

# ACCOUNTING FOR USERS: DESIGN TEAM WORK IN IMMERSIVE VIRTUAL REALITY ENVIRONMENTS

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The study examines how designers account for the use and users of their design in the situation of reviewing the design in an Immersive Virtual Reality Environment (IVRE). The focus is on the interactions whereby designers express the imagined perspective of being users, and on how the design meeting is configured with respect to the concern around the use of the future building by the real users. Observations are made around how designers express these 'narratives' around experiencing a design as imaginary users through various modes (verbal, graphical, behavioural) involving different procedures and forms of representation. The case study is an on-going construction project for a new hospital in the UK, where an IVRE was used performing design review sessions during the bid preparation stage. Drawing on data based on direct observation and audio-video recordings of multiple design meetings, the scrutiny is on how architects adopt the position of end- users in design sessions in which users do not participate. The aim is to examine the nature and dynamics of interactions inside a design team as they imagine users' needs in an IVRE. The focus is on how architects express and test the 'usage' of their design in this particular technological setting, where life- like movements and physical interactions with the design are possible.

Keywords: design, immersive virtual reality environment, interaction

## INTRODUCTION

The aim of this study is to investigate how designers account for their users, from the perspective of examining instances where designers adopt the role of being a user in an Immersive Virtual Reality Environment (IVRE). Concerns around how the 'use' and users of an artefact are incorporated in the design process have been raised across domains of architecture, engineering, product design and software design (e.g. Luck 2007, 2012; Ball and Christensen 2009; Cross 2000; Arvola and Artman 2007). Within the construction field, the issue of how designers account for users tends to be oriented towards designers directly engaging with users (in creating together shared meanings of design schemes) or in using individual experiences and knowledge to imagine end- users' experience of the design. The case study is an on-going construction project for a new hospital in the UK, where an IVRE was used performing design review sessions during the bid preparation stage. The focus is on

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how architects express and test the ‘usage’ of their design in this particular technological setting, where life- like interactions with the design are possible.

## LITERATURE REVIEW

This section identifies two broad strands in the literature around designers and users: the first focussed on designers directly engaging with users, and the second strand investigating design sessions in which users do not participate. Within the second strand we identify two main modes whereby designers account for the use and users of their design: through drawing on their previous individual experience of an existing design, or through imagining an end- user's experience of the design being developed.

The first strand of studies focusses on how designers account for users through investigating design situations in which end users are being directly involved. Building on a participatory design approach, such studies stress the role of bringing users’ perspective on the use of a designed space (drawn on their insights from the lived experience in similar buildings) in conversations with architects, to collaboratively articulate design problems and solutions through establishing together a ‘spatial reasoning’ of a design scheme (e.g. Luck 2012). From a similar standpoint, work oriented on the conversational behaviour in design meetings in which architects engage directly with users in ‘reflecting in practice’ discusses the role of describing the use of space to create shared meanings of the design proposal (Luck and Mc. Donnell 2006 ) or to coproduce design ideas (Luck 2007).

The second strand of research concerned with how designers address issues around the use of the design as final product draws the attention on the interactions inside designers' teams, and examine design situations in which users do not participate. These studies examine how architects reflect on the use of space from the clients’ perspective through simulating users’ experience of occupying the designed space, in various modes involving different procedures, technologies and forms of representation. In this sense, some studies focus on the role of mental or graphical scenarios accompanied by ‘narratives’ developed and expressed through verbal description and/ or through drawings and gest-draws, and discuss how architects imagine ‘stories’ about their users, in which they refer to “the ‘roles’ they play and to the ‘rituals’ in which they are set” (Lawson 2006: 205). It is also examined the use of ‘narrative’ as strategy for conceptualizing and testing design ideas (Lawson 2006:267), and of how new technologies mediate the expression of such ‘narratives’ through drawings and gest-draws (e.g. Buscher 2005). Other work examines how the embodied references to the design are mediated through multiple visual means and models (e.g. Buscher 2006), or discuss the use of various forms of design representations for enabling a viewing experience of the designed space, as similar to users’ perspective (e.g. Yaneva 2005- the scaling process, the use of physical mock-ups and of the model-scope).

