JOURNEYS THROUGH THE CAVE: THE USE OF 3D IMMERSIVE ENVIRONMENTS FOR CLIENT ENGAGEMENT PRACTICES IN HOSPITAL DESIGN

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One of the benefits of the growth in BIM use in the design and construction industries is the opportunity for increasing the involvement of, and interaction with, various stakeholders and end users through the design process. This includes the use of virtual models in collaborative 3D immersive environments, such as the CAVE (Cave Automatic Virtual Environment), during critical moments of client engagement. These opportunities and developing work practices have, however, received little academic attention. These encounters provide the opportunity for stakeholders to virtually experience the proposed design of buildings and spaces ahead of construction, and for design teams to communicate in a sensory and embodied way that the contract and design requirements are being met. This research uses video-based methods to study the collaborative, 'real world' design review work undertaken during client engagement sessions in the CAVE, in the context of a bidding process for a new NHS hospital. In this immersive setting, the navigable space is both a site of interactive encounter and an architectural model. It is argued that design teams establish a narrative to support the navigable space which the client participants experience, through the careful consideration and planning of their journey including what can be revealed or concealed along the way.

Keywords: hospital; stakeholder; user participation; virtual reality; virtual prototyping.

INTRODUCTION

Major clients are increasingly demanding that 3D modelling is used on their projects, and there is a UK government mandate to make Building Information Modelling (BIM) compulsory on public projects by 2016. This presents new opportunities for allowing various stakeholders to virtually experience the proposed design of buildings and spaces ahead of construction, to which attention is turned in this paper in the context of hospital design.

Virtual, immersive environments offer a form of modelling and visualization that can compliment BIM technologies since, as Brandon (2008: xviii) explains, "CAD models

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are mathematically defined, and they support a wide variety of analyses, simulations and visualisations, but they abstract away from tactility". 3D immersive environments, like the CAVE (Cave Automatic Virtual Environment), instead move towards providing end-users with physical and embodied experiences of building designs (CICRP, 2011). The CAVE is a multi-person, room-sized, high-resolution 3D collaborative virtual environment, which projects video onto three walls and the floor which can be viewed with active stereo glasses, one of which is equipped with a location sensor. As users move within the display boundaries, the perspective is displayed in real-time. One participant at a time (the 'driver') uses a joystick to travel through the environment.

Fig 1: The CAVE

This research concerns a project to relocate an existing specialist NHS hospital to the bio-medical University campus of a nearby town. The NHS Trust chose the Private Finance Initiative for the procurement of the new hospital, and one consortium utilised the CAVE as part of the tendering process. It was adopted to help better communicate the design of this hospital project to the NHS client, and to enable them to review the model of key spaces in the hospital design, including the main entrance atrium, an operating theatre, and an inpatient ward. Immersion in a 3D model can help to physically convey the sense of scale and space of a building, the size of single bed rooms etc., and to communicate to stakeholders in a sensory and embodied way that the contract and design requirements are being met. The collaborative work of navigating, and narrating, stakeholders' journey through the virtual model during the stage/s of design review is examined in this paper. This is done through video analysis of client engagement sessions in the CAVE during the bidding process for this new NHS hospital.

VIDEO-BASED RESEARCH METHODS

During this project, a researcher first followed, ethnographically, the early stages of the tendering process for the new NHS hospital, including attending design team meetings which took part from the preliminary Invitation to Negotiate (ITN) PFI phase up until the consortium were selected to participate in the final ITN stage. Team collaboration in the CAVE was then explored by studying interactions between members of the infrastructure provider and NHS client during design review, and to do this required analysing detailed social interaction with and around technology. For, while ethnography and video-based studies share a commitment to the study of social interaction, "it is not possible to recover the details of talk through field observation alone, and if it is relevant to consider how people orient bodily, point to objects, grasp

artefacts, and in other ways articulate an action…it is unlikely that one could grasp little more than passing sense of what happened" (Heath and Hindmarsh, 2002:102).

