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**Surprise: Challenging design perceptions in immersive**

**virtual reality environments? The case of designing a**

**hospital project using a CAVE (Cave Automatic Virtual**

**Environment)**

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**Surprise: Challenging design perceptions in**

**immersive virtual reality environments? The case of**

**designing a hospital project using a CAVE (Cave**

**Automatic Virtual Environment)**

**Purpose**

**-**

 The purpose of this paper is to examine how the use of immersive

virtual reality (IVR) impacts on the surprise aspects of designing.

**Methodology**

 - The empirical case is a new hospital in the UK wherein a

CAVE (Cave Automatic Virtual Environment) type of IVR was used

performing six design review sessions during bid preparation stage. Drawing

from a former video-based study, we conducted follow-up discussions with the

participants to access their perspectives on design surprises emerging from

their engagement with the IVR. The study developed a reflective

methodology, interviewing participants about their experiences of doing

design in the immersive environment. Retrospective discussions were

conducted in a data review format, through playing back video-clips of the

IVR design sessions and asking the participants to reflect on their IVR design

experience and on design surprises emerging from their engagement with the

IVR.

**Findings**

 - The findings indicate that IVRs such as the CAVE are not only

enhancing existing understandings of design, but also challenging the

participants’ understanding of the design as they experience the immersive

version of it, provoking ruptures in current procedures and driving

unanticipated changes to the design.

**Originality/ Value**

 - This qualitative study of surprise in design work using

IVRs (for a real-life design project) brings new insights into emerging

practices of designing using immersive technology such as the CAVE.

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Keywords: design practice, immersive virtual reality (IVR), design surprise,

retrospective reflection

**. Introduction**

**1**

*“Actually there are quite a few architects who when they go into built form at the completion*

*of a project, are a little*

***surprised***

 *at the body metric nature of the space, too big, too large,*

*too high, too narrow, whatever it might be. Didn’t think that was going to look quite that*

*way, even though architects and designers are trained to do exactly that […]”*

Project Lead, design team, interviewed in December

2012)

(

The above quote exposes a design practitioner’s view on the surprise encountered when

entering the built version of a design for the first time. Design practice is “frequently

displaying surprising features that defy our understanding, descriptions, and planning

capabilities” (Lanzara, 1999: p. 334) and is as “much about re-design, interruption,

resumption, continuity, and re-contextualising as it is about design, creation, invention,

initiation, and contextualising” (Weick, 1994: p. 6). This paper takes an interest in how/ if

using immersive virtual reality (IVR) technologies might be impacting on the role of surprise

emerging within design processes and on broader design practice.

The potential and use of IVR technologies in performing design has been extensively

addressed (e.g. Zhang et al., 2020; Kahkonen, 2003; Whyte and Nikolic, 2018). The research

interest in virtual reality (VR) and IVR has become an established trajectory of inquiry in the

architectural design and built environment literature (Salama, 2019). The themes addressed in

this literature range from immersiveness, experience, complexity, spatial perception and

cognition, problem solving, decision-making, collaboration, user engagement, to value and

cost or time. Overall, these studies suggest the potential of visualisation and collaboration

environments to support the creation, communication, development and understanding of

design through supporting and extending other design procedures (Whyte and Nikolic, 2018;

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Mastrollembo Ventura et al., 2020; Goulding and Rahimian, 2015). However, much of the

literature focusses on developing/ testing technology in experimental studies, or examining

the practical use of immersive technology using standard metrics. Much less examine the role

of these technologies in ‘real-life’ practice situations, and seldom if ever address the way

surprise and novelty impact both experience of these technologies, and of the designs they are

representing.

Therefore this study asks: How might IVR be impacting on the surprise aspects of designing

and on broader design practice? The paper addresses this question by taking a practice-based

approach to examine IVR in a real-life design project through focussing on the actors and

materials bound up in the situated design process and accounting for the participants’

reflection on their design activities performed using the IVR. The empirical material is drawn

from the early design of a new hospital project wherein design and contractor teams used a

particular type of IVR, a CAVE (Cave Automatic Virtual Environment) set up in the

Authors’ University to demonstrate particular design requirements to the client and to

perform design review meetings. The study builds on previous research (Author Ref) which

studied the use and implications of IVRs for design activities by drawing on direct

observation and video recording of design meetings held within the CAVE (Figure 1).



Figure 1. Video study instances of design in the CAVE suggesting the idea of surprise

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This paper is concerned with the participant’s own reflections on design in IVRs, and

especially the aspects of surprise as part of the design process. The following sections address

this research interest by: firstly, examining how the idea of surprise is treated in the design

and broader practice literature; secondly, by analysing particular design practitioners’

reflection on their design surprises experienced using the CAVE as design setting; thirdly, by

discussing the empirical findings in relation to both the literature on surprise and the research

question set in the paper; and fourthly, by concluding that IVR enabled distinct types of

design surprises through a more immersive experience of the designed spaces, resembling to

visiting the built version of the design. The findings indicate that, using CAVE as design

setting encouraged distinct design surprises –particularly focussed on the experience of the

designed space, it challenged usual design procedures and understandings drawn on other less

immersive media, it enabled noticing issues not previously observed and it drove new ways

of making sense of and addressing the design.

**. Surprise in (design) practice**

**2**

The aspect of surprise is scarcely considered in the literature on IVR for design. Some

experimental studies (e.g. Rieuf et al. 2017) account for designers’ surprise as emotion

relating to experience of early design processes in immersive VR by drawing on psycho-

physiology measures. Other experimental studies on architectural design education (e.g.