In other domains of design, literature around designers enacting the role of users and/ or of system components of a design, discusses the role of ‘personal analogies’ in the creative process, as for example through imagining circumstances of being the user of a designed object, or a part of the designed system (Cross 2000). Studies around the social dimension of teamwork in design discuss how assessing the ‘human factor’ issue of a designed object is guided through designers’ personal knowledge on the use of their design, based on individual experience of a design situation (Cross 1995). Empirical studies of engineering design meetings (Ball and Christensen 2009) address issues of analogical reasoning and mental simulation in design with regard to features

of end- user's experience of the design. From a similar concern, other studies investigate how collaborating designers simulate experiencing a design through gestures and taking on the role of users or of system components (e.g. studies that examine types of enactments employed by designers to express a design concept - "means of expression", such as through gestures and improvising playing) (Arvola and Artman 2007). This study draws the focus on how architects adopt the position of end- users in design sessions in which users don't participate. Compared to the above studies, which focus mainly on the spoken interaction, this paper extends the scrutiny on how the visible means of enacting user's behaviours interplay with the verbal modalities of reflecting on and expressing the use of the design.

## **METHODOLOGY**

This research examines the nature and dynamics of design interactions in an IVRE from the concern with how architects consider the usage and the experience of their design from the perspective of imagining themselves as users. This concern with understanding specific interactional aspects regarding the practical and situated accomplishment of design is consistent with the methodological choice of observing in detail how this set of practices are naturally performed in this particular setting. 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 is a surround large display visualisation technology that may allow multiple users to experience an immersive simulation of tri dimensional life sized virtual objects at a time. The classic CAVE (Cave Automatic Virtual Environment) as the one designed and implemented at the University of Illinois at Chicago in 1991, is a 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 the model. One user's movement in the space of the CAVE is being tracked and, consequently, the correct scene perspective rendering is displayed in a continuous responsive manner. CAVE participants see their arms and bodies and can easily interact between themselves during the simulation (De Fanti 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 research used video recording and direct observation of a series of six sessions held within the CAVE, involving project and design managers, architects and designers, and modellers and visualizers, in various combinations. These were spread across five months, between November 2011 and March 2012. These sessions produced 12hours of audio-video recordings. Various combinations of video cameras have been used to capture the design meetings: one hand-held camera, a second camera fixed on a tripod, positioned in one corner of the CAVE and a third camera fixed on the CAVE's ceiling to offer an aerial top down view. In conducting the

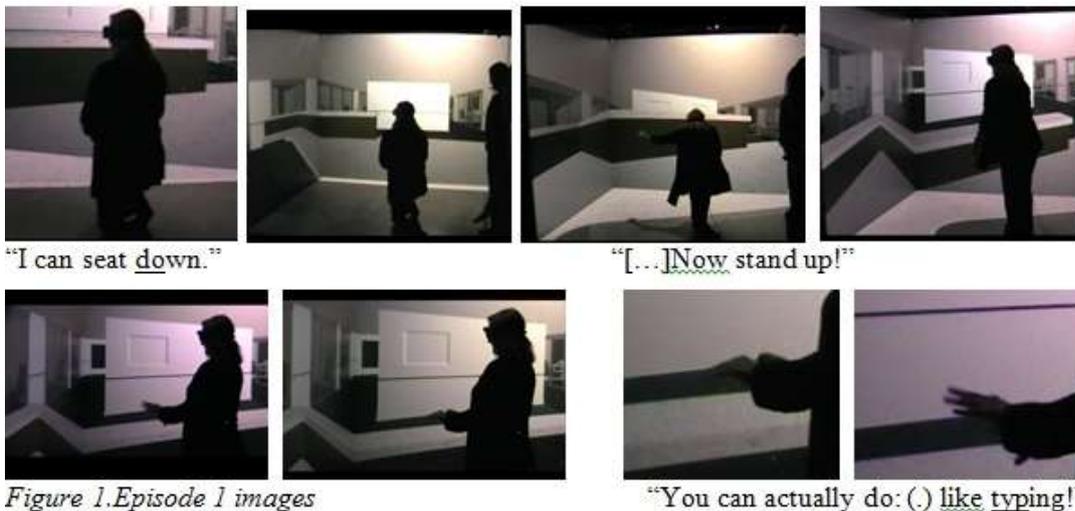
research, we followed the University's ethical procedures regarding the participants' consent, and the confidentiality and data protection.

