Acting in Virtual Reality

M. Slater, J. Howell, A.Steed, D-P. Pertaub, M. Gaurau
Department of Computer Science
University College London

Sharon Springel
Centre for Communications Systems Research
University of Cambridge

ABSTRACT

Three pairs of professional actors and a director each met in a shared non-immersive virtual reality system over a two-week period to rehearse a short play. The actors and director never met one another physically until a short time before a live rehearsal in front of an audience. The actors were represented by avatars which could be controlled to make a range of facial expressions, and some body movements, including navigation through the space. The study examined the extent to which virtual reality could be used by the actors and director to rehearse their later live performance. Four indicators captured by questionnaires show that over the period of the four days their sense of presence in the virtual rehearsal space, their co-presence with the other actor, and their degree of cooperation all increased. Moreover their evaluation of the extent to which the virtual rehearsal was similar to a real rehearsal also increased. Debriefing sessions with the actors and director are reported, which suggest that a performance level was reached in the virtual rehearsal which formed the basis of a successful live performance, one that could not have been achieved by learning of lines or video conferencing.

Keywords
Virtual reality, multi-user, networked applications, facial animation, virtual rehearsal, acting

1. INTRODUCTION

Practical applications of virtual reality are normally in the realms of engineering, product design, and skill rehearsal. Users enter into a virtual environment in order to learn something new about the real situation to which the simulation corresponds, or to improve or learn a skill set. Professor Frederick Brooks Jnr recently carried out a survey of such applications [1] which included vehicle (aircraft and boat) simulators, design and prototyping systems, a NASA astronaut training system, and a nano-manipulator for visualization. The one application in Professor Brooks' review that seemed to step outside of the design/engineer/skill-rehearsal applications suite was psychotherapy for fear-of-flying and post-traumatic stress disorder. However, even in this case, users engage with an external simulated environment in a way that is consistent with the approach of behavioral exposure therapy. Here a patient interacts with a psychotherapist using the simulation and the experiences it evokes as a common point of contact.

A characteristic of each of these types of application is that groups of people interact with one another through their shared interest in some simulated objectified process: flying the aircraft, viewing the design prototype, or examining the visualization. The virtual reality in each case provides a scenario, and the fundamental interaction is between each individual user and the environment; interaction between people occurs with respect to their common interest in the scenario.

In this paper we explore a different virtual reality paradigm in which the objective is emotionally significant interaction between people, rather than between people and some other situation or thing. The virtual environment provides only the setting in which person-to-person engagement takes place, it is the interaction between the people, and the 'emotional atmosphere' which this generates which is the major objective of the experience.

The scenario in which this is explored is that of dramatic acting, in particular virtual rehearsal for live drama. Suppose actors and their director never meet one another, except in a virtual reality setting, until a short time before a live stage rehearsal. We consider the question: to what extent can they create sufficient acting performance so that a *live performance* can take place with *hardly any live face-to-face rehearsal*?

The practical motivation for this was first suggested by the head of research at the BBC: If it is possible for rehearsal to take place in a distributed virtual environment, then significant savings could be made in pre-performance production and planning. Actors could stay situated wherever they may be in the world, continuing with their current commitments, while nevertheless devoting some time to rehearsal of a new production via a shared VE. The actors, director and others involved could get to know one another. The technicians could work out camera angles and lighting in parallel with the performers working out their *blocking* (i.e., the spatial arrangements of the performance in synch with the dynamics of the narrative).

Acting rehearsal is more than just learning of lines, which is the least important part of the rehearsal process. Actors must *act* in

order to rehearse. Acting involves accessing and expressing the full range of human emotions in a way that produces the appropriate affect in the audience. Actors also, of course, play from the emotional expression delivered to one another. The same must be true during rehearsal:

> "In the beginning, during rehearsals, I would replace Fritz's name with my fiancé's, and pretend I would never see him again," Vujoshevich says. By personalizing the situation, she found she was able to convey the pain and sadness and fear the character was feeling."

This describes a strategy used by actress Tania Vujoshevich in her rehearsal of a role in a Berchtold Brecht play [2].

