Designers' perspectives on the use of immersive virtual reality technology in practice

DESIGNERS' PERSPECTIVES ON THE USE OF IMMERSIVE VIRTUAL REALITY TECHNOLOGY IN PRACTICE

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The role of emerging virtual reality (VR)/ BIM enabled technologies on the construction design process is examined in this paper from an angle of understanding the contextual use of technology in practice. Drawing attention to the dynamics of interrelating the social, perceptual and material/ technical mechanisms involved, the study takes an interest in issues of understanding and reflecting on the effect of immersive technologies on construction design activities as used in concrete 'real – life' settings and as perceived by practitioners. The case study is an on-going construction project for a new hospital in the UK, where an immersive VR environment (IVRE) was used performing design review sessions during the bid preparation stage. It is about understanding practitioners' reflection hence the study augments previous insights based on direct observation and audio-video recordings of multiple design meetings with interviewing the design participants. The focus is on designers' perception of the events, their reflection back on their actions, their conceptual understanding of using IVRE in the process, and their view on the possible connection with broader practices of design. A particular strategy was applied in conducting retrospective discussions with the participants in a data review session format, consisting in both playing back video-clips (thematically selected from the video data set), and revealing the researcher's interpretation around what was happening during the design sessions. This was aimed to allow the participants' reflection on how they experienced particular episodes and to engage them with the research questions, for asking them to describe their understanding and reasoning behind the events. Early analysis suggests that the interview data is particularly informing with regard to participants' perspective on how using IVRE in the design review connects with other VR/ BIM enabled ways of performing the process and exposes their insight on the potential impact on the broader construction context.

Keywords: [designers' reflection-on-action, immersive virtual reality environment (IVRE), construction design practice].

INTRODUCTION

Although the potential of IVRE technologies (immersive virtual reality environments) has been widely addressed from a number of approaches (Kahkonen 2003, Whyte 2002), more research adopting sociological perspectives on the use of immersive technologies in the real life design practice is still needed. This study addresses this through examining the practicalities of the technology in an on-going construction project. The empirical material is drawn around the early design of a new hospital project wherein design and contractor teams used a CAVE (Cave Automatic Virtual Environment) set up in the University of Reading to demonstrate particular design

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requirements to the client and to perform design review meetings. This paper builds on a previous stage of research based on observing and video recording several design meetings held within the CAVE. The current study draws on retrospective discussions with the participants which had been involved in the CAVE design meetings. Mobilising Schon's (1983) idea of design as 'reflective practice', the paper focusses on the designers' retrospective reflection on their experience of performing design in this particular technological setting.

LITERATURE REVIEW

The broad argument of the paper is around Schon's (1983) theory of design as 'reflective practice', which considers design as a process of both reflecting and acting, or 'thinking' and 'doing' that are inseparable and bound up in the situations of practice. Schon positions design as situated activity, across different individuals and materials (design representations and technology). It stresses the context dependant character of the process, accomplished through locally constructing and collaboratively sharing meanings to iteratively shape the design. It is a process of making sense *in situ*, an interactive mechanism of both defining and addressing, creating as well as discovering the situation. Design as 'reflective practice' is not a uniform process, but dependent on how it becomes configured in the unique, complex and messy situations of practice. It involves mobilising existing repertoires of knowledge, prior understandings, media, procedures etc. which the participants draw on to collectively make sense of and address particular situations through conversation and action.

Distinguished in two states as reflection –in and –on action, the first refers to thinking about actions while performing, and the second is a form of thinking back to action previously accomplished outside of the situation, as a process of connecting with the understandings developed during action (1992). The process of addressing a design situation affects and reshapes appreciations and existing repertoires, therefore informing both the local episode and broader practice. Schon's idea of 'reflection-on-action' is the participants' reflecting back to enhance understanding and enrich repertoires of experience, applicable to subsequent situations of practice.