Video-based field studies provided unprecedented access to study social interaction around technology, in the sense that video captures multiple features of an event or scene (talk, body movement, physical context, use of technology etc.) which could be replayed over and over again. One particular affordance of video data was the opportunities it provided to share, discuss and debate 'raw' data with others. This practice of 'data sessions' (Tutt and Hindmarsh, 2011) involved the team undertaking collaborative, real-time video data analysis with other colleagues, to identify sequences of action and examine their construction and organisation, and to explore alternative, multidisciplinary perspectives. That version of events was then scrutinised, with fine-grained analysis of video fragments and transcriptions of the action, and in light of new analytic perspectives etc.

Rich video data recording of six sessions held within the CAVE were collected, involving various combinations of stakeholders: project and design managers, architects and designers, modellers and visualizers, NHS end users (clinical and managerial) and representatives of the client. These sessions took part between November 2011 and April 2012, by which time only two consortia were still left in the competition for the contract, and over 12 hours of video recordings of group interaction were collected in the CAVE environment. The data consisted largely of fixed camera footage, which was supplemented with a roaming camera and a ceiling/bird's eye view camera on occasions where the access to the social interaction was compromised (by multiple bodies in the CAVE or the view obscured by equipment etc.). The video data provided access to CAVE activity during this client engagement process, which involved presenting the models to the NHS client, to demonstrate diverse design requirements, ranging from the size of single rooms, the visibility of patients from nursing stations, to the amount of natural daylight utilised, and the design of interior objects and materials etc. The sessions also enabled design teams and contractors to explore and review the design environment more generally.

There is a long tradition of video-based field studies of workplace interactions that considers how technology can be understood as a feature of interactional work. Suchman (2007: 276) traces how the turn toward the social by computer scientists in the 1980s coincided with a growing interest in the "material grounds of sociality" among social scientists, particularly by ethnomethodologists and conversation analysts who already acknowledged the importance of nonverbal action in the organization of face-to-face interaction. These interests led to the emergence of a corpus of 'workplace studies' that attend to the accomplishment of work and interaction in various complex organizational domains, such as air traffic control rooms, emergency dispatch centres, newsrooms, and hospitals (See Hindmarsh and Heath, 2007). This work has helped explicate the different ways in which objects and technologies, such as the screen, are collaboratively used to help coordinate everyday workplace practices (Tutt and Hindmarsh, 2011).Video-based studies of social interaction have provided one way of examining collaborative design, that is, the ways in which the social, technological and material come together in and through the interactional practices of everyday work.

Attention has also been paid, in the extended fields of workplace studies and CSCW (Computer Supported Cooperative Work), to the collaborative work of coordination among stakeholders in the design process. For example, Tory et al (2008) provide a

video-based examination of the use of artefacts during the design development of a new building project to identify and resolve conflicts and accomplish design coordination. Luck (2010) has also studied the use of artefacts and drawings in early design conversations between architects and users. She argues that when artefacts are used in engagement with end-users, at the early stages of a building's design, they can act as 'mediating devices' as well as embodying the current status of the design. Indeed, Luck (2010: 641) stresses the importance of design representations and artefacts throughout a project as knowledge carrying and mediating objects, irrespective of whether they are material objects or virtual objects. However, the use of virtual prototypes and technologies, particularly immersive environments, and their role in interacting with clients during this crucial time of stakeholder engagement, is little understood and has been little explored in the literature.

Elsewhere close conversation analysis has demonstrated how participants in the CAVE need to develop new codes of interaction in order to first establish a 'shared seeing' of things before their design or collaborative work in the environment can be accomplished (Tutt, et al., 2012). During their group interaction, users are required to orient to the screens displaying the projected video, as well as to the physical and material environment of the CAVE room, and to each other. This all has to be done whilst maintaining proximity to the person wearing the 'headtracker' (active stereo glasses equipped with a location sensor), in order to view the optimal 3D perspective of the video. Yet a key difficulty in terms of the current use of this technology in the design process is that most end-users and stakeholders only enter into the CAVE for one or two sessions, or at least have limited engagement, and so will get a short opportunity to learn and develop the best ways to interact and collaborate in this environment. With this narrow window of time in which to make an impression and communicate the design, it is therefore logical that a large emphasis is placed by the design team on the marketing role of the CAVE experience in best 'showcasing' the prospective design to clients. In this paper, the video dataset is returned to with a new analytic inquiry, namely to examine how the design team construct a narrative to support the navigable space which the clients experience in the CAVE. Rather than fine-grained analysis of talk-in-interaction, this requires focusing on instances in the data set where the design decisions on what (/not) to show, edit, remove etc. from the model are negotiated, in practice, through the interactions of design review work, including how they are referred to and made sense of in discussion with clients. The data is analysed through the lens of new media theory, particularly revisiting Lev Manovich's Language of New Media and discussion of navigable space.