In physical reality actors have complete access, both consciously chosen, and unconsciously generated, to the display of their emotional state through the normal everyday employment of their facial expression, body posture, and vocal chords. To what extent can the impoverished substitute for emotional expression available through today's VE technology support acting performance?

2. BACKGROUND

Research into the exploitation of virtual environments for drama has concentrated mostly on the creation of synthetic characters with believable personalities which can perform, and interact with human participants, for example [3][4][5][6]. Another goal is the exploitation of the medium for story-telling. For example, Disney's Aladdin immersed and allowed participants to interactively explore a virtual world based on the animated movie [7]. More recently the VRMLDream company created a performance with actors directly controlling virtual characters[1]. This simulated a traditional drama, except that it occurred entirely in a distributed VE. Viewers could navigate the scenario with a standard VRML browser, and thus choose their own viewpoints, unlike the situation in live theater or film.

A system which synthesizes a collaborative VE with live TV broadcast is described in [8]. In this case members of the public interacted with professional actors in a game, which was simultaneously edited and broadcast for live TV. This was an attempt to exploit a collaborative virtual environment (CVE) as a medium in itself for the creation of a new form of entertainment.

The use of a VE for rehearsal of a later 'real life' performance of a play has not, to our knowledge, been described elsewhere in the literature. The closest to what is reported in this paper was the use of video-conferencing to rehearse an adaptation of the Diary of Vaslav Nijinsky, developed by the New York based Gertrude Stein Repertory Theatre[2]. The artists involved were employed on other projects at regional theaters throughout the US and Europe. The video-conferencing system was used in order to allow choreography changes to be agreed by the performers, director and other designers involved. The major advantage of such an approach is that live video of the real performer is distributed. However, this is at a cost of fragmentation of the total space: the performers never actually share the same space together.

The situation we are examining, virtual rehearsal for a live performance, is from a technical point of view a CVE, where the participants meet to carry out a shared task that they will later perform together in real life. Such situations have been rarely studied. In [9] an experiment was described where 10 groups of 3 people each met first in a virtual environment to try to solve a set of riddles plastered on the walls of a virtual room. After meeting virtually for a while they then met in the corresponding real room and continued the same task. The point was to see how their social interaction changed from the virtual to real experience. The participants were represented by simple block-like humanoid avatars, with no possibility of exhibiting facial expression. Arm movements were only possible for the one immersed participant in each group. The major findings, that relate to this paper, were that the avatars took on personal and social significance, notwithstanding their extreme simplicity, reproducing an earlier result [10]. In two follow-up studies [11][12] similar results were found. However, it was always found that the avatars' lack of expressiveness (they were only able to turn and move through the environment) impeded the development of significant social interaction between participants.

It is important to distinguish different types of avatar expressiveness. In [13] an experiment is reported that compares the efficacy of emotional and envelope feedback for automated avatars in conversation with humans. *Emotional* feedback employs specific emblems such as a smile or scrunched eyebrows to express underlying emotions such as happiness or puzzlement. *Envelope* feedback refers to non-verbal behaviors such as gaze timing and distribution, precisely-timed eyebrow changes, head movements, hand gestures, and expressions with the mouth. These punctuate the conversation as a secondary feedback channel, helping, for example, to regulate turn-taking and hesitations in speech. The experiment showed that envelope behavior was not only more important for regulating the conversational flow, but that avatars exhibiting such behavior were rated as more helpful and lifelike compared with avatars that exhibited only emotional feedback, or only a constant neutral expression.

Envelope behaviors are not consciously initiated by the speaker, not consciously noticed by the onlooker, but their absence is detrimental to interaction. In [14] the principle of automated envelope behaviors was applied to embodied avatars, i.e., those representing people in a collaborative virtual environment. The BodyChat system provides semi-autonomous avatars for participants. Users may control their navigation, and type messages to others, but the envelope communicative behavior is automated based on the current intentions of the user towards others, as set by the user for their corresponding avatar. For example, an avatar may be put into a state of 'availability' with respect to another user, meaning that there is interest in having a conversation. The avatar then automatically generates the appropriate non-verbal behaviors, given the opportunity, such as glancing towards the other avatar and making appropriate salutations.

