

a future framework

virtual reality as an architectural instrument

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abstract

Architects work within the medium of digital space on a day-to-day basis, yet never truly get to experience the spaces they are creating until after they're built. This creates a disconnect in the design process that can lead to unexpected and unwanted results. Human perception is a powerful instrument and Virtual Reality (VR) technologies, coupled with more complex digital environments, could enable designers to take advantage of this. Through virtually inhabiting the space they are creating while they are creating it, designers can pre-visualise spatial qualities. These digital tools are experiencing a shift from technology still in development to a fully-fledged research instrument. With a growing level of technical literacy within the architectural discipline they could have the same revolutionary impact that the introduction of computers had in the late-twentieth century.

This thesis explores the potential of VR technology for processes of architectural design by assessing their combined ability to analyse a user's perception of spatial qualities; in particular the sensation of people density within the work environment. Starting with a review of current literature in architecture and perception based science. A framework is proposed by which to assess the impacts of spatial characteristics within an Immersive Virtual Environment (IVE). This is followed by a design-led series of iterative framework developments centred on increasing user immersion within digital space. Through this methodology a greater understanding is obtained of users perceptions of spatial characteristics and of the process required to design iteratively within an IVE framework.

keywords: immersive virtual environment, digital framework, workplace density

To my supervisors, to my mentors, to my family, to my girlfriend,
to my friends, to everyone else that's helped me along the way.
Thank you.

preface

This research began with a study investigating the relationship between workplace density and office workers' self-reported productivity. Undertaken in collaboration with Studio Pacific Architecture, this study highlighted the complexity of user experience within an open plan office design. The results showed that there is a complex workplace cultural system in place that helps mitigate the effects of growing density within the office. Those workplaces that had the highest levels of density tended (counter-intuitively) to report better levels of user satisfaction, and the report hypothesises that this may be due to a high level of engagement between the workplace environment and management. Design decisions made in conjunction with good corporate support allowed workers to handle higher levels of density and respond more positively than those environments without support. This research uses spatial perception within an office environment as a case study through which to develop a digital environmental framework for use in the architectural design process.

1.0 introduction

2

1.1 problem statement	4
1.2 aims	6
1.3 scope	8
1.4 structure	10

2.0 literature review

12

2.1 workplace environments	16
2.2 digital environments	24
2.3 virtual reality	34

3.0 digital framework design

48

3.1 framework	86
3.2 results and data	88
3.3 limitations and scope	90
3.4 conclusion	92
3.5 PACT conference	94

phase one

4.0 developed framework design

96

4.1 framework development	100
4.2 results	110
4.3 limitations and scope	110
4.4 conclusion	112

phase one reflection 114

5.0 VR framework integration

118

5.1 framework development	122
5.2 limitations and scope	124
5.3 conclusion	126

phase two

6.0 spatial analysis and data collection

128

6.1 methodology	134
6.2 results and data	142
6.3 designed response	144
6.4 limitations and scope	150
6.5 conclusion	152

phase two reflection 154

7.0 conclusion

156

definitions

In order to provide clarity to later sections of this research the following definitions are given:

Digital Environment - An environment constructed digitally, such as through 3D modelling software.

Immersive Virtual Environment (IVE) - An environment designed to create an experience that the user feels completely a part of. This does not necessarily require a photo-realistic environment.

Virtual Reality (VR) - Technology that produces an environment that is seen entirely digitally, viewed via a headset such as the HTC Vive.

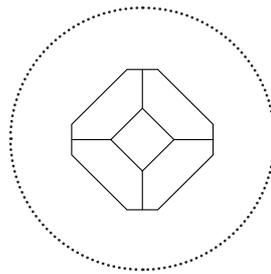
Augmented Reality (AR) - Technology that layers a digital environment on top of the existing environment; for example projecting a digital screen onto surfaces using a headset such as Microsoft's Hololens.

Mixed Reality (MR) - A middle ground between VR and AR, mixed reality introduces digital elements into the real world with the goal of seamlessly integrating the two.

Perceptual Space (PS) - The extra layer of information an individual places over an environment that impacts the way each individual sees a space.

User Interface (UI) - The means by which a user interacts with the digital environment they are in; common forms include menu systems and interactive buttons.

Within this thesis are a range of interactive experiences that test the impact different spatial factors have on user behaviour. Traditional 2D visualisation techniques are not always fully adequate for portraying the impact of these spaces. Weblinks will be placed throughout this thesis, in the form of digital buttons, that provide a link to the interactive experiences discussed. These are only available in the digital copy; however if you're reading a physical copy of this thesis a list of each button and the embedded URL can be found in the Interactive Experience Links section at the end.



When this symbol appears, clicking on it will take you to a website link. Here you can experience the various interactive experiments trialled in this thesis. You need an internet connection and to download the Unity Webplayer plugin to activate the experiences (instructions on how to do this can be found within the link).

In addition a USB has been included with the printed copy. If viewed on the USB, a windows PC is required. Navigate to the correct Figure number folder and, once inside, double click on the title.exe file within the folder.

1.0

introduction

1.1 problem statement

Architects work with the medium of digital space on a regular basis, yet there is a lack of connection between the architectural discipline and other disciplines that work within similar digital environments (Schnabel, 2009). With the recent advances in virtual reality technology, the ability to create an immersive digital environment is improving. These environments now have the potential to create a space that the user perceives as real, giving architects the ability to better simulate spatial qualities before a space is built. This research grapples with the issue of how digital environments can be used not simply as a representative tool, but as a design instrument.

How can architects work within immersive digital environments to better design spatial experiences?

1.2 aims

Architectural representation covers a broad range of media and ways of working. With the increased use of computers in architectural practice the way we conceive of design has shifted to a hybrid model of traditional and digital methods. This research proposes advanced digital environments and virtual reality as an extension of existing digital methodologies, and asserts that digital environments (and by extension IVE's) exist beyond purely representational use. This research seeks to establish a basic framework for the use of more advanced digital environments as a part of the architectural design process. This framework is intended to be a template for tailored development attempted by others, and is not intended as an end in itself but as a starting place.

The purpose of this framework is to expand and develop the capabilities and understanding of the current 3D workspace to augment existing architectural design research methodologies.

1.3 scope

This research seeks to explore what digital environments and virtual digital environments can achieve as instruments for spatial understanding and creation, rather than as a representational tool.

A broad approach is taken in order to create a flexible framework on which later research might build. The iterative framework developments constitute the **design methods and processes** used within this research.

Spatial perception within office environments is used as a case study through which to develop the framework. As a familiar yet often poorly understood environment (Kim and de Dear, 2013) the workplace is a good testing ground for new methods of designing and new ways of understanding spatial qualities. This research focuses specifically on the perception of people density within these environments. This research is not intended as a comprehensive investigation into the spatial qualities of the office workplace.

While there is potential for new creative expression utilising this digital framework, the strength of this research is in its flexible framework design.

1.4 structure

Examples of digital environmental frameworks used within architectural research are limited and, where found, too focused on a particular aspect and not publicly available. This research seeks to demonstrate a transparent development process for a more flexible digital framework, and provide a starting point for future research.

The research is broken into two phases; the first phase creates a framework for architectural research within a digital environment and the second phase introduces virtual reality into this framework and runs initial spatial analysis tests.

- c. phase one
- 3.0 create a digital environmental framework and run a proof-of-concept test analysis
- 4.0 develop the digital environmental framework by increasing the complexity of the environment and user interaction, with a focus on enhancing user immersion

phase two

- 5.0 integrate immersive VR interaction into the framework using a UI system
- 6.0 evaluate existing VR experiences as an example of digital environmental spatial analysis

The conclusion section pulls each phase together and situates the research within a broader context, providing an indication of what further research might cover.

2.0

literature review

This section relates this study to current literature in three areas; workplace environments, digital environments and virtual reality environments/ representation, as each contributes differently to this research.

Section 2.1 gives a brief history of office workplace design in order to situate the case study experiment. It delves into the philosophy behind the shifts in thinking about the design of office space to build the methodology proposed within this research. To understand the spatial qualities of an office, some knowledge is required of the complex cultural layers workplaces foster, and where these originate from.

Section 2.2 discusses the concept of a digital environment and explores three precedents that display strong digital environment toolsets. Precedents include both creative environments and environments that induce particular moods based on spatial characteristics, as this research seeks to do. Each tool set is analysed, with useful components being incorporated into the framework development.

Section 2.3 introduces the concept of virtual environments and defines the relationship between an IVE and the digital environments currently in use. The concept of 'perceptual space' is defined and the ways in which it can be refined into an architectural instrument are established. This section also situates this research within a broad history of representation and addresses what impact it may have on the field of representation in the future.

Links to the software used in this section may be found at the end of this research in the Software Used section.

2.1 workplace environments

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This research develops a digital environments framework using people density levels within the office workplace as a test example. This section situates this research within literature on the design of office spaces.

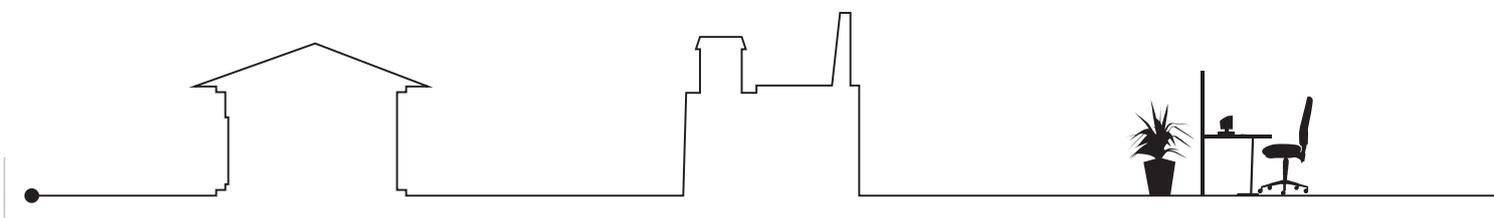
The concept of an office workplace is purported to have originated with the De Medici family of 16th century Italy as a way of organizing clerical staff, so that public and staff members would have easier access to bank workers (Klerk, 2014). This trend of housing banking and administrative staff in a common building for public access continued, becoming popular throughout Europe. The Industrial Revolution went on to introduce other professions in need of centralized office space, such as insurance and accounting companies. In the nineteenth century the concept of physically separating production from management work to maximize efficiency created the typical form of modern cities, with their large, centrally-located office buildings. The first office buildings were made of a series of cellular offices. Around the turn of the twentieth century, large open plan offices, occupied by typists and other clerical workers, became popular. This arrangement allowed for easy supervision of the workers, typically from elevated enclosed offices around the perimeter of the work area.

The science of office efficiency began in this period, when Frederick Taylor, regarded as the father of scientific management, sought to make the workplace more efficient by breaking work down by task, as in a production line. In his book *The Principles of Scientific Management*, he focused on quantifiable data and ways to measure, and thus improve, efficiency (Taylor, 1911). He supported a standardised work environment where impersonal space enabled the clinical fulfilment of each task. An open work environment, with management supervision overseeing the whole floor, continued.

In response to the grid-like open plan system, Eberhard and Wolfgang Schnelle created what became known as Burolandschaft (office landscape). Doing away with the grid of desks, this was a more 'natural' model comprised of clusters of workstations and plants. It introduced flexibility to the workplace and sought to break down managerial hierarchy (Caruso St. John). This evolution in the way people worked prompted new workstation typologies to emerge, in particular the 'L-shaped' desk which was a response to the new space requirement for a computer monitor.

As a response to the loss of aural and visual privacy introduced by the open plan office and Burolandschaft, Robert Propst of Herman Miller released a furniture range titled Action Office One (later superseded by Action Office Two) (Herman Miller). This range was built around the concept of a dynamic worker: it created individual work areas isolated by partitions that allowed workers privacy whilst still retaining some ability to interact with their neighbours. In a debased form, these became known as 'cubicle farms'. Regarded as inhuman and oppressive, due to their stark appearance and dense configuration, the 'cubicle farm' layout has been subject to popular criticism. Open plan solutions emerged, seeking to address employee needs as well as retaining the efficiency of the Action Office system. It is not clear that these solutions represent a better alternative than 'cubicles' (Brennan et al, 2002; Hedge, 1982).

Fig 2.01. ▼
Diagram illustrating the shift from enclosed cellular offices to a more open system defined by the furniture.



In the 1990's Francis Duffy displayed a new way of thinking in his book *The New Office*. His key argument was that different people and businesses work differently from each other, that creating varying spaces based on these differences would be more efficient than a single homogenous system. Technological innovation and the more mobile workplace brought about a significant change in the way work environments were designed, which led to Duffy breaking office types down into four categories; The Hive, The Cell, The Den and The Club (Duffy, 1997). Each one supported different degrees of autonomy and worker interaction. This became one of the first published recognitions of a more fluid environment where workplace culture and corporate identity were considered important factors in improving worker productivity. Duffy's ideas took a while to gain traction as the Action Office system was still immensely popular, however shared working and task specific areas continued to emerge in the form of hot-desking and Activity Based Working (ABW).

Given a workplace spectrum ranging from rows of isolated cubicles to an adaptable environment where people work in different places each day, there is no clear solution to the problem of 'work place efficiency' (Haynes, 2008; Kim and de Dear, 2013). What some may find a productive environment differs from person to person and company to company. Concepts like ABW and hot-desking, where a combination of shared facilities, activity specific areas and individual workstations cater to a range of working styles, have emerged, yet the success of any of these depends on the nature of the building and company itself; there is no one solution that fits all.

This thesis seeks to introduce new tools, such as VR, that allow for assumptions about the relative benefits and problems of open plan office design to be tested.



The impact of people density levels on users of office environments was chosen as a case study test, as it presents an area of design that is not fully understood, as evidenced by the divided literature. A densified office environment is a space that many can relate to, and is an ever present issue. A simple metric value is an inadequate measure of the impacts of environment density and satisfaction, and does not allow architects to fully comprehend the impact an office environment may have on an individual whilst they are designing it. This research seeks to develop a framework to give a perceptual view of what changing levels of density within an office environment looks and feels like, and thus allow for the architectural profession to better design for these environments.

2.2 digital environments

redacted quote

The design of the office, along with other standardized architectural environments, has long been performed using computer software. The introduction of new digital technologies, such as Gaming Environments (GE's), allows us to imagine this design process in new ways. A GE is one produced through a 'game engine'; an engine that imposes certain constraints on the user and their surroundings. The nature of these constraints is infinitely flexible, allowing for the simulation of any other type of media (Gauthier, 2005). Due to this flexibility, the interaction between occupants and the environment (or other occupants) can be structured in many different ways, allowing for controlled testing of the impact environmental changes have on their occupants. Separated from the constraints of buildability and cost, users of gaming environments are free to conceptualise more holistic spatial and creative elements; this can range from the city scale down to the individual scale, involving complex mechanics where not just structures but whole ecosystems are created. This allows for different perspectives and different drivers through which to create and understand the design process. Whether a human or a digital avatar is used, factors such as wayfinding, group behaviour, sound quality and ambience are equally as important to both architectural and gaming disciplines (Hoon and Kehoe, 2003). Though there is research into the collaborative strength of digital platforms for group design (Brown and Berridge, 2001; Hoon et al, 2003; Hoon and Kehoe, 2003; Moloney and Harvey, 2004; Segard et al, 2013) current literature doesn't fully explore the potential gaming environments can have on the way architects design space. The following precedents illustrate the flexibility and capability of different GE's to influence user behaviour and provide new creative perspectives.

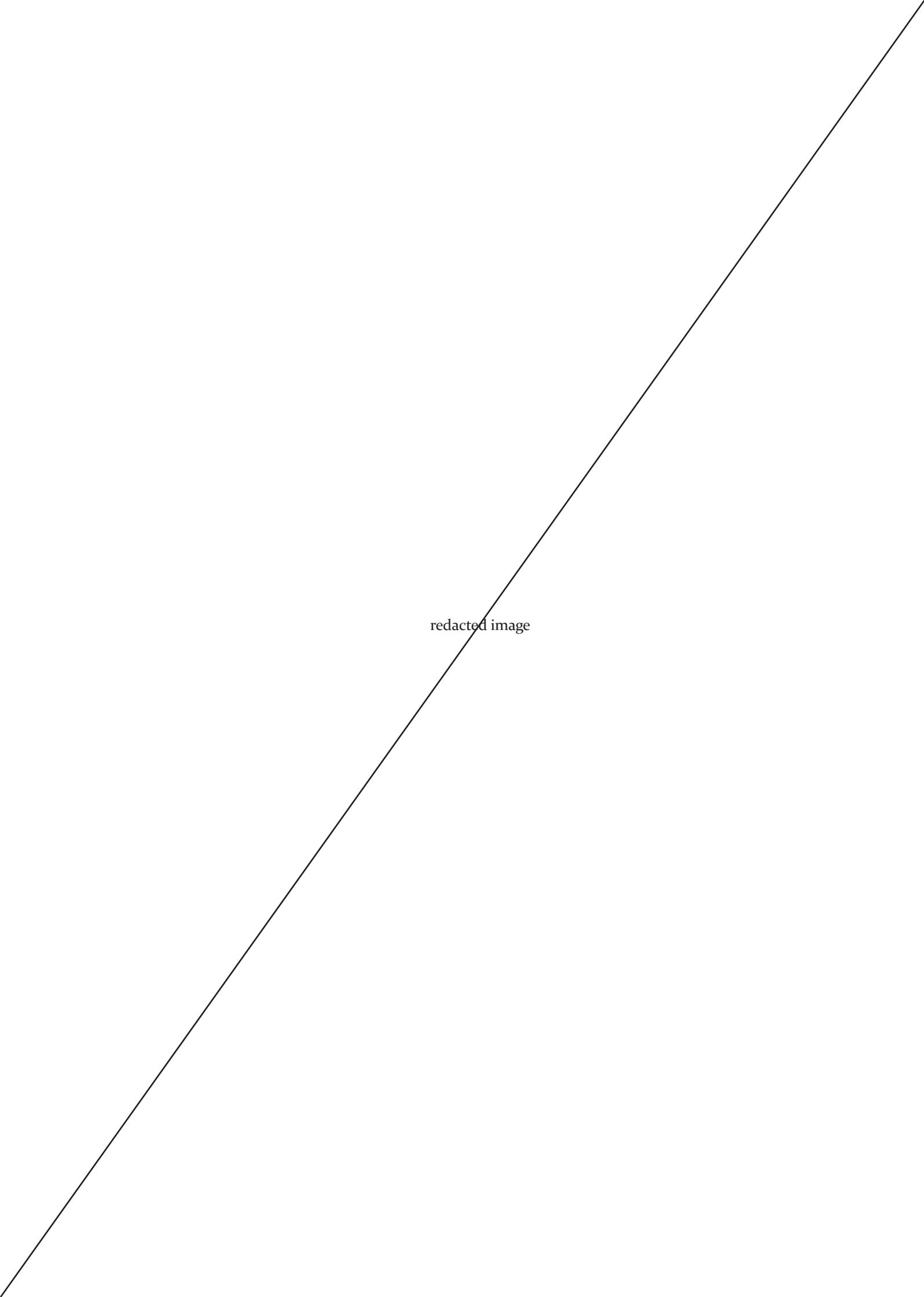
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2.21 *block'hood* (Plethora Project, 2012)
/ *minecraft* (Mojang, 2011)

Block'hood and *Minecraft* provide examples of GE's that give the occupants a new kind of creative system where the user may take advantage of the lack of real world constraints. Jose Sanchez (2015) experiments with this freedom in his computer game *Block'hood*; users are tasked with creating a functioning neighbourhood through a modular binary input/output system. He concludes that, though *Block'hood* could serve as an opportunity to educate individuals to the complex nature of local ecologies, the gaming medium itself provides an invaluable resource for creativity and innovation by providing a new design toolset to users.