This study examines how designers account for their users and express this in an immersive environment. The focus is on the particular interactions whereby designers make sense of the 'usage' of the designed spaces and enact user's behaviours, and on how the IVRE is used in configuring these interactions. The analysis draws on a collection of such situated enactments whereby designers reference their actions to how the design might be experienced by their users. The empirical material has been structured in four episodes analysed below. The initial fragment has been selected to provide preliminary sense of the interactions that will form the focus of attention. The following episodes examine several instances whereby designers imagine themselves as users experiencing the space of the hospital. This approach draws on video ethnography based studies of workplaces and of interactions (Heath and Luff 2008; Heath, Hindmarsh and Luff 2010). The transcripts presented in the paper have been produced using a simplified transcribing system provided by Silverman (2006).

## ANALYSIS

### Between virtual and real: Simulating the experience of inhabiting the space

This fragment supports introducing a chronological frame of the design events occurring in the CAVE in the context of preparing the bid for the hospital project. The fragment is extracted from the first from a series of six sessions of reviewing the design in the CAVE, and it refers to how the architects and contractors teams first encountering the immersive environment perform a walkthrough of the hospital's virtual model. It has been selected to illustrate an instance whereby the design participants envisage potential benefits of using the CAVE for presenting the design to their client.



### Episode 1 (E1)

- Designer1 (09:00): I can seat down.  
 (09:16): ((the designer is kneeling))  
 Contractor 1 (09:17): And if you could look a bit further to the right?  
 ((the contractor points the direction with the hand))  
 (09:19): ((the designer follows the suggestion and orients the head and gaze towards the right; the other participants take photos with the designer inside the space of the hospital))

- Contractor 1 (09:20): And if you turn to the left?  
 ((the contractor points the direction with the hand and dynamically gestures towards the left side of the model))  
 ((the designer reorients the head and gaze towards the left))
- Contractor 1 (09:22): That's good.  
 ((the other participants take another set of photos with the designer facing the opposite direction of the reception area))
- Contractor 1 (09:24): Now stand up!  
 (09:26): ((the designer begins to gradually stand up))  
 (09:28): ((the designer is standing up))  
 (09:30): ((the other participants take a final set of photos with the designer standing on the reception desk))
- Designer 1 (09:38): You can actually d:o (.) like typing!
- Designer 1 (09:46): ( ) You got to get the TRUST ((the client)) in here!

In the course of examining the main reception area of the hospital, the participants decide to record a series of photos with the spatial effect of the virtual model as previewed in the CAVE for demonstrating the compliance of the design scheme with the visibility requirement. In consequence to noting the advantage of a 3D life size scaled model which allows real-time interaction through physical motion, they decide to augment the sense of scale and realism in the photos by including a designer acting as nurse while performing activities at the reception desk, as personage in the picture. The project team employs an active simulation of the visibility scenario for illustrating various viewing angles of the reception area from different height levels around the desk as in the real use of the hospital. Following a contractor's guidance, the designer acting as nurse gradually changes the position of her body as from sitting down on a virtual chair to standing up. A rich range of visual behaviour accompanies the verbal coordination between participants and the interaction with the imagery throughout this sequence of the design meeting. Multiple changes of gazes and gestures of pointing (with the arms and fingers) towards different areas of the hospital, or reorienting the head direction and body motion in the space of the CAVE are frequently being engaged.

