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Conference Paper · January 2001

DOI: 10.1145/365024.365033 · Source: DBLP

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Orchestrating a Mixed Reality Performance

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ABSTRACT
A study of a professional touring mixed reality performance called Desert Rain yields insights into how performers orchestrate players' engagement in an interactive experience. Six players at a time journey through an extended physical and virtual set. Each sees a virtual world projected onto a screen made from a fine water spray. This acts as a traversable interface, supporting the illusion that performers physically pass between real and virtual worlds. Live and video-based observations of Desert Rain, coupled with interviews with players and the production team, have revealed how the performers create conditions for the willing suspension of disbelief, and how they monitor and intervene in the player's experience without breaking their engagement. This involves carefully timed performances and "off-face" and "virtual" interventions. In turn, these are supported by the ability to monitor players' physical and virtual activity through asymmetric interfaces.

Keywords
Mixed reality, performance, traversable interfaces

INTRODUCTION
The increasing use of computer technology to create engaging public experiences in galleries, museums, exploratoria and theme parks raises new challenges for HCI. How does the design of such experiences differ from that of more traditional workplace technologies? Should a new breed of HCI practitioner – the "imagineer" – address new aspects of human-computer interaction?

This paper explores HCI issues that have emerged from the study of a professional public experience; a touring mixed reality performance called Desert Rain. A combination of interviews, and direct and video observations of participants have been conducted throughout the touring process. These have revealed the ways in which the production team orchestrates the participants' experience, especially how the design of Desert Rain affords different opportunities of monitoring and subtly intervening in this experience without disrupting their engagement.

AN INTRODUCTION TO DESERT RAIN
Desert Rain was developed as joint venture between the performance art group Blast Theory, The University of Nottingham and Nottingham NOW Contemporary Art Festival. Desert Rain is a combination of performance, installation and computer game. Six players are sent on a mission into a virtual world to find six human targets. They explore motels, deserts and underground bunkers, communicating with each other through a live audio link. Once in the virtual world, they have twenty minutes to find their allocated targets, complete the mission, and get to the final room, where the identities of the targets are revealed. The virtual world is projected onto six rain curtains, screens made of water through which performers and players physically pass.

The artistic foundation of Desert Rain
The central artistic concern of Desert Rain is virtual warfare, the blurring of the boundaries between real and virtual events, especially with regard to the portrayal of warfare on television news, in Hollywood's films and in computer games. Whilst remaining deeply suspicious of this kind of theoretical position, Desert Rain draws inspiration from Jean Baudrillard's assertion that the Gulf War did not actually take place because it was in fact a virtual event. Both the content and the form of Desert Rain are designed to provoke participants to reevaluate the boundaries between reality and fiction, and between the real and the virtual. As the players eventually discover, the targets are six people who have quite different perspectives on the Gulf war:

- an actor who was on holiday in Egypt at the time;
- a soldier who served in the gulf war, driving a personnel carrier that collected Iraqi casualties;
- a soldier who was bedridden at the time of the war and watched it on TV;
- a peaceworker who helped establish a peace camp on the Iraqi-Saudi border in December 1990;
- a journalist who was in Baghdad on the night the air war started;
- an actor who played a soldier in a TV drama about the Gulf War.

The set for Desert Rain is a combination of the real and the virtual, each mirroring the design of the other, and connected through the permeable and physically traversable rain-curtain. Finally, it remains a puzzle for the participants what the nature of their mission is; is this a game, a drama or an interactive installation?

Desert Rain from a player's perspective

Perhaps the best way to understand Desert Rain is to follow a player's experience from start to finish.

The whole experience lasts for approximately forty minutes. It begins in the physical world. Players buy tickets in advance and usually gather in their groups of six at the venue, although in one location, they gathered in the city centre and were then bussed out to the venue – a disused warehouse on the outskirts of the city. A performer leads them into a bare physical antechamber (colour plate, figure 2) where they are asked to remove their outer clothing, deposit mobile phones and similar possessions in a box under their chair. They don a uniform, an anorak, and are briefed as to their mission. The briefing introduces the six targets by name and photograph, explains how to navigate through the virtual world, and stresses the time critical and cooperative nature of the mission. There is no opportunity for questions.

