Experiencing a Presentation through a Mixed Reality Boundary

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ABSTRACT

We describe a pilot study of the use of a mixed reality environment for distributed presentations involving virtual and physical audiences and speakers. Our aims were to establish mutual awareness between all participants; to present physical and virtual worlds as being spatially integrated; and to support moderate sized audiences. We used a mixed reality boundary to join a physical space to a collaborative virtual environment so that the two appeared to be adjacent but distinct components of a single space. Two presentations were staged to a mixed physical and virtual audience, one by a virtual speaker and one by a physical speaker. Each presentation was followed by a question and answer session. Qualitative analysis of semi-structured interviews and video recordings revealed that some degree of mutual awareness was established between participants and that physical participants may have viewed the environment as being more spatially integrated than virtual participants. We propose that improving avatars and video textures in the virtual environment may further enhance the experience.

Categories and Subject Descriptors

H.5.3 [**Information Interfaces and Presentation**]: Multimedia Information Systems – *artificial, augmented and virtual realities*

General Terms

Experimentation, Human Factors

Keywords

Distributed presentations, mixed reality boundaries, awareness, spatial integration

1. INTRODUCTION

The idea of staging distributed presentations, where speakers and audiences communicate over a computer network instead of physically travelling to meet face-to-face, has been in common currency for well over twenty years. Even though the need to reduce travel has become more acute in recent times, not least as a result of environmental concerns, and although some audio/video conferencing and text chat systems have enjoyed commercial success, it has proved difficult to replace face-to-face presentations with virtual ones.

Considering just a few examples from the many that have been published highlights some of the reasons why this is case.

Forum [8] transmits presentations to remote audiences using video and audio. Speakers and audiences communicate via audio or text, and audience members communicate with each other using a text chat facility.

Telep [9] allows local as well as remote audiences to attend a presentation. The speaker gives a talk in front of a local audience, but is also presented with a video representation of the remote audience. Remote audience members see a live video window on their desktops, but communication takes place via text.

Mark et al [12] have studied the use of *MSNetmeeting* to support distributed groups at a large corporation. This system features application sharing and a shared whiteboard, supported by telephone conferencing.

These papers raise a number of recurring problems. Speakers report that it is difficult to understand the local situation of the audience and are often unable to gauge audience reaction. Similarly, audience members are often unaware of each other and cannot gauge each other's reaction to the material presented. All parties experience difficulties with many of the subtle but important aspects of everyday face-to-face communication such as turn taking, gaze direction, and pointing at objects.

Researchers have argued that these problems arise at least in part because the participants do not share a common integrated space – the meeting space is fragmented [5] and "seams" are introduced between the subjects of interaction and the space of interaction [7]. In response to these observations, new distributed presentation technologies have been developed that attempt to establish an integrated space for virtual meetings. These include collaborative virtual environments, where participants meet as avatars in a virtual world, possibly enhanced with video views to create shared augmented virtualities [13] and [14], and shared augmented realities, where local participants see remote virtual participants overlaid on their local environment [2]. They also

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include various attempts to arrange multiple video views into a spatially consistent framework, for example, overlaying them on a semi-transparent drawing surface [7], through an arrangement of small displays and cameras [15], or larger projected displays and cameras [6].

However, although such approaches may provide a greater degree of spatial consistency among participants, it is not clear that they can support presentations involving more than just a few participants, for example the larger audiences envisaged for applications such as *Forum* and *Telep*.

This paper describes a pilot study of giving distributed presentations in mixed reality. The aims were as follows:

- To see whether we could establish mutual awareness between physically embodied speakers, physically embodied audience members, virtually embodied speakers and virtually embodied audience members;
- To understand the issues involved in creating an integrated mixed reality space containing these various participants;
- To see whether we could support distributed presentations involving moderate sized audiences – i.e., more than just two to four participants.

2. DESIGN OF THE STUDY

Our pilot study involved two sequential distributed presentations. In one of them, a physically embodied speaker presented to a local physically embodied audience and a remote virtually embodied audience who were attending via a computer network and were represented as avatars in a virtual environment. The other presentation was a mirror image of the first; a remote virtual speaker (an avatar) presented to both the physically and virtually embodied audiences.