In *Minecraft* players understand a series of resource tiers that allow certain components to be built based on what the player has available. This simple system has given rise to a vast range of projects; from the *We are the Rangers* project (Blockworks et al, 2015) that aims to increase awareness of poaching in Africa, to the UN supported *Block by Block* project (Mojang and UN-Habitat, 2012) being used to improve public spaces in third world countries. In both 'games' the player has to comprehend a level of information beyond the built physical structure; it is this complexity that leads users to create massive ornate structures or whole cities. The 'ambivalence' of gamers puts the gamer in the perfect position to create these intimate digital structures, as they carry with them all the personal idiosyncrasies that cause an individual to characterise space in a way current architectural software does not allow for (Aydin and Schnabel, 2015).

Fig 2.02. ◀
Block'hood video game
screenshot, by Plethora
Project, illustrating the
complex built structures
possible.



redacted image

2.22 polyomino/ wireflies/ reon (Sanchez)

The *Polyomino*, *Wireflies* and *Reon* projects created by Plethora Project (Sanchez) give examples of the potential for GE's to be used for education and creation, by merging environmental micro-systems with structural and design components. The *Polyomino* project experiments with the digital configuration and re-configuration of discrete parts to form wholes using an emergent form finding system. *Wireflies* and *Reon* respectively use a similar configuration system to generate structures to respond to contextual micro-ecologies such as harnessing wind and tidal forces. All three use an 'emergent design' digital system to generate unique user guided forms that respond pragmatically to a local context. The term 'emergent design' originates in computing technology and refers to a process whereby each code iteration was an ongoing development of the previous version and represents a less dogmatic approach to writing software, allowing answers to emerge organically without a strong predetermined outcome (Bloomberg, 2013). This shift in agency presents a strong design approach that takes advantage of a cross-disciplinary set of instruments to create new perspectives on design. These emergent design approaches would not be possible without the game engine they are built on, or the cross-disciplinary knowledge needed to comprehend the coding logics behind them.

2.23 journey (thatgamecompany, 2016)

Journey by ThatGameCompany features no creation aspect, yet this GE provides an example of an environment designed to produce high levels of user emotions. *Journey* does this through lighting, texture, sound and the physical environment; setting a precedent for the creation of emotionally charged spaces. Environment creation is key to immersive video game development and is used to tell a narrative as well as provide a physical setting. Whilst the architectural discipline may have highly developed pragmatic instruments, the game industry has similar instruments for the generation and control of user emotions.

Fig 2.03. ◀
Journey video game
screenshot, by
ThatGameStudio,
illustrating the contrast in
scale often used to induce
user emotion.

Gaming environments provide a useful precedent as they give examples of developed digital environment toolsets that focus on providing specific functions within a digital space. The chosen precedents were selected as they illustrated how different digital environments gave certain types of interaction to the users, and how this interaction shaped the users spatial interactions. *Block'hood* and *Minecraft* both gave examples of a creation toolset that led users to create structures that would be outside the normal thought space of traditional digital creative software such as Rhinoceros 3D. *Polyomino*, *Wireflies* and *Reon* take emergent digital design techniques and structure them in an interactive educational environment that becomes accessible to anyone. *Journey* gives an example of a toolset that allows for the manipulation of player emotions. Each of these precedents are used as an example of what is possible for a digital environments framework that is engineered for a specific outcome. In this research a general framework is developed that, in future research, could be adapted to focus on any of these specific toolsets, or others, as research requires.

2.3 virtual reality

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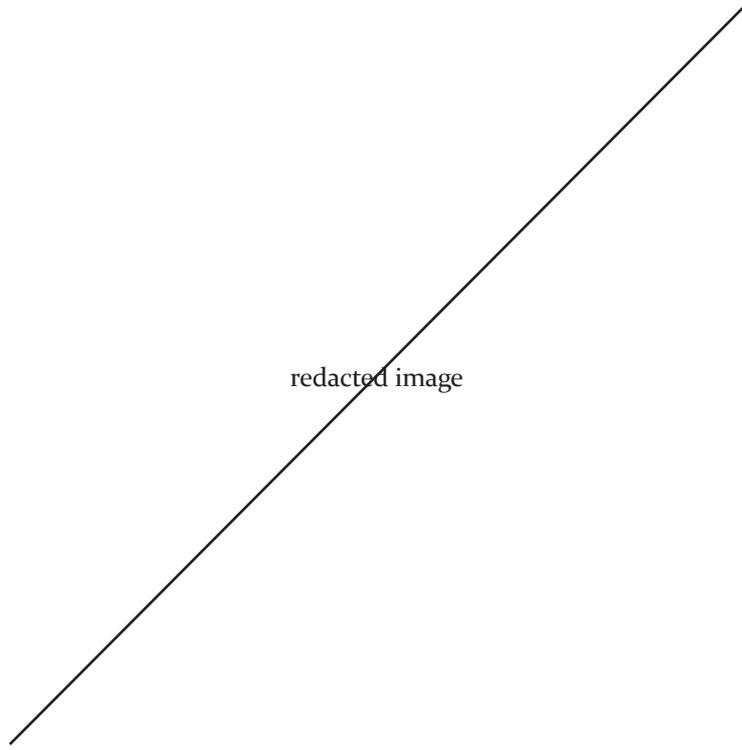


Fig 2.04.▲
Graph of experiment validity
vs. level of control trade-off
across immersive and non-
immersive environments
(Loomis et al, 1999).

The increasing sophistication of computer technology allows for a greater degree of flexibility and freedom within which to create and inhabit digital space (Schnabel et al, 2007); this has led to the creation of the Immersive Virtual Environment (IVE). An IVE is characterised by its ability to create a Virtual Environment (VE) in which the user feels a high level of presence and, thus, immersion. Singer and Witmer (1998) define immersion as:

“...a psychological state characterised by perceiving oneself to be enveloped by, included in, and **interacting with an environment** that provides a continuous stream of stimuli and experiences...”

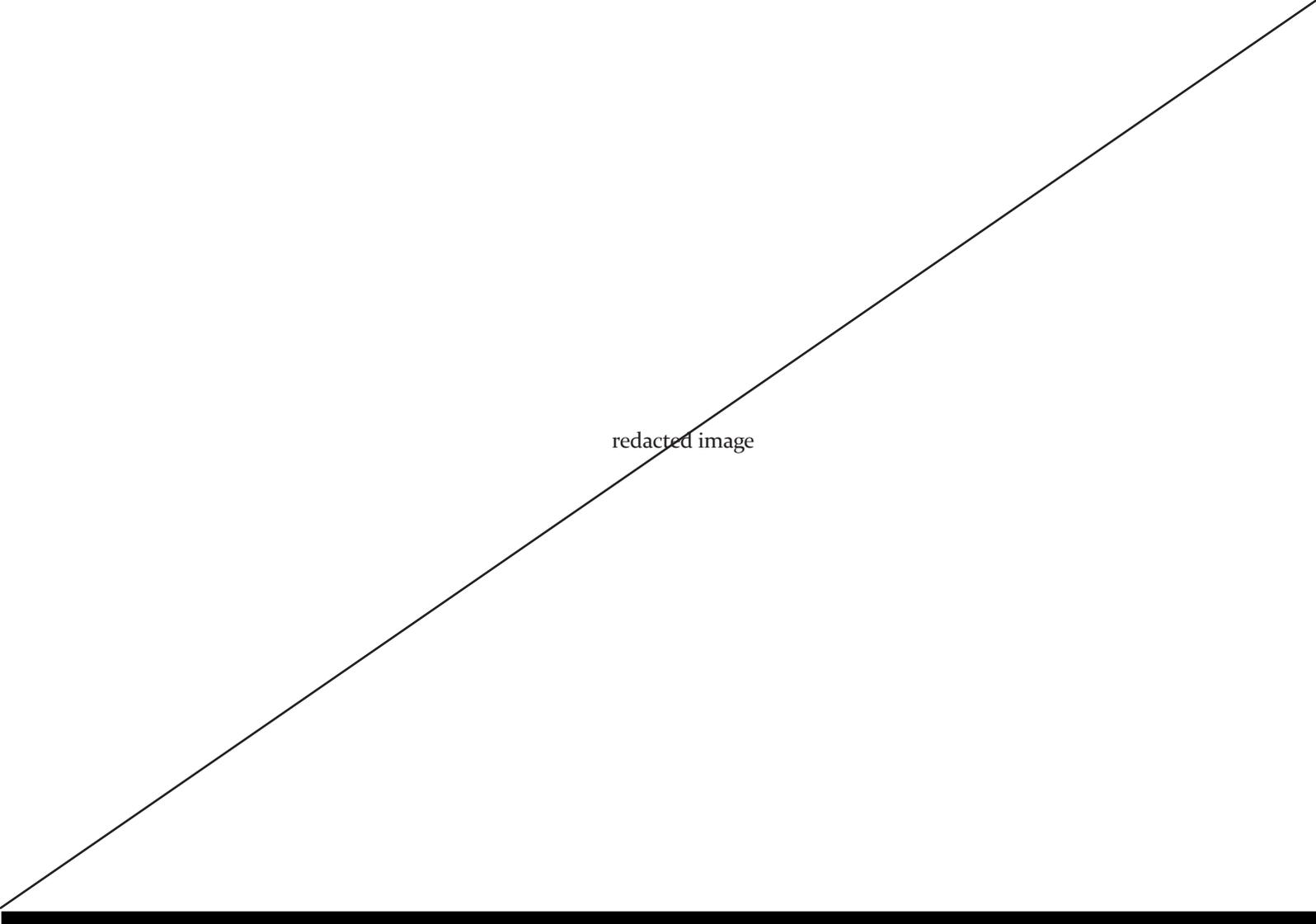
Through the use of an IVE it becomes possible to more thoroughly test the psychological impact of different spatial factors on the user, as this research explores later. Blascovich et al (2002) cite three main advantages for the use of an IVE in psychological experimentation: the ability to create an environment that is realistic and highly controlled, able to be replicated easily and potentially more representative due to better sampling methods. Figure 2.04 illustrates the approximated level of trade-off between ‘experimental control’ and ‘ecological validity’ for traditional methods, non-IVE digital methods and IVE (labelled ‘virtual displays’) methods. Loomis et al demonstrate that ‘virtual display’ methods can attain a high level of control over the experiment whilst still retaining a high level of accuracy and ‘realism’; in comparison to screen-based and physical based simulation which both suffer issues of achieving a good trade-off between cost and validity.

It is important to note, that presence doesn't exclusively rely on visual realism, it is often the inclusion of those other senses (i.e. haptic, aural) that refines user focus and generates immersivity. Behavioural realism (that is the natural behaviour of other occupants within the environment, i.e. animals, and other effects, i.e. rain) is deemed more important than photographic realism by Blascovich et al (2002) in their experimentation with IVE instruments. Research by Slater and Wilbur (1997) shows that a high degree of participant immersion induces reactions comparable to those in 'real life', allowing VR to be used as a valid experimentation media. As an architectural instrument, human perception allows for intuitive decisions to be made that generate not only a physical environment but a 'perceptual' environment too; dubbed in this research as Perceptual Space (PS). In order to explore environmental impact on PS a set of instruments are required that allow for interaction within an IVE.

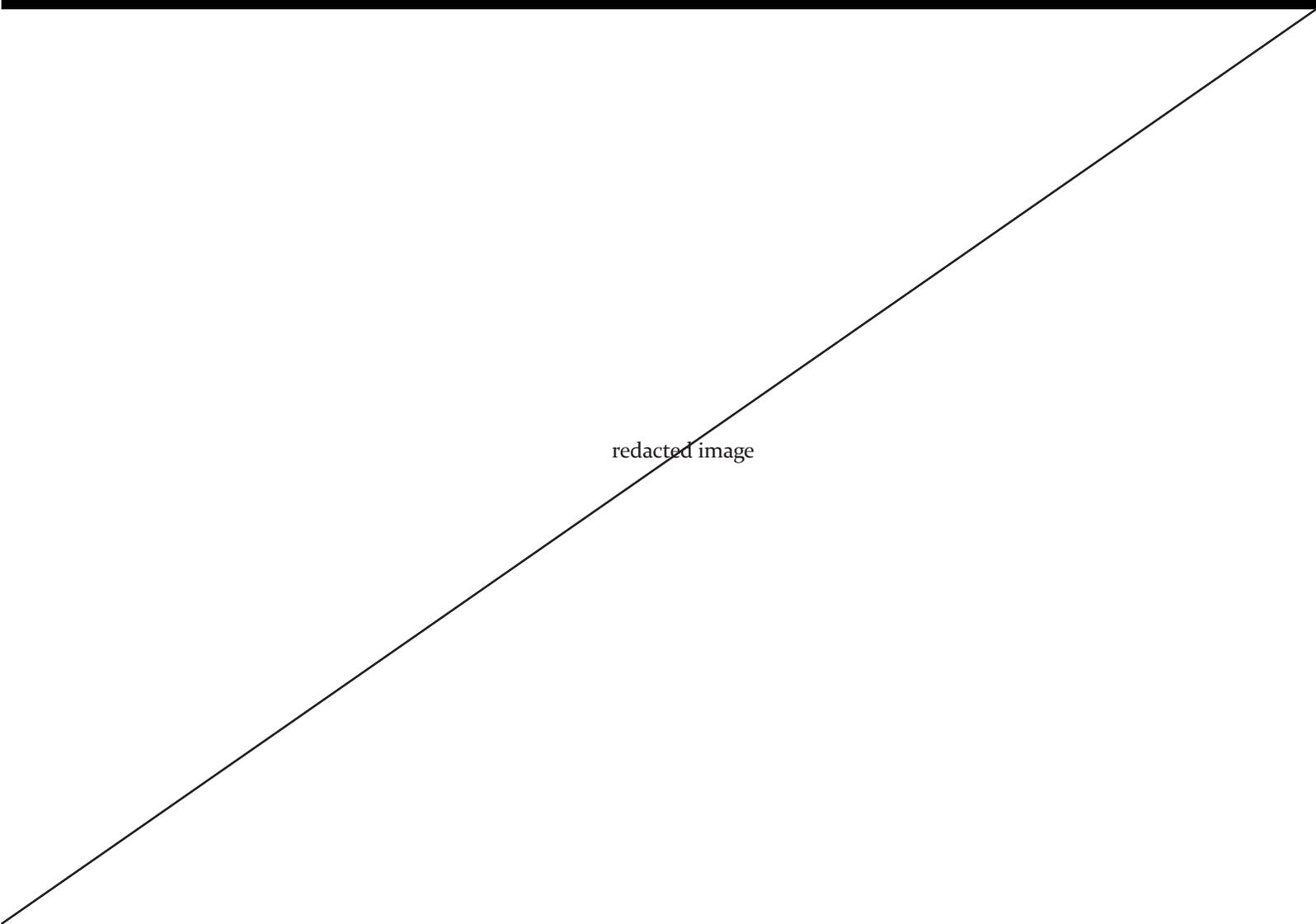
Greg Lynn and Kelly Therese introduces a dynamic digital methodology in *Animate Form* (1999) bringing into question the nature of 'digital design'. This saw further development by writers such as Patrik Schumacher (Schumacher, 2009, 2011). Current 'digital' work now spans a wide range of areas; from the robotic work of Achim Menges to Jose Sanchez' game environments, and the

question of ‘what is representation?’ in digital architecture becomes harder to answer. Instead a better question would be ‘what is ‘digital?’; some even going so far as to ask ‘is ‘the digital’ dead?’ (Retsin, 2016). This research doesn’t attempt to challenge the notion of digital architecture; it situates itself in the ‘post-digital age’ where the pragmatic application of cross-disciplinary ‘digital’ methodologies is intended as a means to achieve a tangible outcome, and not purely as representation. This lifts the digital environments within this research into a digital analogue. The question of representation is outside the scope of this research, though, as Mixed Reality (MR) technology continues to be developed, the difference between ‘real’ and ‘digital real’ will be a topic of interesting and pivotal debate.

As digital instruments become increasingly more complex the possibility to create fully immersive environments increases (Slater, 2014). With the release of this technology to the consumer, the general level of skill and familiarity with these instruments will rapidly increase, allowing research to take advantage of a growing literacy in the area. Gaming environments already have a precedent as a research instrument for education (Sanchez, 2015), psychology (Bertuzzi and Zreik, 2011) and cultural preservation (Aydin and Schnabel, 2015). The following precedents illustrate different aspects of the capabilities of VR for its use as an architectural instrument and establish the project scope.



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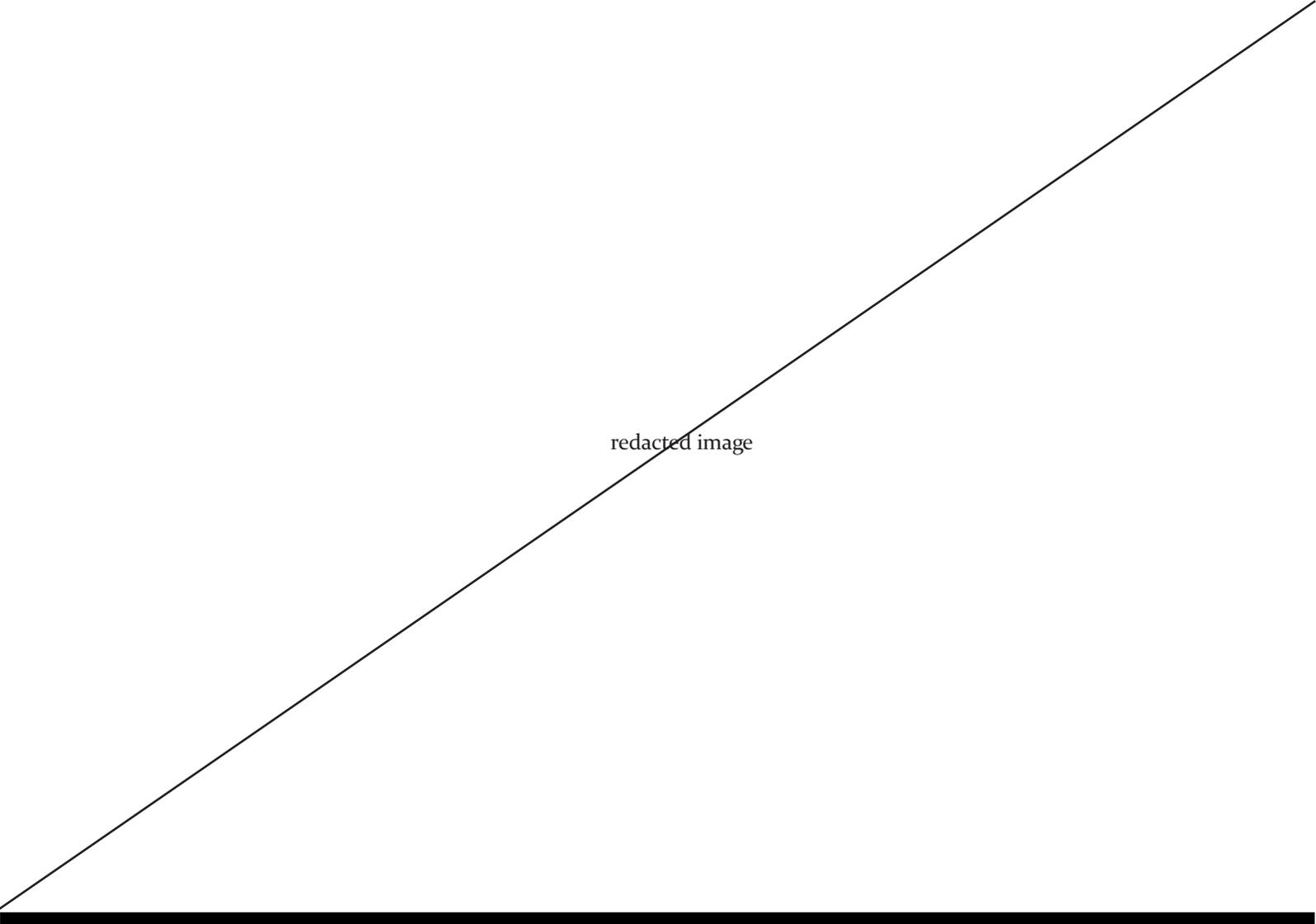