Next, each player is led in turn by a performer to a fabric cubicle and is zipped inside (figure 3). There they stand on a personal footpad and put on a combined headphone/microphone headset. When all six players are in place, the water is switched on. Each player is facing their own personal rain-curtain – a large screen, roughly two meters tall by two and a half wide, composed of falling water, onto which is back-projected an image of a virtual motel room (figure 4). The image in the curtain has some striking aesthetic qualities: one's attention tends to switch between the image that appears to hang in the water, the water itself and the bright projection lamp that can be seen through the curtain (appearing like a hot sun in the desert sky). The sound of the curtain is also striking, even when wearing headphones. Behind the six curtains, unseen by the players, lurk two performers. The asymmetric nature of visibility through the rain curtain means that these performers can observe the players, without being observed in return.

Each footpad acts as a giant joystick; by shifting their weight on its surface the player can move forwards and backwards or can rotate clockwise and anti-clockwise, navigating through the image of the virtual world that is projected onto their own personal rain curtain.

The action now switches to the virtual world. The six players begin their journey through this world isolated from one another, each in a separate virtual motel room. Each motel room contains a virtual TV set that plays back a short video recording of the Gulf War coverage from CNN news (as a video texture with audio). Eventually the player leaves the motel room through a door, passes into an open desert landscape beyond, and heads towards the centre of the world.

As the six players draw closer, they find that they can hear one another through the live audio link, mixed in with an ambient soundtrack. They may also hear voices (those of the performers) advising them where to go if they are lost or what to do if they are experiencing difficulties. When they meet, the players see one another represented as cube-like avatars with text labels (e.g., "player 1") and the texture mapped image of the relevant target for that player on the front. Each player eventually locates the virtual doorway that is labeled with the name of their target. On crossing this doorway, they find that they are standing inside a rotating white virtual cylinder, facing a sign that says "wait here".

The action now swaps back to the physical world. One of the performers who has been observing from behind the rain curtain, physically steps through the curtain (figure 8), slowly approaches the player on the footpad, gives them a plastic swipe-card and without speaking or otherwise acknowledging their presence, turns away and walks back through the curtain. Given that the players have been concentrating hard on the virtual world and that they are likely to be feeling somewhat disorientated, this is usually experienced as a highly dramatic, even shocking, event by the players. As a critic writing in the Sunday Times notes:

> "This change from virtual to real is remarkably sudden and strangely disconcerting." [Sunday Times, 31st Oct, 1999]

The action now swaps back to the virtual world. The players are encouraged to find the entrance to an underground bunker. Inside they find a maze of narrow corridors, similar in style to many contemporary computer games. Together they have to find the exit before their thirty minutes are up. Once found, the exit will only open if all of the players have found their targets (the players may be encouraged to help one another to find the remaining targets). If the team passes through the open exit within the allowed thirty minutes the performers appear again to lead each player forward, passing through the rain curtain – the reward for success. If they fail, the water is switched off before they are led forward to the next stage.