Each speaker was briefed to prepare a presentation of 10-15 minutes on a topic of their choice and to aid their talk with slides (the speakers chose to talk about their current work topic). Both presentations were followed by a question and answer session that was not moderated and lasted 5-10 minutes. The changeover time between the two talks was about 5 minutes, allowing the speakers to take their new places and some changes in the set-up to take place. There was a period of introduction and preparation before the start of the first presentation, lasting about 10 minutes. The total time for the entire experience was just under an hour.

Ten volunteers took part in the experiment, of whom two were female. The participants' ages ranged between 20-40. Six had a background in computer science. None were involved in the development of the mixed reality presentation system.

Eight of the participants were audience members (four made up the physically embodied audience, the other four the virtual audience). Two participants took the role of speakers – one physically embodied and one virtually embodied. Each speaker became an audience member during the other speaker's presentation.

2.1 Overall Technical Configuration

The virtual meeting environment was created using the MASSIVE-2 system [4]. We then used a mixed reality boundary [1] to link the physical and the virtual meeting space, creating a common mixed reality environment for the participants.

Mixed reality boundaries are a specific approach to mixed reality that involves creating transparent windows between physical and virtual environments. This is achieved by texture-mapping live video captured from a physical space into a collaborative virtual environment and in turn, projecting an image of the virtual environment onto a large display in the physical space. An open audio connection between the two spaces allows their occupants to talk freely to each other.

In contrast to other approaches to mixed reality that focus on superimposing the virtual and physical, the spaces on either side of a mixed reality boundary remain distinct; but become connected and should appear to be adjacent. Although mixed reality boundaries have previously been demonstrated for a variety of applications ranging from information visualisation to poetry readings [10], there has to date been no systematic attempt to determine whether they can successfully support social communication between physical and virtual participants – hence this study.

In order to describe the technical configuration, it is first necessary to define some terms.

- We use the term *physical audience* to refer to those audience members who are present within the physical meeting room.
- We use the term *physical speaker* to refer to the speaker who is present within this meeting room. Both the physical audience and physical speaker are physically embodied – they appear as themselves, either locally or via a video image.
- We use the term *virtual audience* to refer to those audience members who are attending over a computer network. They are embodied in the collaborative virtual environment as graphical avatars. Of course, they must also be physically embodied in some other local physical space somewhere, but this is not seen by any of the other participants.
- We use the term *virtual speaker* to refer to the speaker who is present via the computer network and who is also represented by an avatar in the collaborative virtual environment.

In designing the set-up we carefully considered the different perspectives of these participants. Our aim was to enable both speakers to be aware of both audiences during their presentations and also to enable both audiences to be aware of one another.

2.2 Configuration for the Virtual Speaker

Figure 1 shows the technical configuration used for the presentation by the virtual speaker.

During that talk the physical audience (on the left of the diagram) was seated and faced the mixed reality boundary so that its members were looking directly into the collaborative virtual environment. Each member was given a hand-held microphone.

They could see the virtual speaker and the virtual audience in the virtual presentation space projected onto a screen in front of them (the physical side of the mixed reality boundary – see figure 2).

The virtual presentation space included a virtual screen for showing slides as texture-maps and guide rails and floor markings to help the virtual speaker and audience position themselves (see figure 3). Of course, an essential part of the mixed reality boundary was that the virtual space also contained a live video window looking back out at the physical audience. The virtual audience members accessed the collaborative virtual environment using desktop PCs and wearing a headphone/microphone set. They were physically dispersed over a fast-Ethernet. In contrast, the virtual speaker was more fully immersed in the virtual environment, wearing a Virtual Research V8 head-mounted display and having polhemus sensors attached to their head and both hands. The intention was to provide them with a more expressive avatar that could gesture, point and use some measure of gaze direction (at least head orientation) to interact with audience members.

The virtual speaker (and their virtual screen), virtual audience and physical audience were carefully positioned to establish an approximately triangular relationship between them, allowing each class of participant to see and hear the others. The narrow shape of this triangle was designed to slightly favour the relationships between the audiences and speakers over the relationships between the two audiences.

