Introduction

The movie industry has experienced several major technical turns since its outset, the most recent being the advent of computer graphic images (CGI) and VFX. The Wall Street Journal, in June 2015[1], estimated that today, 95% of the movies contain CGI. Its usage is no longer the prerogative of action or science-fiction movies and has now become widespread over many other genres. Furthermore, these changes not only impact technical crews but the acting profession as well. Indeed, in order to use the chroma-key technique required by CGI, actors must perform in front of green or blue screens and, sometimes, with partners that are only virtual. The chroma-key technique is the process that replaces a colour in an image by CGI in order to obtain a composite image from the real image and the virtual one. Professionals estimate that this is the biggest change in the acting profession since the advent of the talkies.

This way of plying their trade is far from what actors learn in drama school and a growing number of actors are complaining about it. For instance, Ian McKellen burst into tears during the shooting of "The Hobbit" as he becomes so frustrated of filming green screen scenes[2]. In fact, many challenges face actors while performing on green screens. Not being able to see what is around them, they cannot perceive occlusions nor avoid obstacles. The performance becomes even more difficult when they are asked to play opposite virtual partners. First, they must avoid missing eye contact when they are engaged in conversation with a character who is not actually there. Second, they must give the illusion of maintaining a consistent eye-line while following a moving virtual character or a virtual object, given that animations are pre-computed and thus follow an exact timing. Imprecise acting not only increases the time needed for the shooting phase, it can also have unfortunate consequences during post-production. Visual effects teams must recreate or modify animations in order to match what has been filmed. Indeed, as illustrated in figure 2, the post-production phase happens months after the shooting, making it impossible to shoot the problematic scenes again. This leads to extra work that can dramatically impact on the cost of the film production.

Allowing actors to immerse themselves in the virtual scenery before shooting could solve several of the issues outlined above. Through a VR environment that represents the scenery, actors can

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[1]"Actors and Visual Effects: How to Behave on a Green Screen"by Don Steinberg, The Wall Street Journal, June 2015

[2]nme.com : Ian McKellen: 'Filming 'The Hobbit' made me cry with frustration'

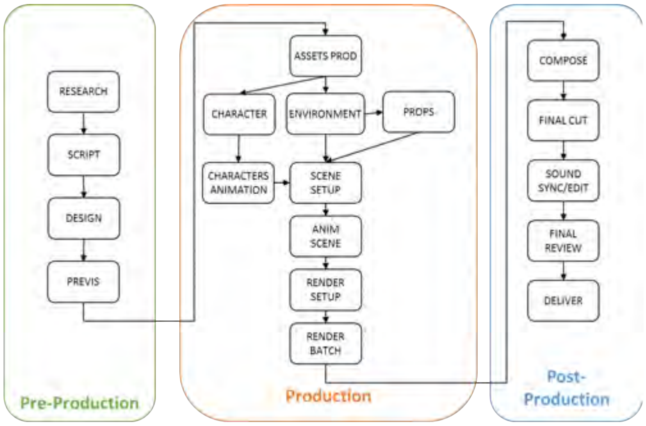

Figure 2: The VFX movie production pipeline: 3D assets are designed before rehearsals making them available for creating a VR environment for rehearsal.

see obstacles, perceive occlusions and train their gaze to follow moving objects or animated characters. A drama school instructor, cited in the Wall Street Journal article above, says to his students: “If you dont see it, the audience wont see it”. Therefore, relying on VR techniques to support actors is especially relevant. Indeed, what better solution than to propose to actors being immerse in the scenery and interact with virtual partners to ”see” ? Furthermore, assets required for the creation of a virtual environment are usually available. Indeed, all VFX movies now include a pre-visualisation phase in their production pipeline. The pre-visualisation, or previs [6], consists of creating preliminary versions of shots or sequences using 3D modelling and animation tools to help plan VFX sequences in pre-production (see figure 2). It helps directors to plan and express their creative intent but it is also used on-set to ensure that the filmed sequences can be integrated with digital sequences [14]. It is therefore possible to use the previs assets to create a VR environment and provide actors with VR training.

Our first contribution in this paper concerns the use of VR for acting rehearsal of green screen scenes. We worked with a professional director and a VFX supervisor to design our approach. It combines an interactive environment and an interactive scenario. The interactive environment enables actors to become familiar with the virtual scenery and objects whereas the interactive scenario makes it possible for actors to practise their play and rehearse their dialogue. Our second contribution lies in the preliminary user evaluations we performed to study if rehearsals in VR can actually replace classic on-set rehearsals. The results of the experiment suggest that actors trained in VR deliver a performance just as well as those trained in a classic way. Furthermore, the actors preferred VR training to classic training.