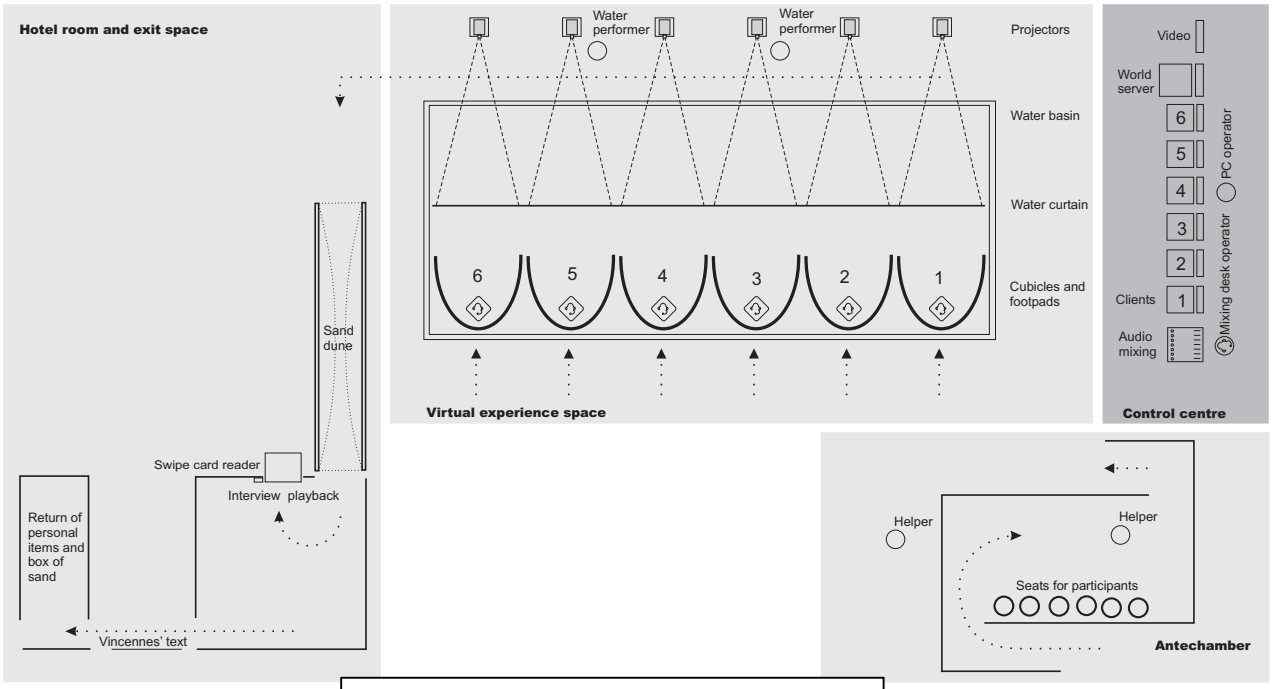

Figure 1: Desert Rain Infrastructure

For the final time, the action swaps back to the physical world. The six players pass along a narrow corridor and climb over an enclosed ramp covered in sand (figure 9) into a physical recreation of the virtual motel room – but one created by pasting wallpaper sized photographs onto the walls (figure 5). Here they find a real television set. Using the swipe card given to them earlier, each player brings up a video clip containing an interview with their target. The six clips show quite different perceptions of the Gulf War, revealed through interviews with the six targets. Finally, the participants change back into their original clothing and emerge from the experience. Sometime later they find that a small bag of sand containing an estimated 100,000 grains – the estimated number of casualties in the Gulf War – has been left in their pocket.

The technical foundation of Desert Rain

Technically, Desert Rain is a practical exploration of using mixed reality technology to create a coherent and engaging public experience. The specific mixed reality technology in question is that of traversable interfaces. These establish the illusion that a physical space is joined to an adjacent virtual space and that participants physically pass from one to the other (appearing to dematerialise from physical space and rematerialise in virtual space or vice versa) [5]. Early laboratory prototypes of traversable interfaces employed walk-through projection surfaces to create the illusion of physically stepping into or out of the image of a virtual world. One of these prototypes was the rain curtain, a fine water spray into which images can be back projected.

Desert Rain has taken the rain-curtain technology and used it to create a full-scale public performance. The rain curtain was chosen for its aesthetic qualities, both in terms of its striking visual image and sound, its asymmetric transparency (see below), and not least, due to the artistic association of projecting a virtual desert into a curtain of water. In fact, Desert Rain employs six rain curtains to create a shared mixed reality experience for six players that involves a journey through a combination of physical and virtual spaces and interactions with performers who appear to cross from one to the other.

The technical design of Desert Rain

Desert Rain is staged on an extensive physical and virtual set that is home to a complex array of technology. The virtual world is implemented in the MASSIVE-2 system. Figure 1 provides an overview of the physical set for Desert Rain (precise positions vary according to the physical constraints of the venue). This physical set can be divided into four main areas:

- The *antechamber* where the initial briefing takes place (figure 2).
- The *virtual experience space* consisting of the six cubicles, each with an associated rain curtain, footpad and projector. Figure 3 shows this from the players' side. Figure 6 shows this from the performers' side.
- The *hotel room and exit space*, consisting of the corridor of sand (figure 9) and the physical hotel room (figure 5).
- The *control centre* (figure 7). This houses the computers and related networking, audio and video technology for the virtual world.