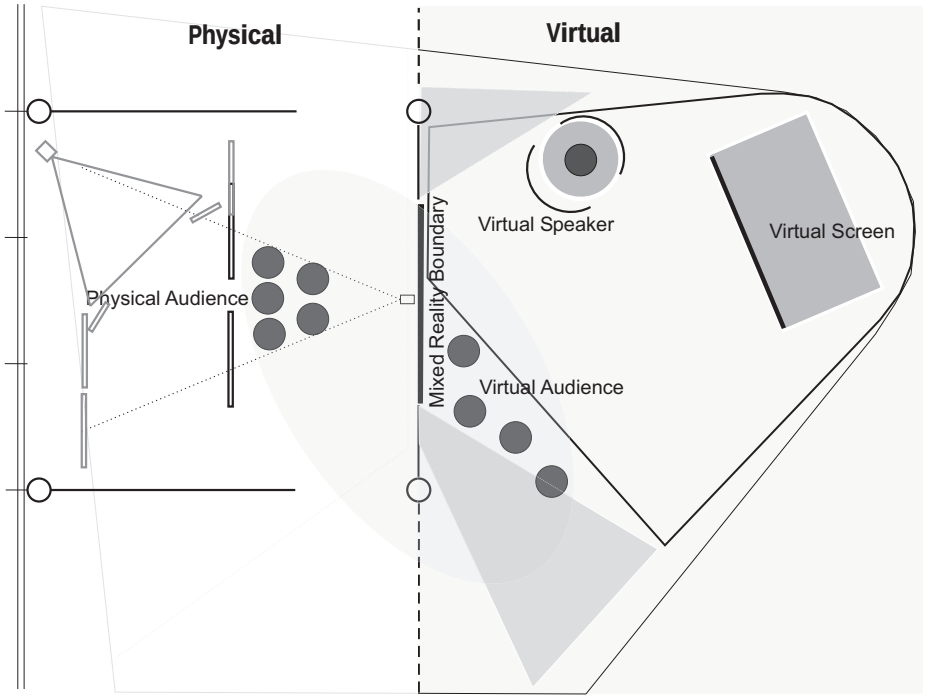

Figure 1. Virtual presentation layout

Figure 2. View into local physical space during virtual presentation

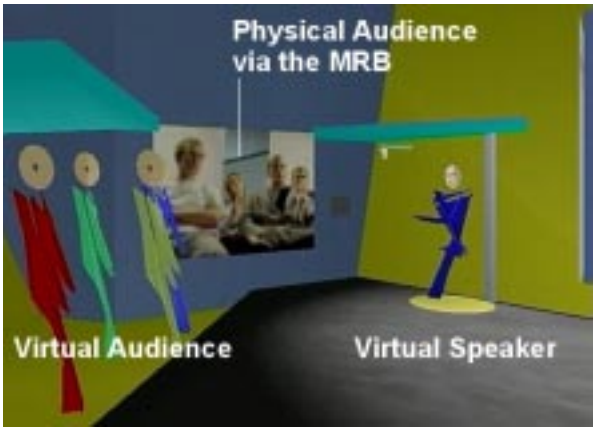

Figure 3. View into virtual space during virtual presentation

2.3 Configuration for the Physical Speaker

After the change of the set-up to prepare the space for the second presentation, the physical audience was now turned round to face the physical speaker and the presentation slides that were projected onto a nearby physical screen. The virtual audience (now including the virtual speaker) directly faced the virtual side of the mixed reality boundary and the rails and markings in the collaborative virtual environment were automatically reconfigured to help them take up their new positions. Again, a triangular relationship was established between the speaker and the two audiences, weighted towards speaker-audience awareness.

Figure 4 shows the resulting technical configuration used for the presentation by the physical speaker.

Figure 5 shows how the local physical space appeared during this phase of the experiment and Figure 6 shows the corresponding view of the virtual space.

As we can see from figures 1 and 4 the set-up was changed on both sides between the two presentations in order to adapt the spaces to the two distinct events and help participants take up suitable positions. This change over took no longer than five minutes, suggesting that a mixed reality boundary can be reasonably quickly adapted to different presentation situations.