BACKGROUND: VIRTUAL PROTOTYPING AND STAKEHOLDER ENGAGEMENT

The need for identifying the clients or stakeholders and understanding their expectations for a construction project is of the upmost importance. Conflict often arises between logical changes and those that will be acceptable to the stakeholders, and Newcombe (2003) explains how this aspect becomes heightened "in public sector projects where a wider spectrum of stakeholders may express active interest in a project" (p.846). While a clear relationship often exists between designers and clients, gaps of understanding commonly exists between designers and the wider stakeholders and end-users (Nykänen, et al., 2008). On hospital projects these stakeholders and end-users of the facilities include diverse clinical staff of doctors, nurses etc., administrative staff, patients and visitors, facility management, as well as representatives of the NHS trust acting as client. Typically the design of healthcare

facilities involves building expensive full-scale mock-ups of critical hospital units, such as operating theatres, patient rooms etc. Dunston and McGlothin (2007) describe how virtual reality enables end users of the client healthcare organisation to have an immersive and interactive experience during design reviews with a multitude of hospital rooms and spaces (potentially an entire hospital) at a fraction of the cost of physical mock ups. However, while in this context Dunston and McGlothin (2007) used "demonstrations to obtain responses to the simulations" (p.8), the example in this research represents the use of virtual reality in a 'real world' project during the bidding process for a large new single bedroom hospital in the UK.

The CAVE visualization technology is essentially an advanced form of 'virtual prototyping', namely digital representations of design proposals which, subject to a process of exploration, testing, evaluation and refinement, may become physically realised. In principle these digital models typically need to be created anyway to serve as design documentation, so it is their integration and interoperability through the design process which needs to be developed on a project. As Morrell (2011) argues, in relation to the plans to make BIM compulsory for all public projects, "it makes no sense for designers to work in three dimensions and then suppress what was learned and hand on a 2D representation, also missing the opportunity to load the model with much other valuable information". As returned to in the later discussion of navigable space, prototypes differ from superficially similar artefacts such as movie set fictional buildings, historical reconstructions etc. by virtue of "its particular antecedent, functional relationship to the real thing" (Mitchell, 2008). Indeed, Dunston and McGlothin (2007) claim that practitioners exploring the virtual CAVE mock-up identified the same design issues known to be in the actual patient room (p.8).

DISAPPEARING WALL SOCKETS: BALANCING DESIGN ACCURACY WITH SELLING THE DESIGN

The potential for users to 'pick up' on errors in hospital design that have not been identified through 2D or non-immersive models was quickly identified as a major benefit by the NHS client in this research:

It works for us as well. You know- some of our recent schemes. We had things as simple as light switches or socket outlets that are in the wrong place…Everybody's missed it. It's been built like that and we've got like 500 rooms with a socket in the wrong place (NHS Client Rep)

In addition to helping users to identify design errors and to collaboratively develop a design, Mitchell (2008) also highlights the importance of virtual prototypes for providing "a basis for choosing among options or deciding whether to proceed to the next stage; and (in a less scientific spirit) to persuade decision makers" (p. xvi). In the context of this research, with the bidding process for a large new single bedroom hospital, this element was crucial, indeed was quite literal. For, the CAVE technology was utilised for stakeholder engagement when two hospital consortia were still left in the competition for the contract. The visualisation of design in the CAVE environment during client engagement processes is therefore fulfilling a different set of objectives beyond checking design accuracy. This is a bidding process for a contract, meaning that the virtual world is being designed to be viewed from a particular point of view and in order to be accepted by the client. This is explicit in the choice of or requirement to model particular rooms and spaces, but more subtle in the selection of lighting, placement of objects etc. Here, the same example of wall sockets is briefly continued, to illustrate simply how the main contractor design team have to negotiate

the job of representing the specificities and accuracies of the design along with problems users' may face in encountering the design as a 3D visualisation:

1 Pam: Anywhere there's a white socket- just delete that
2 James: Oh do you not actually want them on the wall here?
3 Pam: Well. No ha:hha
4 James: Ok alright
5 Pam: They should be behind the TV. That's just the way they
6 were modelled in Revit so they're appearing to the-
7 Alex: That's an interesting one Pam. If you put the- if
8 you show the plugs behind the TV which is where you
9 want them you can't see them=
10 Pam: Exactly
11 Alex: =in the model
12 Pam: I know ha ha ha I didn't want those TVs

In the sequence above, the designers have effectively encountered clashes between various objects, outlets and spaces after importing the model into the CAVE. This requires the team to edit the virtual environment in order to solve issues around the visibility of objects and the objects appearance etc. Part of the issue here is concerned with the creation and management of objects within immersive environments like the CAVE, and carrying out further work of embedding metadata into the model, for example, would solve this. However, this would be costly in time and money through the work of virtual modellers and, in this example, the decision is taken to "just delete" the plug sockets for the purposes of the 'walk through'. Like any prototype, it can fail if its design is too incomplete and inaccurate (as in the incorrect positioning of sockets throughout the single rooms referred to by the NHS Client representative), or equally if it is unnecessarily elaborate and costly (Mitchell, 2008). At one level these are cost-benefit questions, but this example of clashing wall sockets also illustrates how these concerns are balanced with the best way of 'show casing' the design to the clients during this stage of the tendering process.

This research has started to assess what these immersive virtual experiences can provide at critical moments of client and stakeholder engagement, in this case during the design review process for a new hospital. Elsewhere it has explored what type of interaction it facilitates, through fine-grained video analysis of collaborative work sessions in the CAVE (Tutt et al., 2012). Here the narrative within which they are enacted is examined, in relation to the work of Manovich, in terms of showcasing the design and communicating that the design requirements have been met. Or, put more crudely, the work of balancing the accuracy of design specifications with selling the space and design to the client.

DISCUSSION: THEORIES OF NAVIGABLE SPACE AND NARRATIVE SPACE

In his seminal work The Language of New Media, Manovich (2001) describes in detail how navigable space – that is, the navigation through 3D virtual space – has become a key form for new media aesthetics. It is now a familiar, everyday interface in computer games, in addition to its use in other formats such as motion simulators. He also details how it has become a "key tool for labour" for interacting with any kind of data (p. 249). Navigable space has become a particularly important paradigm in human-computer interfaces, which, Manovich (2001) argues, should be seen as a particular case of data visualisation distinct from "architectural models or stock

market figures" (p. 249). However, in the case of collaborative working in the CAVE, the navigable space is both a site of interactive encounter and an architectural model.

Virtual worlds usually involve interaction and narrative, typically with the participant being represented by an avatar literally 'inside' the narrative space. They are usually seen through a rectangular frame, displaying only part of a larger whole, hence Manovich (2001) describes the experience as being "much closer to cinematic perception than it is to unmediated sight… [and] the designer of a virtual world is thus a cinematographer as well as an architect" (p.81-2). However, unlike film architecture which is designed for navigation and exploration by a film camera or, say, 'paper architecture' designs which are not intended to be built, the hospital design has a functional relationship to the hospital to be built (Brandon, 2008), provided that the design wins the bidding process. The CAVE model is also, as discussed, designed to be viewed from particular points of view, enabling stakeholders to review key spaces in the hospital design, namely here, the main entrance atrium, an operating theatre, and an inpatient ward. In addition to the interactional demands of physically collaborating in the CAVE, the users' experience of these spaces is also subject to a level of more discreet design decisions including, but not limited to, what are sometimes called 'perspective renderings'. These architectural representations have been described as being part of the design process itself (Houdart, 2008) and in this particular example include representing the connectivity between the hospital spaces, the selection of lighting, the placing of objects and furnishings, and even, as discussed in this section, altering or distorting the correct design specifications for the means of enhancing the immersive experience.