Figure 2: The briefing room (see color plate on page 549) .

Figure 3: the players zipped into their cubicles (see color plate on page 549).

Three aspects of this set-up are worth particular note as they provide the performers with different ways of monitoring and intervening in the participants' experiences.

- Six computer displays located in the control centre display the viewpoints of the six players in the virtual world (as projected onto the rain curtains). These monitors enable the performers to follow all six players as they progress through the virtual world. Using the arrow keys on the keyboards, the performers can directly influence the movements of the players' avatars, effectively nudging them in particular directions.
- Using an audio mixing desk that is also located in the control centre, the performers can listen in to the conversations of the players. They can also make additional direct audio connections between pairs of players no matter where they are in the virtual world (normally, audio connections are established according to virtual proximity). Finally, they can speak directly and privately to particular combinations of players, giving them assistance or encouragement without the others hearing.
- Performers can also position themselves in the corridor behind the six rain curtains (figure 6) from where they can surreptitiously monitor the players. This is made possible by the asymmetric nature of visibility through the rain curtain. Looking back through a rain curtain, a performer can observe the physical player standing on the footpad, and can also see a (reverse) image of the player's view of the virtual world projected onto the player's body and the surrounding fabric of their cubicle.

The roles of the performers

The following table summarises the typical division of responsibility between the performers.

Performer 1 (antechamber)	Meet and brief the players in the antechamber
Performers 2 and 3 (behind the rain curtains)	Lead players to cubicles and zip them in. Observe players from behind the rain curtains, Cross curtains at the correct moment and hand over swipe card. Lead players to the corridor of sand.
Performer 4 (control centre)	Monitor players' progress through the virtual world and their conversations. Talk to players over audio.
Performer 5 (control centre)	Run, control and monitor software. Help steer players' avatars using the keyboards.

These individuals communicate with one another by whispering when co-located in the control centre or in the area behind the six projectors. They also employ a simple signaling system using flashlights for communication between these two spaces – for example indicating how many players are present in this performance (not always the maximum possible six).

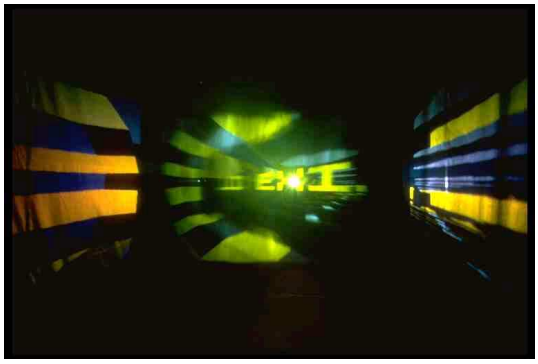

Figure 4: the image of the world on the rain curtain

Figure 5: the physical motel room

(See color plates on page 549) .

Figure 6: the corridor behind the projectors (see color plate on page 549) .

Figure 7: the control area (see color plate on page 549) .

The critics' responses to Desert Rain

Desert Rain emerged from a long period of development that began in the summer of 1997 to begin touring as a polished product in October 1999. It has since toured venues in the UK and Germany: Nottingham (October 1999), Karlsruhe (November 1999), London (May 2000), Bristol (June 2000) and Glasgow (July 2000). Early performances have generated considerable interest among art critics:

> "… is possibly the most technologically ambitious art installation ever made" and "Sombre as its aims may be, Desert Rain is exhilarating to experience first hand." [The Times, May 10th 2000]

> "… the experience does recreate some of the fear and disorientation that those on the ground during the Gulf War must have felt" and "part of a growing trend in performance and installation to blur the line between spectator and participant" [The Guardian, May 18th 2000]

However, our paper does not set out to debate the artistic merits of Desert Rain. Instead, it takes Desert Rain as a rare opportunity to learn from the successful professional application of mixed reality technology.