The approach adopted in this paper builds on Schon's position as well as on more recent studies that demonstrate the potential of mobilising ideas of reflective practice as a means to understand and analyse design work. Some draw on Schon's concern with examining and evaluating existing approaches to studying design (e.g. Dorst and Dijkhuis 1995; Stumpf 2001). Other studies mobilise more explicitly ideas and concepts of Schon to investigate aspects of the design process in empirical situations (e.g. Valkenburg and Dorst 1998; Stumpf and Mc Donnell 2002). Others build on Schon's position to develop models or frameworks for describing the design process and to develop methodological approaches to support the actual performance of design. Among these, McDonnell *et al* (2004) use Schon's reflection-on-action to propose a new approach for design practice. This combines video recordings and the story-telling techniques in an experimental study where the participants video a design event, and subsequently produce a story of the design episode. This is mobilised as research strategy for examining collaborative reflection on their experience, and for focussing on the cognitive mechanisms and social interaction involved. A particular focus is on the designers' critical assessment of their experiences, with envisaged implications for refining their practice. Their study restates the relevance of reflection

in design, and presents an interesting demonstration of how mobilising this idea supports accessing insights around the team design processes.

METHODOLOGY

The focus of the paper is on the idea of design as 'reflective practice' and the aim is to access insights around the participants' retrospective reflection-on-action. This is addressed through examining the participants' reflection on the use of technology and on their practice. This was achieved through discussions with the participants in a format resembling a data workshop reviewing and describing the design processes previously performed in the IVRE. The process consists of showing them the video-recordings of the design sessions in which they participated. The method choice draws partly on Schon's argument on the role of reflection-on-action outside of the situation as retrospective thinking on the previously performed actions through observing and describing. Also, the methodology resonates with what the ethnography refers to as 'closing the loop', as a way of checking the researcher's interpretation through engaging the participants with the research questions by allowing them to reflect back on the events. It is partly about the design participants' retrospective reflection-on-action which they performed during the design meetings in the CAVE, but also about their reflection on the researcher's sense making of the events.

The case study is based on an on-going project for designing a new hospital in the UK. One of the requirements is that all patient accommodation is in single rooms, rather than traditional wards. Single room only accommodation is rare in the UK, and so a key issue for the client was ensuring that the rooms were of sufficient size. At the time of the research, the project was still in bid preparation stage. The project team opted to augment the traditional design and client engagement procedure with the use of a CAVE (a type of IVRE) at the University of Reading. This was to be used to demonstrate to the client that the rooms were of an appropriate size.

As particular type of IVRE, the CAVE (Cave Automatic Virtual Environment) is an immersive, multi-person, room- sized, high resolution multi-display 3D video and audio environment, in which graphics are projected stereo onto the walls and the floor. It offers the user (equipped with 3D stereo glasses and a head mounted tracking device with location sensor) an active stereo and real-time interaction with a life sized 3D model. One user's movement in the space of the CAVE is being tracked and, consequently, perspective rendering is displayed responsively. CAVE participants see their arms and bodies and can easily interact between themselves during the simulation (DeFanti et.al. 2011). The CAVE at the University of Reading has three vertical projection screens (3m by 2.2 m) and a floor projection screen (3m by 3m).

The previous set of data consists of recordings and direct observation of a series of six sessions held within the CAVE) (Maftei and Harty 2012). For this study interviews were set out around showing the participants short clips and asking them questions drawing on the analytical themes generated through the initial stage of research. These follow up discussions were set out as semi-structured interviews in the format of individual data review sessions of 30- 60 minutes (December 2013). The retrospective discussions were supported by video fragments selected to illustrate themes drawn from the previous study for allowing the participants to reflect back on the events and on how they had perceived and experienced particular episodes. This consisted in playing back the video clips, introducing the participants to the researcher's interpretation, and asking them to describe their understanding and reasoning behind the events. The discussions were conducted individually in four sessions with

participants having various roles in the design team: visualizer (REVIT modeller), project director, head of health care (lead of interior design) and lead medical planner. Conducting the research followed the University's ethical procedures regarding the participants' consent and the confidentiality and data protection.

The analysis section below unpacks insights around: the participants' recognition of the analytical themes generated by the previous study of the video data; their reflection-on being in the CAVE (reflection-on the design review process and -on the use of the medium); and the participants' reflection on how the technology fits in the broader practice using other type of materials and less immersive technology.