Rahimian et al., 2014; Abu Alatta and Freewan, 2017; Maghool et al. 2018) indicate the

potential of IVR to enable simulating unexpected events and to support learning by doing and

stepping outside routine. Indeed, early research on VR and IVR broader applications

highlights surprise as related to the sense of presence in VR (Slater et al. 1998) and suggests

the potential of IVR to enable stepping outside routine and performing various disciplines

activities in new and unexpected ways (Slater and Sanchez- Vives 2016). However, the

previous work on IVR for design obscures the processes whereby practitioners perceive and

address the surprise and challenge of designing in immersive settings in situations of practice,

rather than in experimental contexts. There is, however, a well-established interest around the

issue of surprise in areas including design cognition and creativity, organisational

management and learning and use of technology/ information systems in organisational

settings, as well as broader studies of social practices or psychology studies of social

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cognition, cognitive emotion and behaviour. Drawing on a broad identification of two main

perspectives in this literature– 1) scientific rationality/cognitive and 2) qualitative/

experiential–, this paper next reviews how the issue of surprise is treated.

*2.1*

*Cognitive treatments of surprise*

Building on a cognitivist (information retrieving and processing) and cognitive psychology

orientation, the first strand of studies treats surprise as connected to a degree of expectancy

disconfirmation and as affective reaction to unexpectedness linked to ‘causal thinking’ and

indicates surprise as central to sensory processing, adaptation and learning, attention and

decision making (Reisenzein, 2000: p. 268). These studies aim for an abstract theorising of

surprise by developing and/ or testing rational models of surprise preponderantly in

experimental studies in controlled laboratory situations.

Within design, surprise is mostly addressed from cognitive and cognitive psychology

perspectives and it is mainly discussed in relation to its impact on aspects of design creativity

and on the perception and framing of design problems, or in terms of design strategies

employed by designers to trigger users’ surprise around their final design products.

For example, some studies on design creativity (Grace and Maher, 2015) consider surprise as

a metacognitive (thinking about thinking) process and focus on the impact of surprise on

design problems, goals, requirements formulation and relatedly on design creativity. Pointing

the iterative nature of the process of problem and solution formulation and indicating the

reasoning about the cause of surprise as relevant for changing design goals, this experimental

work identifies taxonomies of surprise and responses to develop cognitive and computational

models of surprise (programing computers to measure surprise). Other studies on improving

design methods, tools and approaches to foster creativity (Becattini et al., 2015) focus on the

cognitive processes emerging in relation to the perception of surprise around a new design

product by treating surprise as constituted through human interpretation rather than as effect

of measuring novelty. Such work raises attention to understanding users’ reactions (cognitive

responses) to surprising design products (Becattini et al., 2020). Other studies (Chen and Lai,

2014)

 address the impact of unexpectedness on the communication effect of design by taking

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an information retrieving perspective focussed on emotional aspects. The role of non-routine

contexts is also highlighted in relation to the impact of the design experience on creativity

(

Rahman and Jonas, 2010). Research on the role of emotions in design (e.g. Ge et al., 2021;

Zhou et al., 2020) indicates the relation between designers’ surprise as emotion experienced

while designing and the design process/ thinking through increasing design-creativity, re-

framing and design changes. Surprise as emotion in design is examined mostly in

experimental studies through physiological measures (e.g. speech acoustics, electrodermal

activity, automated facial emotion detection) and behavioural assessment, while rarely being

considered as context dependant and examined through retrospective self -reports (Ge et al.,

2021)

. Overall, most of these cognitive/ cognitive psychology studies draw on experimental

work to develop/ test rational models of surprise based on measuring novelty and

unexpectedness by using standard metrics.

In a different vein, Dorst and Cross (2001) develop a cognitive model of design creativity by

connecting with reflective practice treatments of surprise as interruption of routine and as

essential for triggering reflection in action. Stressing the role of surprise in stimulating

framing and reframing, shaping and changing the view of the problem, these studies find that

creativity is linked with the designers’ identification of surprise in the ‘problem space’ which

triggers their reflection, enabling the seeing of things in new ways and stimulating the

process. This understanding accounts for designers’ views of the terms and relationships

underlying design activities, based on previous experience and knowledge. Similarly,

Rodríguez Ramirez et al.’s (2014) study of designers’ strategies for developing designs

surprising to their users draws attention to designers’ own perspectives to describe their

intentions while designing surprising outcomes. Their situational analysis focusses on the

behavioural, cognitive and emotional aspects of designers’ experience informing their

designing with the aim of eliciting surprise. However, they do not examine how designers

themselves experience and address surprise occurring

*during*

 design. On a similar note, Suwa

et al. (2000) point out the situated nature of designing and draw attention to the role of

representations (sketches in their example) to indicate surprise as unexpected discovery

impacting on creativity. However, Suwa et al.’s (2000) focus remains on the cognitive

aspects around these design surprises.

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*2.2.*

*Qualitative driven studies of surprise*

Contrasting this generally abstracted and more quantitative understanding of surprise, other

work treats surprise as situated, by turning attention to the practice as performed in everyday

life. Surprise is inherently realised in situated social and material interaction and stressing the

connection between knowing and doing instead of focussing on the cognitive aspects. These

studies build on various theoretical standpoints including practice-based approaches,

reflective practice, or sensemaking perspectives. These studies intersect in treating surprise as

socio-materially generated in practice situations and recognise the role of surprise as a

generative phenomenon through driving practitioners’ attention to and reconsideration of the

underlying mechanisms of practice.