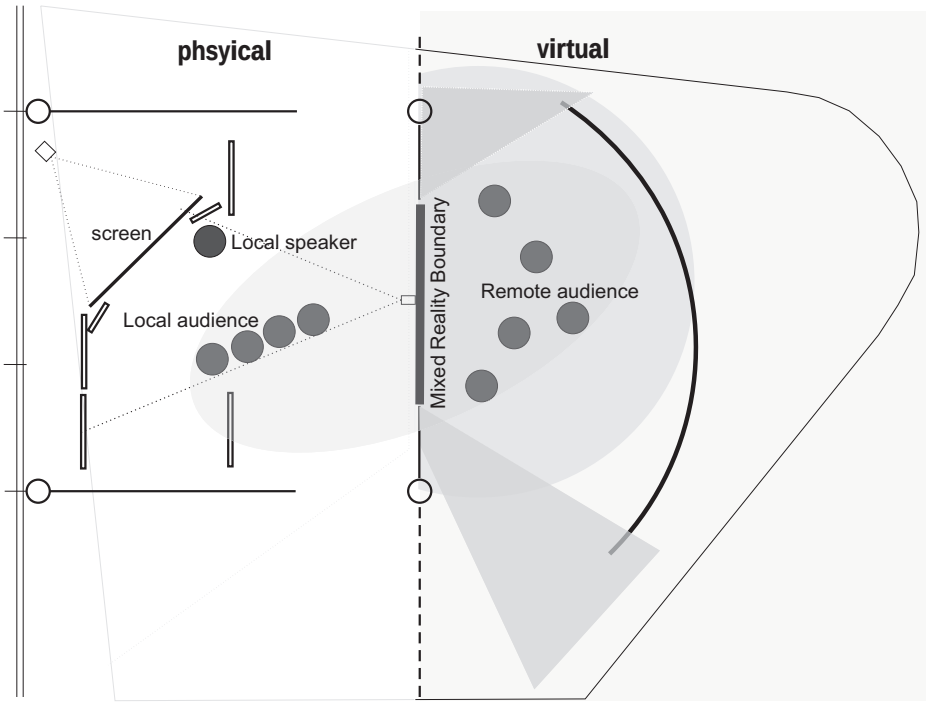

Figure 4. Physical presentation layout

Figure 5. View into local physical space during physical presentation

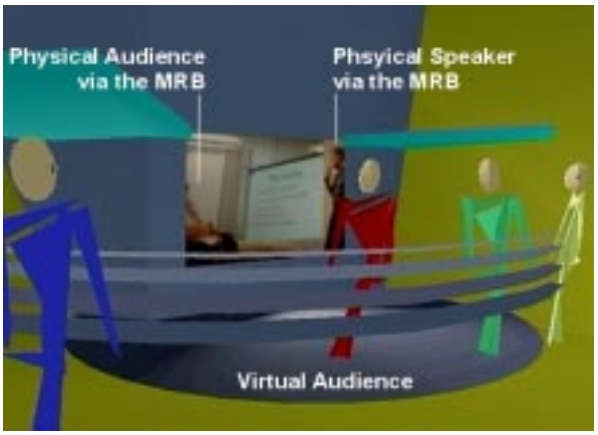

Figure 6. View into virtual space during physical presentation

2.4 Evaluation Approach.

We have adopted a qualitative approach based on semi-structured interviews backed-up with analysis of video footage. This is because our study is formative, seeking to establish the process and relevant aspects of using mixed reality technology to support distributed presentations. In particular, we did not want to miss important issues by pre-structuring the findings with a formalised approach. Relevant examples of the use of video and interviews for the evaluation of new technology and/or issues are provided by Suchman [16] and Lofland [11] respectively.

2.5 Data Capture

A semi-structured interview was conducted with each participant after the experiment. Interviews lasted for an average of 30 minutes and the questions were broadly concerned with:

- Awareness between participants – to what extent did each participant feel aware of the other participants?
- Integration between the spaces – to what extent did the participants perceive that the virtual and physical spaces that were connected via the mixed reality boundary were actually a single integrated space? One part of the questionnaire asked the participants to draw a diagram of the meeting space in order to help clarify their perception of it.
- Functionality of the system – did the system provide the necessary functionality to support distributed presentations?

In addition, the event was recorded with 4 video cameras – 2 located in the physical environment and 2 connected to the virtual environment (in this case the viewpoints captured by two virtual cameras were output as video via a scan converter). These recordings provide us additional information that enables us to better interpret the participant's comments in the interviews. Researchers inspected the video in order to see to what extent participant behaviour in the meeting matched their recollections afterwards.