ANALYSIS

Theme I: Reflecting on the researcher's interpretation of the events

Focussing on the participants' recognition of the themes drawn on studying the video data, this first analytical theme examines broadly how the design team members involved in the IVRE review sessions orient to the technology, and they first configure an understanding of the architectural model in the CAVE. Then the analysis unpacks insights on how the perception of the IVRE as non-familiar design medium provokes ruptures in the routine performance of the process, issue addressed through the designers' sense making and reflection-on the medium and on its use in the ongoing cycle of reflecting and doing, discovering and shaping the design .

Orienting to the technology

This theme of the video-based study focussed on how the participants organize the design review in the CAVE to address the technical specificities of the particular setting, in terms of issues such as orientation, navigation, perspective. Examining how the participants orient to the technology, the study of the video data noted that the designers perceived the ways of interacting with the IVRE as unexpected and needing a prior familiarisation with the CAVE. Among other instances to illustrate aspects of gradually making sense of the technology, episodes of stepping into walls are an example on the designers' initial stage of confusion when they were first getting immersed in the IVRE. This was found as subsequently addressed through processes of familiarising with the elements of surprise and making sense of the environment by learning to orient to the two types of spaces- the virtual space of the 3D model, and the more restrained physical space of the 3m squared CAVE. Reflecting on their experience of first encountering the CAVE technology, the participants commented:

"(…) it threw me a little bit that I just envisaged it would be enclosed and in my mind that would have been better. And looking at the video there, it just brought back some memories in the context of just the initial orientation. So you've got the goggles on and your field of vision, clearly looking at this, is quite narrow. Then you have a cable slightly in the way so I suppose you're a little hindered by the physical and the practicality of the technology that you're working with. And I recall someone else actually walking into the wall but that to me is a fantastic indication of how realistic it is... but I recall in a single room there that I stepped right up at one point to a wash hand basin and all the taps were modelled so you can literally put your hands out and see where that basin is. So for me I was blown away with it, I thought it was a fantastic way in which we can use technology to really convey a sense of space." (Project Director)

Similarly, the Lead Medical Planner' reflection on the experience in the CAVE points firstly the perception of the environment as surprising in terms of not conforming with

the usual ways of interacting within a design sessions: “it’s hard to understand what was happening when you first go in”; “it was exciting but it was a bit daunting as well because it’s something new and you’re kind of, have an expectation”. Orienting to the ‘new’ technology involved noticing constraints-such as the googles, the limited field of view, the cable attached to the head tracker device, or issues of feeling unsafe, but also making sense of the advantages brought by the CAVE. Among the perceived advantages, the designers mention the usefulness of enabling immersion in the designed spaces, providing a sense of being in the model and a compelling real like perception of the virtual design. Secondly, discussing retrospectively with the participants reveals insights into their processes of addressing the unexpectedness of the situation, responding to the surprise brought by the new technology different from their routine procedures through reflecting-in-action, which is of making sense of and familiarising with the IVRE, learning how to use it in order to perform the review sessions: “(…) walking into the screens (…) I managed not to be able to do that. I think I realised quite quickly where the boundaries were” (Lead Medical Planner).

The participants’ retrospective insights reveal their recognition of the analytical theme and expose their reflection on the use of the CAVE and on their processes of responding to the particularities of the technology, familiarising with it through their reflection-in-action in the situation of reviewing the design in the IVRE. Moreover, as inferred from the designers’ comments, showing them video clips from the CAVE sessions helped refreshing their memory of the previously accomplished processes and supported their retrospective reflection on the events (e.g. “looking at the video there, it just brought back some memories”; “I recall”; “you’ve reminded me now”).

Orienting to the design and representing out

Checking the participants’ recognition of the video data based theme concerned with how designers were moving from their understanding and sense making of the model to thinking about representing it out for showing the design to the client, the designers were shown a 20seconds recording when they were reviewing the operating theatre in the virtual design of the hospital. Their reflection on the use of the CAVE and on how the design review in the IVRE impacted on the process of representing the design for the client notes that the CAVE experience generated changes to the representation, oriented to address the concern with the client’s perception of the design.

“It was hugely beneficial because it allowed us to be able to make changes to it. When a client looks at something, that was incredibly cluttered that room, it had a lot of stuff in it. We had shown everything in there and we didn’t need to show everything and that was a mistake. (…) So it was to sell the size of the room to the end users.”