ISSUES RAISED BY DESERT RAIN

Desert Rain has provided us with a valuable opportunity to explore the use of computer technology to create an interactive public experience. We were particularly interested in the activities the production team carries out to fashion the participants' interactions with and in, the installation.

Following a preliminary investigation into Desert Rain while it was being prototyped at Karlsruhe in January 1999, we employed a range of methods such as direct and video-based observation and participant interviews to collect data at five further locations where Desert Rain was actually staged and performed – Nottingham, Karlsruhe, London, Bristol, and Glasgow. The combinations of materials provide insights into a range of issues relevant to the design of interactive public experiences that may not be so familiar from explorations into the use of advanced technologies in the workplace.

Desert Rain is not a stand-alone computer system but critically relies on a *production team* to support participants' interaction with the interface and in the virtual world. We have conducted detailed observations of the production team's actions and interactions carried out "behind the scenes" that provide important information on

Figure 8: crossing the curtain

Figure 9: climbing the hill of sand

Figure 10: rain curtain technology

(See color plates on page 550) .

how experiences are set and illusions are enabled. Also, we have investigated how the production team monitors and intervenes in players' action and interaction. The observational data have been augmented by informal interviews with artists and designers.

Field observation of *player's interaction* with and in the installation augmented by video-recordings of two players' viewpoints in the virtual world provide information on players' engagement with the exhibit and the organisation of their progress from the antechamber, through the virtual world to the motel room. We have also obtained insights into players' use of the interface, both footpad and rain curtain, and observed how they orient themselves to the virtual world and respond to the performer stepping through the curtain. Fifteen intensive interviews with participants after they have left the installation provided further information about their immediate responses to Desert Rain as well as about problems they had with the use of the interface.

Orchestration - managing the players' experience

Computers have traditionally been designed as tools to be applied autonomously by users. Embedded help and tutorial facilities provide users with a means to learn how to tackle problems by themselves. Laurel has offered an alternative view, that designers should consider computers as a form of theatre rather than as tools [6]. The key issue now becomes designing the user's experience so that they become engaged with the content rather than with the technology. "Behind the scenes" activities are required to successfully engage the user and to orchestrate their experience. These have to be hidden from the user's view, so that their engagement with the content is not disrupted.

As an example of an actual performance involving computers, Desert Rain offers insights into these issues of orchestration and engagement, especially how they can be achieved by human performers in real-time. In the following, we will see how Blast Theory have developed a range of tacit working practices and procedures for engaging players with the content – setting their expectations and enabling the illusion of traversal – and for monitoring ongoing events and intervening if necessary, with minimal disruption to their engagement.

Setting expectations and enabling illusion

Our observations suggest that, to a large extent, participants believe (or rather willingly suspend disbelief) in Desert Rain. The crossing of the rain-curtain by the performer creates surprise and excitement and helps to enhance the participants' engagement. In order to establish this illusion of traversal, Blast Theory conduct carefully designed actions that lead participants into and out of the different phases of the performance. At several points in the performance Blast Theory deliberately attempt to set the players' expectations, encouraging them to willingly suspend disbelief.

In the antechamber – participants are introduced to Desert Rain. As they enter the installation guided by a performer, participants are instructed to change their outer-clothing. In a command-like style they are briefed about their mission in the virtual world and engaged with the game. Before they are isolated from the rest of the group and guided one-by-one to their cubicles and zipped inside, they are advised to make use of the communication facilities in the virtual world. The importance of presenting a backstory prior to an interactive experience is well understood by the imagineers who design theme-park rides [4,7]. However, Blast Theory take this a step further. It can be argued that through a range of well prepared stages, participants are gradually desocialized like an inpatient in an asylum who "finds himself cleanly stripped of his many of his accustomed affirmations, satisfactions and defences" [2], and are subjected to a set of discomforting experiences. As the participants normally follow the performers' instructions quietly without showing any sign of resistance towards this desocialisation procedure, it seems that the performers' carefully conducted actions do indeed set the players' expectations and enable the illusion of the game.