The paper is organised as follows. Section 2 introduces existing work addressing actor rehearsal in VR. Next, section 3 presents our system and its potential applications in detail. In section 4, we describe the user evaluation we carried out in order to assess whether VR rehearsals can replace classic rehearsals, and we discuss the obtained results. Finally, section 5 discusses the results and exposes the perspectives of this work while section 6 concludes this paper.

2 Related work

This section presents previous initiatives using VR for actors and explains the extent to which they answer the needs of actors acting in front of green screens. VR has long been demonstrated to be efficient for learning transfer and for reducing the cost of training [4]. As regards rehearsal of actors, significant savings in time and money can be made through two objectives. First, enable actors to rehearse remotely since actors cannot always be available at the same place and at the same time. Second, prepare them for green screen shooting by providing them a clear representation of the digital scenery and of their digital partners. Thus, we identify two main categories of existing works: those that provide solutions for remote actors rehearsals and those that support actors for playing with virtual elements.

2.1 VR for Remote Actors’ Rehearsals

In a pioneering study, Slater et al.[17], proposed a shared virtual environment (SVE) to allow three pairs of professional actors and director rehearse a short play. The actors access the SVE through a desktop application where they are represented by an avatar. They demonstrate that, even if this system cannot replace classic rehearsals, it has several advantages. First, it enables efficient working out of spatial arrangements and establishment of blocking. Second, it helps actors to share a mental model of the scenery. Both actors and directors, after a short adaptation period, appreciated the system and found it helpful in transfer to a real-life performance.

Reeve in [16] focuses on the sense of presence in theatre applications of SVE. He claims that these applications have specific requirements regarding presence that are crucial for their success. He identifies some key relationships that must be as transparent as possible to the user to preserve the sense of presence. For instance, the link between the actors natural actions/reactions and the movements of the avatars must be obvious to the user. These relationships have to be taken into account when designing an SVE for theatre applications.

Another similar solution presented in [13] also uses an SVE to allow two actors and a director to rehearse remotely. Their system integrates a real-time motion capture and display of one of the two actors. Participants of the study appreciated the system that enabled them not only to rehearse the dialogue but also the blocking. Indeed, even without supporting facial expressions, the body language aspect appears to be very helpful. The same configuration is used in [18] but the focus is made on the architecture of the system, not on feedback of the users.

The VR rehearsal systems described above illustrate the potential of VR for acting rehearsals. Nevertheless, they do not fulfil all the requirements concerning rehearsals of VFX-enhanced scenes. Indeed, none of them provides for actors rehearsing with virtual partners. Yet this is a serious requirement for this kind of scene since some characters are virtual and are consequently not interpreted by an actor.

2.2 VR to Support Actors Playing with Virtual Elements

The difficulties of green screen filming has motivated several researches. Most of them are tools designed for the technical team, the director or the cinematographer who needs real-time rendering of the final composited scene, i.e., the real filmed images and the virtual scenery such as the SCP Camera by Goucet et al. [7], RTFX [15, 14] or the ANSWER framework [11].

The ORIGAMI project is in the same category. In [8] and later in [9], the authors present several new production techniques and, among them, several tools addressing actors issues. Their action feedback module provides a perspective-corrected projection of the virtual scene onto the studios walls. In this way, the actors have direct feedback of the virtual scenery instead of the usual green screens. Thanks to the active chroma-keying property of the screens, the set can be filmed even if images are projected on the screens and still enable a robust chroma-key. Indeed, the projected images give visual cues to the actors whithout being captured by the camera. Furthermore, using a mask on the projected images and the computed surface model of the actor, they can disable all light rays that could fall onto the actors surface.

Another work that does not directly address green screen shooting but investigates actors rehearsals in VR is proposed in [3]. Their interactive system enables actors to recite his or her dialogue in front of a virtual co-actor. The co-actor is diplayed on a large screen. Its pre-computed animations enable the virtual character to respond to the real actor with appropriate gestures and emotions. The authors perform a study to compare acting opposite a virtual actor with scene reading and results suggest that participants in the VR condition were able to learn the scene just as well as participants who read the text.

Furthermore, in [10], the authors present a mixed reality action rehearsal system which enables users to practise sword fighting actions using an HMD. This rehearsal system shows the life-size action scene in front of the user through the HMD to help him/her work their timing and position. For this purpose, they add vibration and sound feedback in real time with the scene, such as when the system detects a collision between a CG actors sword and the users virtual sword.