It is argued in [14] with supporting experimental evidence, that allowing the avatar itself to take care of such automatic non-verbal behaviors not only frees the user from having to control every eyebrow and mouth movement, and thereby avoiding the 'dead' moments while they are typing messages, but also adds to the efficiency and smoothness of the resulting conversations. The avatars also automatically carry out low level non-verbal behaviors such as blinking and breathing - adding to their very high degree of 'aliveness' and presence.

The results of the series of three-person experiments in [9][11][12], together with the results of [13][14] informed the

1. http://www.vrmldream.com
2. http://www.ibm.com/sfasp/vr.htm

design of our acting rehearsal system. It was decided that the actors had to have the capability for making facial expressions, and some body gestures - especially to be able to position the head, and make arm gestures. Actors pose a tough challenge: they *must* exhibit both envelope and emotional behavior, but on the other hand they know in advance what they're going to say. So their whole focus is on *how* they say it, and for them to be able to find just that way of saying it that can evoke the appropriate response in their partners and in an audience. It was thought that actors must therefore have significant control over the behavior of their avatars. Accordingly their avatars should not automatically generate envelope behaviors, but allow the actors to choose these as appropriate. However, low-level behaviors, such as blinking, and mutual gaze-locking, were generated automatically.

A second way in which this application differs from traditional conferencing or chat rooms is that the virtual interaction is a rehearsal for real life. So another question is the extent to which through the virtual rehearsal process the actors construct an internal codification of the play that later transforms to their behavior on stage.

3. THE VIRTUAL REHEARSAL STUDY

3.1 The Scenario

A script was developed from a training program previously used at the UK's National Film and Television School. The script was for a play of about five minutes. This involved a man and a woman in a kitchen in the morning having an everyday conversation about mundane matters while preparing to go out. Three pairs of actors took part throughout. (On the first day there was an additional couple, but one of them had to withdraw due to an unexpected acting engagement). They were paid enough to cover their expenses for each meeting, with a bonus after completion of the entire rehearsal process.

There were two directors. One (S) had been directly involved in the design of the study for several months. S had a strong background in film and TV screenwriting and direction. The second (B), not involved in the planning of the study, was a co-chair of the Directors Guild of Great Britain. S directed two of the groups, taking a largely passive role - allowing greater freedom for the actors to establish their blocking and individual expression. B was more directive, suggesting individual moves, frequently commenting on how well the performance was working, sometimes, as is traditional, leading to conflict with the actors.

The actors and their director met four times virtually and then on a fifth time to carry out the rehearsal for real before a live audience. The actors never met each other or the director physically until the fifth and final occasion. On each of the first four occasions the actors and their director met in the virtual environment for about one hour. About 30 minutes of this time was spent in actual rehearsal - the rest of the time was setup, discussion, practice with the system, awaiting for system breakdowns to be repaired, and answering a questionnaire. On the fifth time the actors again met their director for about 30 minutes in the VE, and then they met immediately afterwards physically for the first time in the real rehearsal space. They then had about 10 minutes to carry out some live rehearsal, before the audience was let in and an observed rehearsal was carried out. The four rehearsals took place two per week for two successive weeks, and the last virtual rehearsal was on the Monday of the third week followed immediately by the live rehearsal watched by an audience. The audience, of about 20, were recruited by advertisement around the department.

At the end of each of the first four rehearsal sessions the actors completed a short questionnaire. This was followed by a debriefing carried out by two of the investigators. At the end of the live rehearsal actors were questioned by the audience, and in the evening had a round table discussion where all pairs met together for the first time.

The virtual rehearsals, live performances, and all debriefing sessions were video-taped. During the virtual rehearsals the actors' screen views were video-taped with an inset of their real selves in a smaller screen window. The director's view was also video-taped. The director also acted as a camera controller, so that complete virtual rehearsals were recorded from this third position.