From a reflective practice perspective (Schön, 1983), surprise is central in performing

design) practice by triggering reflection and action to address and engage with unique,

(

conflicting, uncertain, puzzling situations of practice by mobilising appreciations drawn on

existing repertoires through both individual and collective conversation with the materials.

Surprise is discussed as triggering ‘new ways of seeing things’ and leading to ‘questioning

assumptions that had been built into practice’ (Schön, 1992: p. 131,136). The practitioner’s

ability of responding to ‘surprise’, contradictory, unfamiliar states perceived in the ‘back-

talk’ of a design situation, is mediated through ‘seeing’ the situation in new ways, in

association with familiar elements of previous experiences, which guides the process of

shaping the situation by employing action and driving further accomplishment of practice.

Similarly, from a phenomenology oriented practice-based approach to change in

organisations, the issue of surprise as breakdown is treated as means to encounter the ‘world’

suspending, even if briefly, usual attitudes and expectations (Ciborra, 2001: p. 28). Applying

this perspective to study the use of technology in organisations, Ciborra indicates the

processes of bricolage (‘make do’) and improvisation employed by practitioners to “find fixes

to the plans and deal with surprises” (Ciborra, 2004: p. 20) and points out the phenomenon of

drifting i.e. “deviating from planned purpose for a variety of reasons often outside anyone’s

influence” (Ciborra, 2001: p. 4). This kind of phenomenological approach indicates situations

of discontinuity and disruptions related to the use of novel technologies and points out

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practitioners’ reconsideration of existing assumptions built into practices (Lanzara 2009,

2016)

. Surprise is treated as a complex of “features that defy our understanding, descriptions

and planning abilities”, addressed through a range of constructive activities globally

conceptualised as ‘bricolage’ i.e. encompassing “practical experiments, local readjustments

and repairs, extemporaneous improvisations” employed to respond to surprises, novelties,

and other puzzling phenomena interrupting/ rupturing repertoires of practice routines

(

Lanzara, 1999: p. 334, 135).

From a sensemaking perspective, surprise (particularly understood as interruption of routine

and/or as ambiguous event) is seen as “consequential occasion for sensemaking” (Weick,

1995:

 p. 105) and it is often discussed in relation to improvisation and making new sense to

restore interrupted activity (e.g. Weick, 1995; Sandberg and Tsoukas, 2015). Intersecting

with other areas of literature, this perspective acknowledges that interruption and recovery

(

Weick, 2009) drive meaning of experiences and indicate the role of the repertories of

previous experience.

From various practice-based approaches- reflective practice, phenomenology or sensemaking

perspectives-, these qualitative studies treating surprise as situatedly generated through

practice experiences and highlighting the role of surprise as generative phenomenon in

further performing social practices share a number of common ideas as described below.

*Surprise in practice: shifts of awareness.*

These studies intersect in discussing surprise as

enabling practitioners’ shifting from subsidiary to focal awareness around the practice

elements, leading to (re)opening (reflective) inquiry (e.g. Yanow, 2015). From a sensemaking

perspective, ‘jolts’, surprises and other types of disruptions drive interpretations and “expose

tacit, taken for granted assumptions” (Weick, 1992: p. 101). In various ways, these studies

indicate the idea that through surprise ‘elements’ of practice taken for granted may be

questioned, through a change of focus of awareness and attention. Surprise provokes a new

types of awareness- more focal forms of attention employed to address disruptions: “When

routine practices are interrupted by surprises, these disturbances produce a caring, a mattering

–an affective state- that focuses awareness and attention” (Yanow and Tsoukas, 2009: p.

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. Unexpectedness may trigger changes in engagement with the elements involved in a

practice situation, shifting from being ‘transparently available’ (Yanow and Tsoukas, 2009)

to being brought under focus of deliberate attention.

*The openness to perceive surprise in practice:*

Another key idea shared in this strand of

studies is around the openness to perceive surprise as an important feature in social practices.

For example, from a practice-based perspective to organisational management and learning,

Nicolini, 2012: p. 27) indicates the ‘practical wisdom’ as “non-inferential and non-deductive

(

form of knowledge” dependent on practitioners’ flexibility and openness to surprise and

improvisation. From a phenomenological perspective to reflective practice, Yanow and

Tsoukas (2009) discuss surprise as requiring a ‘degree of permeability’ (‘mindful openness’)

to allow perception of an event as surprising. From a reflective practice perspective, Schön

(1983)

 treats surprise as both trigger for, but also triggered by reflection and indicates that

“[…] the practitioner allows himself to experience surprise, puzzlement, or confusion in a

situation which he finds uncertain or unique.” (Schön, 1983: p. 68).

*Repertoires of responses to surprise- a learning process:*

The idea around ‘response

repertoires’ for dealing with interruptions connects with viewing organisational learning as

constituted through these enhanced repertories of responses to ruptures in routines (Yannow,

2015

; Christianson et al., 2009). From a sense making perspective to studying organisational

learning, Christiansson et al. (2009) note the role of rare events- conceptualised as

interruptions- in triggering learning through “exposing weaknesses and revealing unrealised

behavioural potential” (id.: 846). From this perspective, interruptions trigger learning firstly

by acting as audits of existing response repertoires and, secondly, by providing opportunities

to reorganise routines of interpreting, relating and restructuring. Similarly, the reflective

practice (e.g. Schön, 1995, 1983) approach argues that social practices become enriched

through reflective processes mobilised to engage with and address uncertain, conflicting,

puzzling situations of practice. Surprise encountered in practice may therefore impact on

further experiences through building up and shaping existing repertoires (Schön, 1983), an

‘epistemic tool’ with potential for reframing knowledge (Lanzara, 2016: p. 8).