More recently, Wöldecke et al. in [20], proposed MagicLensVS, a framework for visual feedback in a virtual studio environment. Their framework focuses on virtual TV studios rather than on movie sets. In their case, the whole set is green and empty because, due to live production constraints, there is no post-production phase so the chroma-key has to be done in real time. For this reason, they propose to add real counterparts to virtual objects and to link them to their virtual representation. Thus, it is possible to retrieve information from the real to the virtual and from the virtual to the real, like the position of the object for instance. This also means the actor has a visual cue to interact with virtual objects. This system does not manage virtual partner and is not designed for rehearsing but for live shooting.

The techniques explained above provide visual, auditory and tactile cues to help actors with positions, timing and gaze problems. However, except [13], these solutions do not allow actors to rehearse dialogue and actions at the same time, focusing only on one (dialogues in [17],[3]) or the other (action for [8],[10],[20]). Furthermore, action-centred rehearsal systems do not enable actions to be synchronised with the actors play. However, for training purposes, it is essential to allow actors to practise at their own rate. Even if the timing of action is usually fixed when shooting, actors should be able to practise slowly before working up to the final timing.

3 VR Acting Rehearsals for VFX Scenes

This section describes our approach for using VR for acting rehearsals.Its main benefit is that it enables actors to rehearse action and dialogue at the same time. Moreover, the system is capable of synchronizing the progression of the scenario with the actor's play, driving both events and virtual characters.

3.1 Usual issues and motivations

The number of issues encountered by actors playing in front of a green screen is quite large. In fact, each VFX scene produces a set of issues and, even for the same scene, issues can differ for each shot. For this reason, there is no universally accepted solution to a specific kind of problem. Each situation requires different solutions for the same problem. Nevertheless, we can classify usual problems into three categories: positional problems, timing problems and gaze problems.

Positional problems appear when an actor must be at an exact position or make a precise gesture while having no visual cue for reference. For instance, when he or she has to avoid an invisible object, hide behind a virtual wall or check the hands of a virtual character. To help the actor, positional cues are usually given by rough marks on the floor or a few objects are selected to be landmarks.

Timing problems come from the fact that VFX are usually designed during the pre-production phase and are therefore precomputed. Thus, actors have to adapt their performance to the timing of the VFX. For instance, when an actor must fight against a virtual partner, he or she must synchronise their gestures with the animation of the virtual character. The crew usually rely on sound or on timed gestures to help the actors.

Gaze problems are the most intricate. They happen when actors must follow a moving virtual object or when they must interact with a virtual character. Since humans are very good at detecting missed eye contact, it is crucial to help actors maintain a consistent eyeline by giving them cues for where to look. For instance, when an actor must pretend he or she is engaged in a conversation with a virtual partner, the crew rely on laser pointers, tennis balls on sticks or even actors that stand for motion reference.

3.2 Overview

Our approach aims at helping actors to rehearse their play and dialogue while interacting with VFX. It relies on two objectives (1) make the virtual scenery and the virtual characters as concrete as possible to actors, (2) make the proceeding of the scenario as smooth as possible from the actors' point of view. Thus, we combine a reactive environment with an interactive scenario that drives a VR environment accordings to the user's acting.

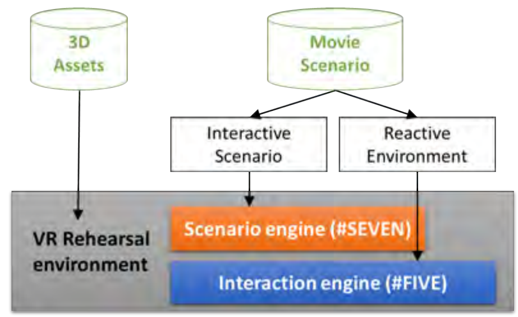

Figure 3: Our rehearsal system : given the *movie scenario* and 3D assets, the actor is immersed in an interactive 3D virtual environment driven by the scenario engine and by the actor's play.

As shown in Figure 3, the VR rehearsal environment is composed of the 3D virtual environment itself, an interaction engine (IE) and a scenario engine (SE). To model the virtual environment, assets produced for previs purposes are used. The virtual scenery, the virtual objects, along with the virtual characters and their associated animations are all elements that can be reused to fill the VE. The IE enables us to make some elements of the environment interactive and to describe their specific behaviour. According to the movie scenario, we identify the interesting elements and their behaviour that should be integrated into the VE. The SE enables us to describe the sequencing of actions and dialogues of every characters in the scene based on the movie scenario. To avoid any misunderstanding, we call the original scenario of the movie the *movie scenario* and the formatted version targeted to the SE the *interactive scenario*. Through this approach, actors can rehearse to avoid the issues listed in Section 3.1 when it comes to filming.