After the project team's members consider they had recorded sufficient photos of the model displayed in the IVR, the designer which had acted as nurse continues playing the role of being medical staff, and spontaneously begins to engage in testing the experience of inhabiting the model. Finding herself standing near the virtual desk she notes how the model interactively responded to her body's motion within the space as in a real building (E1, 09:26-09:30). Observing how her arms seem to rest as on a real furniture object (the effect of the life size scaled model) she begins to move her hands and fingers in gestures of simulating typing on a real keyboard, imaginary placed on the virtual desk (E1, 09:30- 09:38).

The proximity of the virtual desk at a real like height and ergonomically placed as perceived in relation to designer's body stimulate her responsive reaction to simulate performing an activity in the surrounding model and generates the feeling of inhabiting the space: "You can actually d:o (.) like typing!" (E1, 09:38). Impressed by the strikingly compelling sense of being in the model (and the real-like perception of the hospital's space) she points the potential of using the CAVE in the design review and for presenting the design to the client: "You got to get the TRUST in here!" (E1, 09:46). The designer's sudden behaviour (between the moments 09:30 and 09:38 in the fragment E1) infers the effect of the immersive environment on stimulating

adopting a perspective analogue to being an end user experiencing the space. Also, the enactments of user's behaviour instantiated in this fragment reflect a rich interplay of talk with dynamic visual means expressed through body motion and gestures.

In the context of the on-going project for designing the hospital, these observations around the potential of the technology, such as enabling the immersed participants to simulate performing activities in a realistic way, influenced the project teams' members to consequently deciding to use the CAVE for presenting the design to the client. In summary, this analysis points towards how designers adopt the perspective of being users for testing the design requirements through employing a rich interplay of verbal and visual behaviour in the IVRE.

### Reviewing the design in the CAVE: Designers imagining themselves as users

This subsection examines how the architects, designers and visualizers in the project team consider the activities performed in the designed spaces from the account of users. More specifically, it refers to how participants exploring the design in the CAVE interpret and make sense of the virtual model from the perspective of imagining themselves as users experiencing the space of the hospital. The focus is on how designers are moving the design review beyond discussing issues of form and function to address the experience of occupying the space, and on the modes of expressing this design concern in the immersive environment.

The following fragments are extracted from an early design review session when the architects' team is concerned with the compliance of the design scheme to meet the client's requirements and with how the geometry of space fits the functionality, and also with the visual experience of the model (e.g. lights, colours, textures).



“Can I look at the bath?”



“( ) The door looks wide”



“The door is wide”

Figure 2. Episode 2 images

### Episode 2 (E2)

- Designer 1 (15:44): The door seems wide.  
 Designer 2 (15:45): Can I look at the bath?((shows the direction with her arm))  
 Designer 1 (15:46): Wh::at?  
 Designer 2 (15:47): He thinks I'm wide...((laughs))  
 Designer 1 (15:49): Ha, ha, I don't know how you got the conversation that way!  
 ((general laughs))  
 Designer 2 (15:52): I'm gonna go in the toilet.  
 Designer 3 (15:53): The door looks really wide.  
 Designer 2 (15:54): The door is wide=  
 General =The door is wide

This episode depicts an instance when the design team examines the door separating the bedroom and bathroom areas in the patient's room. In previewing the door from