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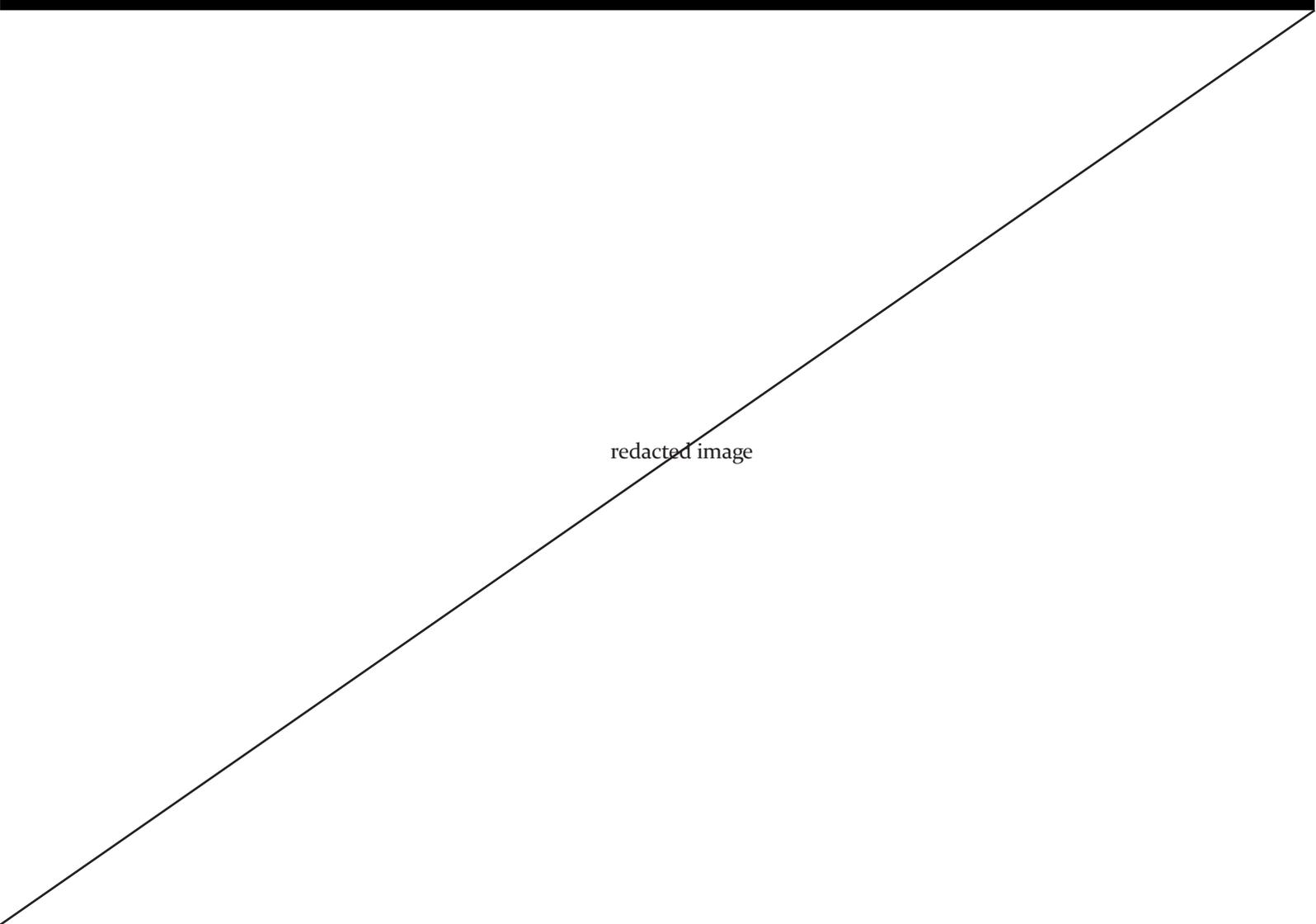
2.31 the cubicle (van Beek et al., 2016)

The Cubicle provides a precedent similar to *Journey*, where the ability for a VR environment to produce a high level of user engagement and induce strong emotions is demonstrated. The ‘player’ finds themselves in an office cubicle in much the same style as the Action Office II system. Given a mundane filing task, and nowhere to go, the user takes note of the basic nature of the cubicle they are in. As they continue, the environment starts to warp and change, subtly at first but with increasing degrees of change. Towards the end of the experience the user is left feeling uneasy, not knowing what to expect next. *The Cubicle* capitalises on the user’s familiarity with traditional office environments to contrast against a series of strange environmental changes, symbolising the ‘plight’ of mundane office work. Overall, the experience emphasises the degree to which environmental factors within a VE can impact the user’s emotions and actions. This provides a useful precedent for the natural use of player UI that doesn’t disrupt player immersion, yet still creates an uncanny environment that induces player emotion.

Fig 2.05. ◀
Screenshots from *The Cubicle* VR experience, by Jespertheend, showing the changing environment used to set the user on edge.



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2.32 fuzor (Kalloctech, 2013)

Fuzor provides a VR design instrument within the BIM process, allowing this research to focus on more holistic VR applications. Fuzor VR integrates the first person strengths of VR into the BIM project pipeline; adding a sense of realism with accurate seasons and environmental effects, such as traffic noises. Giving the architect greater individual agency in the design process allows for changes to be translated into BIM software quicker and easier. Fuzor has introduced a VR component into its package allowing for total authorship of the design development process, where the user can experience and change the design in real-time both as an individual and collaboratively. This application of VR in architecture is the first logical option; this research seeks to create multiple functions for VR within architecture and avoid replicating what already exists. This precedent helps to define the scope of this research.

2.33 mixed reality

MR promises to have a huge impact on the way design disciplines work. It gives the ability to visualise and manipulate computer models and data in a real world context i.e. projecting a project model onto a table in 3D. MR technology, such as the Microsoft Hololens, takes existing components of the user's environment (i.e. a table) and augments it with virtual elements. This creates an entirely different digital environment where issues such as immersivity and realism aren't important; as any object perceived in MR space is seen as 'real'. MR is not used because the technology is currently not good enough to produce an adequate feeling of immersion. However, as the technology improves, this research is likely to shift away from VR and into MR technology as it provides a much greater feeling of realism due to the combination of real and virtual objects. It is included as a precedent to identify the need for the developed framework to be able to adapt to new media.

Fig 2.06. ▶
Microsoft's 'Transform Your World with Hololens' demonstration video showing the potential for interactive MR user interfaces.

Fig 2.07. ▶
A hypothetical engineers demonstration using the Microsoft Hololens illustrating its capability to visualise 3D models in a collaborative setting.

This section defines the scope of the framework developed later. There is precedent for VR in architectural research on interactivity (Boeykens, 2011; Chen and Schnabel, 2011; Dokonal, 2015), and it is important to understand the wider context for the application of VR and MR in architectural research so that this research produces new learning. *The Cubicle* is used as a precedent in the same vein as *Journey*, showing a set of interactive and environmental tools being applied to generate user emotion within a digital environment. Fuzor is included as a precedent as it helps to define the scope of this research. The immediate application for VR within architecture is as a BIM tool to be used in conjunction with existing software, to improve workflow. As Fuzor provides this tool, this function is beyond the scope of this research. Whilst MR is a type of representation, it has more inherent commonalities with architectural creation than VR and is likely to play a pivotal role in future digital architectural frameworks. This research integrates VR into a digital framework as current MR technology is not advanced enough. Flexibility is built into the framework to allow for a shift to MR in the future.

phase one

Phase one represents the early stages of this research, prior to the introduction of virtual reality. The first phase creates an adaptable framework for operation within screen-based digital environments and then develops weaknesses found in user testing. This research is broken up into two sub-phases in order to differentiate between either sides of a pivotal shift; before and after the introduction of virtual reality.

3.0

digital framework design

This chapter creates a framework for experimentation within an interactive digital environment and presents preliminary research into densified office environments. This framework is intended to be used by architects, game designers, environmental psychologists and any discipline concerned with the way people inhabit environments.

Early experiments begin by looking at office density in a screen based environment. In the literature, interaction with the environment was a key part of feeling presence within a digital space; these experiments represent an attempt to create user interaction with a densified digital office environment. The goal of each form of interaction is to create a natural feeling mechanic that doesn't distract the user from their task and ruin their immersion.

The term 'node' is used to describe the objects being created within the scenes to approximate environment density. A plain geometric shape was chosen for its homogeneity so that users may concentrate on their task and not get distracted by a particular shape.

Each form of interaction devised, bar the Generate series, uses a linear selection mechanic to select objects. This means that when the user clicks their mouse on a point on the screen a beam of 'light' is cast from the user in the direction of the mouse and the form of interaction will react differently based on what it hits. This is known as raycasting.

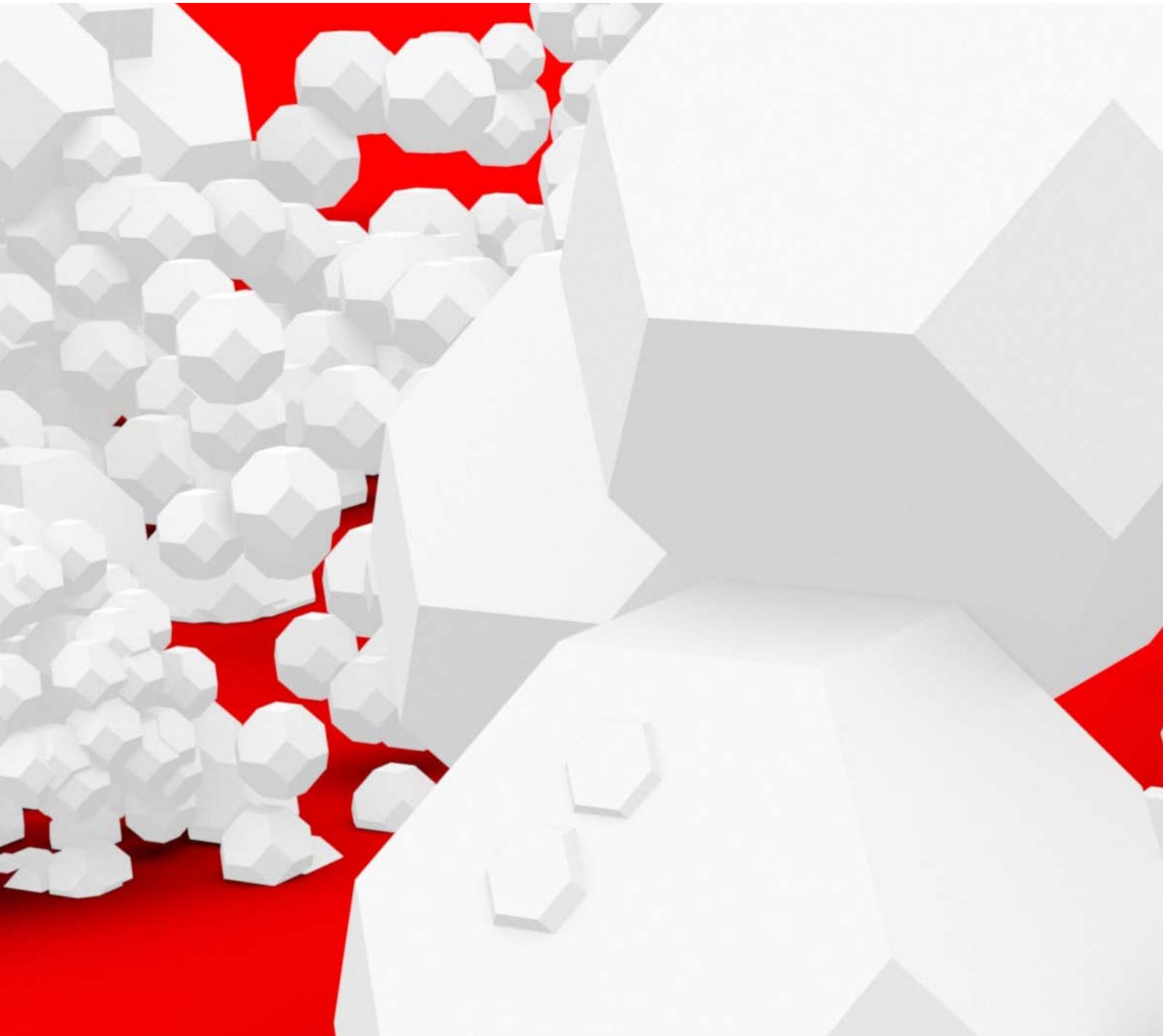
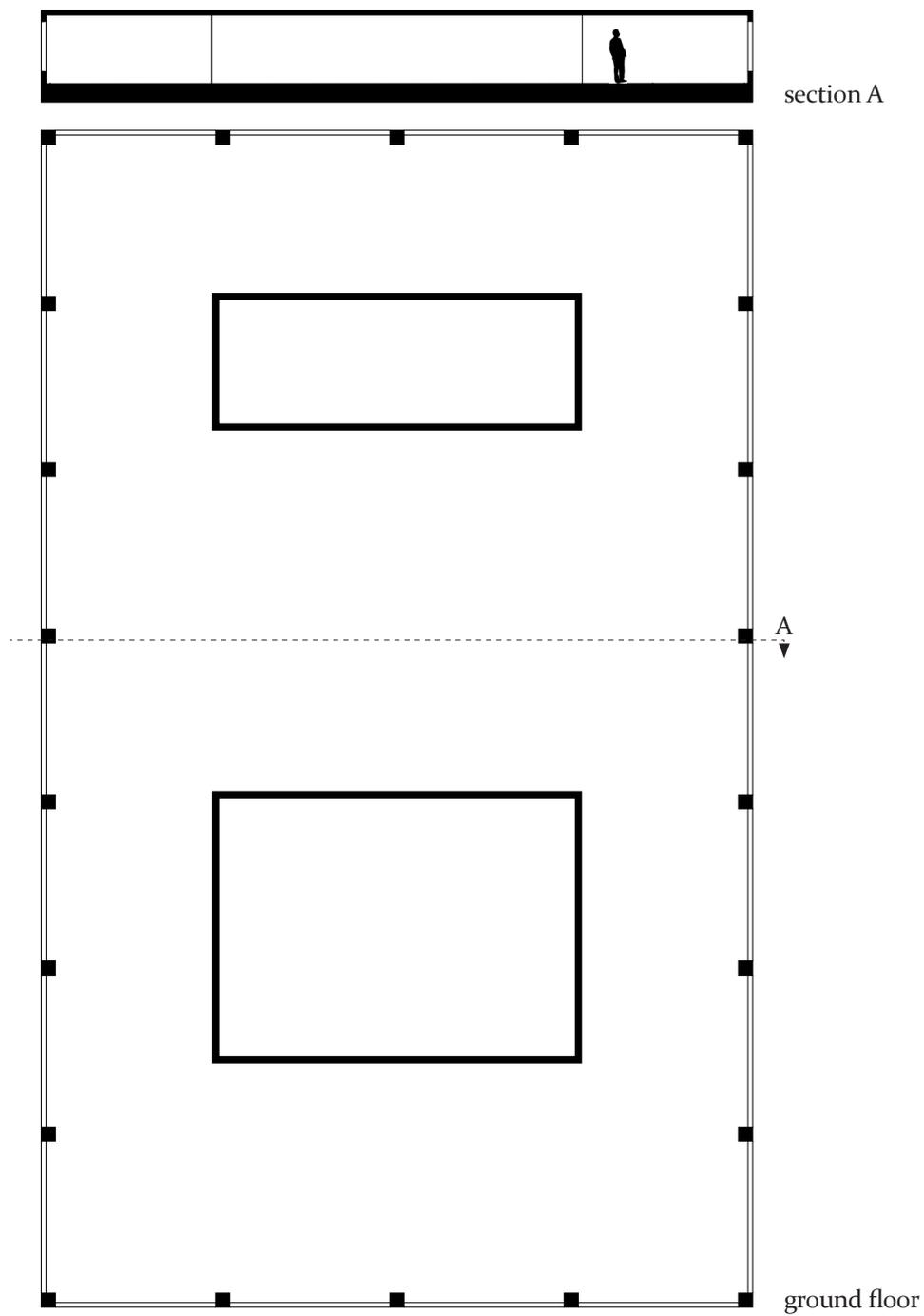


Fig 3.01. ▲
A visualisation of a digital
environment with a high
amount of manifested
objects, dubbed 'nodes'.



experiment space #1



The Raycast series of user interaction techniques represents a user controlled creation technique designed to increase environment density, in this case a simplified version of a typical open plan office space as shown by Figure 3.02. The initial 'Create' experiment gave the user too much agency, so each subsequent iteration focused on introducing different more organic elements to the instantiation scripts.

Both 'Spawn' interaction types focus on creating a more natural instantiation mechanic with a local random direction component; the second introducing a distance based scale mechanic.

The 'Shape' interaction types trial a more diverse physical node set including a 3, 8, 10 and 12 sided node.

The 'Generate' interaction types completely remove individual user agency; reducing their actions to a set of prescribed tasks. They also introduce a moving and an aural component in order to test user response to different aspects of perceived environment density. 'Generate' was used to give the user minimal agency, so that the environment may become overwhelming without their intervention.

The interaction techniques are as follows;

- Raycast Create
- Raycast Spawn
- Raycast Spawn Distance
- Raycast Shape
- Raycast Shape Distance
- Generate
- Generate Other

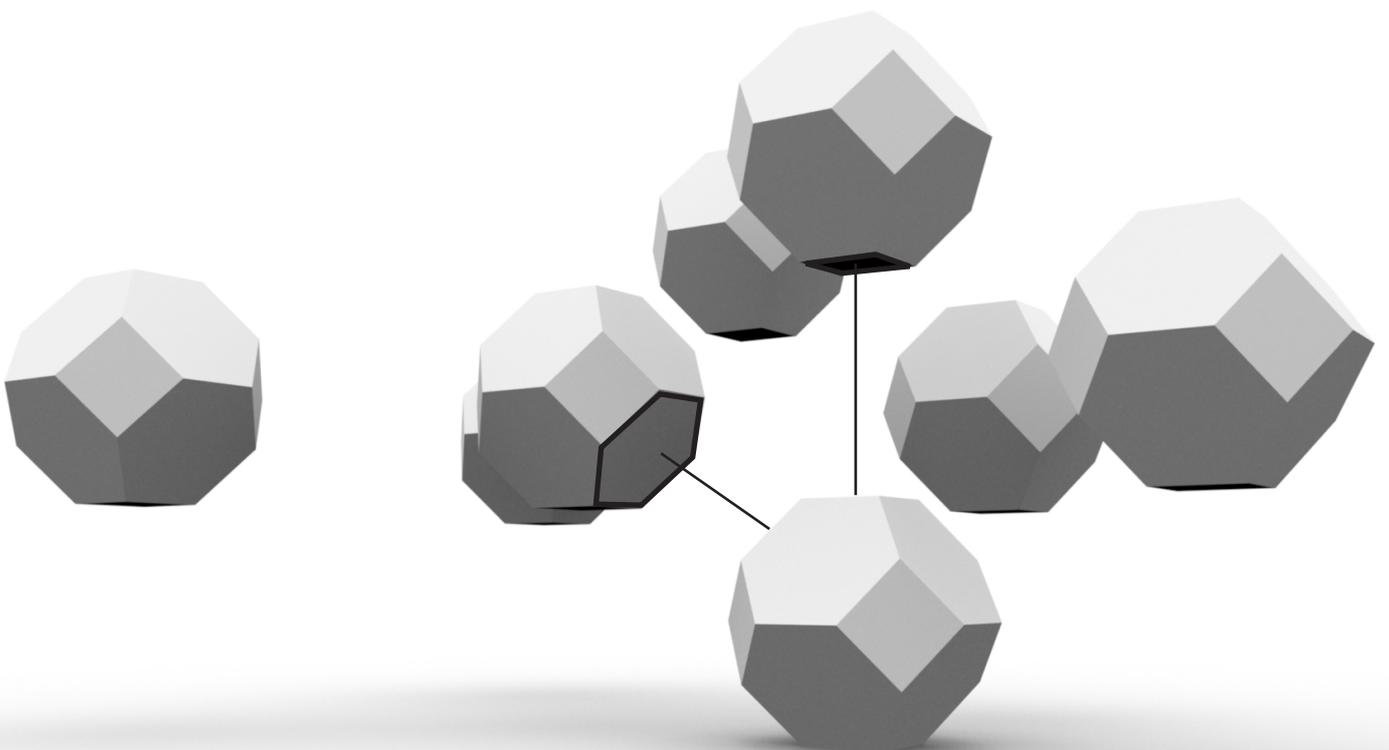
The following pages illustrate the various forms of user interaction with the environment. These are early developments of different types of user interaction with a digital environment and help refine the form of interaction the user is allowed to take in subsequent iterations. Each iteration develops the form of interaction to feel more 'natural', based on user feedback.