3.3 A Framework to Support Acting with Visual Effects

The combination of immersion, interactivity and rehearsing facilities are provided respectively by VR, the IE and the SE, leading to a flexible and scalable framework.

3.3.1 The Reactive Environment

We use our IE, called #FIVE, that has been previously described in [2]. Thanks to #FIVE, we can describe the behaviour of each in-

Figure 4: Our VR rehearsal sample environment running in a large-screen immersive room and on a portable projection screen: the actor rehearses the scene under the supervision of the technical team.

teresting object in relation to other objects in the environment. The IE can be used in two different ways. First, the actor can interact naturally with the objects that surround him. He can take a glass, move a chair or switch the light on, providing that all these elements have been referenced in the IE. Whatever the interaction device, using #FIVE, the interactive objects and their behaviour remains the same. Thus, the actor can perform just as he would have done in real life and experience the result of his action. Second, he can explore the environment and discover the interaction capabilities of the scenery. For instance, when pointing out a hammer, he will be notice that he can use it to repair something in conjunction with a nail. The way this information is displayed to the user is out of the scope of this paper. The IE allows to customise it to fit the context of the scene. Furthermore, the IE takes into account collaborative interactions so as to allow multi-user rehearsal.

Providing an interactive environment is a feature that makes the rehearsal more easy to remember for actors. Experiencing the set by handling virtual objects, visually measuring their size and weight when actors are supposed to interact with them is of great help. In the same way, seeing and interacting with a virtual partner in VR and perceiving their size and stature makes it easier for actors to pretend they are having a conversation or that they are walking alongside. Indeed, many actors complain about the frustration caused by the fact that they have to wait for the release of the movie to see what they were actually fighting against.

Data computed by the IE and/or the physics engine can be used by post-production teams. For example, it is possible to record the trajectory of an object thrown by an actor to increase the realism of the final rendering. In the same way, lighting and shadowing of the scene can take advantage of this data produced during rehearsals.

3.3.2 The Dynamic Scenario

Using the *movie scenario*, we can describe in our SE the exact sequencing of events in an *dynamic scenario*. Our SE, #SEVEN [5], is a Petri-based reactive scenario engine that allows to describe bi-directional interactions. Through sensors, #SEVEN is indeed capable of perceiving or triggering any required type of event. These events can be a dialogue (i.e. the actor utters a given sentence), an event in the environment (i.e. a light turns on), an action of an actor or an avatar (the actor is at a given position). The *dynamic scenario* defines the events ordering as well as what (i.e an object or the environment) or who (an actor) triggers them and the SE is in charge of the unfolding of the *dynamic scenario*. Thanks to the *dynamic scenario* feature of our framework, it is not the actor who must adapt his acting to the virtual world but the virtual world that is synchronised with the actors play. Moreover, the SE does not presuppose the nature of the actor; he or she can be real (i.e. a user) or virtual (i.e. an avatar) with no impact on the engine scenario. Thus, without changing our *dynamic scenario*, the rehearsal can be for a single user or several users. Finally, thanks to the SE, we can easily modify the *dynamic scenario* while using the same virtual environment in order to rehearse a different scene that takes place in the same virtual scenery.

Through the *dynamic scenario*, actors can not only rehearse dialogues but also actions in a single session. Furthermore, depending on the familiarity of the actor with action sequences, the proceedings of the *dynamic scenario* can be adapted. To begin, the event of the environment or of the virtual characters can be synchronized with the actor's play. Later, when the actor feels comfortable with a demanding sequence, the proceedings of the *dynamic scenario* can follow a given timing. Indeed, currently, animations are pre-computed in pre-production, so that actors must respect an exact timing to synchronise their play with the animations. It is possible with our SE to define such a timing to match the constraints imposed on actors during shooting. Nevertheless, it remains essential to allow less constraint when rehearsals begin. Indeed, just as dancers who learn a new choreography begin by performing the movements slowly, actors need to learn at their own pace. For instance, rehearsing a fight scene requires learning the movements at a slower pace to be able to perform it with a given timing later.

3.3.3 The VR Rehearsal Environment

The VR environment not only provides a feeling of immersion to actors it also helps them to construct a valid mental model of the virtual scenery and of their virtual partners. As stated in [17], this ensures that the same mental model is shared by every person involved in the making of the movie (actors, director, VFX supervisor, etc.). Indeed, the ability to see the scenery in real-size is worth a thousand words It avoids misunderstandings, poor blocking or wrong interpretations. Moreover, the flexibility provided by VR makes it easy to add useful information by, for instance, displaying emotional and gestural feedback, auditory signals or advice and anything that can help actors. Finally, it is easy to update the virtual scenery on demand if the director or the actor realises that something needs to be moved. For example, if an object disturbs the trajectory of the actor or the camera, it can easily be moved in the virtual environment and then back up to be transferred later to the post-production team.