the bedroom, one of the designers estimates the door's dimension as appropriate to allow a person's way between the two adjacent spatial units: "the door seems wide" (E2, 15:44). This infers a lack of certainty about the door's dimension, as the accuracy of the evaluation is not based on a precise measurement tool (like it would have been available on a scaled drawing on paper, or on a scaled physical or virtual mock-up visualised on a computer screen): "seems". It also implies another mode of measurement through considering how the door fits its use and referencing the door's width to the human body's size (therefor the door is described as "wide"). This remark relates with the immediately following moments when the way in which the designer leading the navigation formulates the intention to move the examination of the model in the bathroom as "Can I look at the bath?" generates a reaction of surprise in the first designer's in exclamation "Wh::at?". This constitutes an interestingly atypical reaction during a design review, in which shifting the spatial analysis between different areas of the design, as these are progressively being examined, is a routine procedure. The element of surprise is further augmented in the second designer's reaction: "He thinks I'm wide..." (E2,15:47). Being aware that she is visually situated in close proximity to the virtual door, previously estimated as wide, the second's designer (wearing the head trackers) ton of amusement questions the sense of relating the door's width with the size of her own body. The immediate response "I don't know how you got the conversation that way!" marks a particularity of the immersive design review and infers the overlay between the real-life like behaviour in the virtual hospital and a mode of relating design dimensions to own bodies and of referencing the ergonomics of the design to designer's enactments in the virtual space.

The sequence between the moments 15: 44 and 15:49 captures an example of how, consequently to being immersed in the virtual space with their own physical bodies, the design participants begin to perceive in a real like manner not only the design information, but also the way in which they interrelate with the virtual model and among each other. As the designer enters the bathroom through the virtual door, the other participants which are visually following her movement note the ergonomics of the space to accommodate her action (E2, 15:54). Almost simultaneously, the designer confirms that, as person wearing the head trackers, she has a similar perception of the door's dimension and augments her verbal utterance with visual gestures (raises and opens her arms to indicate the door's width) (E2, 15:54). Her verbal and visual demonstration brings about the final confirmation of the group: "the door is wide" (E2, 15:54).

Summing up, this episode shows how the designers immersed in virtual environment enact the experience of imagined users of the real hospital. Also, it reflects how multiple members of the design team organize the review by behaving like a group of end-users.



Inspecting the bathroom



Counting grab rails



"Would have been nice ( ) a window"

*Figure 3. Episode 3 images*

### Episode 3 (E3)

General (15:58): Yuh:::u!!!

- Designer 1 (15:59): ((entering the bathroom))  
Would have been nice if there was a window.  
((gestures pointing towards the blind wall of the bathroom))
- General (16:02): It ((the room)) looks giant!
- Designer 2 (16:05): These ((toilet, basin, etc.)) don't look centred
- Designer 1 (16:07): One, two, three,..., seven, eight grab rails!  
((counting the grab rails in the room and following this action with hand gestures of indicating their location on the wall))
- Designer 2 (16:11): It is, yes, cause they have to be!

The design team's members express a general enthusiasm when, consequently to the designer's wearing the head trackers motion through the space of the CAVE, they find themselves in the patient's bathroom. The group notes the satisfactory dimensions of the room, which is unanimously perceived as having a better size than expected from the previous examination of the model via other non-immersive and smaller scale representational modes (Revit model, on screen). Examining how the design meets the clients' requirements and corresponds to typical norms of a hospital bathroom scheme, their review addresses the geometrical and functional configuration of the design with regard to issues of area, heights, and the location of sanitary objects in the room.

The instance whereby a designer remarks that a window would have enhanced the quality of the bathroom's space (even though it was not a compulsory design requirement) (E3, 15:59) constitutes an example of reflecting on the perception of the space from both a professional angle, and, also from assuming how real users might perceive the design. As it does not address the specific focus of review (it is not compulsory like, for example, the grab rails that "have to be"- E3, 16:11), the observation around the window which would have enriched the quality of the space is not further expanded in the meeting in a collaborative discussion, like other spatial elements previously examined. The way in which the remark about the window juxtaposes in the sequence infers the effect of being immersed with own body on the direct perceptual experience of the designer who formulates it. Therefor the situated review of the design becomes constituted through interlacing both observations around meeting the specific design requirements (e.g. eight grab rails, 1.7 metres height for the mirror- E4,16:37) and also spontaneous reactions of the design team encountering the space with their own physical bodies and imagining the perspective of users. This episode reflects a particular mode of reviewing the design not only through measuring a space by moving through it, but also through testing the experience in the space. It moreover illustrates an example of designers making sense of the space both through the design knowledge of a scheme, and from assuming a real user's perception of the not yet built hospital.