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*Surprise as method:*

Beyond highlighting the role of surprise in performing social practices,

these studies also see surprise as an enhanced methodological route to inquire into the

dynamics and processes of configuring practice (e.g. Weick,1992; Nicolini et al., 2003;

Ramiller and Wagner, 2009). Methodologically, practice is “better observed when some

“breakdown” occurs in an entrenched practice or when some substantial change requires

major realignments of the extant configuration of practice” (Nicolini et al., 2003: p. 26).

Hence, the importance of surprise consists in both its role as generative phenomenon essential

to practice and as a research means of grasping underlying mechanisms of practicing.

Whilst there are differences in treatments of surprise, for instance between surprise as a

response (Bruner, 1986) or part of a series of events (Ciborra, 2002), or locating surprise as

an individual (Schön,1983) or collective (Weick, 1995) phenomenon, there is an important

distinction between cognitive and qualitative approaches. The latter identify themes of

surprise as

*generative phenomenon*

 in performing social practices; surprise as driving

*shifts of*

*awareness*

, the

*openness/ permeability to perceive surprise*

 in practice; the role of developing

repertoires of responses to surprise -relating to a

*learning process*

; and the role of surprise as

-

*methodological means*

 to research into practice. This paper explores how these qualitative

accounts of surprise might be mobilised in design work using IVRs.

**3**

**. Methods**

As indicated in the literature, surprise is an important aspect in design work (relating to

creativity, innovation, framing and re-framing etc.). This paper focusses on surprise to

understand the impact of IVRs on the surprise aspects of designing and on broader design

practice. Recognising surprise as an important aspect in design seen as a socio-material

process realised in situations of practice, this paper treats surprise as a situated phenomenon

and it examines how design practitioners make sense of and address surprise within design

processes performed using IVR and how this relates to broader design practice. Drawing on

this approach to surprise in design, this paper operationalises the research by examining a

situated use of IVR in design work through an empirical case of a real-life design project.

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The case study is based on a real-life 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 an IVR environment - a CAVE

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 facility set

up in the Authors’ University (Figure 2). This was to be used to demonstrate to the client that

the rooms were of an appropriate size and more generally to communicate the design of this

hospital project to the NHS client, to support reviewing key spaces in the hospital design and

to demonstrate how the design meets the requirements.





Figure 2. Simulation of the hospital project using the CAVE at the Authors’ University

Building on insights of former research based on observation and video recording of six

design meetings performed using the CAVE , the methodology here draws on reflective

discussions with the participants involved to access their views on the surprise emerging in

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The CAVE (Cave Automatic Virtual Environment) is a multi-person, full scale IVR environment, in which

graphics are projected stereo onto the walls and 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

D model. One user’s movement in the space of the CAVE is being tracked and perspective rendering is

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displayed responsively. The CAVE at the Authors’ University has three vertical projection screens (3m by

 and a floor projection screen (3m by 3m

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their CAVE design experience and the implications on the design process. This was aimed to

allow the participants’ reflection on how they experienced particular episodes and describe

their understanding and reasoning behind the events. The method connects with Schön’s (e.g.

1992)

 argument on the role of reflection-on-action outside of the situation as retrospective

thinking on previous actions and understandings through observing and describing.

A

retrospective data review format was developed, both playing back video-clips from the

video data set and revealing the researcher’s interpretation around what was happening

during the design sessions.

The discussions were conducted nine months after the last CAVE design session and they

consisted of four individual interview sessions (30-60 minutes) with participants having

various roles in the design team: visualizer (REVIT modeller), project director, lead interior

designer and lead medical planner. The interviews were initiated by playing back video-clips

selected from the video data both to refresh the participants’ memory and to enable their

retrospective reflection (Jewitt 2012) on the design events they had experienced in the

CAVE. The research followed the University's ethical procedures regarding the participants'

consent, confidentiality and data protection. Informed by the previous video-based study

(

documented in Author Ref) by taking into question the findings indicated by the video

analysis, this paper draws on designers’ retrospective reflection on both the CAVE

technology and on its use in design practice and it focusses on the participants’ views on the

surprise and challenge encountered in the immersive simulation of their models and on the

impact of the CAVE on broader design practice. The interviews were recorded, transcribed

and analysed with a focus on understanding the design surprise emerging in the CAVE by

examining the participants’ interpretation of the phenomena.

The empirical material is structured along the reflective practice (Schön 1983) process of

reflecting before, during and after an experience. Following this structure, Section 4 describes

the interview data by focussing on the participants reflection on: their expectation from the

CAVE design sessions; their experience of surprise in the CAVE; and the impact of this

design experience on further developing the hospital project outside the CAVE.

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Subsequently, Section 5 discusses the relation between the interview-based findings and the

themes identified in the qualitative literature on surprise.

By drawing on a situated approach to designers’ experience of surprise when designing a

real-life design project in a particular technological setting (CAVE as a type of IVR), the

empirical findings indicate a close and detailed understanding of the situated use of the

technology by the particular group of design practitioners. Whilst the empirical findings are

limited to the particular situation/the case (dependant on the characteristics of the technology,

of the project, and the particular design participants perspectives at that moment in time),

insights of the study may be meaningful to better understand the use and impact of IVRs such

as the CAVE in other design situations.