Crossing the curtain – the moment when a player finds her target and a performer crosses the rain-curtain is the climax of the dramatic performance. After the players have navigated the virtual world for some time they have become familiar with the game and are ready for new experiences that help to maintain their engagement in the game. Blast Theory have designed the players' discoveries of their targets in a particular way that creates surprise and excitement and makes possible that their engagement with the game is strengthened by the crossing of the curtain. However, the crossing is a moment that is fraught with danger for the performers. The timing of their movement with the players' actions in the virtual world is of crucial importance. When players see the rotating virtual cylinder for a long time they become disoriented and question its part in the performance. They sometimes assume that the system has crashed and wait for a continuance of the program. If the performer walks too quickly through the rain-curtain the illusion of her emergence from the virtual world does not work. If the timing of the crossing is not right, it disengages the players from the game, and they attempt to involve the performer in conversation.

Leaving the cubicles – the virtual game ends when the players have found the exit to the virtual world and leave the cubicles. The performance, however, continues as the players are led to the motel room. This is perhaps the point in Desert Rain when it is most difficult to sustain engagement. It seems that players often assume that with the end of the virtual game the performance comes to an end as well. In early performances, they would meet their co-players in front of the cubicles where all of them would take off their anoraks, and then discuss with each other their experiences in the virtual world. Sometimes they would

attempt to return the swipecards to the performers. Only when they were asked to climb the sandhill did the tension build up again. However, it then collapsed again only a few seconds later after they have gathered in the motel room. Their excitement about the experiences in the virtual world appeared to take over and they began discussions with each other. They disengaged from Desert Rain prematurely.

In response to these observations, Blast Theory altered their orchestration of this part of the performance. The players no longer removed their anoraks until after the final motel room. Furthermore, the performers carefully planned the order in which to take the players from their cubicles, so that the players spent the minimum possible time together before moving on up the sandhill, and also so that the performers were best positioned to shepherd them on.

This last observation shows the level of detail that has to be considered when planning and executing a performance. This is a key point. The interactions with the players are meticulously planned and repeatedly rehearsed, including dialogue, inflexions, gestures and speed of movement. Potential problems are identified in advance and responses are rehearsed, with a particular focus on how they can be woven into the experience.

Monitoring and Intervening

Our observations indicate that the performers largely manage to lead the participants into the installation and engage them with the game. However, to ensure that the players' engagement with Desert Rain is maintained throughout their journey, performers continually monitor events in the virtual as well as in the real world. If the players' engagement with the game seems to be endangered at any point performers have to hand a range of prepared actions through which they can intervene in events. The players are never really isolated in their cubicle as the design of the installation allows the performers asymmetric access to the players, both in the virtual and physical worlds (through the computer monitors in the control area and the asymmetric nature of the rain curtain respectively). Monitoring and intervening can therefore largely be accomplished without the players noticing it. We have identified three styles of intervention.

Off-face Interventions are conducted by the performer at the control-centre to advise players about actions in the virtual world. Occasionally, the performer also attempts to influence the player's movement on the footpad. Off-face interventions are produced by means of the audio link to talk to a player and to advise her on which directions to take in the virtual world or on the use of the footpad. They cannot be conducted without the players noticing them. But performers use a specially designed, dramatic voice and almost always manage to embed the intervention within the game, thus avoiding the players from becoming distracted from their actions within the virtual world.

As with other recent digital media artworks [1], Desert Rain is designed to promote collaboration among participants. Another opportunity for off-face intervention is therefore encouraging the players to help each other, for example, suggesting that players who have already found their targets go back and help their team members who have not. Given that we found communication between the players to be an especially enjoyable and engaging aspect of Desert Rain, this provides an ideal way of intervening without breaking engagement, indeed possibly even enhancing it.

Virtual Interventions are carried out from the control-centre by virtue of the arrow keys on the computers. They are very carefully conducted so that the players do not notice them. For example, when a performer observes that a player has been circling her target for some time without crossing it, she focuses her observation on this player's movement in relation to her target. As the player comes very close to her target the performer presses an arrow key to push the player's avatar through the target and thus triggers the rotating drum. The performer makes her decision about the exact moment when she pushes the arrow key with great care so that it is neatly timed with the player's movement in the virtual world. She moves the avatar only a tiny bit, thus making sure the push remains unnoticed for the player. Virtual interventions are closely timed with the player's movement in the virtual world. They can be carried out without disengaging the player from the game. Indeed, they ensure that players do not get frustrated as they circle their target.