3. FINDINGS

On the basis of the interview results and the video recordings we will now examine how well our mixed reality system provided awareness between the different groups of participants and achieved spatial integration between the physical and the virtual meeting space.

3.1 Did Our System Support Awareness?

When discussing to what extent a collaborative system provides awareness between its users, it is useful to distinguish between the following types of awareness:

- Awareness of the presence of others.
- Awareness of the identity of others.
- Awareness of the actions of others.
- Reciprocity of awareness – awareness of the awareness that others have of you.

3.1.1 Awareness of the Presence of Others

Our results suggest that our presentation system did provide the physical and virtual speakers and audiences with mutual awareness of presence during both the physically and virtually presented talks. Evidence to support this comes from direct interview questions regarding awareness. The answers to four key questions that focused specifically on awareness of other audience members are summarized in tables 1 and 2.

Table 1. Awareness during the virtual presentation

Virtual Presentation	Physical audience	Virtual audience	Speaker
Awareness of virtual audience	5/5	4/4	1/1
Why	Within my direct field of view (3) From start-up phase (2)	I turned around to see them (3) From start-up phase (3)	Within my direct field of view (1)
Awareness of physical audience	5/5	4/4	1/1
Why	Within my direct field of view (3) I could hear them (2)	Turned around to see them (2) From start-up phase (2) Peripherally visible (1)	Within my direct field of view (1) They were moving a little (1)

Table 2. Awareness during the physical presentation

Physical presentation	Physical audience	Virtual audience	Speaker
Awareness of virtual audience	3/4	4/5	1/1
Why	I got used to them being there (2) I turned around to see them (1) Speaker addressed them (1)	They moved around (2) I moved and in doing so, I saw them (2)	Within my direct field of view (1)
Awareness of physical audience	4/4	5/5	1/1
Why	Same as for virtual presentation (4)	Within my direct field of view (5) Speaker was addressing them (1)	Within my direct field of view (1)

The first table deals with awareness of the virtual and physical audience during the virtual presentation. Similarly table 2 deals with awareness of the physical and virtual audience during the physical presentation. The columns are the groupings of participants who might experience this awareness. The numbers in brackets next to the text comments indicate how many participants specifically mentioned this particular point.

As tables 1 and 2 show all participants were aware of each other, with an exception during the physical speaker's presentation when one physical and one virtual audience member were not aware of the virtual audience. Both participants explained that they were focusing on the talk in the physical space.

Video/audio recordings of the start-up phase (before the first presentation begun) reveal that participants were immediately aware of each other's presence. The following excerpt from the conversation is typical of the exchanges that took place in this start-up phase:

Virtual participant MC: I can see DS at the back.

Physical participant DS: Yes, that's me.

Virtual participant MC: So, who have we in the front row?

It is interesting to note that participants reported in the interviews that the communication that took place during the start-up phase strengthened their awareness of the presence of others during the first presentation (see table 1).

3.1.2 Awareness of the Identity of Others

In terms of awareness of identity, as the excerpt above suggests, the quality of the video texture on the virtual side of the mixed reality boundary was good enough for virtual participants to be able to identify known individuals in the physical space. However, it seems that the avatars of the virtual audience members should have been customized more so that the physical audience members could identify them. We used different colors for the avatars, which allowed individuals to be distinguished, but names were not displayed. Supporting evidence comes from the interviews (two of the physical participants reported that they would have liked the avatars to be customized more) and from the video recordings (a large proportion of the conversation during the start-up phase was concerned with identifying which color avatar belonged to whom).

An important point relating to identity emerged from the interviews. Four participants speculated that knowing everyone involved positively affects the experience of a distributed meeting. The following two quotes illustrate the opinion of someone who was familiar with everyone versus someone who was not.

"So if I was with a group of people that I'd never met before, it would be very different because I would not know their character. I would not know if they are normally like that. And also you might be a bit more intimidated about asking questions."

"Because it was my first week here I did not know who was behind the figures, the avatars. I personally knew X so I had an image in my mind but the others I did not know them so there was no feeling, no relationship, no idea in my mind who could that one be."