**. Findings**

**4**

This section describes the empirical material with a focus on surprise. The empirical vignettes

from the interview data are structured along the participants reflection on: their expectation

from the CAVE design sessions; their experience of surprise in the CAVE; and the impact of

the CAVE design experience on further developing the hospital project outside the CAVE.

*4.1*

*. Expectation from the CAVE design sessions*

The participants shared a perception of surprise in relation to realisation of design intentions,

mostly with regard to spatiality of the layout in reference to design assumptions based on

previous work. The IVR was seen as a way of checking design discrepancies and avoiding

possible design surprises later in the process.

*“[…] my main purpose of going to the CAVE […] was to check the representations of […]*

*elements within the model […]and […] that there weren’t any major […] discrepancies*

*between what we thought the spaces were going to be like and […] what [the contractor]*

*thought the spaces were going to be like.”*

 (Visualiser)

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*“[I had] to make sure that what I needed to have inside the building [medical equipment and*

*workflows] fitted within [the] architectural envelope.”*

 (Medical Planner)

The participants’ reflection indicates that the ‘mattering’ (e.g. Yanow and Tsoukas, 2009)

associated with the perception of surprise connects with their roles in the project and their

focus of concern in using the CAVE: the body metric nature of the space (for the Project

Lead), the representation aspect of the design, in terms of consistency between the designers’

and contractors’ assumptions and intentions on the appearance of spaces (for the Visualiser),

or the ‘fit’ of the hospital equipment and activities workflows in the proposed architectural

envelope (for the Medical Planner).

The following sections describe the participants’ reflection on how surprise was actually

experienced in the CAVE design sessions and how the CAVE design experience impacted on

further developing the design project.

*. Experienced surprises in the CAVE design sessions*

*4.2*

*. Surprise around the technology*

*4.2.1*

The Medical Planner’s reflections indicate the disruption caused by the technicalities of the

environment:

*“it was exciting but it was a bit daunting”*

 and points the source of breakdown

in the distorted viewing perspective, relating to the technology:

*“you have an expectation*

*…] but […] the perspective of what I was looking at was completely wrong”.*

*[*

At first, the

CAVE was perceived as unusual and surprising in reference to participants’ repertoires:

*“it*

*was a bit daunting because, it’s something new and you have an expectation”*

. This indicates

a tension between the expectations drawn on previous work and repertoires of usual

representations (like REVIT/ CAD models visualised on computer screens) -

*“this space that*

*I’ve designed, this was my layout”*

 and the CAVE version of the model as perceived from

-

the participant’s viewing perspective:

*“what I was looking at was completely wrong”*

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Alongside noting the disruption caused by an unfamiliar technology and representation, the

participants reflected on the use of the CAVE on a more frequent basis, suggesting

familiarisation with the specific procedures of navigating and using the model:

 *“Initially, there was an instantaneous reaction about something which was new and that we*

*hadn’t seen before. But in the fullness of time […], that newness is off […] Wow, that would*

*be really powerful, […] so imagine you looking around a design […] and suddenly you’re*

*somehow saying this is not quite right, that needs to be resolved in a different way. […] So*

*that would be very powerful.”*

)

Project Lead

(

This suggests through repeated experiences designers would familiarise with the technical

particularities of the setting and suggests that a more routine way of performing design in the

immersive environment would lead to diminished novelty. These insights also highlight the

envisaged potential impact of the CAVE on design practice through to better enabling

designers’ noticing design surprises over technical or representational unfamiliarity,

supporting discovery of new issues about the design.

*4.2.2*

*. Surprise around the design*

*Visibility requirements*

The participants’ comments indicated their perception of surprise around their design as

experienced in the IVR simulation. For example, the CAVE model revealed surprise around

the design conformity with the clients’ requirement on visibility of patients’ beds from the

nurses’ station area.

*“[…] one of the big issues was observation of the bedrooms from the staff base and that [the*

*CAVE] was really good validation of our design because we could see more beds than we*

*thought we could so that was very exciting.”*

Medical Planner

(

)

By enabling the participants’ discovery that they

*“could see more [beds]”*

, this is a case of

surprise not as interruption, or disconfirmation but instead as excitement through discovering

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an unexpected realisation of previous design intention. The participants’ view on the CAVE

design experience shows that surprise occurred not only as unconfirmed expectation, but also

as unexpected confirmation.

Surprise emerged through designers’ exploration of their design within the CAVE also

connected with their increased awareness of the actual use of their design, driving reflection

on the clients’ requirement and leading to reframing:

*“I remember saying [to clinicians] you’ve given us this criteria […] to see 60% of the rooms*

*from one single point, and I said […] is that really necessary, […] do people really stand like*

*that? And I just walked one step one way, one step the other way and I said, if I did that I can*

*see a lot more. So is it such a concern?”*

 (Project Lead)

The Project Lead’s reflection on the surprise around the visibility requirement connects with

surprise as relating to an affective state, a ‘mattering’, a ‘caring’ (e.g. Yanow and Tsoukas,

 focusing awareness in this case on the client’s requirement and on the actual usability

2009)

of the designed space.