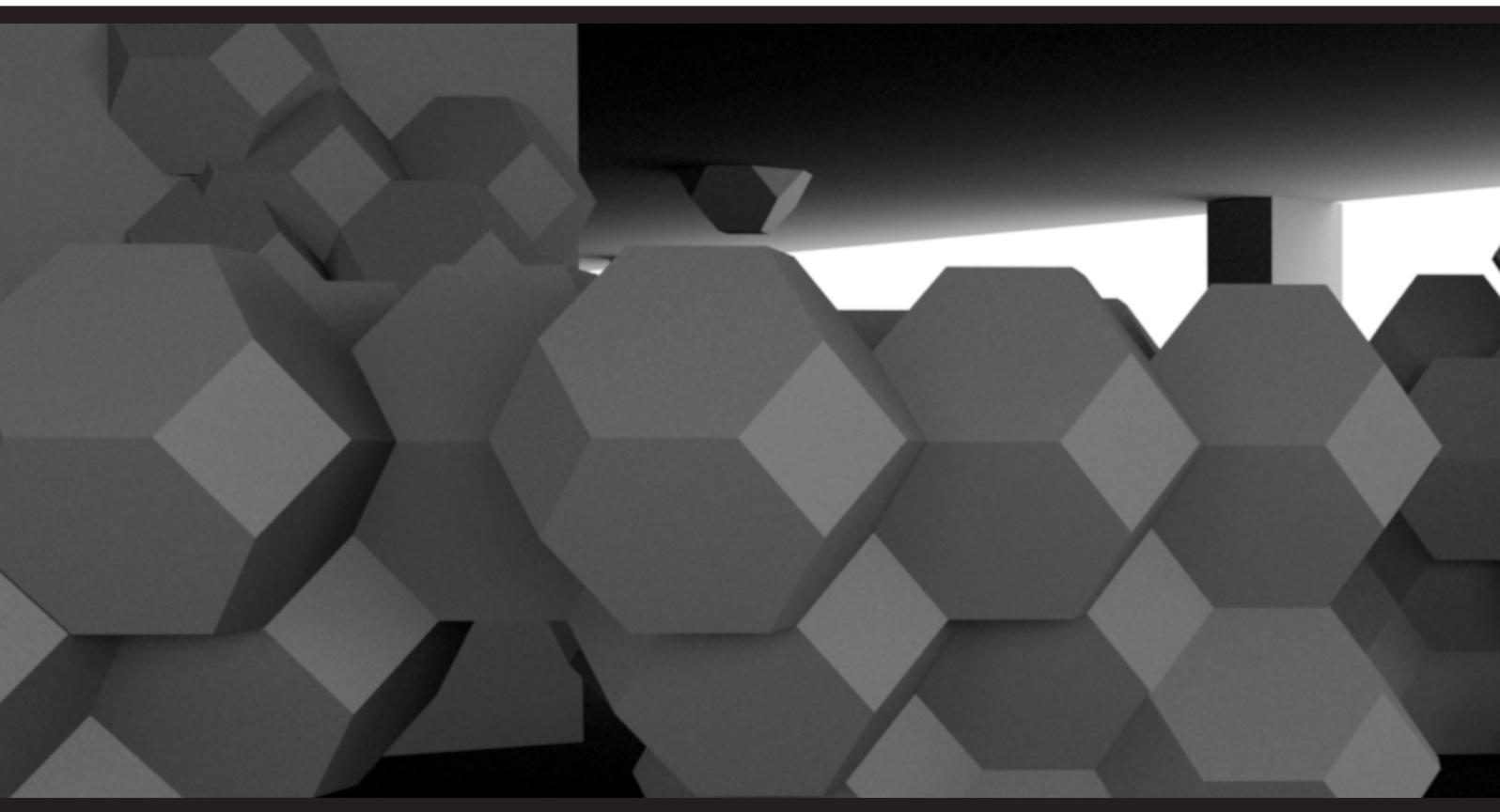
*Fig 3.02. ◀
Floor plan and section of
experiment space one, the
initial experiment space
used, based off a simple
office floor plan.*

raycast create
raycast spawn
raycast spawn distance
raycast shape
raycast shape distance
generate
generate other

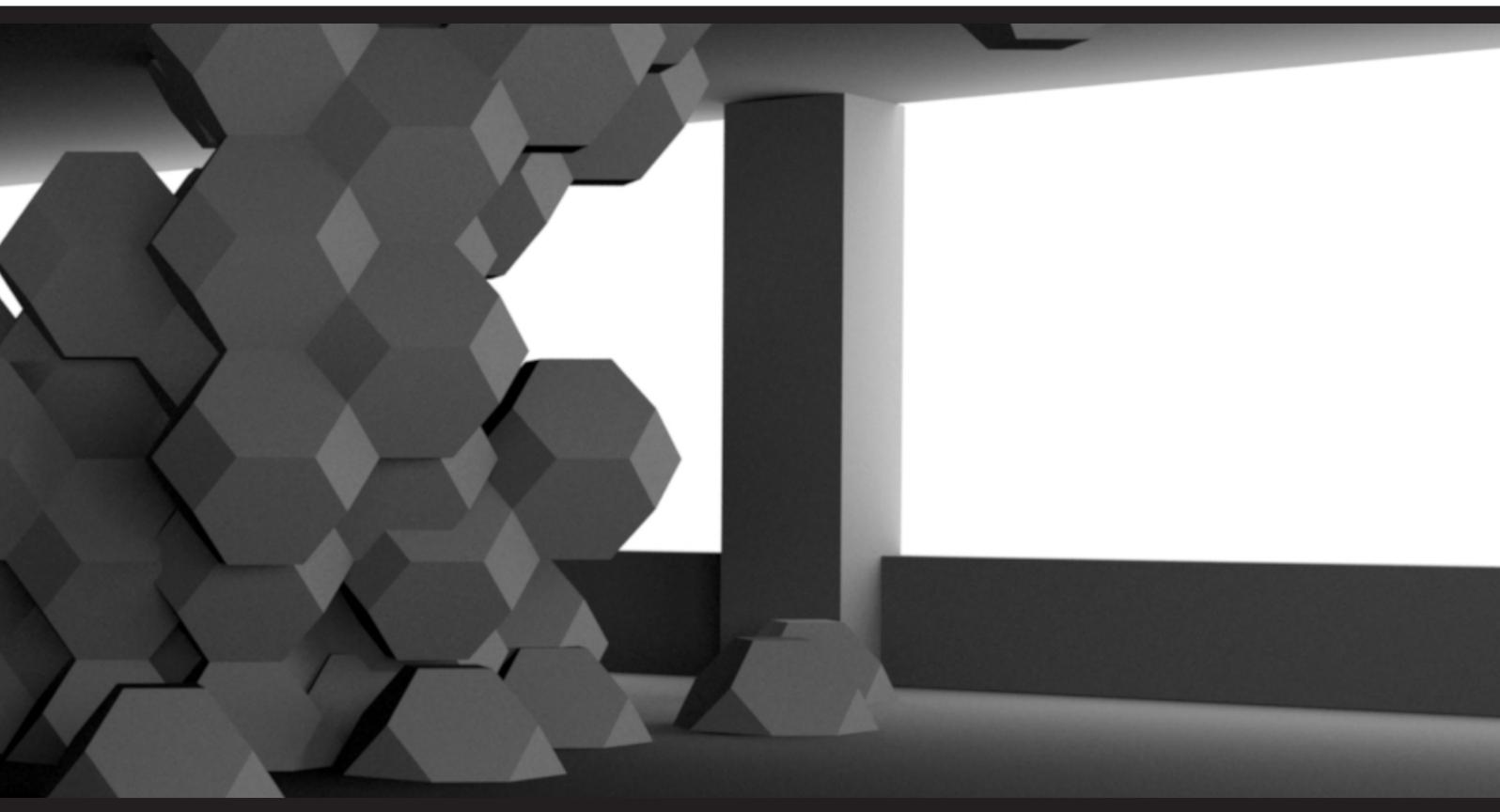
Fig 3.03.►
Example node configuration
for Raycast Create, showing
the distance between each
node and the face of the
initial node (center).

This form of interaction gives the user the ability to create a node (a randomly created polygonal shape purposely chosen to be non-figurative) at any position they select. If they select a position on an existing node then the new node manifests in such a way that it packs perfectly with the existing node. If the face of the object that the user has selected is a horizontal or vertical face a node is created at a certain distance; if the face is angled a node is created at a different distance. This is done to ensure the created node stays at a fixed distance from the center of the existing node.





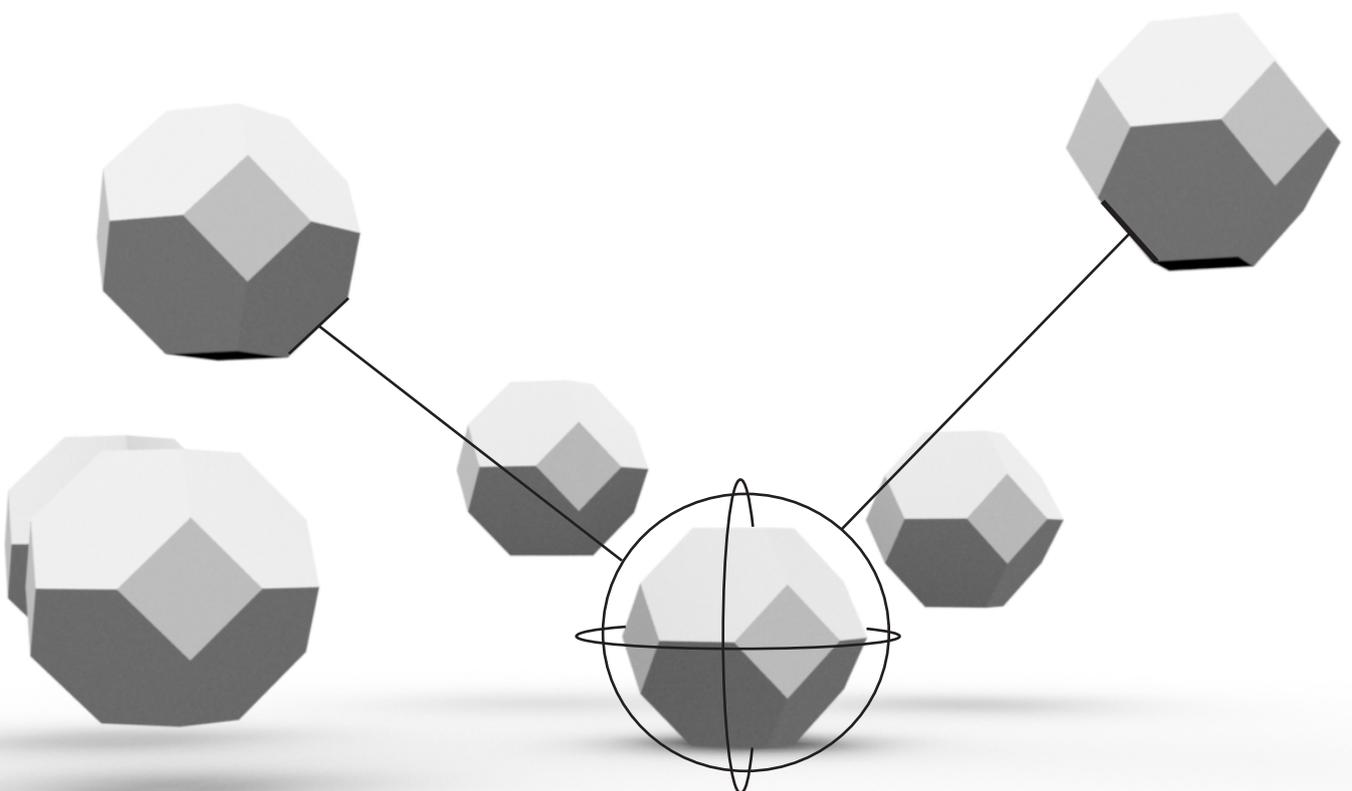
*Fig 3.04.▲
Screenshot of user
perspective of interaction
form Raycast Create, within
an environment where a
high level of 'nodes' have
been manifested.*

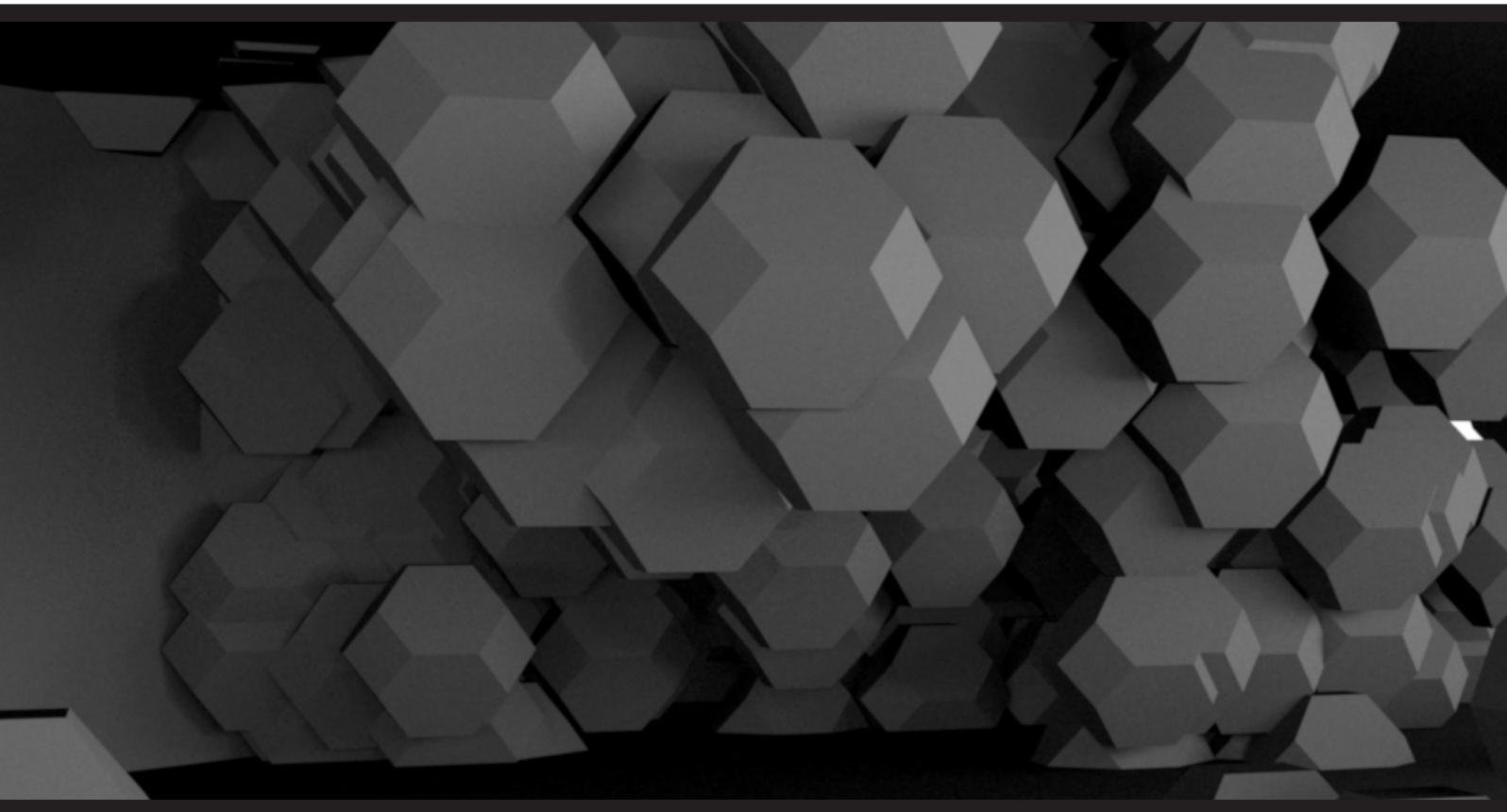


raycast create
raycast spawn
raycast spawn distance
raycast shape
raycast shape distance
generate
generate other

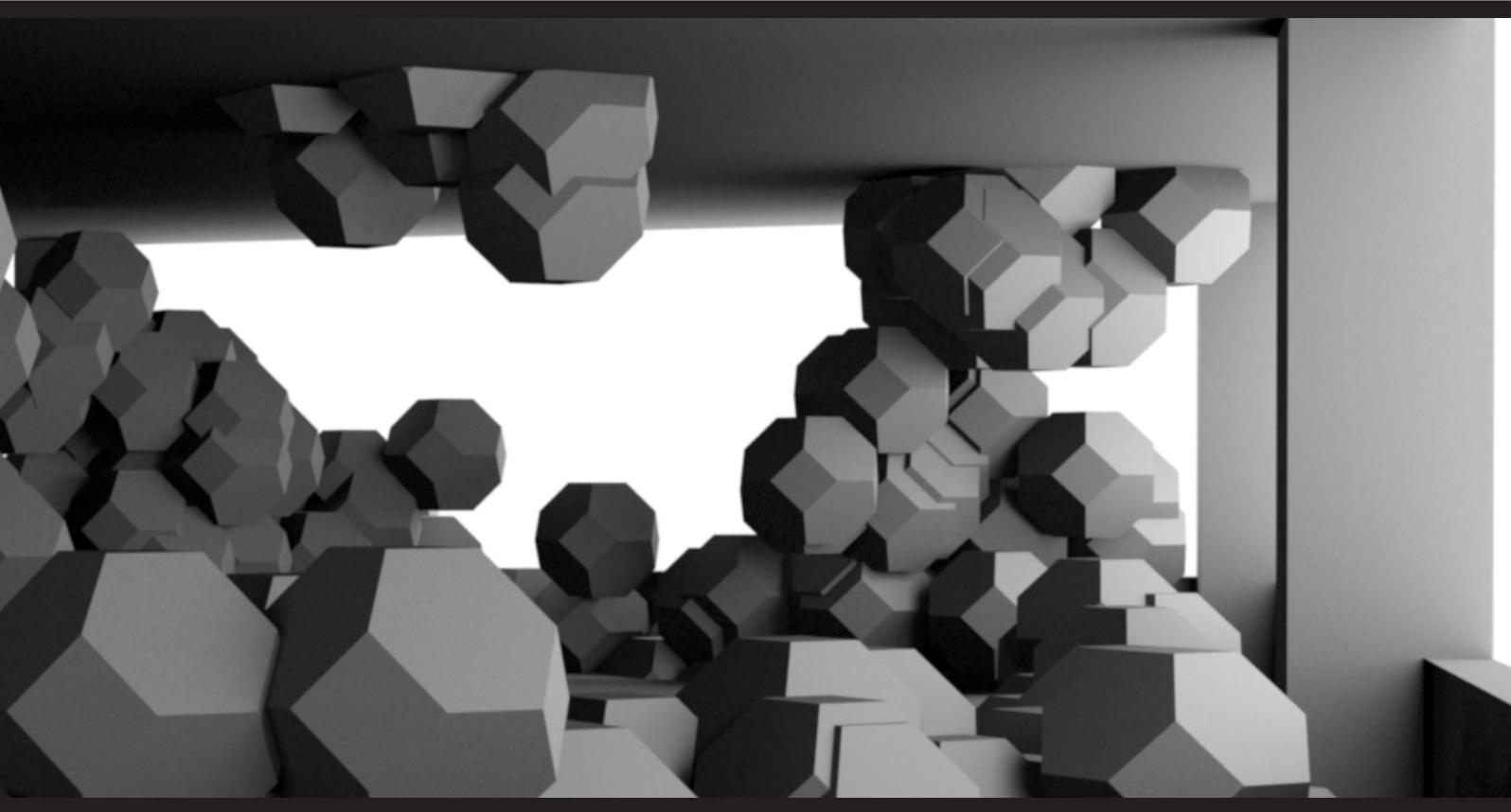
Fig 3.05.▶
*Example node configuration
for Raycast Spawn,
illustrating random distance
and direction of creation.*

This form of interaction gives the user the ability to create a node at a random distance and direction (within a range) for a selected position, including on other nodes. The script sets the nodes position in a random direction at a specified distance from the selected point. The node is then created. This gives the user only partial control of the interaction, making the node creation process feel more natural.