To first recap, in this example the CAVE environment is enabling the 'real world' design work of engaging with clients, rather than simply offering simulation or role play. It is a form of data visualization and an (immersive) architectural model. It is not viewed through the rectangular frame of VR, or through desktop 3D or Revit, but instead involves viewing and interacting with 3D video projected onto room-sized multiple screens. It is a navigable space, which the participants 'walk through', but also a narrative space constructed both through building a more detailed picture of the social context of use for the hospital spaces (provided by the client and clinical stakeholders' expertise), and, as will now be discussed, through the designers' 'showcasing' of the design to try and win the bid.

The benefits of allowing client and clinical end-users to probe at how a space can be used, and to re-asses the lived spaces of an architectural design in a way that non-immersive building design does not allow, are potentially considerable. This user knowledgebase is returned to later in this section in relation to the design of a hybrid operating theatre. Yet, in addition to the social context of use as a working space (in terms of clinical practices, facilities management etc.), is the more basic connotation of a space's usage and function, which can be taken for granted as being self-evident by designers but can too easily fail to be communicated in virtual models. A simple example is that of encountering a restaurant. Here, in the transcript below, the design team are trialling the 'walk through' of the atrium prior to bringing the NHS clients into the CAVE:

Alex: So when you're actually in this main reception area, Pam, you can't actually see people eating inside the restaurant
Pam: No you won't
Alex: So how does FM feel about that?

Pam: They're not happy about it

The designers decided against the use of avatars, which the team believed would bring a different set of problems. This included distracting participants from the design details, interrupting the group interaction, and leading participants to draw inaccurate comparisons of the avatars with the specifications of objects such as grab rails, and size of beds, single rooms etc. However, the use of the space as a restaurant could be conveyed in different ways as Alex concluded:

I think we can make a bit of an improvement on that bit by wayfinding or something that draws the attention- because at the moment, standing here, I don't know there's a restaurant … I'm supposed to know that behind that beautiful purple chair is a restaurant. I'd never know that (Alex, Director of Design)

A senior design manager felt that this is "another wayfinding thing, saying what these things are. I think these things are important but- we can add maybe reception text or something to this desk". Such issues of wayfinding in the complex organisational environment of hospitals are frequently encountered throughout the buildings' life (Rooke and Rooke, 2012). The opportunity to experiment with how the system works ahead of construction, especially with stakeholder input, again represents a real benefit of immersive environments. Visual wayfinding is also identified as key to selling the space and the design to the client, and hence of winning the bidding process. During a CAVE session, a senior designer for the main contractor described this as the "route you will take these people on- the journey". While the stakeholders potentially have the opportunity to engage and interact with any aspect of the model, the journey on which they are taken on by the design team is significant "to see that connectivity. For the visual wayfinding [of] how do you bring yourself through this space". The 'intro sequence' for the NHS clients led the participants virtually from the main entrance into the main atrium, which was selected to gives an impression of the space and dimensions, and the designers also announced that the journey would "show what the adjacencies were and where you could find your way out of the atrium to different spaces". However, the selective modelling of hospital spaces for the CAVE environment puts restrictions on the routes and physical movements that the participants can make. When looking towards the entrance at outpatients, it was remarked by an NHS client representative that it would be "nice to have that-to see something visual", with the view to outside and natural daylight considered a key design feature of these outpatient clinics. Yet, taking the decision to texture the 'end' of modelled spaces also lead to some confusion around the connectivity of the spaces as client participants navigated them. This is captured in the comment: "So in practice, that wall isn't a wall in fact". This brings us back to the earlier discussion of virtual prototypes and striking the balance between not making a design too incomplete and inaccurate, and equally not unnecessarily elaborate and costly.