Overall, the participants’ view on the surprise experienced around visibility requirements

shows that in this case surprise enabled: 1) excitement through discovery of their design’s

unexpected conformity with the requirement; and 2) inquiry into the requirement itself, and

relatedly a ‘caring’, a ‘mattering’ about the use of their design and increased awareness of the

actual usability of the space, and reconsidering the requirement together with the client.

*Spatial size and relation with the equipment*

The participants’ view on their surprise encountered around the size and equipment in the

operating theatre indicates a breakdown of realisation of design intention - although designed

of sufficient size, the room in the CAVE looked overcrowded populated with equipment. For

the Visualiser, the surprise emerged around the representational impact of the equipment in

the operating theatre, enabling reflection on the representation and driving changes to the

model:

*“looking at it [the operating theatre] from that [the CAVE] perspective […], seeing*

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*the equipment and how crowded rooms were […] was a way of us saying […] it’s better if we*

*strip some of it out so they [the client] can understand the space better.”*

For the Medical Planner, the surprise perceived in the unsatisfactory relation between the

spatial size and equipment in the operating theatre enabled her attention on the actual use of

the space, leading to questioning and reframing the client’s requirement:

*“[…] we were*

*concerned that there was so much [equipment] in that space that it wasn’t necessarily*

*workable despite […] that they had asked for everything in there.”*

The CAVE design experience challenged existing understandings and procedures by not

confirming expectations of former design intentions and assumptions based on previous

experience (the size of the operating theatre), or by revealing new issues about the design

unexpected discovery of their design conformity with the visibility requirement).

(

*4.3*

*. Impact of the CAVE design surprises on further developing the design*

*project outside the CAVE*

These surprises emerging in the CAVE provoked interruption of the routine performance of

the process and enabled designers’ reflection on the medium, on their understanding and on

the ways of addressing these unsatisfactory issues perceived in the design. The designing

process built up on such disruptive aspects, through participants’ making sense of and

addressing these surprises to accomplish their practice. The participants’ discovery of

unexpected issues about their design drove changes to the design and affected the process:

*“to see the spaces in the CAVE […] was very useful and we certainly used that experience in*

*our thinking later on in the process."*

 (Visualiser).

The designers’ reflection revealed how the experience in the immersive environment affected

their further process of developing the project outside the CAVE:

*“We made changes (to the design) 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*

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*CAVE. So my corridor that was a bit too low and narrow would have stayed a little bit too*

*low and narrow and we wouldn’t have necessarily known.”*

 (Medical Planner)

The participants noted the potential of the immersive environment to enable noticing design

issues which could not be previously perceived using other media and pointed the impact on

the particular design development. The Visualiser noted that

*“when you have a different*

*perspective on something, you think of things in a different way.”.*

The participant’s comment

infers the distinctiveness of the CAVE design experience, which suggests that, through

challenging and surprising previous understandings and assumptions, the CAVE enables new

ways of seeing.

The participants’ retrospective insights indicate the connection between the particularity of

the CAVE- as enabling a more immersive simulation of the design, resembling visiting a real

building- and the impact on the design process by enabling noticing design issues (e.g. the

depth of space, the spatial experience of the too low and narrow corridor) which could not be

previously noticed using other media (e.g. the underlying CAD model):

*“It was very helpful to actually see things that we felt needed changing before it was actually*

*built. And you couldn’t, even with the 3D BIM model, you still can’t see depth […] the CAVE*

*felt much more immersive”*

 (Healthcare Lead)

These findings indicate the design surprises in the CAVE as enabling new ways of making

sense of the space and seeing things in new ways, impacting on the process through

informing further design decisions. Particularly, the participants pointed out the potential

brought by the immersiveness of the CAVE through enabling noticing design aspects which

needed to be changed during design rather than building stage.

**5**

**. Discussion**

The empirical material was described in terms of the reflective practice (Schön 1983) process

of reflecting before, during and after an experience. The interview-based findings (Table 1)

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were drawn on the participants reflection on: their expectation from the CAVE design

sessions; their experience of surprise in the CAVE; and the impact of the CAVE design

experience on further developing the hospital project outside the CAVE. This section

discusses the relation between the interview-based findings and the themes identified in the

qualitative literature on surprise.

Table 1. Summary of findings

Overall, these empirical findings on surprise support understanding the impact of IVRs (such

as the CAVE) on the surprise aspects of designing and on broader design practice. The

findings show that the surprise encountered by the participants in the immersive environment

around both the newly experienced technology and the design played an important role in

performing design review in the CAVE. The element of unexpectedness triggered not only

constraints -subsequently addressed by the participants-, but it also enabled noticing new

issues about the design and seeing the situation in new ways. The participants’ reflection on

using the CAVE on a more usual basis for design work indicated benefits but also suggested

that a more routine way of performing design in IVRs may lead to diminishing novelty.

These insights indicate the eventual extinction of surprise around the technology. However,

whilst noting the effect of familiarisation with the technology through repeated experiences,

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the findings also indicate the on-going potential of the CAVE in challenging designers’

previous understandings and assumptions about the design itself and encouraging generative

design surprises. By focussing separately on participants’ views on their surprise around the

technology and around their design, the findings indicate that the element of surprise emerged

and played an important role within the both. Therefore, the study argues that even as the

immersive technology becomes familiar, surprise may still be central in orienting to the

design in the CAVE for performing work on new design projects.