The designer’s reflection on the use of the CAVE for representing out the design indicates a role of the IVRE as commercial tool through mediating decisions regarding the way of presenting the model for the client from the concern of ‘selling the size of the rooms’. This points the advantage of the CAVE simulation by mediating the designers to evaluate the consequences of previous design intentions, appreciated as unsatisfactory- “it was a mistake”-leading to reconsidering the situation. The excerpt from the retrospective discussion with the participant reveals a sample of the designer’s reflection back on the thinking and doing involved in the processes within the CAVE through indicating the way in which her sense making of the design and the process of shaping it (intention, representation, evaluation, and re-appreciation) entangled in the CAVE experience. Also, beyond the representational level, the designer’s retrospective reflection suggests the effect of using the CAVE in the review

on deciding changes to the design, by supporting the design and contractor teams together with the client to reconsider the equipment needed in the operating theatre. The designer's insights indicate the role of the CAVE to mediate collaboratively reshaping the design decisions through engaging with client in the IVRE.

"So we had the benefit of being able to convince them that the space was acceptable. We would have had that meeting anyway regardless of whether we'd been in the CAVE. But what the CAVE allowed us to do was actually say, there is too much stuff in here for you to move around. How do you even work in this space? [an operating theatre]... So it was good for us to be able to say to them, we think there's a problem with the size of this room even though it's massive that you've got too much equipment in here." (Lead Medical Planner)

The designer's reflection on experiencing the simulation of the operating theatre in the CAVE revealed first that although the design of the room was of big size, it seemed overcrowded when bringing all the equipment; and second, it allowed the designers to reflect on the need of equipment in the actual use of the theatre and to question and discuss it with the client. Consequently, reflecting on the requirement, the client confirmed that not all the equipment will be actually needed in the room at the same time and hence the size of the room was considered as satisfactory.

Summing, the participants recognized the research themes drawn on the video study. The designers' retrospective insights are a sample of their reflection -on their experience in the immersive environment and -on the particular medium, and point the use of the CAVE as a convincing representation, as well as supporting discussing and negotiating the design requirements with the client.

Theme II: Reflecting on the CAVE experience and on the use of the medium

This theme focusses on the participants' reflection-on their past accomplished process of reviewing the design in the CAVE and –on the use of the immersive technology for performing design activities. The designers' retrospective thinking about the CAVE experience infers an overall usefulness of the technology through enhancing the spatial understanding, either by confirming expectations or enabling noticing clashing issues and driving changes to the design, or by mediating discussions with the client:

"I think it was very beneficial. It made me realise, you always worry that the space is not big enough, that's the first issue you sometimes have, because we had a real pressure on area for the whole project, and some of the rooms were slightly squeezed down in size but it made me recognise that in fact the rooms were good. They were a good size, they were a good layout, so from that point of view it just reinforced, it validated. It confirmed that we had done the right thing." (Lead Medical Planner)

The retrospective discussions with the designers around their reflection on the CAVE sessions and on the use of the medium triggered also the reflection on how the immersive experience compares with their existing repertoires of procedures and technologies involved in their mundane practice. As the Project Director comments: "Where I thought the CAVE came into its own and was really very compelling was in the operating theatre, because you've got a lot of equipment in that space, (…) and the dynamic, three dimensional dynamic of that space changes quite dramatically. And there were certain elements that, even though we'd gone through it really, really very carefully, certain elements just weren't right, and it was only when we were in that environment that we noted they were not right. Could we have done it by other means? Probably. Would it have been as effective? Probably not. Would we have got

the same kind of feedback from our users? I doubt it." The Project Director's reflection on being in the CAVE points how the immersive environment enabled noticing clashing issues regarding the arms of the equipment in the operating theatre of the designed hospital, which could not be perceive using other types of representations and technology. Similarly, reflecting-on what the CAVE brings in the process in addition to other representational ways and technologies, a Visualizer points the enhanced understanding of the relationships between elements, the awareness of the scale of space, and the potential to inform decisions regarding what to emphasise in the representation of the project:

"(…) the CAVE made me aware of what we needed to do. The spaces that you kind of didn't think about developing actually needed to be developed a bit more in order to understand certain direction points and certain pathways. I think that actually physically being in the space helps you to understand the scale which is important especially when we're designing. And understanding the scale is something you don't get from a Revit model. So that was the most important thing in the CAVE for me, it made me understand the hierarchy of the space better."