3.4 Implementation

An implementation of this approach was realised in a sample VR rehearsal environment. We worked closely with professionals to design the sample scene and write the sample scenarios. As a result, four scenarios were defined to be played in one single virtual scene. Each one of these scenarios covers a set of specifics issues of VFX scenes. They include a virtual character and two real actors. One actor was represented in the environment by an avatar for single-user rehearsals. We also implemented a scene with no *dynamic scenario* but with more interactions than those required by our scenarios. This scene was used to show actors the virtual scenery and to let them discover all the possible interactions by themselves. Furthermore, in order to cover as many rehearsal situations as possible, the sample VR rehearsal environment runs on different devices and configurations. We have successfully tested it in three different configurations. First, a large-screen immersive room for an off-set rehearsal. The actor wears active 3D glasses and a flystick to interact with the environment (see left picture of Figure 4). Second, a portable projection screen with stereo video-projector and a tracking system. It can be used either off-set or on-set and the actor must wear 3D active glasses and a flystick for interaction (see right picture of Figure 4). Third, an HMD combined with a Razer Hydra™for interaction. It can also be used on- or off-set.

The second configuration with a portable projection screen was actually used on a film set. One of the four scenarios cited above was filmed in the context of our research project (see Figure 6). The VR rehearsal environment was used to make actors rehearse their play before shooting the scene. The shot scene implies that the actor plays with a virtual character. The actor that used the system was really enthusiastic and confirmed that it helped him to visualise the virtual scenery and his virtual partner better.

3.5 Synthesis

Our approach could help actors while rehearsing for a green screen shoot. VR rehearsals provide interactive and creative rehearsals compared to the way actors currently rehearse. Moreover, it is a flexible and scalable approach that can fit various movie scenarios as well as various rehearsal conditions.

Nevertheless, our approach relies on the hypothesis that VR rehearsals can effectively replace classic rehearsals whithout disturbing actors. Hence, the VR application used for the evaluations does not include the interactive environment and dynamic scenario feature. These features makes the VR rehearsals too much different from classic rehearsals.

4 Evaluations

This section presents the study we conducted in order to compare classic rehearsal to a rehearsal in VR for green screen shooting.

4.1 Objectives and Study Design

Our experiment aims to evaluate whether VR rehearsal can replace classic rehearsal for green screen shooting and if it is appreciated by actors. For this purpose, we decided to compare in a between subjects study, the performances of two groups of actors: one trained in a classic way and one trained in VR. After the training, their respective performances are then compared during an identical shooting phase in front of a green screen. Our experiment relies on a scenario that includes a set of well-known issues encountered by actors during green screen shootings for scenes that summon a virtual character. In this scenario, we extract three synchronisation points (SP), i.e moments in the scenario that require precise synchronisation from the actor with his virtual partner, a tiger:

SP1 : when the tiger passes between the legs of the actor,
SP2 : when the tiger is sitting on the bar, looking at the actor,
SP3 : when the actor takes the orange back from the tiger.

Figure 5 shows the key positions of the virtual tiger during the scene. For SP1, the actor must pretend that a tiger passes between his legs at the exact time and position of the tiger's animation (see picture 1 in Figure 5). SP2 implies that the actor looks into the eyes of the tiger when it is standing on the bar, looking in the direction of the actor (see picture 2 in Figure 5). Eventually, SP3 must happen when the tiger is facing the actor (see picture 5 in Figure 5) with the orange in its mouth and before the tiger leaves the room (see picture 6 in Figure 5).

Using techniques recommended by film professionals, we implemented cues to guide the actor in the training and shooting environments. These cues are of three types: positional cues, synchronisation cues and eye-line cues:

Positional cues are marks in the scenery represented by dark green crosses. We include four: one for the starting position, one for the standing position for SP2, one to mark the position of the basket and one for the position of where to put the orange.

Synchronisation cues are given by sounds. We added six sounds: one ringing sound at the beginning of the scene that stands for the typical clap and five blips, one for each SP and two other for when the actor should take an orange and one when he should put it on the bar.

Eye-line cues are given by a stick with a ball on it. The ball was placed at the same height as the tigers eyes. We used two sticks in the training scenery: one for the position of the tiger when it is facing the actor for SP2 and one for its position when it presents the orange to the actor for SP3.