Face-to-Face Interventions are carried out by a performer who directly approaches the player's cubicle to give her practical advice on using the footpad. This form of intervention is very intrusive and always results in an interruption of the player's engagement in the game. Therefore, it is only employed on very rare occasions. A few players have been observed who despite of having received advice through the audio-link, could still not use the footpad; in order to enable them to engage in the game a performer accessed their cubicle from behind to give them hands-on support. Face-to-face interventions were only employed when off-face interventions did not work and were normally preceded by communication between the control centre and a performer behind the rain-curtain.

These practices can be contrasted with previous approaches to orchestrating performances in virtual worlds. Out of This World (OOTW) was a television gameshow that was staged on-line in a shared virtual world with actors and members of the public controlling avatars [3]. The gameshow format demanded precisely timed and coordinated interactions, especially avatar movements, so as to fit in with the rigorous timing constraints of television production and camera work. OOTW introduced a solution to this problem in the form of dedicated management software. This allowed a member of the production crew to monitor the action in the world and dynamically introduce movement constraints –

invisible bounding boxes with different sizes and trajectories – so as to limit participants' freedom to move or shepherd them to particular locations. This interface was used extensively throughout the show. The participants were given no choice and were clearly aware when they were being controlled (their screen would flash red whenever they were being moved or pushing against a constraint). Although apparently acceptable in a gameshow context where the action is staged for the benefit of external viewers, this relatively heavyweight approach would be too overt and disruptive for Desert Rain, which instead relies on more subtle techniques.

As a further comment, it might be possible to use more sophisticated navigation techniques to gently steer participants around the world without directly taking control of them, for example force-field based navigation in virtual environments as proposed by Xiao and Hubbold [9]. However, such techniques need to be extended so that performers can define and shape them in real-time in order to improvise responses to unanticipated circumstances.

CONCLUSIONS

Blast Theory's Desert Rain takes Brenda Laurel's concept of 'Computers as Theatre' literally. A computer system and its use by members of the public are embedded within a dramatic performance. In order to ensure the success of Desert Rain, the performers carefully set the participants expectations and produce a range of performances and unobtrusive practices to orchestrate their experiences. Key aspects of this orchestration are:

- Carefully planned and thoroughly rehearsed briefings and interventions at all stages of the performance;
- The use of off-face and virtual interventions so as to sustain engagement;
- Encouraging the players to help one another as a way of intervening and yet increasing engagement;
- The ability to monitor action in both the physical and virtual worlds through asymmetric interfaces.

We think that these observations may have broader implications for HCI.

As the need to monitor and intervene might be seen as a downfall of the 'usability' of Desert Rain's interface, it is worthwhile considering that currently, more and more computer systems, such as information kiosks and touch screen devices are placed within public places. Appropriate user-support for such applications is often not available, leaving the user alone and sometimes frustrated or even embarrassed in the public eye. We suggest that the ability for technical crew to dynamically manage a participant's experience will be increasingly important in a range of applications.

Continual and unobtrusive observations of the user's (inter)actions with the system and within the virtual world are necessary so to be able to embed interventions within ongoing actions and experiences. This requires a repertoire of social practices supported by appropriate technical facilities. Of course, this should come as no surprise – traditional theatre already has well established practices and facilities for managing performances – lighting, sound, curtains, scenery and so forth. Similar facilities are now required for managing computer-based experiences.

Finally, despite the public accessibility of computer systems as they are currently deployed in museums and galleries, they are normally developed for the use by individuals, isolating the user from her companions and the wider environment [8]. In contrast, Desert Rain indicates that participants may be willing and able to support each other, while remaining engaged in an experience. Indeed, the communication involved in mutual support might even strengthen their engagement.

ACKNOWLEDGMENTS

We gratefully acknowledge the support of: The European i[3] programme (eRENA project), EPSRC, The Nottingham NOW contemporary art festival, DA2, The ZKM and The Arts Council of England. We are especially grateful to Andrew Chetty for his support and participation.

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