3.1.3 Awareness of the Actions of Others

Considering the next type of awareness, our experimental environment failed to provide complete and symmetrical information about the actions of the remote participants. The virtual members could see those present in the physical meeting space. The video-texture quality, however, was not good enough to read subtle gestures and expressions. The information received by the participants in the physical space through the projected view of the virtual environment was even more limited as the avatars did not show the actual/physical actions of those that they represented.

In their interviews, both speakers reported that it was difficult to gauge whether the virtually present participants were paying attention and whether they could follow the presentation. The speakers expressed a wish for the avatars to better convey the reactions of those audience members.

3.1.4 Reciprocity of Awareness

Finally, regarding reciprocity, the system was designed to be relatively symmetrical and no explicit information was provided to the participants about what others could see or hear. This is in contrast to previous video based media space environments such as MTV1 [12] where a second "vanity monitor" was employed to explicitly show a participant how a remote participant was seeing them.

Video recordings and interview answers indicate that most participants in the experiment understood the symmetry provided by the system. The conversation during the start-up phase revealed that the groups of participants could see each other and seven of the eight audience members reported in the interviews that they believed that the remote audience and remote speaker could see them.

It is believed that the system's support for mutual awareness between all groups of participants contributed to the successful conduct of the question and answer sessions. After the virtual presentation the first three questions were asked by physical participants and answers were given by the speaker. An additional comment was made by one of the other physical participants regarding the second question. The forth question was asked by a virtual audience member, which led to an interesting dialogue between the speaker, the virtual audience member and a physical audience member with a total of ten turn changes between them. After the physical presentation, the first two questions were asked by two physical audience members. Then a virtual participant asked two more questions. Each question received an answer with no ensuing discussion.

The system did not provide any special support for asking questions. The two discussion sessions, described above, worked because the audio quality was adequate and delays were not noticeable. Participants could therefore accurately judge when there was a pause in the conversation and thus an opportunity for them to speak. Additionally virtual participants received a visual cue as to when a physical audience member was going to ask a question – they could see them lifting their microphone to their mouth. Finally it is interesting to note that during the question and answer sessions the virtual participants tried to compensate for their inexpressive embodiments through movement. Two interviewees reported that they moved their avatar in order to

show that they were paying attention, while another called the phenomenon “virtual fidgeting”.

3.2 To What Extent Did Our System Integrate the Physical and Virtual Spaces?

There are a number of sources that provide us with information about the extent to which the physical and the virtual meeting spaces were perceived as being spatially integrated.

First, all interviewees were asked the direct question if they perceived the two spaces as integrated. Four answered that they did. The other participants gave the following reasons why (or when) they did not perceive the spaces that way:

- The textured video window in the virtual environment was too small (3)
- The video resolution not high enough (2)
- The spaces were perceived as less integrated during presentations than Q+A (1)

Second, the participants were asked to draw a diagram of the meeting environment. We used the resulting drawings as a means to verify each participant’s understanding of the layout. We found a correlation between the participant’s answers to the previous questions and their subsequent drawings. The following two examples illustrate two extremes.

Figure 7 is a drawing by a virtual participant who stated that they considered the two environments to be separate. They have drawn their local virtual environment exclusively, representing the major elements (screen, speaker's podium, virtual audience, boundary) with roughly the correct relationship between them. However, the physical space on the other side of the boundary is only represented as a video display. This participant explained that the view into the physical space appeared like a tunnel and that they could only see a small portion of that space.

In contrast, the drawing in figure 8 shows both environments, virtual and physical, as an integrated whole. This participant had stated that they had experienced the set-up as coherent. The set-ups for both the virtual and the physical presentation are included in the same drawing. All the major elements on the virtual side (screen, speaker's podium, virtual audience line up, boundary) as well as the major elements on the physical side (screen, speaker, physical audience for the two set-ups, boundary) are clearly marked and the relationship between them is represented correctly. The drawing also includes a representation of the field of view of the physical camera. This participant shows a clear understanding of the spatial relationships across the boundary.

More indirect evidence as regard to spatial integration was obtained by asking audience members if they felt addressed by the speaker. Table 3 summarizes their answers. These suggest a difference in perception between the physical and virtual audiences. On the basis of this data it could be argued that the participants in the physical space perceived the two spaces to be more integrated than did those in the virtual space. A contributing factor for the virtual audience’s lack of involvement may be the fact that they accessed the virtual environment through a desktop computer located in an office. In contrast the physical audience viewed the virtual world on a large screen and were located in a physical meeting space where the layout and atmosphere were carefully orchestrated.