These findings indicate that the surprise perceived in the CAVE simulation of the design

enabled the participants to notice unintended consequences of previous design intentions,

and, in some circumstances, it did not confirm their expectations. Unexpected issues drove

changes on the design and affected the process. Therefore, the study complements the VR

literature by suggesting that using IVRs for design work not only supports daily practices

based on less immersive media and representations, but also challenges the designers’

understandings, provoking ruptures in current procedures, which need to be addressed by the

practitioners’ reflection on and reconsideration of previous understandings and assumptions

based on other media, driving changes to the design.

These findings also indicate the relevance of adopting a practice-based, situated approach to

examine the surprise phenomena by focussing on the particular participants' experience i.e.

their making sense of and addressing surprise in practice situations. By focussing on the

practicalities of using IVR in design, this paper contributes to the design and qualitative/

experiential literature on surprise by bringing empirical insights on the surprise emerging in

design work using IVRs, as detailed below.

*Surprise as generative:*

The study reinforces the central idea of the literature on surprise as

generative phenomenon in performing social practices. IVR encouraged discovery of new

things and noticing issues not able to be perceived using other media. Using the CAVE as

design medium enabled what the literature (e.g. Schön, 1983) refers to as “seeing the things

in new ways”. The findings suggest that, through enabling a more immersive simulation of

the design, the CAVE enables distinct design surprises -particularly focussed on the

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experience of being in the designed spaces-, challenged assumptions and the potential of

seeing things that need to be changed before the actual building is built.

*Surprise in practice: shifts of awareness*

:

 The CAVE design surprises stimulated the

participants’ awareness around and reconsideration of taken for granted constituents of their

practice. The CAVE design surprises drove inquiry into previous design procedures and

understandings by, for example leading to reframing the client’s requirement, which shifted

from being transparently available to being apparent and under focus of scrutiny (as referred

to in the literature by, for e.g., Yanow and Tsoukas, 2009).

*The openness to perceive surprise in practice:*

 The findings contribute to the literature idea

on the role of practitioners’ openness to perceive and respond to surprise (e.g. Nicolini, 2012;

Yannow and Tsoukas, 2009; Weick, 1995) by suggesting that, although design practice is

generally allowing space for surprise, the use of the IVR environment may encourage a

higher

*permeability to surprise*

. The CAVE encouraged seeing things in new ways (

*“When*

*you have a different perspective on something, you think of things in a different way”*

, it

)

enabled noticing issues which could not be previously observed (

*“my corridor would have*

*stayed a little low and narrow and we wouldn’t have necessarily known”*

, and it stimulated

)

attention to different design aspects, particularly related to the experience in the design

spaces:

*“It was very easy to think about the building as a final building by using the CAVE. It*

*really felt like you were in the space… so it made it very easy to pull out observations about*

*the space.”.*

 By supporting a more immersive experience of the designed spaces- resembling

to visiting the built version of the design (relating to awareness on distinct design aspects ,

particularly the spatial experience), the CAVE enabled a higher permeability to surprise, it

challenged usual design procedures and understandings drawn on less immersive media,

driving new ways of making sense of and changing design issues before the building stage.

*Repertoires of responses to surprise: a learning process:*

 The findings also connect with the

idea around surprise as triggering learning through driving auditing of existing repertoires of

responses (e.g. Christiansson et al., 2009). This process of questioning previous

understandings and procedures is suggested by the empirical material through the

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participants’ transition from initial intention of ‘checking’ if everything ‘fits’ with the client’s

requirements and previous design moves to actually questioning the fit, the issues that have to

fit, the requirement itself, and their former ways of going about the designing process.

Another way in which some studies (e.g. Christiansson et al., 2009) suggest that surprises/

interruptions connect with a learning process is by providing opportunities to reorganise

routine of interpreting, relating and restructuring current understandings and procedures. On

the particular project level, this aspect is suggested by the CAVE data through the

participants’ making new sense and reframing of, for example, the client’s requirement

around the equipment in the operating theatre or the visibility towards the patients’ rooms.

To some extent, the findings show the participants’ awareness of the impact of the design

surprises experienced in the CAVE. This is indicated through participants’ recognition of

changes brought by the CAVE design experience on the design process (“

*We made*

*amendments to the design on the basis of the experience in CAVE*

”, and through suggested

familiarisation with the technology –in terms of both using the CAVE (the ‘

*newness*

’ of the

CAVE will be ‘

*off*

’) and developing awareness around its potential for design work (“

*that*

*would be really powerful*

”). To a broader extent and relating to the literature on surprise and

particularly on the relation between surprise and learning (Lanzara, 2016; Christiansson et al.,

; Schön, 1995, 1983) these findings indicate that the impact of design surprises

2009

experienced in the CAVE may span beyond the particular design episode by informing the

particular participants’ further practice. In this sense, through newly shaped understandings,

shifted visions/ new ways of seeing, enriched repertories, etc. which the particular

practitioners might not even be aware of, the surprises experienced in the CAVE design

process connect with a learning process. However, as noted by the literature (e.g.

Christiansson et al., 2009), this may be less about ‘lessons learned’ away from action and

more about skills acquired during action and the nature and impact of learning through

interruptions/ surprising events may not be apparent until subsequent interruptions (id.: p.

. As suggested by a reflective practice perspective, a potential way to support

857)

practitioners acquiring more from past experiences is by encouraging their retrospective

reflection-on-action as a way to stimulate their awareness of how they made use of the CAVE

as design medium and on how their ways of using it interacted with their approach to the

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designing process. This aspect may be interesting to be closer addressed in further work by

supporting designers’ articulation of these insights in an explicit form to be purported by

“reflective transfer” (Schön, 1995) to future practice situations perceived as similar.