Figure 6 shows the two training environments: the VR training environment on the left and the classic training environment on the middle. The left image shows the real shooting environment. It is similar to the set used for the real shooting and contains the same cues as in the training environment. Both training modalities as well as the shooting scenery contain these cues but differ in several ways (see Figure 6). The classic training is a whole green screen set with a green bar like the set for shooting but it also contains an animated stick that depicts the tiger and follows its trajectory and speed to guide the actor. The VR training fully represents the scenery in a VR environment and instead of an animated stick, we represent the tiger.

In order to preserve the same experimental conditions between both training modalities and the shooting environment, we decided to perform the whole experiment in our large-screen immersive room. Thus, we avoid disturbing the participant with differences in lighting, sounds or configuration of the room.

4.2 Materials

The three environments (trainings and shooting) were implemented using the Unity 5 game engine and run on a cluster of PCs in our VR immersive room. The VR immersive room is composed of four screens (front, two sides and a floor), tracking cameras and stereoscopy is provided by active stereo glasses. In order to record the performance of participants, we implement an application in Unity with the Kinect V2 using the MS-SDK plugin. This enables us to perform a real-time compositing of the user with the virtual scenery. Thus, we record the performance of the actor to use it as a reference. Figure 1 illustrates the experimental environment: the VR training environment, the green-screen shooting with real-time compositing feedback and the resulting image.

4.3 Participants

Twenty-four participants (4 women and 20 men aged from 21 to 61, mean=29.45, sd=10.07) took part in our experiment. The experiment was divided into two experimental groups of 12 participants: one that was trained in green screen and one that was trained in VR. According to their level of knowledge in acting, each participant was assigned to one of these two groups, giving each group a balance of novices and experienced actors, i.e. six novices and six actors in each experimental group. All the subjects had normal 3D perception and normal or corrected-to-normal vision. Participants were volunteers who received no compensation and were recruited through professional and personal contacts.

4.4 Procedure

Each experimental group followed the same protocol. They made three trainings (T1,T2 and T3) in their attributed training environment then a shooting (S1) in the green-screen environment. After the shooting, they were asked to answer a post-hoc questionnaire to give their subjective impressions and comments. To conclude the experiment, they were invited to test the other training modality and to fill in a final questionnaire about their training preference.

Figure 5: The scenario used for our experiment includes a virtual tiger with which the actor must interact: the 6 images show the key positions of the tiger during the scene.

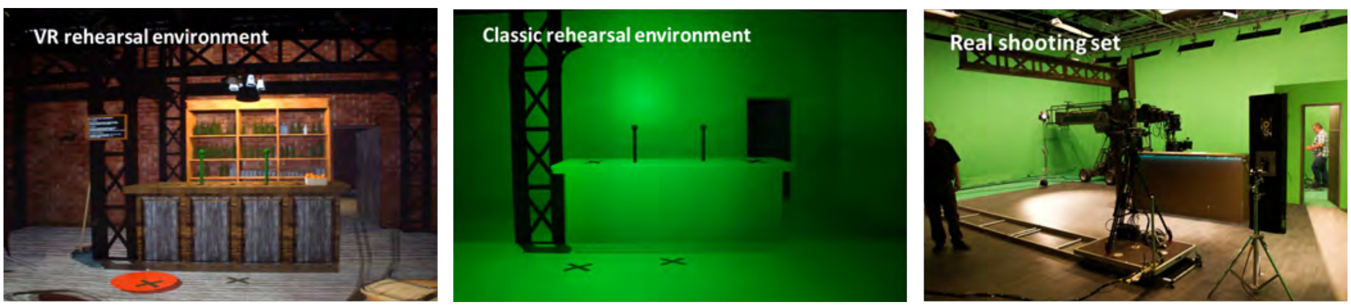

Figure 6: The training environments for the two modalities (right and middle image): both contains two crosses on the ground, two crosses on the bar and two sticks as well as sounds for synchronisation.The left image shows the real shooting set to compare with the experimental shooting sets.

4.5 Collected Data

We record the distance from the target and the distance of the gaze from the target of the SP presented in section 4.1. The recorded SP and their target are as follows:

SP	Position target	Gaze target
SP1	D1 :1st mark on the ground	-
SP2	-	G2 :ball on the 1st stick
SP3	D3 :2nd stick	G3 :ball on the 2nd stick