Finally the use of spatial language by all participants during the experience and afterwards in the interviews to describe events across the boundary provides further anecdotal evidence that a common spatial frame of reference was often assumed. For example, during the start-up phase physical audience members directed the virtual speaker to the podium using phrases like “move forward”, “turn left”, “a little bit to the right”. Whereas interview answers contained descriptions such as “the (remote) speaker was facing away from us” and “the virtual audience were in a group to the right”.

Table 3. Did you feel that the speaker was addressing you?

	Virtual presentation		Physical presentation	
	Physical audience	**Virtual audience**	**Physical audience**	**Virtual audience**
Yes	3/5	0/4	4/4	1/5
Why Yes	His character came across (2) Communicated well (1)	N/A	Presenter’s body language (2) Eye contact (2)	Presenter’s body language (1)
Why no	Often the presenter was not facing us (2)	Often the presenter was not facing us (2) Lack of eye contact (1) No facial expressions (1)	N/A	Speaker mainly looking at physical audience (3) Speaker was outside my space (2)

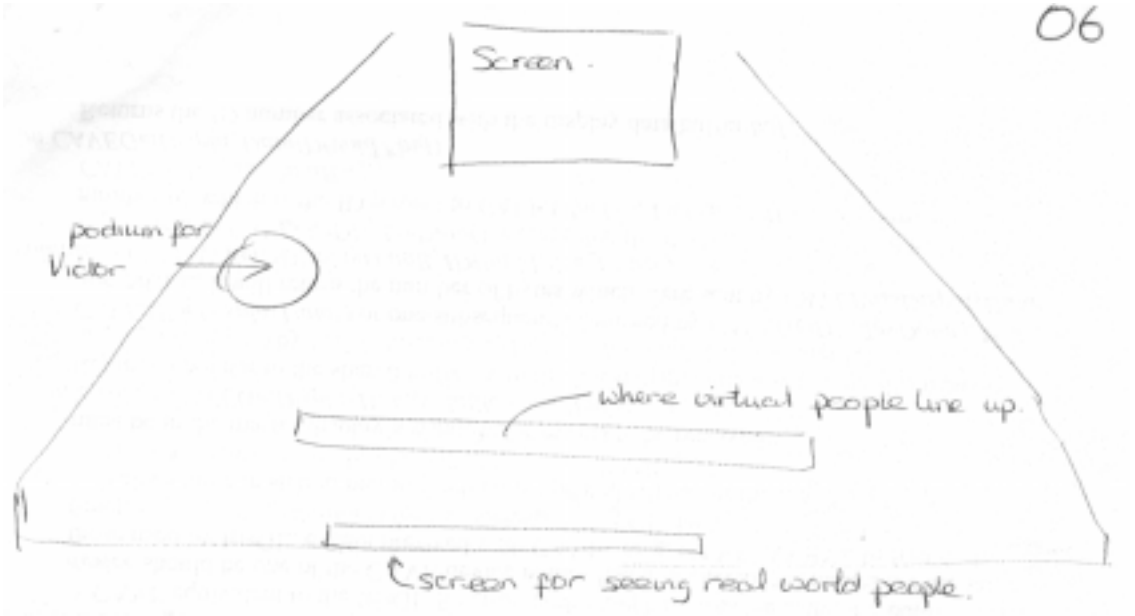

Figure 7. Layout drawing by a participant who considered the spaces to be separate