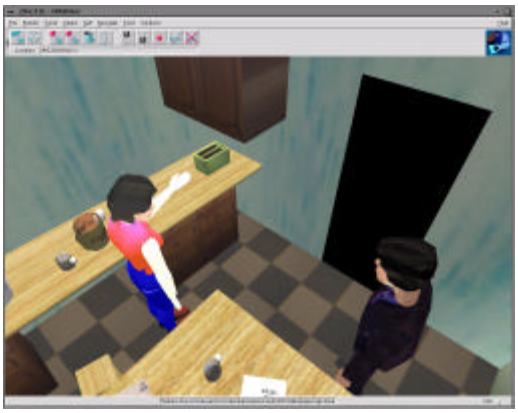


Figure 1 An Overview of the Rehearsal Space

The virtual rehearsal system was implemented using the DIVE 3.3x platform [15][1]. Both actors and the director used desktop displays. One actor used an SGI Onyx with twin 196 MHz R10000, Infinite Reality Graphics and 64M main memory. The scene was shown on a 21 inch monitor covering the full screen. The second actor used an SGI High Impact system with 200Mhz R4400 and 64MB main memory, again with the scene shown on the full 19 inch display monitor. The director used an Onyx2 system comprising a Graphics Rack with 8 R12K processors, 8Gb RAM, 180Gb disk and 4 IR2 Graphics pipes each with 2 Raster Managers. The monitor was 23 inches and the full screen was used for the display.

The actors were embodied as avatars who could see and talk to one another in the shared virtual space. The director was a disembodied voice with no visual representation. The actors were often reminded that the director was taking the 'downstage' position, equivalent to where the audience would sit.

The scene was a virtual kitchen with an outside ante-room representing off-stage. The kitchen and avatars consisted of about 3500 polygons and was rendered by DIVE using OpenGL calls. An overview is shown in Figure 1. The frame-rate was at least 20 frames per second on all machines.

1. http://www.sics.se/dive

Although the script was emotionally neutral, and remained substantially the same throughout, each time the actors met they were told by the director to act according to a different sub-text. For example: it was early morning and the night before one of them had crashed their brand new car. Or, they had been sharing the same house together for some time as friends, but last night after a party they had slept together for the first time - but neither knew if the other really meant it. Or the woman was awaiting a phone call that would give the results of a biopsy. On the fourth rehearsal they chose a sub-text themselves, either one of the previous ones that they had rehearsed or a new one. This sub-text was the one to be rehearsed before the live audience.

3.2 The Avatar and Facial Model

The male avatar originated with the DIVE system, but was edited to improve the face and hair in particular. Some very basic animation capabilities were provided that allowed the avatar to sit, stand up and move its arms either singly or together. In addition, the body was texture-mapped for clothing.

The body of the female avatar was an adapted version of an H-Anim compliant avatar called Nancy, created by 3Name3D[1]. A modified subset of the geometry was used since the original avatar had no facial animation. A new head, hair and eye geometry was devised and fitted to the female avatar and various of the body parts were scaled and adjusted.

Both the male and female avatars were fitted with a new face to enable facial animation. The face was texture-mapped to help with the required masculine or feminine appearance. Facial animation was based around a muscle model originally proposed in [16]. The face itself was obtained from a program supplied in [17], and the accompanying animation algorithms were rewritten for DIVE. The facial animation interface allowed five major expressions to be displayed: happiness, anger, surprise, sadness and a neutral expression. The code was designed to enable the actor to specify an intensity for any one of the four major expressions and also to allow for asymmetric facial expressions. Some examples are shown in Figure 2.

3.3 The Controller for Facial Expressions

It would have been simple to provide a visual menu of facial expressions from which the actors could select by point-and-click. However, this was not employed for two reasons. The first is that actors would need to continually scan the set of displayed faces in order to choose the one that they wanted - this at the same time as speaking their lines, watching the other actor, and moving through the environment. The second is that we wanted the actors to be actively engaged in determining their facial expression - giving them the feeling that it was somewhat under their control, and also making the actions that they carry out somewhat consistent with the expression that they were trying to induce. So instead of a menu system, the actors controlled their facial expression by means of mouse strokes on an abstract 'smiley' type face. Intuitively, to evoke a smile they would draw one.