The decision of what (/not) to show for the purposes of the engagement sessions with the NHS client extends to the objects, materials and equipment within the hospital spaces. The materiality of objects in immersive design environments is explored in greater detail elsewhere (Tutt et al., 2012), but here the paper briefly refers to how the designers virtually moved or removed prescribed equipment in certain modelled rooms (such as the operating theatre which will now be discussed) because of the effect it had on participants encountering them in the immersive environment. Yet, these alterations in the virtual model extended to altering the curve of a corridor, the height of grab rails and, as already discussed, the removal of plug sockets.

In this one particular example, the communication of a space's usage and function in the virtual model is questioned through the application of NHS clinical knowledge, which provides a social context of use for the room as a working space. In this case, however, there is not a failure to communicate the basic function of space (as in the restaurant example), but rather a failure of the model to match the complex, organisational procedures of surgery:

This isn't biplane, though is it? This must be- It's not biplane (1.2) set up (.) configuration. You normally have the image intensifier come over the top of a patient (NHS surgeon)

The surgeon assesses the immersive space as a future operating hybrid theatre that she will work in, and she picks up inaccuracies in the designed layout of the biplane platform, a system which will provide diagnostic imaging and accommodate multiple clinicians and ancillary equipment. Here, the sociotechnical knowledge and (clinical) expertise of the end-users, which was partly brought into the design review by the affordance of the immersive CAVE environment, starts to unpick the design accuracy of the virtual model. The decisions for the (re)moving of prescribed materials, equipment and other alterations are made fully transparent to the Trust clients as in the architect's explanation below:

[T]o be quite honest the first layout that we did there was too much stuff in here- that we actually took a few pieces- shifted them to the edges and um- Just so we can actually get in here (Architectural Assistant, Architects on project)

The intended use of the CAVE at the design review stage was not to subject the spaces to workflow scenarios as if they were fully-equipped mock-ups. However, this example is useful for an analysis of how the design team describe and make sense of this process of balancing the accuracy of design specifications with selling the space and design to the client. Indeed, it was referred to, during the design team discussion, as "strategically taking some of it out", but one designer related these decisions more directly to, what might be seen as, the careful structuring of narrative space. During discussion in the CAVE with the rest of the design team, he explained that "if you went to town on a space… there's something a bit climactic- and then you've got a problem". This comment again stresses the need to make sure a design space/model is not unnecessarily elaborate, but the word "climactic" also suggests sensitivity to the emotive, embodied and sensory experience of the spaces along "the route you will take these people on- the journey". As the client participants are taken on their 'journey', work has been undertaken to establish a narrative to support the navigable space which the participants experience. This careful planning of the journey (and what can be subtly revealed, concealed or distorted along the way) hints at an entire series of work practices and concerns which, by virtue of the increasingly important role of immersive environments and virtual prototypes, are becoming part of the design process itself.

CONCLUSIONS

This research uses video-based methods to study how a design team experiment with the virtual technologies of the CAVE to engage with clients and accomplish 'real world' design review work. These collaborative encounters are providing the potential for client and clinical end-users (without extensive or even any design expertise) to explore how a virtual building can be used, and to re-assess the lived spaces of an architectural design in a way that non-immersive building design cannot. Video-based

methods provide a way of accessing these emerging methods for design, and encourage a close and detailed consideration of interaction and the situated and contingent use of technologies and artefacts in the CAVE environment. This paper turns an analytic lens on to how client engagement sessions in 3D immersive environments are accomplishing different work, in attempting to demonstrate, in a sensory and embodied way, that the contract and design requirements are being met (e.g. that single bedrooms in the hospital are big enough), and in presenting (or selling) a design vision. The virtual world is being designed to be viewed from a particular point of view and design teams, tasked with convincing decision makers to proceed to the next stage during the bidding process for a contract, have the opportunity to use these sessions to best 'showcase' their design to the clients. During collaborative working in the CAVE, the navigable space is both a site of interactive encounter and an architectural model, and it is argued that design teams establish a narrative to support the navigable space which the clients experience through the careful consideration and planning of their journey, included what can be revealed or concealed along the way.

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