"This basin needs to be centred" "()" basin's moved" "This mirror should be up like that"  
*Figure 4. Episode 4 images*

#### Episode 4 (E4)

- Designer 1 (16:25): The basin on the wall is off centred.

- Designer 2 (16:29): ( ) It looks ok (0.2) Quite low, though.  
 Designer 2 (16:37): Eye level, 1.7 ((metres))  
 Designer 3 (16:40): If you're a tall person you have a different point of view  
 Designer 1 (16:43): So if you're saying it looks low, it must be low  
 Designer 1 (16:48): Does it seem low to you?  
 Designer 2 (16:50): Yes, it does.  
 Designer 2 (16:52): And this mirror (0.2) should be up (.) like that.  
 Designer 1 (16:56): And this basin should be centred between the two rails!  
 ((the other designers change gazes and reorient their heads towards the left side of the room))

In this fragment, the design team continue the exploration of the bathroom. The designer wearing the head trackers is the person having the most accurate visual perception of the rendered model, and who interacts directly with the imagery (her motion in the space of the CAVE drives the active real time animation of the virtual model). After examining the door, the window, and the grab rails, designers moving around in the bathroom employ a thorough examination of the wall with the sanitary objects. Their situated behaviour infers that the group acknowledges that the designer wearing the head tracker is experiencing the simulation of the model in the most similar way to how a real user of the bathroom might perceive it: “( ) if you're saying it looks low, it must be low” (E4, 16:43). Consequently, the collective judgement in reviewing the space becomes organized around her perceptual feedback.

The sequence of reviewing the position of the mirror on the wall develops through referencing the height levels in the virtual space to the designer's body. This reflects both in how she becomes the comparison point to give sense of scale to the model and she is integrated in the visual examination of the group, and also through how the designer enacting the use of space makes sense of the height and formulates her evaluation: “( ) this mirror should be up ( ) like that”. This is complemented through expressing a visual way of describing the height when the designer gradually raises her arm above the head's level to indicate the position of the mirror. Examining the present, past, and future states of the design (“it looks ok”, “is off centred”, “should be up”, “has moved”) is realized through interlacing a multitude of gestures like pointing the directions or indicating the location of sanitary objects by moving arms, fingers and reorienting the head direction and changing gazes. As instantiated in these episodes, the awareness of own body size in reference to that of the designed building via interacting with the virtual model rendered in the CAVE enables designers to explore the space in a manner resembling to how users might experience it.

This fragment reveals how the design team members organize their collaborative evaluation around the perception of the designer who is acting the role of user. This is mediated through a complex interplay of both verbal and visual behaviour employed in simulating the experience of a user, in communicating it within the design team, and in collaboratively making sense of the design.

## CONCLUSIONS

The findings showed that the specific context of interacting with the building model and around it among designers immersed in the virtual environment in a real-like manner (responsive interactions in real-time through body motion in the virtual space and seeing own bodies and other team members) mediated a particular way of accomplishing the review. This consisted in: realising spatial measurements through referencing design elements to designers' physical body size; evaluating the

ergonomics as referenced to designers' body motion through the virtual space; testing the visual and functional perception of the design through spontaneous enactments of inhabiting/ using the design (instances of taking on the role of users performing activities in the designed spaces). Regarding the issue of how designers imagined themselves as real users, the study suggested that the team made sense of the review both in instances of multiple designers playing roles of users, and in sequences of organising the collective judgement around the perception of the designer taking on the role of the user. Also, the study reveals that the design team members accomplished the review and configured end-users' enactments in the IVRE employing a complex interplay of both verbal and visual behaviour (gestures, gazes, body movement and change of orientation). This suggests the potential to augment addressing the end- users' experience of a design in the process, and to complement other design methods like bringing users' participation in developing an architectural project.

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