The distance D3 has the main subject's hand as reference and the D1's reference is the subject's body. Gaze distances are given by the intersection of the ray that begins between the eyes of the user with the orthogonal plane that contains the target point. This data has been recorded for shooting but also for each training. We recorded each training and each shooting and recorded a real-time compositing of the actor with the virtual scenery. The post-hoc questionnaire collected subjective data with Likert scale (1: not agree at all, 7: totally agree) for the following criteria: (1) the training environment helps **positioning** on the set during shootings, (2) the training environment helps with **following the tiger with the eyes** during shooting, (3) the training environment helps me feel comfortable with **gestures** during shooting, (4) the training environment helps me rehearse **facial expressions**, (5) the training environment helps me rehearse **envelope expressions**, (6) the training environment helps me rehearse **emotional engagement**, (7) the training environment helps me to **use the space** better, (8) the training environment helps me feel **confident** during shooting. The second part of this questionnaire, filled in after the subject tested the other training modality, collects their training environment preferences. We asked them which one they prefer overall but also which one they prefer in term of support for positioning, for gaze and for synchronisation with the tiger's animation.

4.6 Results

Post-hoc questionnaire part 1

The results obtained for our eight Likert scales are summarised in Table 1. For our eight criteria, we conducted Mann-Whitney tests that indicated a non-significant difference suggesting a validation of the null hypothesis. Hence, the notation of our eight criteria did not differ significantly from VR-trained users and Classic-trained users. This suggests that participants in the VR condition were as satisfied as participants in the Classic condition for each of our eight criteria. Nevertheless, in each category except for positioning, the mean score for subjects that have been trained in VR is higher than the mean score of subjects trained in a classic environment. The results obtained for positioning are counter-intuitive and would require further investigation.

Table 1: Post-hoc questionnaire results: VR-trained actors are as satisfied as Classic-trained actors by the training.

Question	Condition	Mean	Std Dev	N	Median
Positioning	Classic	6.154	0.899	12	6
	VR	5.25	1.865	12	5.5
Eye following	Classic	6.077	1.553	12	7
	VR	6.333	0.778	12	6.5
Gesture	Classic	5.231	1.739	12	6
	VR	6.167	1.030	12	6.5
Facial expressions	Classic	3.167	1.528	12	3
	VR	3.833	1.942	12	4
Envelope expressions	Classic	4.583	1.782	12	5
	VR	5	1.537	12	5
Emotional engagement	Classic	3.250	1.865	12	2.5
	VR	4.417	1.881	12	4.5
Use of the space	Classic	5	1.414	12	5
	VR	5.667	1.435	12	6
Confidence	Classic	5.333	1.435	12	6
	VR	5.750	1.485	12	6

Post-hoc questionnaire part 2

The second part of the post-hoc questionnaire was filled by the participant after having tried both rehearsal modalities. As shown in the first column of Figure 7, every participant preferred VR rehearsal to classic rehearsal. Twenty-three of the twenty-four participants preferred VR rehearsals for positioning and synchronising with the virtual characters (column 2 and 3 of Figure 7). Otherwise, twenty-one preferred VR training to rehearse gaze (fourth column of Figure 7).

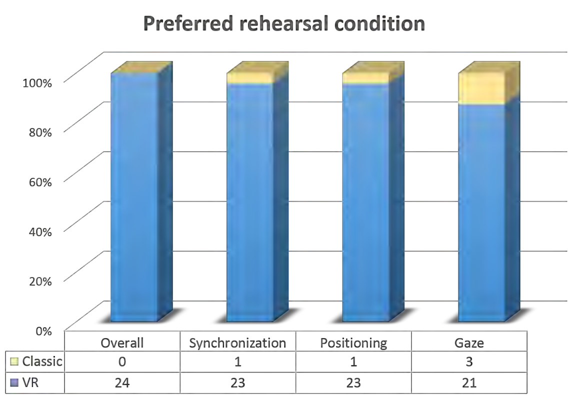

Figure 7: Preferences of training modalities : all participants preferred VR training and most of them preferred VR training to rehearse synchronisation, positioning and gazes.

Measured data

Post-hoc questionnaire part 2 The measured data obtained are summarized in Table 2. For both positioning and gaze data, we conducted independent t-tests that show no significant difference between the two modalities. This suggests that actors trained in VR deliver a performance as precise as actors trained in a classic environment.

Table 2: Measured data: VR-trained actors delivered a performance as precise as Classic-trained actor.