Referencing the use of the CAVE as design medium in relation to other less immersive technology (the repertoire of mediums used in the designer's daily practice) points the influential role of the IVRE to inform and guide further designing. Reflecting back on their experience in the CAVE, the designers identify how reviewing the 3D model in the IVRE contributed to developing the project by enabling noticing issues about the design which had not been perceived using other mediums, fact that consequently lead to changes of the scheme:

"I think it definitely did influence it. How much? We made changes as a result of having experienced the CAVE and that's perhaps something that wouldn't have happened had we not had the benefit of being in the CAVE. So my corridor that was a little bit too low and narrow would have stayed a little bit too low and narrow and we wouldn't have necessarily known." (Lead Medical Planner)

The designer's insights note that the CAVE experience brought about changes to the design, drawn on the experience of simulating and reviewing the model in the IVRE, which enabled the designers to 'see' issues about the design which had not been previously perceived, such as revealing the unsatisfactory appearance of the "too low and too narrow corridor". With a similar perception around the CAVE experience, another participant's reflection on the use of the technology points the potential of the immersive medium to enable seeing the things in new ways, reframing the understanding of the model through drawing awareness on different issues, informing the thinking and leading to re-evaluating the design: "I guess it just gives you a different perspective. So when you have a different perspective on something you think of things in a different way." (Visualizer)

The designer's reflection-on the use of the medium indicates benefits brought by the CAVE in the process in addition to the other representations of the design mediated through non-immersive technologies (on screen or on paper, Revit, 2D or 3D). The participants' insights refer to perceived advantages of the CAVE such as confirming design expectations, or enabling a different way of making sense of the design by supporting noticing issues not perceived through using other, less immersive mediums, and by stimulating attention to other aspects (e.g. spatial awareness). The participants' reflection-on their practice in the CAVE is about reflecting retrospectively on the doing and thinking involved in the CAVE, but also about

reflecting on the repertoire of experiences and of mediums, and comparing the design review in the CAVE with doing design routinely, using other types of representations and technology. As the Lead Medical Planner commented:

"It was just much more exciting because you were actually in, you feel like you're in the space. You can immerse yourself in it much more. Generally, we would look at the 3D perspective and say, yes, that does, we think that does what, you're never quite sure with a 3D image on paper or on a screen that it's not slightly exaggerated or that the technology used to spit an image out of the model hasn't done something to just distort what you think it should look like, whereas being in the space is different."

Summing, the participants' retrospective perception of reviewing the design in the IVRE stresses the immersion as distinctive feature of the technology perceived as bringing advantages in the process as compared to their existing repertoires of less immersive materials and procedures. Reflecting on the experience in the CAVE, the designers note the role of the immersive medium in the process, not only within the local situation of reviewing the model but also through guiding the subsequent adjustments and changes made to the design in terms of scheme, representation and even at requirements' level in consequence to performing design in the IVRE.

Theme III: Reflecting on the use of the CAVE in the broader design practice

This theme addresses the interest about the participants' perception around using the CAVE in the broader design practice and the potential to complement other less immersive design procedures and technologies. Invited to reflect on the potential connection of using this technology with other usual ways of doing design, and to express their view on the utility of the CAVE, the Medical Planner commented:

"I think it would be hugely beneficial to be able to use it on a daily basis if you would need not have to do that level of pre preparation. So if it's getting easier to actually put what we develop naturally as architects into the format that we could just put on the goggles and walk into it without having to do anything extra to it, I think it would be hugely beneficial. I loved it. I thought it was brilliant and helpful on so many levels."

The designer's reflection suggests the envisaged use of the IVRE in a complex of situations of practice, through enabling checking the design and the atmosphere inside as well as outside the 3D building before it is actually built, and not only during later review, but also in earlier phases of conceptual design. The participants' reflection on the potential use of the CAVE as design medium in the context of the broader practice indicates a range of possible advantages brought by complementing the daily design procedures with designing in the IVRE. As perceived by the participants, if certain constraints would be mitigated through the development of the technology (e.g. issues regarding the time for travelling to a CAVE set up in a university, or the conversion between various versions of the digital model), the CAVE might usefully complement the practice and support performing activities in a variety of stages in the process.