1. http://www.ballreich.net/vrml/h-anim/h-anim-examples.html

The abstract face was divided into a top and bottom half. A stroke on the bottom half would affect the mouth - determining a smile, a grimace or a neutral expression - controlling the degree of happiness or sadness. A stroke on the top half would affect the eyebrows - controlling the degree of anger or surprise. These two sets (happiness/sadness, anger/surprise) were orthogonal, so that combinations of the two could be produced. Moreover the intensity of each could be controlled, thus allowing a wide variety of facial expressions.

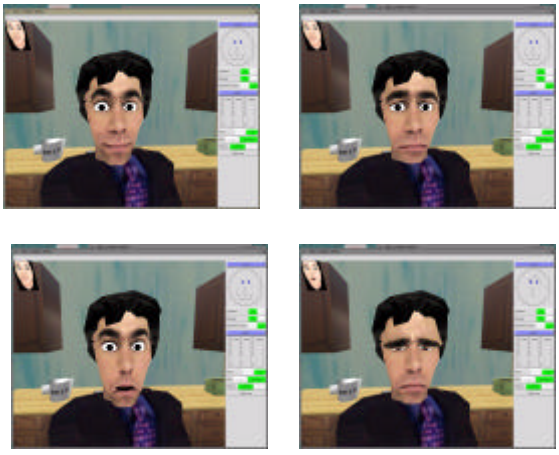


Figure 2 Some Examples of Facial Expressions

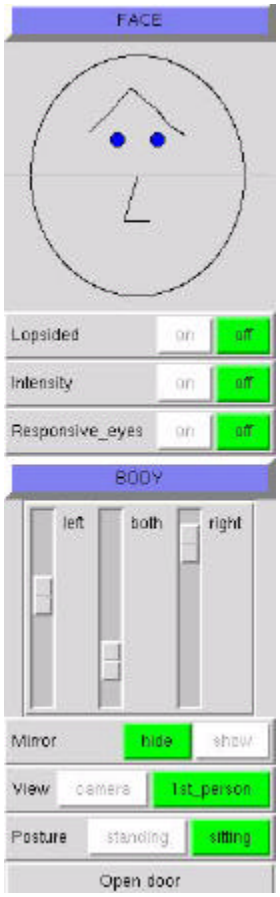
A very simple recognition algorithm was used. For the mouth a triangle was determined from the stroke action. A stroke such as $\wedge$ would be interpreted as 'sad' and $\vee$ as 'happy'. The sizes of the gradients on each side together with the area of the triangle were used to determine the intensity of the expression, and also the degree of symmetry. A similar method was used for the eyebrows with $\wedge$ used for surprise and $\vee$ for anger. An approximate horizontal line would result in a neutral expression in each case. The intensities were truncated to a maximum before being passed to the face plugin. After a relatively short degree of practice (specifically by the second rehearsal session) all of the actors but one were using facial expressions with ease.

3.4 Other Controls

The screen was divided into two windows. The main screen-sized window showed the scenario. An overlaid smaller window had the face controller at the top, and other controls in the lower half. This is shown in the inset below.

By using the mouse in the main window, the actors could move their avatar's head in any direction, thus changing their viewpoint, while leaving the body stationary. They could also use the arrow keys to move the body forwards or backwards in the direction the head was facing. Thus in principle the head and body direction were independent. At first this movement was completely free, but after the first session the actors complained that this freedom was too confusing (their heads could be twisted back-to-front reminiscent of The Exorcist) so the system was adjusted such that when

the head turned around more than 60 degrees from the front, the body was swivelled around automatically.



The arms could be raised or lowered independently of one another using sliders.

It was possible for the actors to move between a first person, egocentric point of view, or a second person disembodied point of view where they could see their own avatars. All the actors always used the first person ego-centric viewpoint. Although they could see the facial expression of their partner they were very concerned to ensure that their own expression was as they intended. Since it was inconvenient, and caused a break in their sense of presence to shift between ego- and exo-centric viewpoints, they requested a 'face mirror' that could be switched on and off. This was displayed as a small rendition of their own avatar's face at the top left corner of the main window (as can be seen in Figure 2). The expression intensity control could be switched on or off (it was left 'on' by default), and similarly for the ability to create asymmetric expressions (the 'lopsided' switch in the inset). The actors complained in the earlier sessions that they were not sure when the other actor was 'looking' at them. Hence a gaze lock was installed, so that eyes momentarily locked when the avatars faced each other.