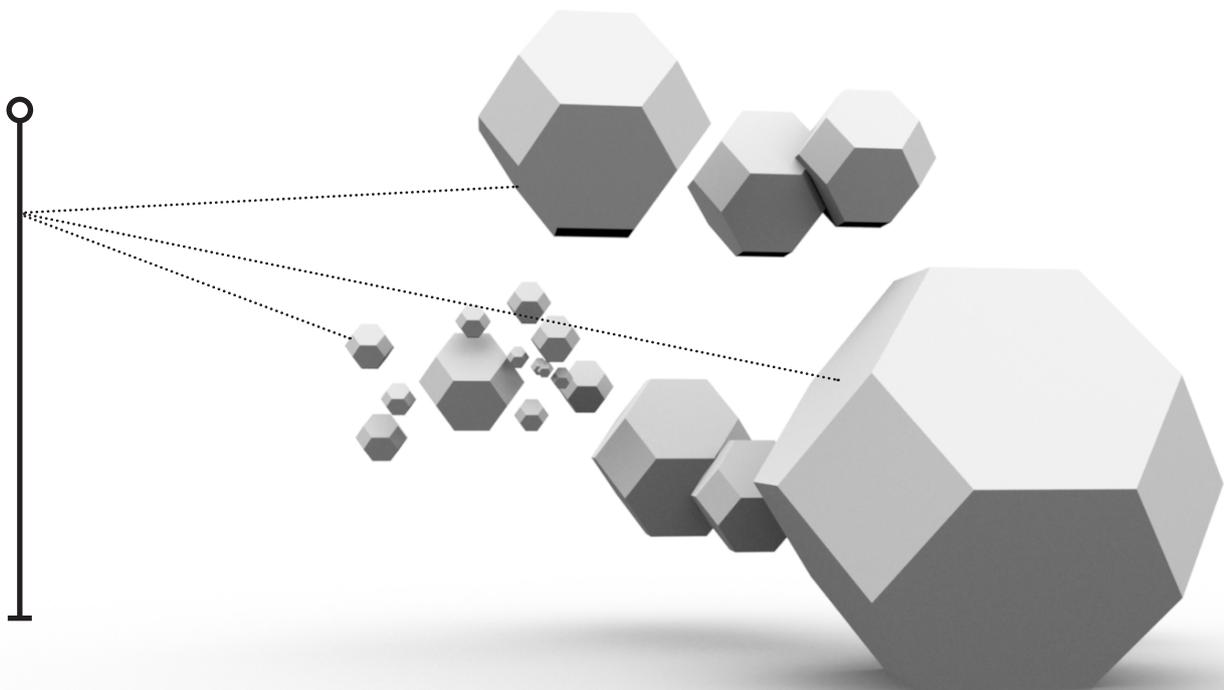
*Fig 3.06.▲
Screenshot of user
perspective of interaction
form Raycast Shape, within
an environment where a
high level of 'nodes' have
been manifested.*

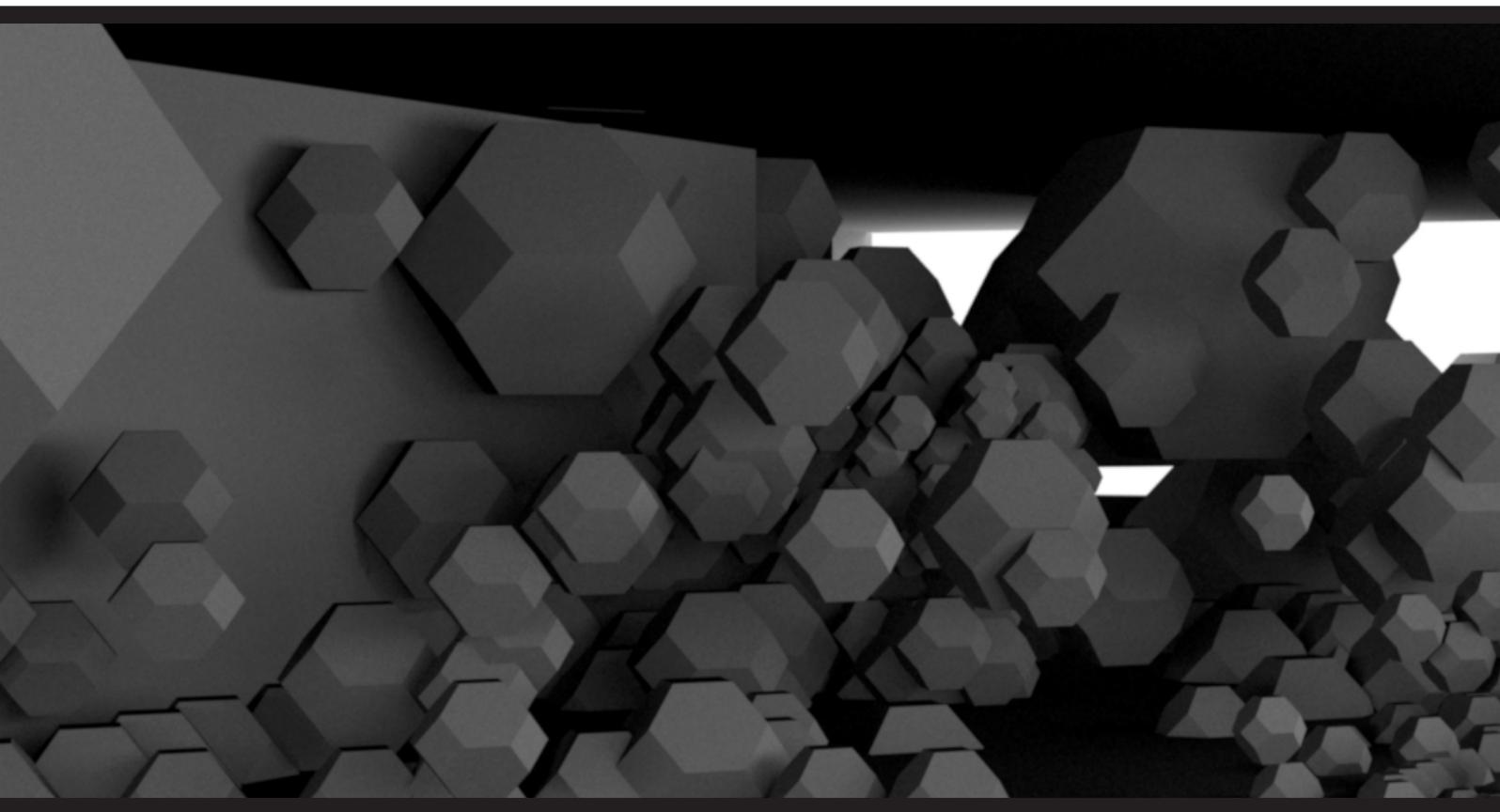


raycast create
raycast spawn
raycast spawn distance
raycast shape
raycast shape distance
generate
generate other

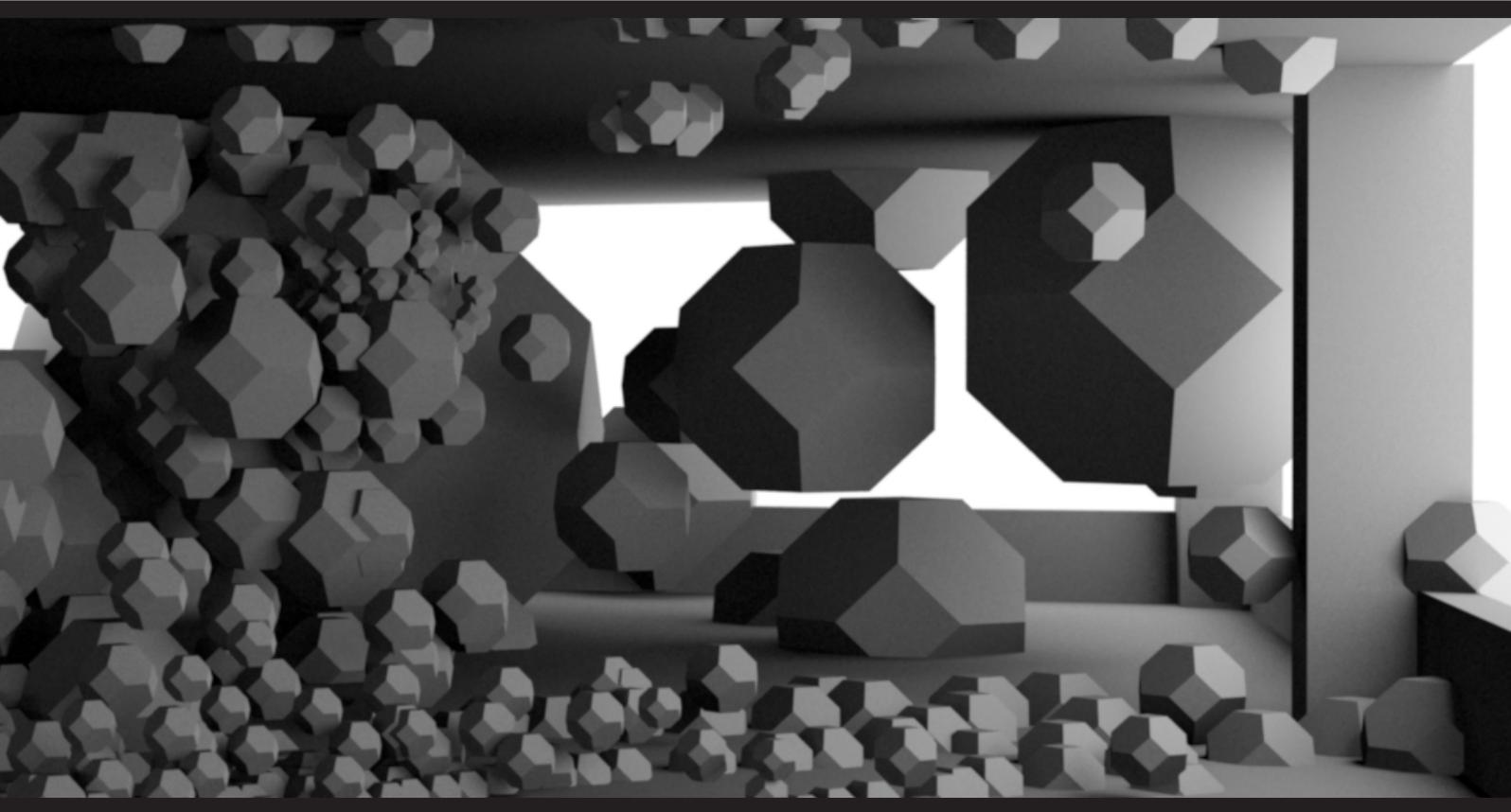
*Fig 3.07.▶
Example node configuration
for Raycast Spawn Distance,
illustrating how increased
creation distance increases
node size.*

This form of interaction creates a node at a random direction from the selected location. In this experiment the nodes size is proportional to the distance from the user to the selected point. The object script sets the nodes position in a random direction at a specified distance and at a scale proportional to the distance from the selected point. The node is then created. Note that there is a minimum size in order to reduce 'unusable' nodes. This provided more diversity to the environment so that the user didn't find the shape repetition unnatural and lose immersion.





*Fig 3.08.▲
Screenshot of user
perspective of interaction
form Raycast Spawn
Distance, within an
environment where a high
level of 'nodes' have been
manifested.*



raycast create
raycast spawn
raycast spawn distance
raycast shape
raycast shape distance
generate
generate other

Fig 3.09.►
*Diagram showing different
available nodes for Raycast
Shape.*

This form of interaction creates one of four different nodes at the selected location. The nodes shape is chosen randomly if a non-node is selected, otherwise if a node was selected then the same shape is created again. The node is created in a random direction at a fixed distance from the selected point. The object script identifies whether the user has selected to create a node either directly on the environment, or on another node. It then creates one of the shapes at a fixed distance from the selected point. This develops on the previous interaction form by introducing even greater diversity through multiple different shapes.



1.



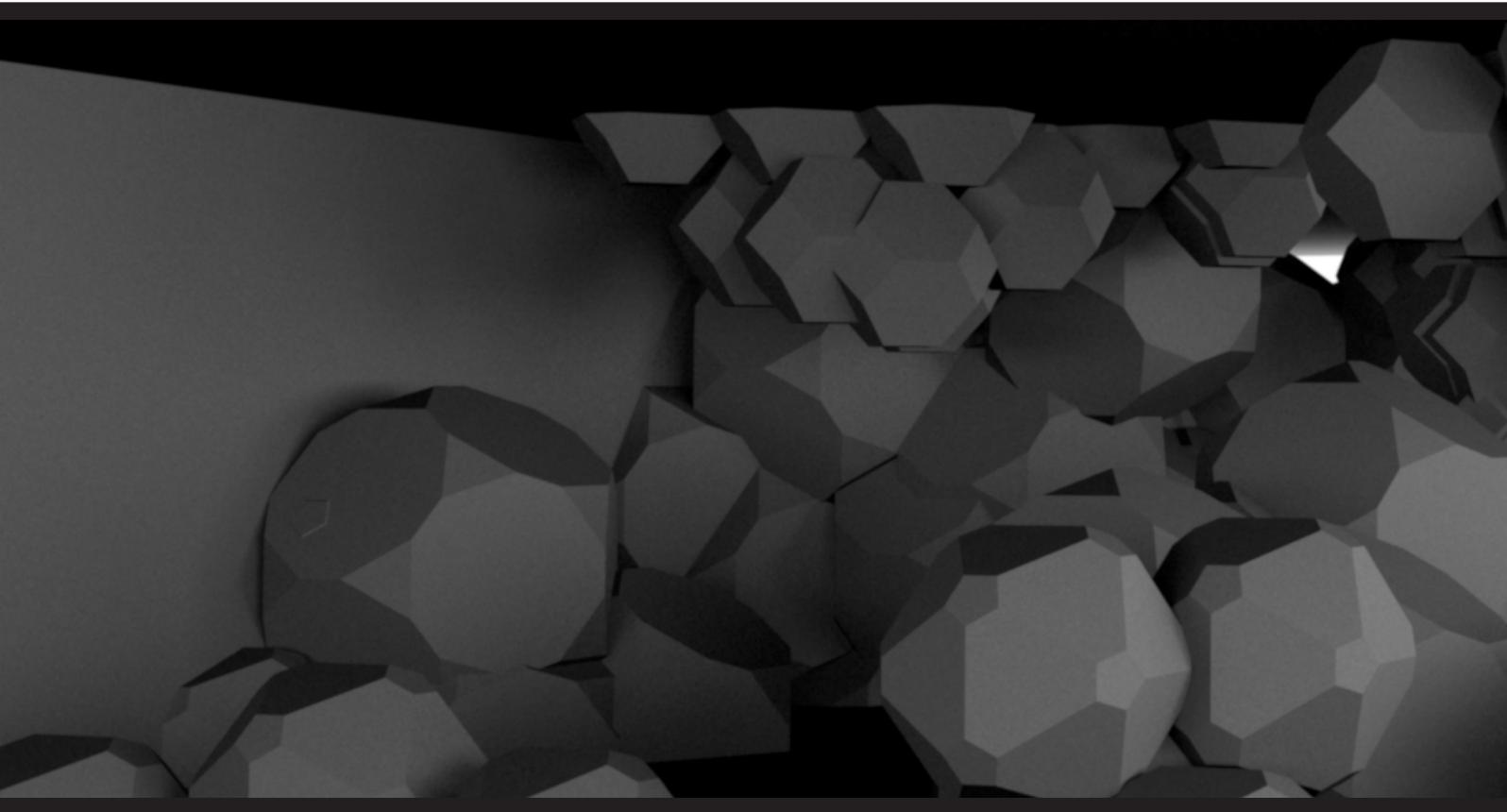
2.