		Mean	SD	Median
SP1 position	Classic	0.339	0.223	0.259
	VR	0.262	0.177	0.186
SP2 Gaze	Classic	0.216	0.374	0.082
	VR	0.157	0.136	0.109
SP3 position	Classic	0.472	0.279	0.427
	VR	0.535	0.352	0.506
SP3 Gaze	Classic	0.141	0.069	0.138
	VR	0.362	0.595	0.110

Synthesis

Our study demonstrates that VR rehearsal can replace classic rehearsal since actors perform equally whether they are trained in VR or in a classic environment. Moreover, the qualitative data collected shows that actors appreciate VR rehearsals. In their comments, actors enjoyed training in VR and declared they had a better vision of the virtual scenery. Several of the VR-trained actors declared that experiencing the size of the tiger in VR, significantly helped them to simulate the tiger passing between their legs. They found it easy to improvise the action of the tiger during rehearsal and to reproduce this during shooting. They declare to feel more involved in their play and that less concentration is required to integrate the skills needed during shooting. Finally, our study revealed that actors prefer VR training over classic training. Participants commented that being engaged in their play is easier when rehearsing in VR. The green scenery requires more concentration to deliver the same mental engagement.

5 Further Work and Perspectives

Through our experiments we demonstrate that the use of VR in acting rehearsals for VFX-enhanced scenes has a great potential. However, the full benefits of our approach are still to be explored. Indeed, the interactive environment and the dynamic scenario features can significantly help actors to better prepare for complex VFX scenes. Film professionals who took part to our project, gave us many informal feedbacks. When we presented them with the final demonstrator they found it very interesting and anticipated that such a setup would be extremely useful, especially in a portable configuration (i.e HMD).

Our VR rehearsals system can be improved by several technologies which would improve its efficiency while reducing its cost. First the use of markerless capture systems would remove the need of wearing invasive equipments such as reflective marker suits. New technologies will also provide more accurate visual cues adapted to actors. For example, we can imagine actors wearing AR glasses to rehearse. It is also possible to use low-cost tactile devices to provide actors with haptic feedback. For example, when a collision occurs between the actor and a CG element. It can also be used by the director to point out a key moment to actors. The use of AI techniques on avatars could also be explored to make the world react according to the actors engagement as described in ([12]).

Eventually, by combining the aforementioned technologies with active chroma-keying screens our system could also be used during the shooting phase. Chroma-key screens and clothes are already available and used in TV studios but their usage can be extended to movie sets. Thanks to polarisation filters (see [19]), it is now possible to project images on a retro-reflective screen: the camera then only captures the combination of real objects, actors and monochromatic surface used in chroma-keying. In [1], the authors propose several ideas concerning possible feedback from real to virtual scene elements and vice versa. For instance, it is possible to extract positional information, shapes or reflectivity of objects and actors in order to make a rough 3D model. Thus, it is possible to model visual feedback such as the shadow of the actors on the virtual environment. Projection systems that allow visualisation of the virtual scene without interfering with the set illumination and without losing the possibility to perform chroma-keying would open an avenue of possibilities. In this way, positional cues could be added but also temporal and textual cues such as avatar-based emotional feedback.

It is worth noting that screen projections have already been used for filming. A sequence in the movie Oblivion by Joseph Kosinski has been filmed on a set surrounded with screens where images of skies were projected[3]. These images not only help actors to remember that they are supposed to be in a tower 3,000 feet above the ground but the reflectivity of the screens was used to light the set and the actors. Very realistic shots were obtained, and changing the weather and the time of the day could be performed at the shooting stage, thus saving a lot of time and money in post-production.

6 Conclusion

This paper presents the use of VR to help actors in rehearsing scenes that include VFX. In the majority of VFX movies, actors have to perform in front of a green screen, an exercise that summons very different skills than those used in traditional acting (a full-detailed scenery vs. a neutral green screen, real partners vs. virtual or symbolic partners, etc.). Furthermore, the actors' performance must respect a precise timing, precise positionings as well as precise gestures to avoid an extra cost in post-production when adapting the CG to the real footage.

Our VR acting rehearsal approach relies on two main features: an interactive environment and an interactive scenario. On the one hand, the fully interactive environment enables actors to interact freely with objects in the environment as well as with virtual characters. On the other hand, the interactive scenario allows scenario-driven actions to be synchronised with the acting of the user. Thus, actors can focus on acting and on dialogues rather than on the timing of the animations.

In an experimental study, we compared the classical rehearsal process with a VR rehearsal. The results of this study show that VR trained actors perform as well as classical trained actors during shooting. Moreover, after having tried both rehearsal conditions, every participants expressed a preference for VR rehearsal to standard rehearsal. It demonstrates that VR rehearsal can replace classical rehearsal while offering much more flexibility in where and when the rehearsals can take place. Moreover, our VR acting rehearsal approach provides other supports for actors through the combination of an interactive environment with an interactive scenario. This work needs further investigation to clearly evaluate if and how our global VR approach can help actors. "Does the interactive environment help the actor to be more involved during shooting ?" and "Does the interactive scenario help the user to be ready more rapidly ?" are some of the questions we want to answer.

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