4. RESULTS

The authors of this paper were sceptical about the possibility of this virtual rehearsal system offering the possibility of performance rehearsal. It was believed that the actors would feel alienated by their inability to express themselves, by their disembodiment, and would quickly walk away. The positive results achieved were therefore surprising. All six of the actors saw the process through to the end. Five of the six had no difficulties with using the system after the first session, and experimented with its possibilities. One of the six found great difficulty even in navigating through the environment at all, was at first extremely ill-at-ease with the whole process, but voluntarily suggested attending for 'out of hours' additional practice with the interface, and so attended 30 minutes earlier on the next occasion. By the end of the process she was capable of using the system expressively.

The results are reported through the questionnaire responses, debriefing comments including those of the director (B), and most important of all direct observations of the process, since it is impossible to objectively quantify the degree of acting performance achieved.

4.1 Questionnaire Responses

After each of the first four sessions a brief questionnaire was issued to the actors. This concentrated on four issues, each elicited by one or more questions on a 7-point scale with 1 indicating a low degree and 7 a high degree of the corresponding attribute.

Similarity to real rehearsals

- Think about your recent rehearsals in real life. To what extent did you feel that the rehearsal you have just experienced was similar to those rehearsals?

Co-presence

This is the extent to which the computer becomes transparent and there is a sense of being with the other people in the VE. It was elicited by two questions:

- In the rehearsal you have just experienced to what extent did you feel that the other actor was in the space with you?
- When you think back about your experience, do you remember this as more like just interacting with a computer or with other people?

Presence

This is the extent to which the individual is able to suspend disbelief and have a sense of being in the virtual space. It was elicited by two questions:

- To what extent did you have the sense of being in the rehearsal space? (For example, if you were asked this question about the room you are in now, you would give a score of 7. However if you were asked this question about whether you were sitting in a room at home now, you would give a score of 1).
- To what extent were there times during the rehearsal when the rehearsal space became the reality for you, and you almost forgot about the real world of the lab in which the whole experience was really taking place?

Cooperation

- To what extent, if at all, did you have a sense of cooperating with your acting partner?

The questionnaires were used as approximate indicators of what was taking place. The results on all four indicators are clear (significance tests are not appropriate for such small samples). For each actor individually, and for all as a group, there was an improvement in all indicators over the four sessions of the experiment as shown by the scatter-plots of mean responses in Figure 3.

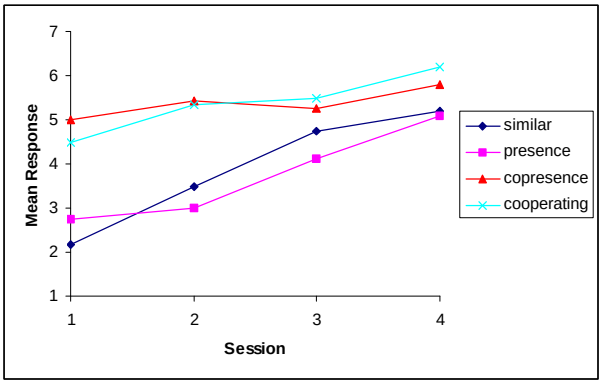


Figure 3 Questionnaire Results

4.2 Debriefings

A free-format discussion was held, where possible, with each of the actors separately after the sessions. The actors were encouraged to talk about their experience, and the focus was on the similarity to a real rehearsal, and the extent to which the virtual rehearsal system could be used for some level of acting rehearsal. The general impression, as would be expected, was that after the initial session the actors were doubtful. By the end of the process they were clearly all very much at ease with the system, and had positive comments about the virtual rehearsal process. Here are some of the comments:

Session 1

> "I felt clumsy... I can smile and walk and talk like this [points to self] but until I can connect the virtual reality aspects to the way that I work - or not with the way that I work, with the way that I am - then I'm not actually going to be rehearsing."
>
> "It's so completely alien to the way that you usually rehearse, do you know what I mean? because you're thinking about such a different set of things. You don't ever think about walking into a room - you just do it, and you know, you never have your body twisted one way and your head another way."
>
> "... I couldn't really enjoy that space, I was still trying to move around ... it's like any actor's worst nightmare, it's the recurring nightmare - you're on stage, you're on a set, and you can't move, you're stuck there, you're having problems ... that's a real experience."