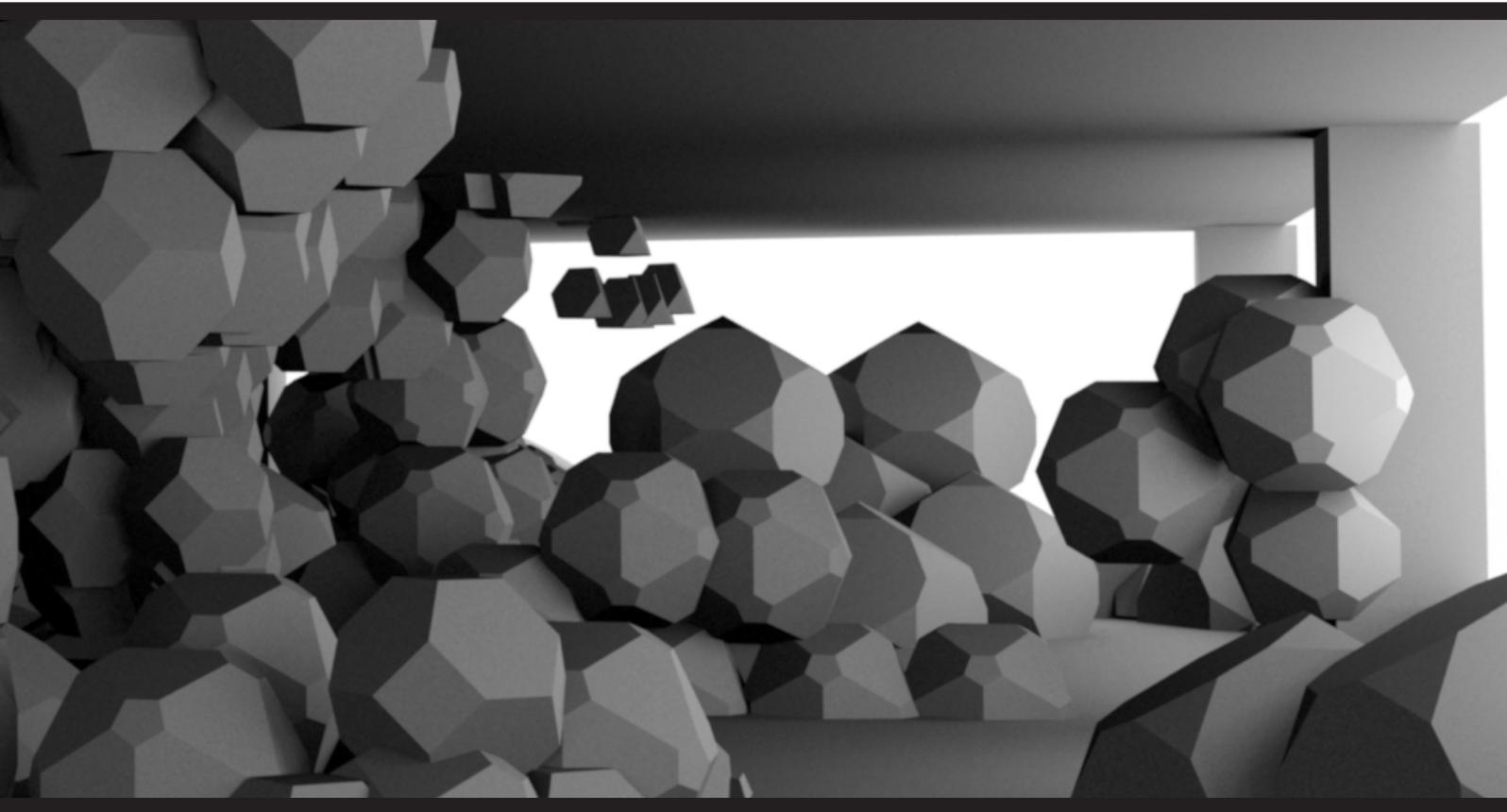
3.



4.



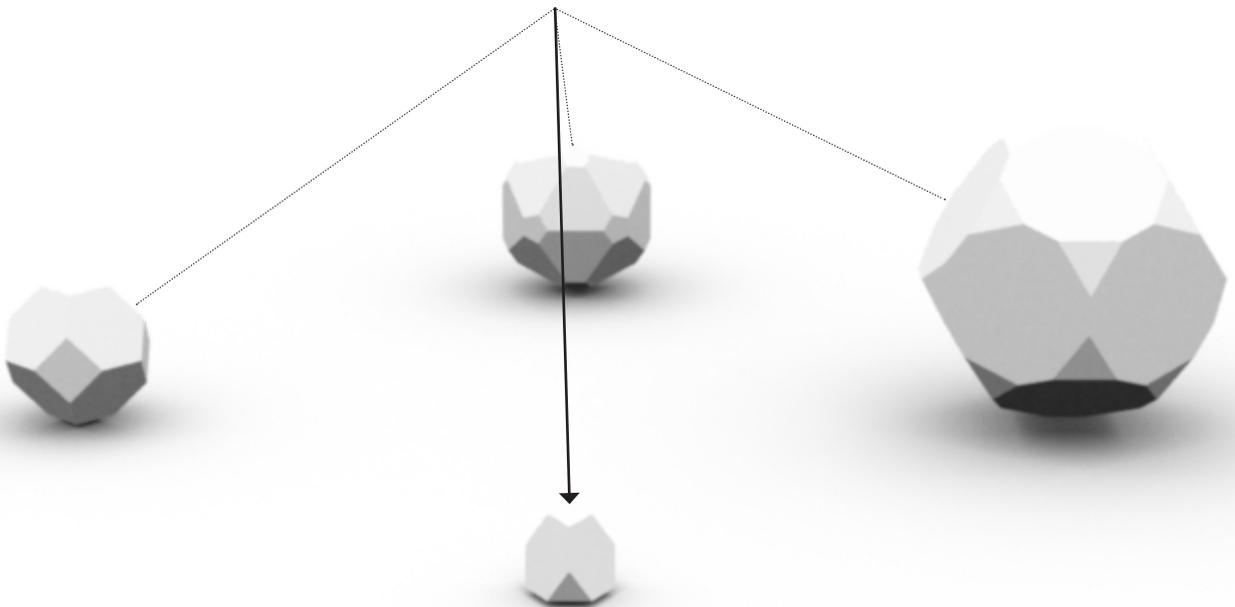
*Fig 3.10. ▲
Screenshot of user
perspective of interaction
form Raycast Shape, within
an environment where a
high level of 'nodes' have
been manifested.*

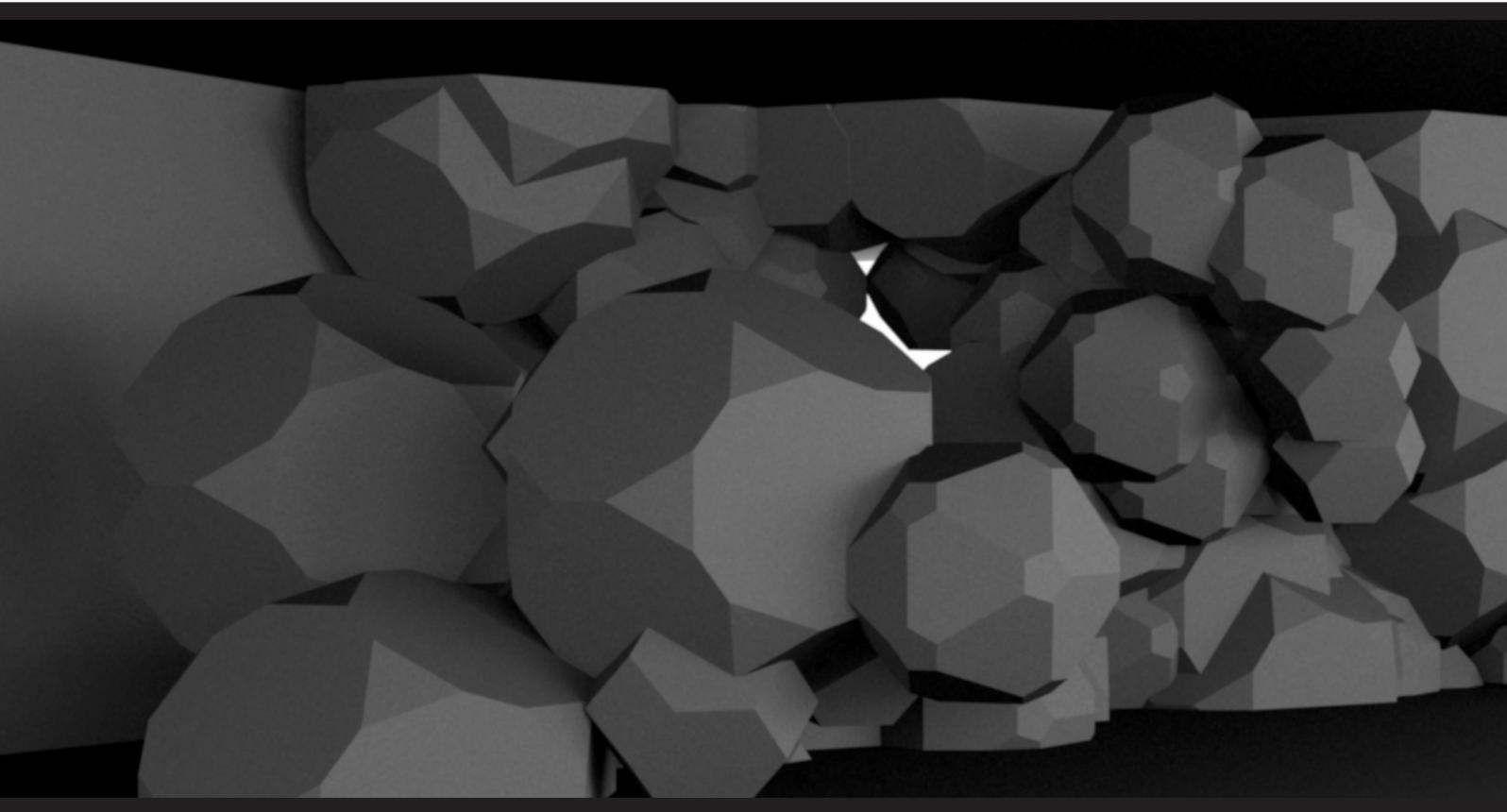


raycast create
raycast spawn
raycast spawn distance
raycast shape
raycast shape distance
generate
generate other

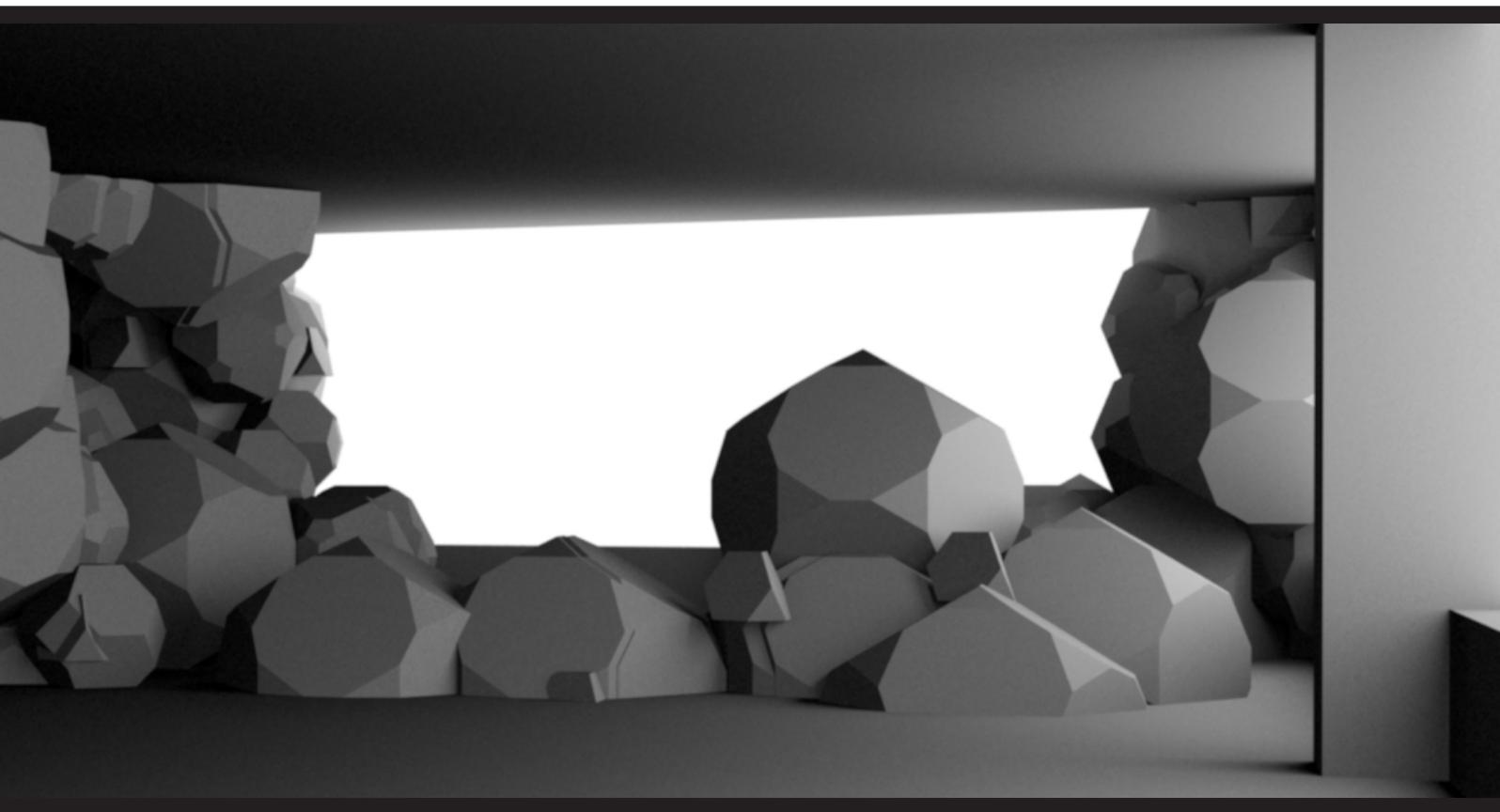
Fig 3.11. ►
*Diagram of Raycast Shape
Distance, illustrating
randomness component.*

This form of interaction creates one of four different nodes at the selected location. The nodes shape is chosen randomly. The node is created in a random direction, at a size proportional to the distance selected and at a fixed distance from the selected point. The object script identifies whether the user has selected to create a node either directly on the environment, or on another node. It then creates one of the shapes at a random size and in a random direction from the selected point. This introduces more diversity similar to Raycast Spawn Distance.





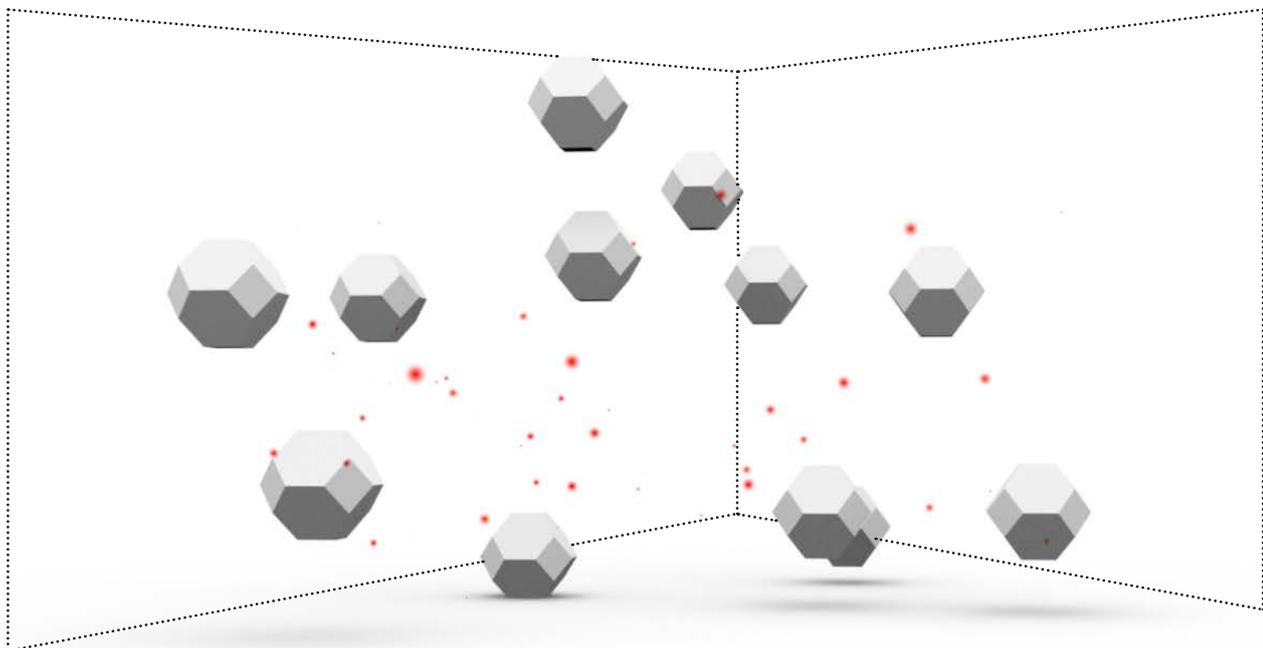
*Fig 3.12. ▲
Screenshot of user
perspective of interaction
form Raycast Shape
Distance, within an
environment where a high
level of 'nodes' have been
manifested.*



raycast create
raycast spawn
raycast spawn distance
raycast shape
raycast shape distance
generate
generate other

*Fig 3.13. ▶
Example node configuration
for Generate, showing room
boundary and particle
effects.*

This form of interaction took the agency away from the users by introducing node generation, rather than creation. Nodes were generated within the space at a rate decided by the user (by pressing a number key on a scale from 1 to 9). In addition to the nodes, a particle cloud, that produced an ambient noise, was also added that was generated with the same script to attempt to simulate the aural aspect of people density. The generate function has a minimum and maximum function that restrains the boundaries it can create within. Users were given only the ability to influence the rate of node production, thus creating a system that acted partially outside of the users control. This was intended to produce a more natural sensation of density within the environment by giving the player no control over the environment, in a similar way that the occupant of an office space has no real control over the density of their office.