*Surprise as methodological means to research into practice:*

Connecting with ideas of the

qualitative/ experiential research on surprise as encountered and addressed in practice

situations, the study recognises the relevance of surprise as methodological means (e.g.

Nicolini et al. 2003) to understand the dynamics of design practice. Methodologically, the

participants’ views on the design surprises encountered in the CAVE and their reflection on

the ways of addressing these surprises enabled insights into underlying mechanisms of

accomplishing design practice.

*Surprise as response or as event/ experience:*

Reflecting on the interest placed in the

literature on the response (e.g. Bruner, 1986) or on the experience (e.g. Ciborra, 2002)

aspects of surprise, this study indicates that, whilst design surprises in the CAVE emerged

partly as response to previous expectation - “violated presuppositions […] of what is taken

for granted” in Bruner’s (1986: p. 46) words, illustrated in the data through, for example, the

Medical Planner’s comments: “

*You have an expectation […] but what I was looking at was*

*completely wrong*

”-, these ruptures became interestingly configured as experience of the

designed spaces, shifting to challenged assumptions and reconsideration of what was taken

for granted. Design surprises in the CAVE were distinctively configured as what Ciborra

 p. 121) refers to as “events […] representing disjunctures, where existing frames

(2002:

assumptions and values fall apart”. The findings indicate the relation between the immersive

experience resembling to being in the designed space and the CAVE participants’ shift from

initial intention and potential expectation of surprise around their design in terms of

‘

*checking*

’ if everything ‘

*fits*

’ with the client’s requirements and previous design intentions to

actually questioning the fit, the issues that have to fit, the requirement itself, and their

previous ways of going about the designing process (e.g. questioning the client’s

requirement: “

*How do you even work like this?*

”).

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*Surprise as individual or as collective event:*

Relating the empirical findings to the different

focus of the literature on the individual (e.g. Schön, 1983) or the collective, organisational

surprise (e.g. Weick, 1995), the findings indicate the surprise emerging in the CAVE as

connecting to both particular individuals’ roles in the project and focus of concern -through

their attention on particular aspects around surprise and distinct strategies of addressing them-

and collaboratively reflecting on individual surprises and addressing the challenges, ruptures

and surprises as a group. For example, whilst for the Visualiser the surprise emerged around

the representational impact of the equipment in the operating theatre, triggering reflection on

the representation and driving changes to the model, for the Medical Planner the surprise

perceived in the unsatisfactory relation between the spatial size and equipment in the

operating theatre enabled her attention on the actual use of the space, leading to questioning

the client’s requirement. However, the disruption was addressed through the design teams’

collaborative reflection, adjustments and repairs, driving changes to the design and further

discussions with the client.

**. Conclusions**

**6**

This paper has examined how IVR might impact on the surprise aspects of designing and on

broader design practice. Adopting a particular strategy of accessing design practitioners’

reflection on the use of technology and on their practice, this question was addressed by

looking at designers’ views on their design surprises experienced using a CAVE type of IVR.

The study indicates that, by supporting a more immersive simulation of the design, using

CAVE as design setting encouraged distinct types of design surprise, particularly focussed on

the experience of being in the designed spaces. The study showed that CAVE challenged

usual design procedures and understandings drawn on other less immersive media, it enabled

noticing issues not previously observed, and it drove new ways of making sense of and

addressing the design, supporting changes to the design before the building stage. The study

suggests that, although design practice is generally allowing space for surprise, the use of the

IVRs may encourage a higher permeability to surprise.

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The study argues that CAVE may be useful for design practice by triggering surprise not just

as a new technology and new way of visualising the design, but also on a more usual, daily

basis, through enabling a more immersive simulation relating to distinct ways of making

sense of the experience of designed spaces and connecting to challenged assumptions drawn

on less immersive media and procedures. Of particular relevance to design practice, these

findings highlight the role of surprise as design discovery in the CAVE, through leading to

design changes/ refinement and guiding the further process.

These findings contribute to the design literature on surprise and extend current

understanding around the surprise and challenge in IVR design settings by highlighting

aspects around the actual impact of the situated use of IVR technology on design practice.

The study also enhances current understanding around and supports integrating the practical

consequences of using CAVEs in design activities by indicating that immersive technologies

might be useful for design practice and practitioners through extending and challenging

designers’ own understandings of their previous work. Finally, the study demonstrates the

relevance of mobilising the idea of reflection-on-action facilitated through the use of video as

methodological means to access the participants’ view on the use of the IVR and the surprise

emerged through their engagement with the technology through direct experience in situ.

As in all research, there are limitations to this paper. Whilst the accounts of design surprises

presented in this paper unpacked design practitioners’ views on the surprise phenomena

drawn on their design experience using an IVR environment to develop a real-life design

project, they are limited to the perspective of four design participants working on a particular

phase (design review, during bid preparation) within a particular project. It would be

interesting to also examine possible design surprise which might emerge using IVR settings

in other design stages such as early design as well as later, during detailed design and

construction. Further research could extend or challenge the findings of this paper by

exploring possible patterns of design surprises emerging across multiple situations of using

IVR for design work for other design projects, involving other design teams. Other future

work could investigate the impact of design surprises emerging through the use of

collaborative IVR on design stakeholders’ engagement and focus on related implications

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around managing design users’/ clients’ expectations. Another interesting avenue for future

research would be to examine possible design surprise and the related dynamics of design

practice emerging through integrating IVR within design usual work and procedures.

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