Session 2

> "I was using it more today, I was going over to the window moodily and things like that, and moving away and things like that - so that was quite good yeh..."
>
> "As it is now, I think it would be useful for establishing blocking, but not very much more - and I find myself tending to go through this exercise of storing up what I *will* be doing when I'm in real life."

The last point is particularly significant. It expresses one of the major goals of the virtual rehearsal. It is, after all, for the actors to collectively work out together with their director what they will be doing in real life. It is not meant to completely replace the live rehearsal process as a whole - but to lead into it where circumstances are such that meeting for real is not possible. As the director B said in an interview:

> "We're talking about remote rehearsal here, and if you can't get a group of people together in the same room, it looks to me like this is on the right lines."

Session 4

The actor who had the greatest difficulty with the system commented:

> "It's kind of becoming - having its own kind of reality ... we've only done it four times now, and now that that horrible beginning is kind of finished ... you could see that it then becomes quite absorbing, and you kind of enter into it."

Post rehearsal discussion

Not all actors agreed that this type of rehearsal could ever replace real rehearsal (though that is not the point). One in particular strongly missed the sense of 'body heat' that is generated when people are near to one another. However, in the round table discussion that followed the live rehearsal, one made an important point, generally agreed, that again strongly fits the intended goals of the virtual rehearsal system:

> "Virtual rehearsing *isn't* actual rehearsing, in the same way that a telephone conversation *isn't* a real conversation. However, you can communicate on a telephone very effectively but using a different skill set."

Spatial Organization

As mentioned above one of the actors commented, and again this was a general agreement, that the rehearsal system could at least be used for establishing blocking, working out of the spatial arrangements of the actors during the play. This in itself could be a significant saving - one of them remarking that in even a modest production just the blocking itself could take a full week to agree. The fact that this occurred is evident on the video recordings, where actors are seen to be adopting the same positions and orientations in the virtual and real rehearsals.

This is a crucial area where the virtual rehearsal system would differ from, say, on-line audio or video conferencing. In the virtual rehearsal the actors share the same space, and are able to position themselves in that space in relationship to the script and the other actors. Different alternatives can also be tested, as was frequently observed during the virtual rehearsal process. Moreover it may have an advantage here over a normal live rehearsal room, where the space and objects within it are usually marked out by tape and chalk-marks on the floor. As one actor said:

> "... part of the normal experience - is to use your imagination, get these little anchor points, then you go on the set and you go 'It's nothing like how like I imagined it' [breaks into laughter]."

From a computer graphics point of view, modeling the set is the simplest part of the process.

The actors clearly did construct an internal mental model of the rehearsal space. Each one was asked during the debriefing session to imagine that the rehearsal space was embedded in the debriefing room itself, and then point to where the various items in the rehearsal space would be located. Each one was able to do this with complete success.

4.3 Observations

Director B was asked, after Session 2, whether he thought that the actors had achieved the sub-text of the session (that the woman was waiting for a telephone call about the results of a biopsy):

> "Yes, yes, and what's more I think that they achieved it not only vocally; and re the remarks that Bill was making that this being like a radio play, I think that they were beginning to achieve it physically as well.... they seemed to be physically downcast, looking down a lot - in an emotional sense they were varying their distance, the distance between them, quite truthfully I felt ... At this stage I think that still they don't quite trust it.... Their actions were more - a little more - sophisticated towards the end of the exercise, you could see that they were beginning to use their head movements *in character* rather than simply looking about or trying to find each other..."

An example of a such a head-move 'in character' is shown in Figure 4. An example of the actors choosing an appropriate distance between themselves, to reflect the current emotional demands of the script is shown in Figure 5.