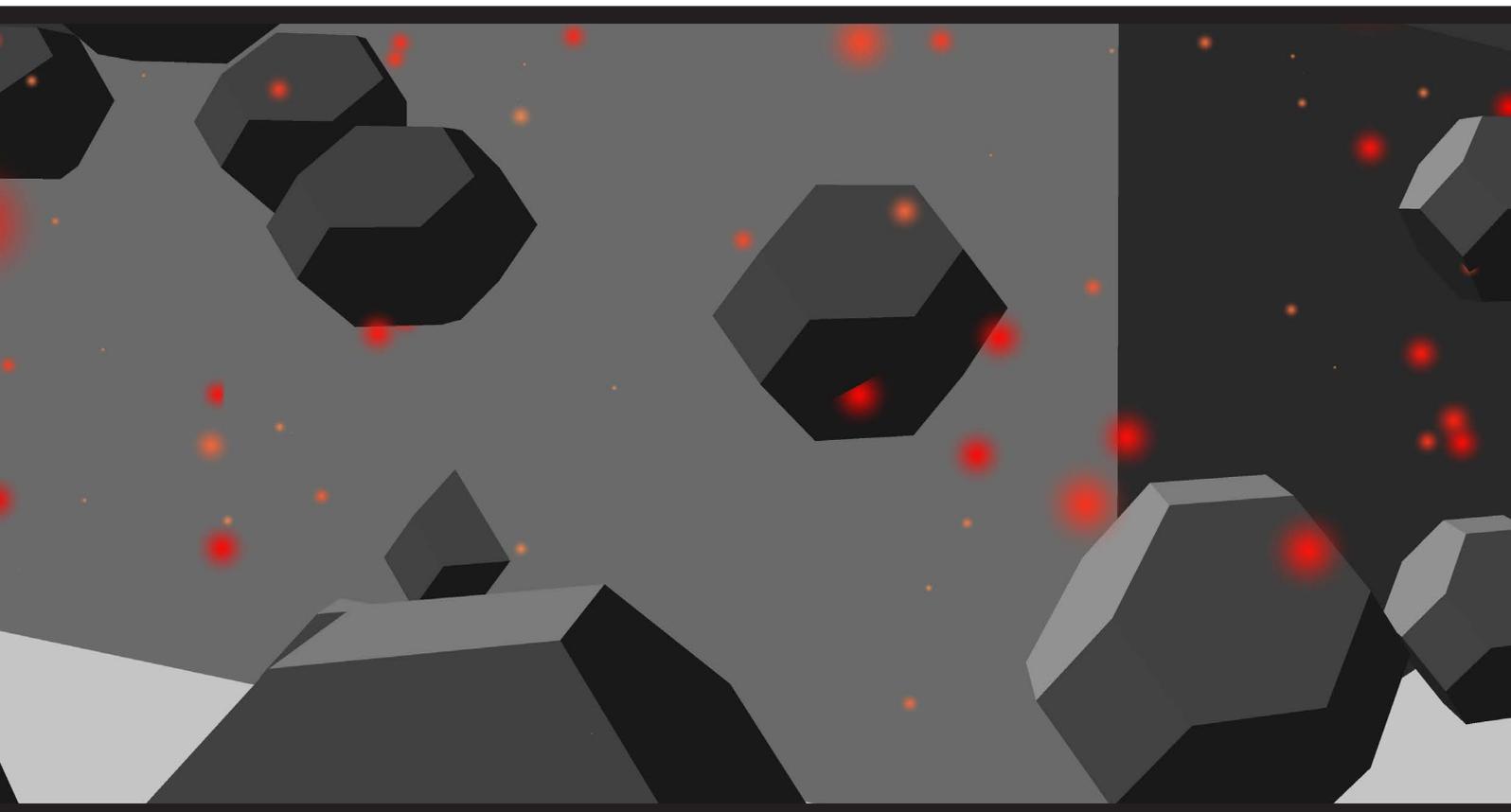
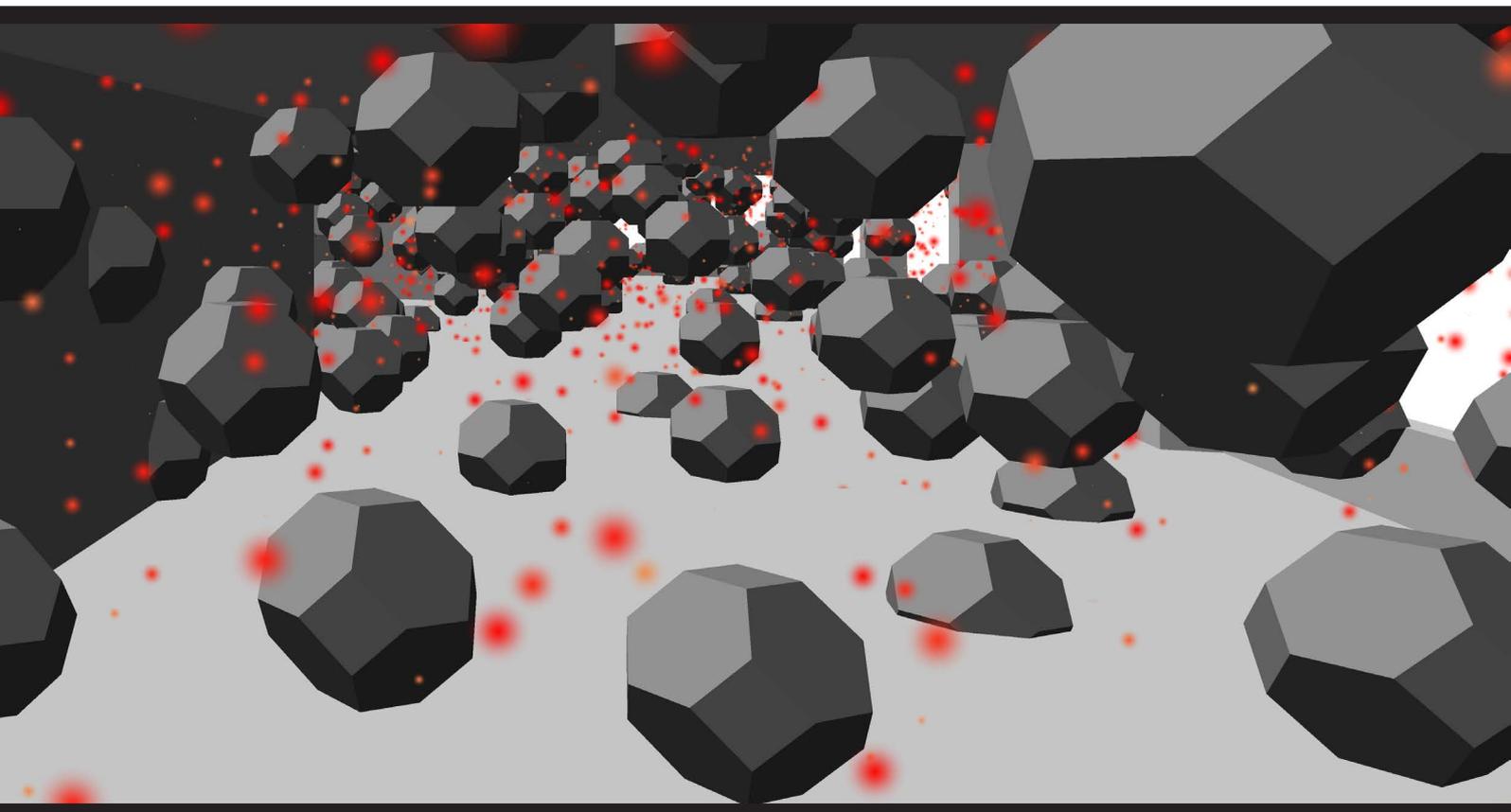


Fig 3.14. ▲
Screenshot of user
perspective of interaction
form Generate, within an
environment where a high
level of 'nodes' have been
manifested.

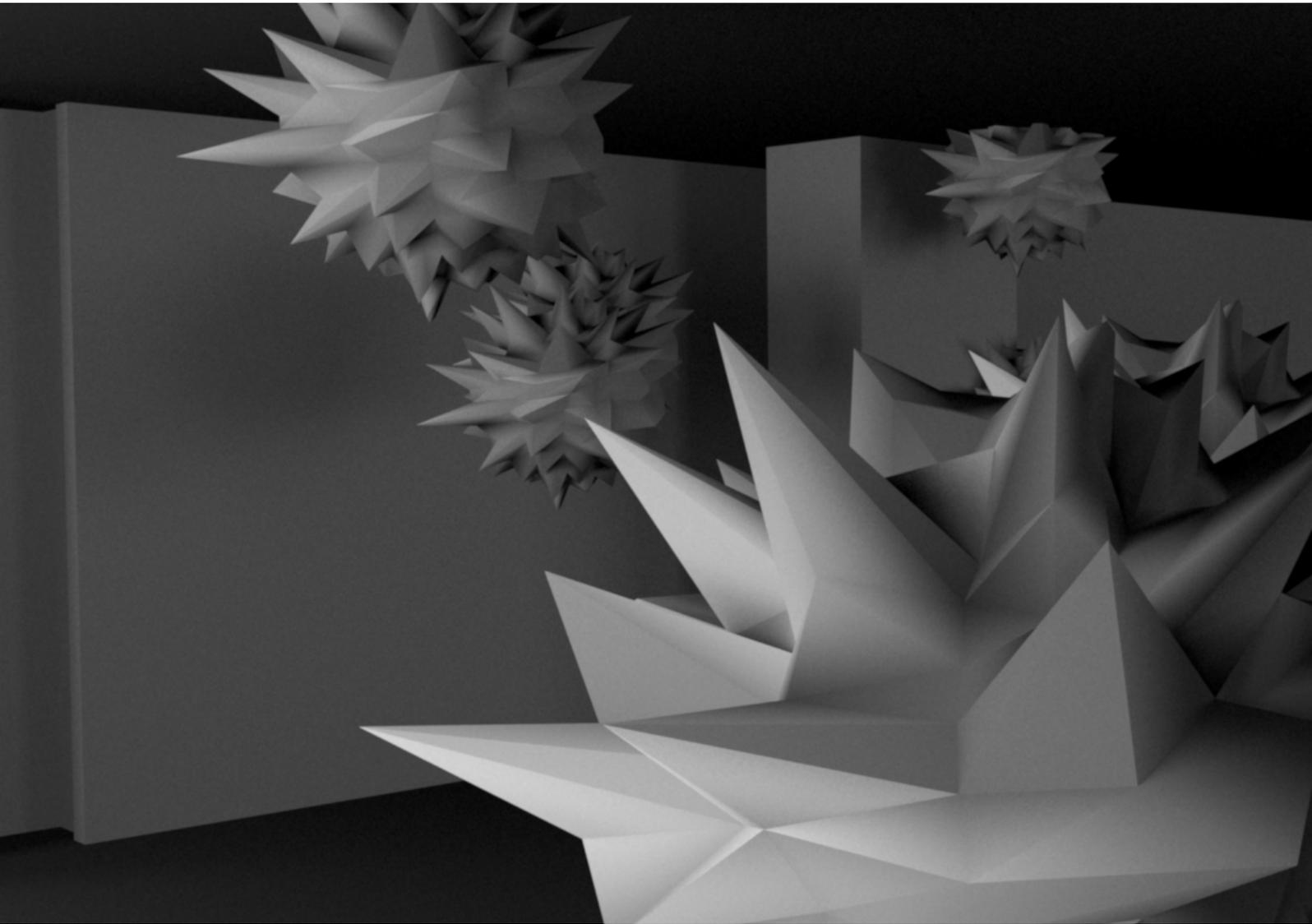


raycast create
raycast spawn
raycast spawn distance
raycast shape
raycast shape distance
generate
generate other

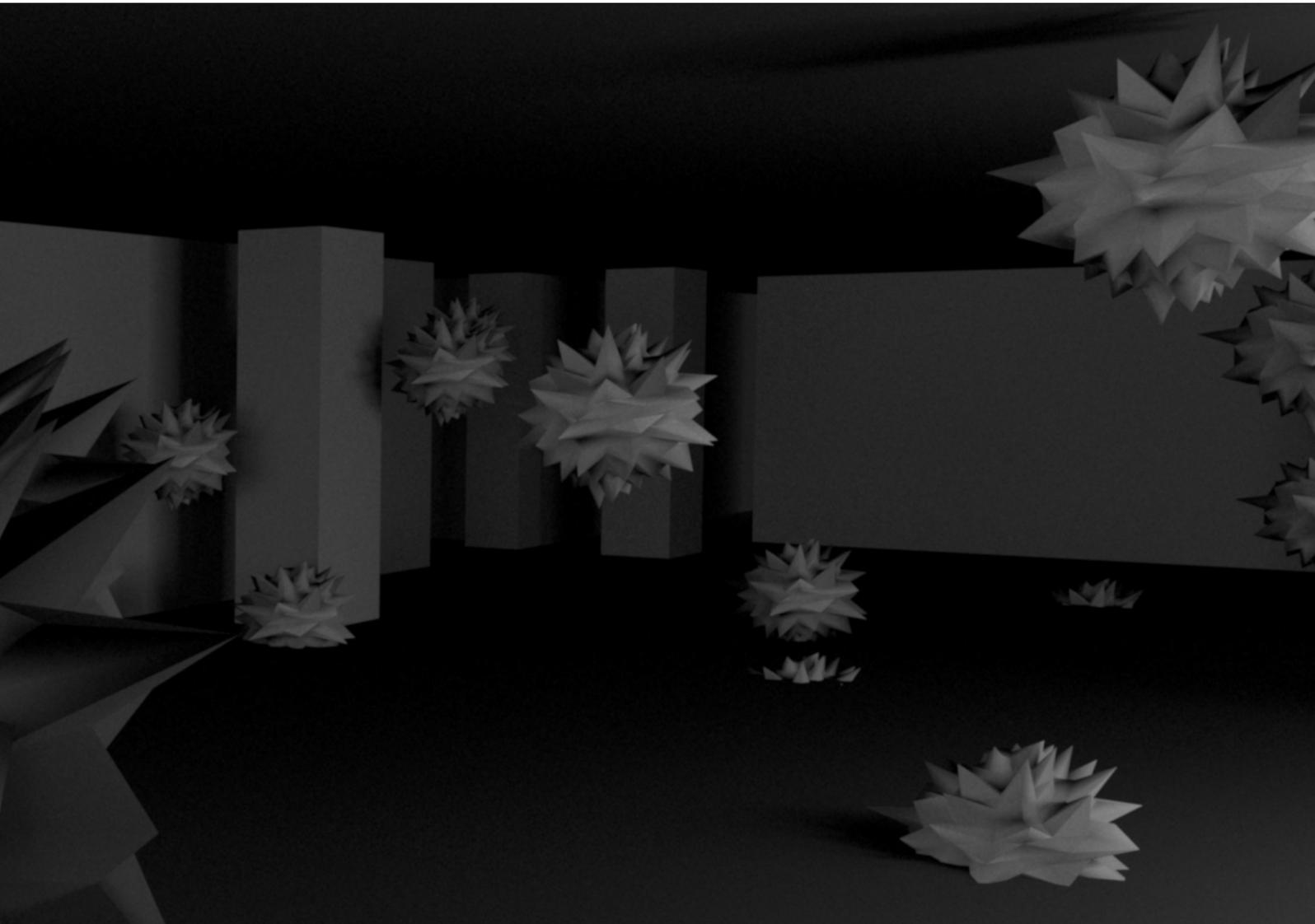
Fig 3.15. ►
Diagram showing example
configuration and example
node shape used in Generate
Other.

Using a similar script to the Generate form, this form of interaction changes the nodes to a different shape to assess the impact this has on user behaviour. A more complex 'spikeball' node was trialled as well as a simple gravity-affected sphere. These were both rejected by users as being too distracting.





*Fig 4.01. ▲
Screenshot of user
perspective of interaction
form Generate Other, within
an environment where a
high level of 'nodes' have
been manifested.*





raycast create



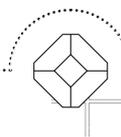
raycast spawn



raycast spawn distance



raycast shape



raycast shape distance



generate

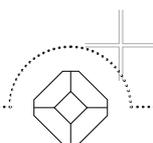
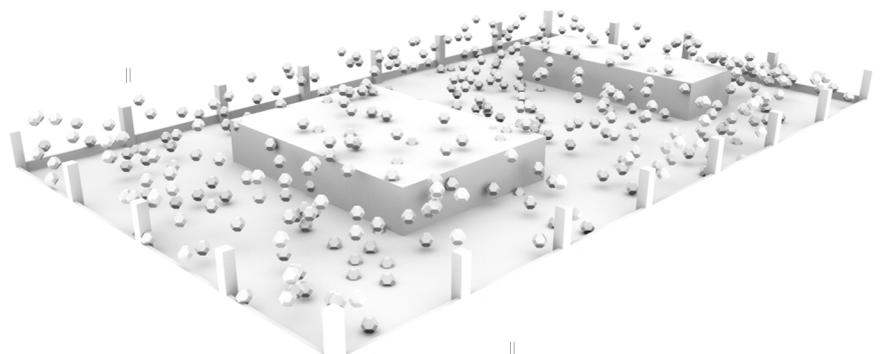
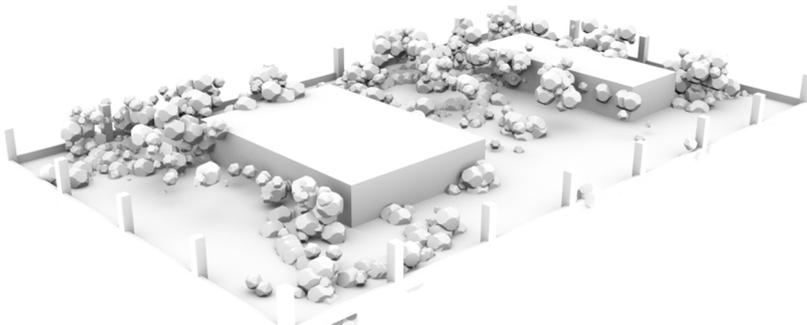
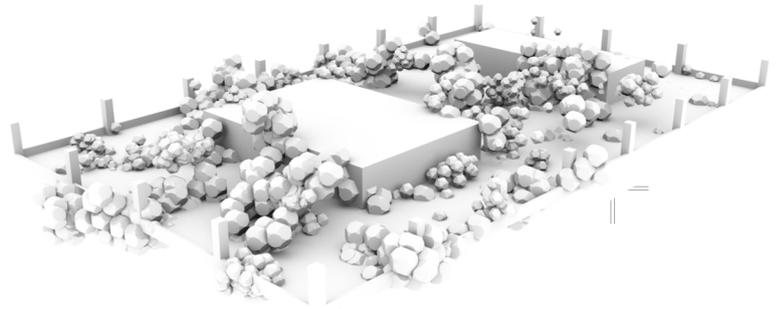
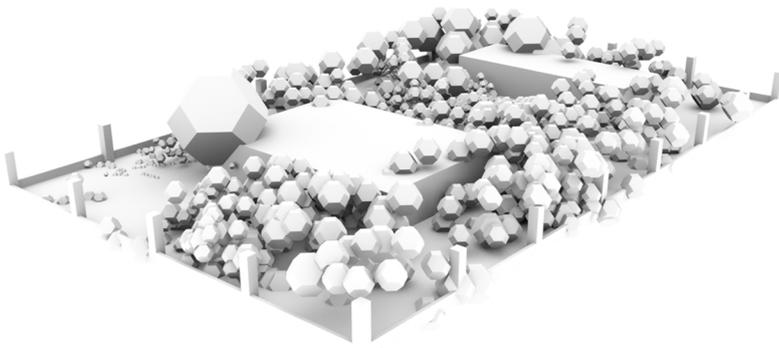
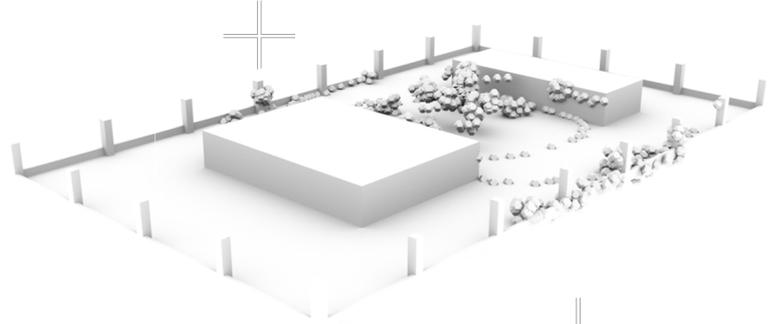
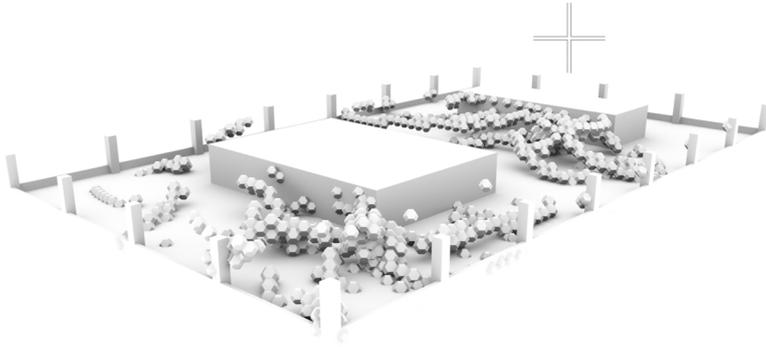


Fig 3.16 ▾
Example configuration for
each interaction form, and
experience links.



3.1 framework

Participants' reactions are observed while they interact with the IVE framework. This is used to establish a classification system of comfort-levels of density in open plan office environments.

The environment created is a basic representation of an office workplace which, through its homogeneity, creates fewer distractions for the users, thus generating greater focus on the variables being assessed and immersing the users further.

The users are asked to navigate around an office space while completing a set of tasks. They are 'disturbed' by an increasing level of nodes created around them, increasing the density of the space. At this stage, observations are made on users' behaviours and actions. The users continue navigating through the space until they are unwilling or unable to continue doing so.

Directly after the users have terminated the experiment they are asked to complete a questionnaire that assesses the self-rated impact of the increasing node count on the user's ability to complete their task and their feeling of immersivity. The gathered data is used to generate a set of classifications of comfort-levels of density in open plan office environments. These classifications can allow conclusions to be drawn on the impact of various levels of density on users' performance within an open plan office workplace. The results offer to establish architectural and design guidelines for spatial analysis.

For a breakdown of the methodology see Appendix 01.