On the same argument around the usefulness of the CAVE as design medium in relation to the broader set of activities and processes involved in the practice, the Project Director draws the focus on the advantages brought by the IVRE through supporting aspects of social interaction as a "very, very powerful" tool. In this sense, it is pointed the benefit of the CAVE to mediate collaborative designing through supporting 'reciprocal reflection-in-action' (Schon 1983) among multiple participants involved in a project during exploring, understanding and refining a design. Moreover, the Project Director's reflection-on the use of the medium indicates possible

adjustments to the technicalities of the CAVE to improve the team group experience of exploring a virtual model. In this sense it is suggested the provision with an 'endless floor' as solution for enabling real like walking in large areas of a virtual building without being constrained by the physical boundaries of a 3 meters square environment:

"Let's just assume we've been in the CAVE for 15 times, that newness is of (…) Wow, that would be really powerful, because we all see things in a drawn way or even a model way in a slightly different way, I think, so having the benefit of a group discussion around things. Or if you took my example of the endless floor, and you were walking through that space with a nurse and you were just saying, OK we're going to go to that inpatient room. And the nurse is saying, well that seems like a long way from a scrub or from a dirty or a clean utility, or if it's like this I've got to go back six or seven times. But you wouldn't have that opportunity if you were doing it on your own. I mean if you had that very focused social interaction, (…) it's just you walk through a space and people offer observations about, that's not right or this could be better or there's an issue here. So that would be very powerful." (Project Director)

The participant's reflection on the future use of the CAVE as design medium within the broader practice points that in further situations when the immersive technology would no longer be perceived as a novelty or as surprising, with elements that could interrupt the routine performance of design activities, the IVRE might enhance the development of the process. Subsequently to the designers' familiarisation with the CAVE, the processes of thinking and doing involved in their accomplishment of the practice might be better supported by the immersive environment with regard to issues of noticing things about the design (e.g. clashing elements) not perceived from other types of representations, then developing ideas and refining the model collaboratively. The designer's perception on the potential of the CAVE to be used in connection with the mundane design procedures in the broader practice stresses the advantage of the immersive environment to enable developing and establishing shared meanings of evolving design intentions between multiple participants involved in a design project.

Summing, the participants' reflection on the use of the CAVE to complement the broader practice points the envisaged usefulness of enabling simulating activities or experiences such as moving in the designed spaces, and of supporting a collaborative process based on shared understanding. The use of the CAVE is seen as potentially fitting into various stages in process, from developing the concept design though to later phases of design review. Moreover, reflecting back on the CAVE experience and on the use of technology, the designers offered suggestions for the future development of the technology in terms of overcoming the perceived constraints and adjusting the configuration to better support the practicalities of using the CAVE for design work.

CONCLUSIONS

Concluding, the retrospective discussions with the design team members revealed their recognition of the analytical themes drawn from studying the video data around the IVRE design events they had previously attended. Engaging the participants with the research questions, exposing them to the themes and showing them video clips triggered their reflection-on the processes involved in the design situation of reviewing the hospital project in the CAVE. The designers' reflection revealed how the experience in the immersive environment affected their further process of developing the project outside the CAVE. In Schon's vocabulary, this points how the designers' appreciations are being shaped through their reflection-in-action within the

ongoing performance of design review in the CAVE, and their repertoires of knowledge, understandings, of mediums and procedures become enriched through the design experience in the immersive environment. Also, through bringing the designers awareness of their understandings that underlined their past actions through encouraging their retrospective reflection on the previously accomplished design episodes, these are contributing through informing their further practice in future design situations. Moreover, the retrospective reflection-on how they had performed design review activities in the CAVE and their reflection-on the use of the CAVE as design medium revealed how the use of the technology and the process of performing the design cannot be separated and bound up together in accomplishing the practice. Insights of this study are envisaged to enhance understanding and support integrating the practical consequences of using CAVEs in design activities, and also to potentially inform the development of technology from the practice perspective.

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