The actors made use of pointing gestures, for example, as shown in Figure 6. They clearly made use of emotional facial expressions. What is impossible to show with static pictures is that they also generated envelope feedback. For example, there are scenes (shown on the video recordings) where the man is seated at the table, and glancing towards and away from the woman as their

conversation progresses. There is another scene where they are standing together and each is making head nods and shakes punctuating their conversation in a very realistic manner. This took the investigators by surprise. The possibility of using the head control for this effect was never told to the actors. However, most of them quickly realized that they could use the mouse in order to make rapid small head moves. Just as in Figure 5, where the woman actually sees nothing useful on her display (the viewpoint is too close to the texture map) the whole point of this was to create an effect in the other actor (and ultimately for the audience).

Figure 4 The man is telling the woman not to worry after she admits opening his letter by mistake.

Figure 5 Varying the emotional distance between themselves.

5. CONCLUSIONS

This paper has described a system for virtual rehearsal and an in-depth study of its use by professional actors and directors. In most applications of VEs the nature and style of interaction between the participants is to help them achieve some other effect - such as having a discussion, learning a new skill, or understanding some complex visual structure. In virtual rehearsal, it is the interaction itself which is the purpose of the application. Emotional and envelope expression, gestures, and the use of the space is the whole point of the VE, together with the question of whether the virtual performance is helpful in a transfer to a real-life performance.

Figure 6 The use of pointing.

The addition of the ability to make some facial gestures and to create envelope feedback compared to previous CVEs was exploited to the full by the participants. Although the purpose was rehearsal for a later real-life performance, it was the impression of observers (admittedly an entirely subjective point of view) that the director's viewpoint of the virtual rehearsal showed significant acting performance. The actors, professionals, clearly wanted to impress, and used everything in the armory given to them in order to do this.

Of course what was feasible is impoverished compared to what is possible in real life. As one actress repeatedly commented, it was impossible in a virtual rehearsal to reach out and touch, and really feel this in an emotionally significant way. However, in spite of the relative complexity of the interface and the paucity of what was possible, the actors learned to use it, and mostly to use it well, in a remarkably short amount of time. Moreover, precisely because the virtual reality was so far from reality, expectations were relatively low: no actor ever commented on the fact that there was no lip synch for speech. We hypothesize that there is a type of avatar that is so poor that no useful interaction can take place between people. On the other hand as avatars improve there is a point at which they raise expectations to such an extent that the illusion breaks. This was noted in [13] where some expected behavior did not occur because: '... when an agent is so successfully human-like in its communication style ... it raises user expectations past what can be currently met.' The avatars used in the virtual rehearsal system seem to fall between these two extremes.

Finally, was there transfer from virtual rehearsal to the real-life rehearsal? The answer is almost certainly yes: the directors agreed that what was done in the ten minutes of live rehearsal before the audience entered could not possibly have produced the performance that was observed. Of course, once again this is subjective, but what can be seen are transitions from virtual to real in the use of the space (Figure 7). In a question and answer session after their live performance actors generally agreed that the virtual rehearsal had made their performance possible. For example, when asked "Was it a fruitful transition [the transfer from VR to 'on-the-floor']?", one replied: "Yes, absolutely ... all the detail went in just in that 10 minutes we spent ['on-the-floor']. It was detail that I'd

planned [during the virtual rehearsals]." His partner concurred: "Yes I agree that we rehearsed in that virtual reality space, and therefore, you know, that's where all the stuff came from."

The whole notion of 'performance' is, of course, beyond quantification, so the authors can only rely on the directors and actors to judge this. An independent visitor during the *first day only* of rehearsals later wrote [18]:

> "It was remarkable watching the actual actors on separate monitors as they rehearsed on-screen under the gentle, succinct control-booth guidance of [the director]. Of the four couples that I witnessed, seven of the actors clearly reached some level of emotional engagement with their virtual partner at some point; one or two were almost consistently emotionally expressive and responsive. When present, the emotional content was clearly perceivable, vocally and gesturally. The lone exception was a young woman who, by her own admission, was computer illiterate and completely befuddled by the keyboard/touchpad/monitor set-up. Her acting partner rushed, on-screen via his avatar, to her aid in the VR kitchen and did his best to help her through her dilemma. An off-script, rehearsal-like, emotional exchange was occurring."

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Figure 7 Virtual and Real at the same moment in the play.