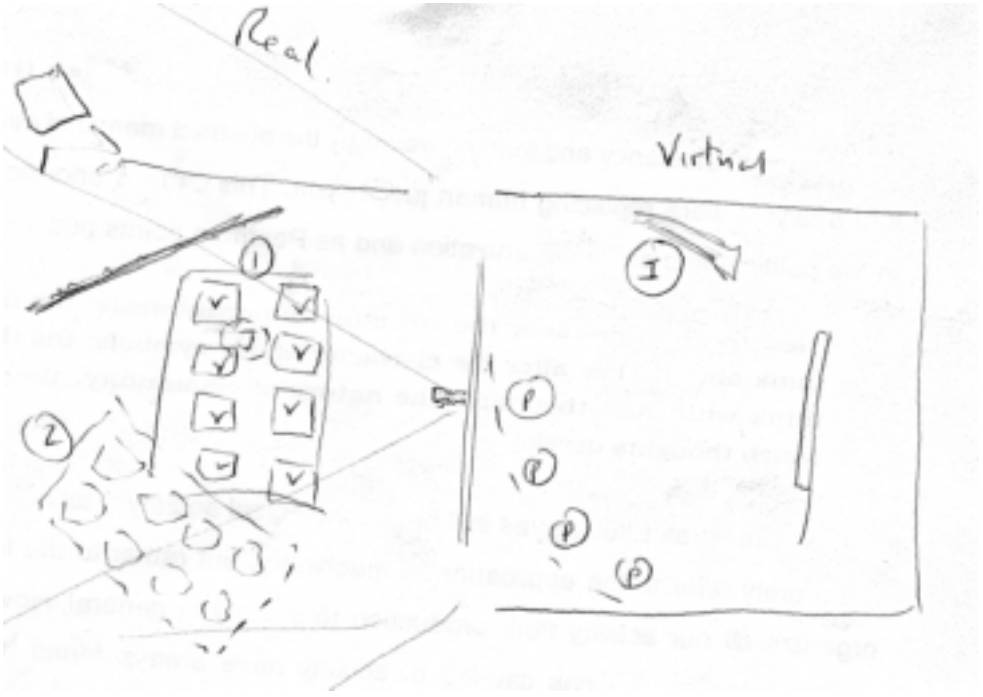

Figure 8. Layout drawing by a participant who considered the spaces to be integrated

4. CONCLUSIONS

We have described an experimental use of a mixed reality environment for distributed presentations. The main aims of this experiment were to enable mutual awareness between virtual and physical speakers and audiences; to combine physical and virtual environments into a coherent and integrated space; and to support presentations to moderate sized audiences. To what extent were these met?

With regard to mutual awareness, we believe that our experimental environment generally succeeded in establishing mutual awareness of presence among physical and virtual participants, but that it established only limited and occasional awareness of identity and activity. There is evidence to suggest that reciprocity of awareness was partially established. A key factor to address in order to improve awareness may be the low-fidelity design of the avatars and their lack of fine-grained expression and control. It would be useful to repeat the experiment with avatars that have clear identification and greater expressiveness (e.g. through video-based face tracking).

With regard to the integration of the two spaces, we also obtained mixed results, with possibly the physical audience perceiving a greater degree of integration than the virtual audience. Key factors to address in order to improve spatial integration may include both the size and resolution of the live video texture in the virtual environment and the size and resolution of the physical display used by the virtual audience. Thus a further topic for future study would be to investigate the experience of virtual audience members who access the virtual meeting environment through a more immersive interface (such as a head-mounted display or a CAVE).

With regard to the size of the audience, we managed to support presentations to audiences of nine participants distributed between real and virtual worlds. However, scaling up some more should be feasible. The use of wide screen projection systems coupled with multiple video windows in the virtual environment might allow us to add several more rows to both the physical and virtual audiences. Key bottlenecks would then become the resolution of the video image and the number of avatars requiring real-time audio connections which could cause congestion on the network.

Given our experience of designing and utilizing a distributed mixed reality system for presentations, we conclude by raising some more general issues for the design of mixed reality environments for collaborative applications.

- It is important to consider the different categories of participant in an environment and the extent to which they need to be mutually aware. Do they need to be aware of presence? identity? actions? Does awareness need to be reciprocally understood? The answers to these questions may well depend upon how many users are present, the nature of the task and how well they know each other in advance of the experience. For larger audiences, it may make more sense to be able to dynamically raise levels of awareness of a given participant, for example when an audience member asks a question.
- The layout of the space and the spatial arrangement of the participants impact on awareness. A triangular arrangement of a speaker and two audiences can allow all participants to be mutually aware to some degree.
- An informal introductory phase provides a valuable opportunity for participants to get to know one another and establish a sense of the space.

Our future plans include refining our mixed reality boundary deployment in the light of these findings. We then aim to establish a permanent and open mixed reality boundary that extends our own lab meeting space into virtual space so that we can study more formal meetings and casual encounters between physical and virtual participants over an extended time period.

5. ACKNOLEDGEMENTS

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