Density (Node Count)	% Opted Out	Density Classification
0-499	0 %	Low
500-999	0 %	
1000-1499	10 %	Medium
1500-1999	20 %	
2000-2499	60 %	High
2500+	10 %	

*Fig 3.17. ▲
A table showing node count
vs. user opt-out rate, broken
down into three density
classifications.*

3.2 results and data

This chapter establishes a basic digital environments framework. An example survey is conducted as a means by which to validate and test the framework so that later sections may improve upon it.

In order to establish a threshold with which a user becomes uncomfortable with the density of an environment, data on when each user left the experiment was collected. Data, collected primarily through observation, showed increased levels of agitation as the node count went up. Agitated behaviour included erratic path deviation, rapid head movements and undirected verbal responses (e.g. cussing) during the experiment. As nodes increased the amount of occupants 'opting out' increased, yet after a certain point (at the 2000-2499 bracket) additional nodes made little difference. A density classification system was devised to signify thresholds of behavioural changes in the users as the node count increased, see Figure 3.17. The data returned from this showed that after the high classification the majority of users would not continue.

Overall as the environment became denser the users displayed a higher level of agitation. In the medium classification was when the nodes began to affect the users, with the high classification being the range where the majority of the users opted to leave the environment. Past the high classification the effect of adding more nodes became diminished.

3.3 limitations and scope

The first stage of this project consisted largely of establishing an experimentation framework. The main limitation of this stage was the simplicity of the framework components used; in particular the physical environment and interaction forms were too simple and reduced user immersion.

Data was collected through post-experience interviews and observation. However, for future stages a combination of post-experience interviews and surveys with 'in-experience' behavioural analysis would provide a much greater breadth of both qualitative and quantitative data (Wallis and Tichon, 2013).

Another limitation is inherent to the technology used; whilst improving rapidly, the instruments used to generate and experience IVE's are not fully developed research apparatus and the skills required to work with these instruments are relatively new, as such there are restrictions on what is currently possible. This will lessen as architectural and non-architectural disciplines become more familiar with the technologies, and the instruments become more adapted to research tasks.

Many alternate ways of simulating occupant density could be devised. This system provides a simple aggregation of shapes that physically densify a space. A more realistic approach could be taken with a range of objects, such as furniture, placed in a planned way and then increased following traditional furniture placement principles. Another option could be the introduction of simulated crowds, and the occupant's response to an increasing level of people movement and noise could be measured. The experiments within this research were intended as a part of an iterative framework development process and future research in this area would require more rigorous experiments.

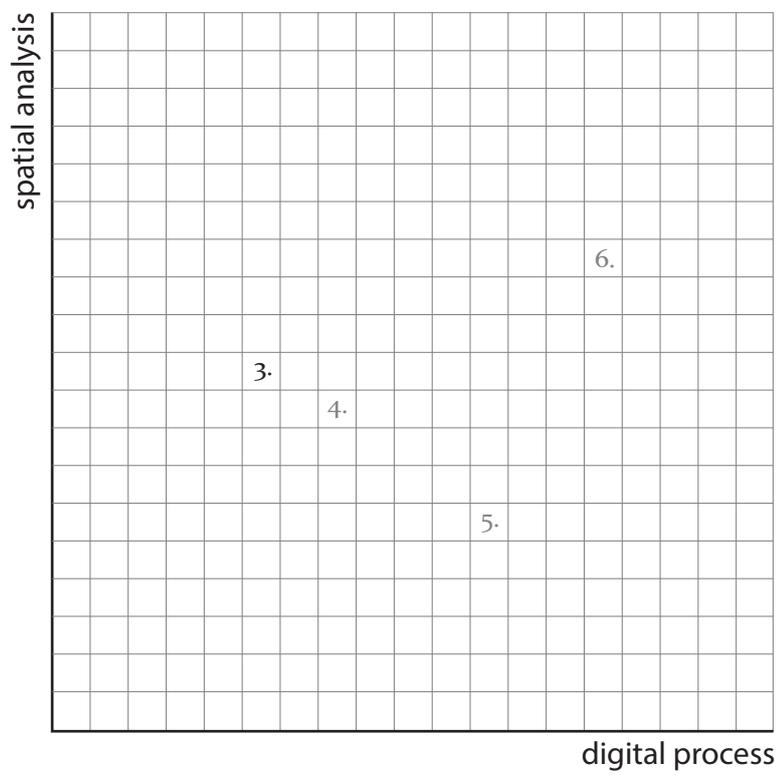


Fig 3.18. ▲
A context grid situating
this chapter, across both a
spatial analysis and digital
process scale, in comparison
to the other chapters within
this research.

3.4 conclusion

This study presents a new way of creating, testing and experiencing a VE that allows for strengths across multiple disciplines to be incorporated into a design framework. IVE's provide the opportunity to work beyond a representational level and start to explore and create within PS. This allows architectural and non-architectural disciplines to gain greater agency over designing spaces that have an impact on the user.

The first stage of this project demonstrates how an IVE framework can be applied as an instrument to analyse PS. Users displayed increasingly agitated behaviour as the environment became more crowded by both physical and aural nodes; after a certain node count this effect reached its peak. Shown similar scenes through a visual display unit users displayed no discomfort, instead enjoying the abstracted experience of traversing the densified digital environment. This acts as a proof-of-concept for the use of digital environmental frameworks as an instrument for spatial analysis.



Fig 3.19. ▲
Photo of myself (left in the bottom photo), other VUW scholars and the conference organisers at PACT 2016.

3.5 PACT conference

Partway through the thesis research, a version of this chapter was presented at the Parallelism in Architecture, Environment and Computing Techniques PACT 2016 conference in London (Holth and Schnabel, 2016). Keynote speakers included Patrik Schumacher (Director of Zaha Hadid architects) and Mario Carpo (who has taught architectural history and theory at MIT, Bartlett and Yale schools of architecture). Whilst well received, this research presented only an early stage and feedback was limited. Overall this conference reinforced the important role digital design techniques have on the architectural design process, and the potential a cross-disciplinary approach has to enhance architectural discourse.

4.0

developed framework design

In order to ensure that the framework is robust and functions across a wide range of potential uses, this stage of research develops the physical environment model, including the wider context, and the task-based forms of interaction, in response to user feedback. These areas were highlighted as disrupting user immersion through a lack of complexity. The development of the framework is a part of the iterative design process and, in this way, the framework becomes the design itself.

In this stage of research, the physical environment's complexity was increased to fall more in-line with a typical office environment, including the introduction of a second floor, furniture and basic textures and lighting. Though these elements improve the complexity of the environment, they are intended to make the environment feel more natural, as opposed to photo-realistic.

More complex interaction forms improve immersion through increased user focus, and allow for a more sophisticated framework development process, where specific areas may be targeted for improvement. The Wayfinding interaction form involves placing the participant randomly within the new experiment space and giving them a destination they must find, whilst navigating around created nodes. This task requires more focused thinking and will create a more immersive user experience. The Find & Collect interaction refines the process developed in Wayfinding further. The participant is tasked with finding a single unique node, amongst other manifesting nodes, somewhere within the environment. Once found, the node will reappear elsewhere and the participant is tasked with finding it again. This task involves constant activity, both through movement and object recognition, and produces an overall more immersive experience. As the user focuses more on the environment and the tasks, they focus less on the experiment as a whole, this creates the sense of immersion as discussed by Slater and Wilbur (1997).



*Fig 4.02.▲
Hypothetical experiment
layout showing example user
position (circle), example
user path (dashed line),
object nodes and sound
nodes (crosses).*

4.1 framework development

This section discusses the main changes made on the digital environments framework established earlier. The key areas of development were the physical environment and the tasks used to test that environment; in the prior framework these areas were basic and incapable of providing a strong sense of immersion.

4.1.1 environment

Key aspects of this environment are developed further to retain user immersivity within an IVE. It is important to note that the goal is not photo-realism, as Blascovich et al stress (2002), but an environment that the user experiences naturally. In the case of an office workplace items such as furniture and the scale of the doorways and ceiling heights are those that impact a user's sense of immersion the most. In a familiar environment small discrepancies create jarring artefacts within the space that reduce user focus and lower immersion. As such, the changes made involve the increased complexity of the physical models and the introduction of basic lighting and a plain white texture map to improve shading. The level of realism within the environment is dependent on the experiment and in this case a 'clay' textured form and context is adequate for the development of the framework as it suits the homogeneity of the office environment typology

Count: 2024

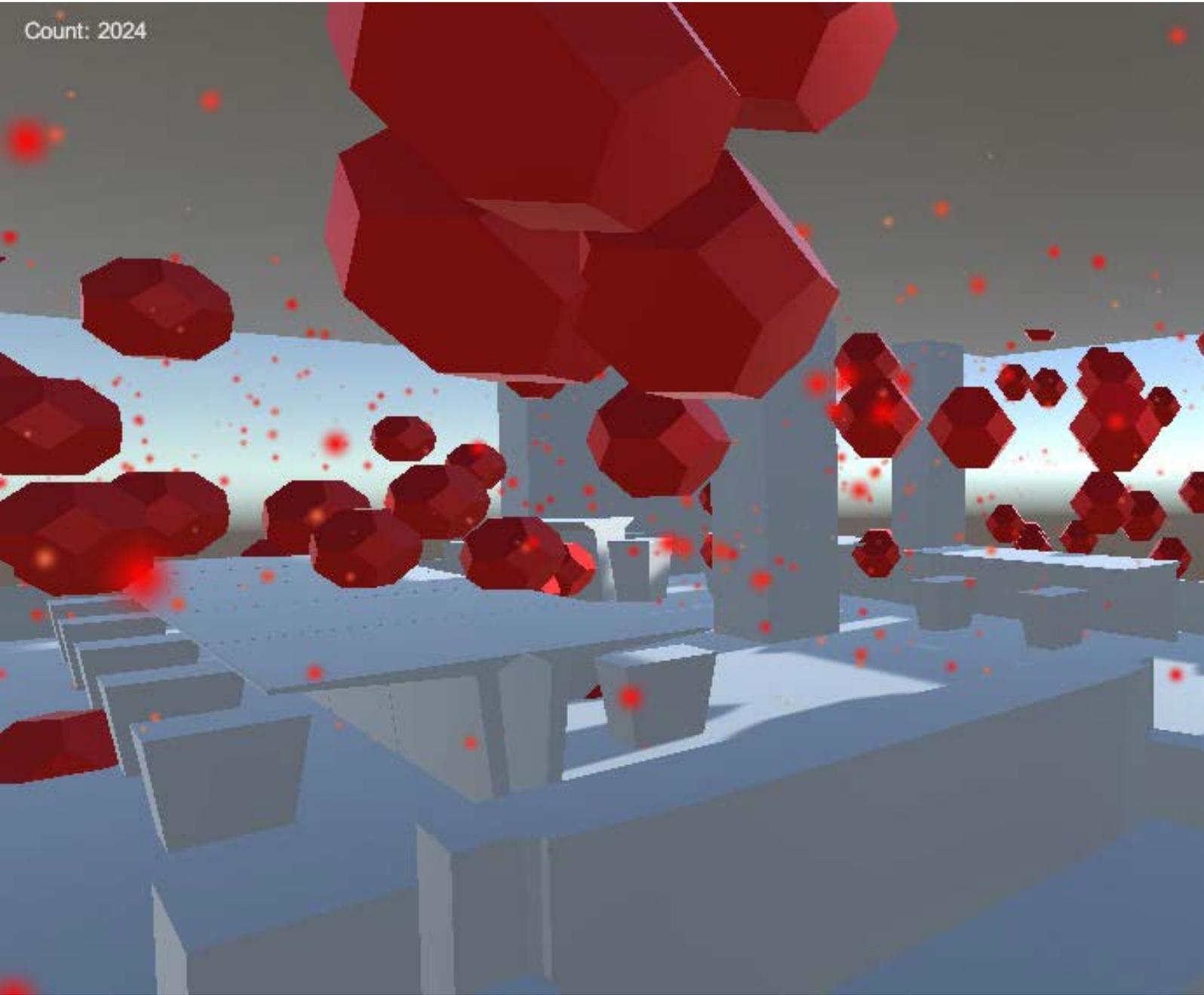
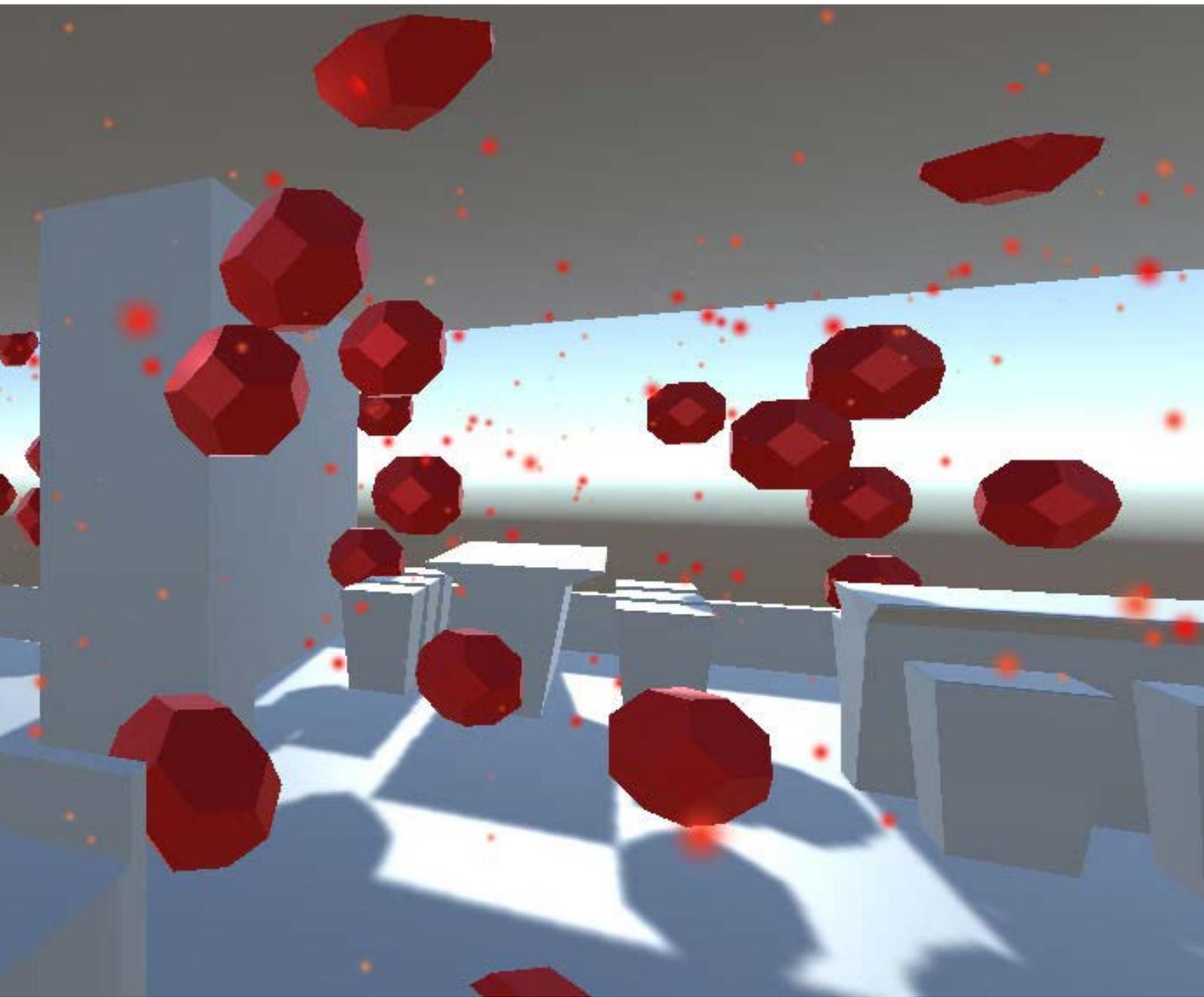
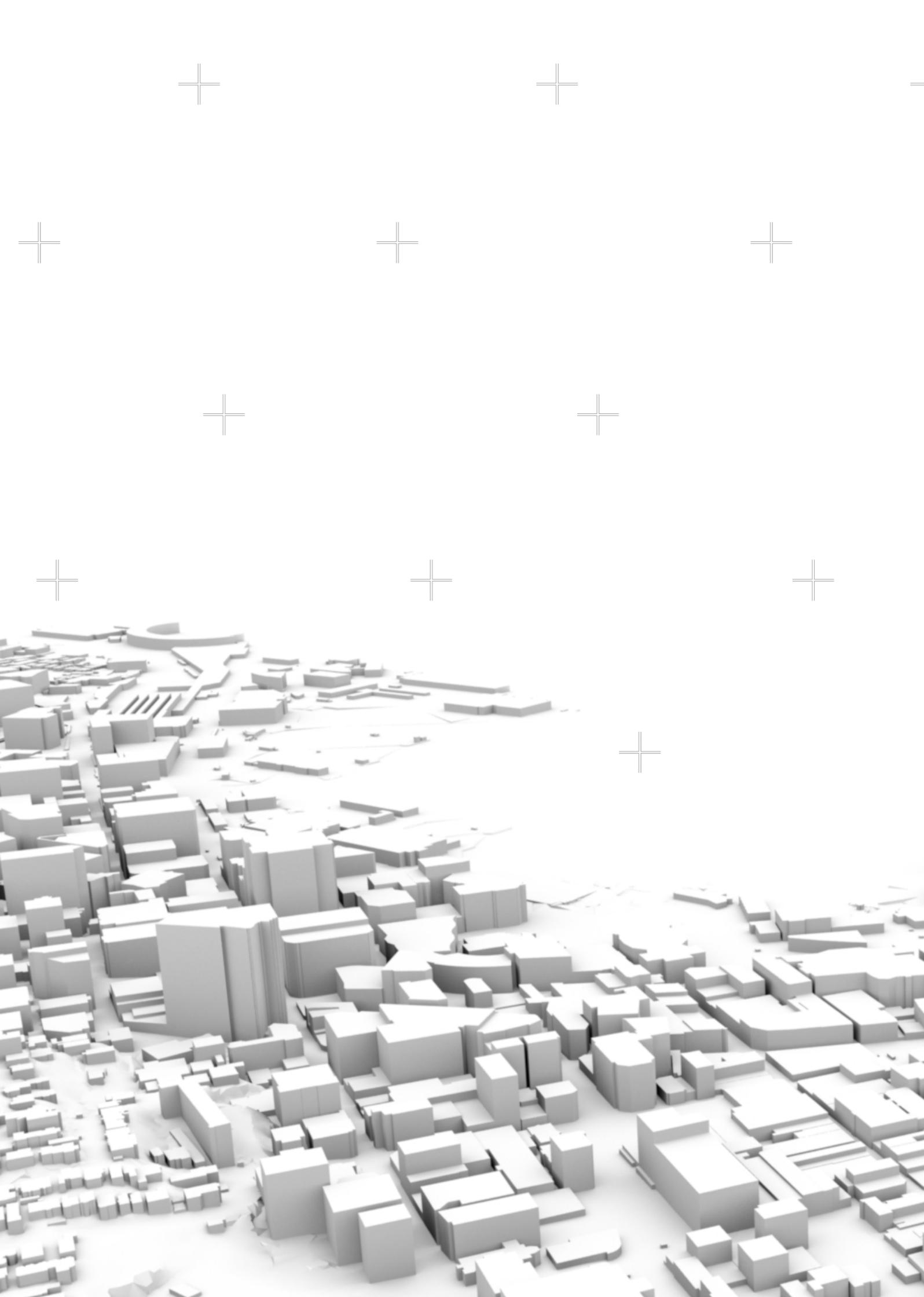


Fig 4.03.▲

Screenshot of a typical scenario with a high node count and an increasing level of aural distraction, as shown through the particle effects. Node count displayed in upper left corner.





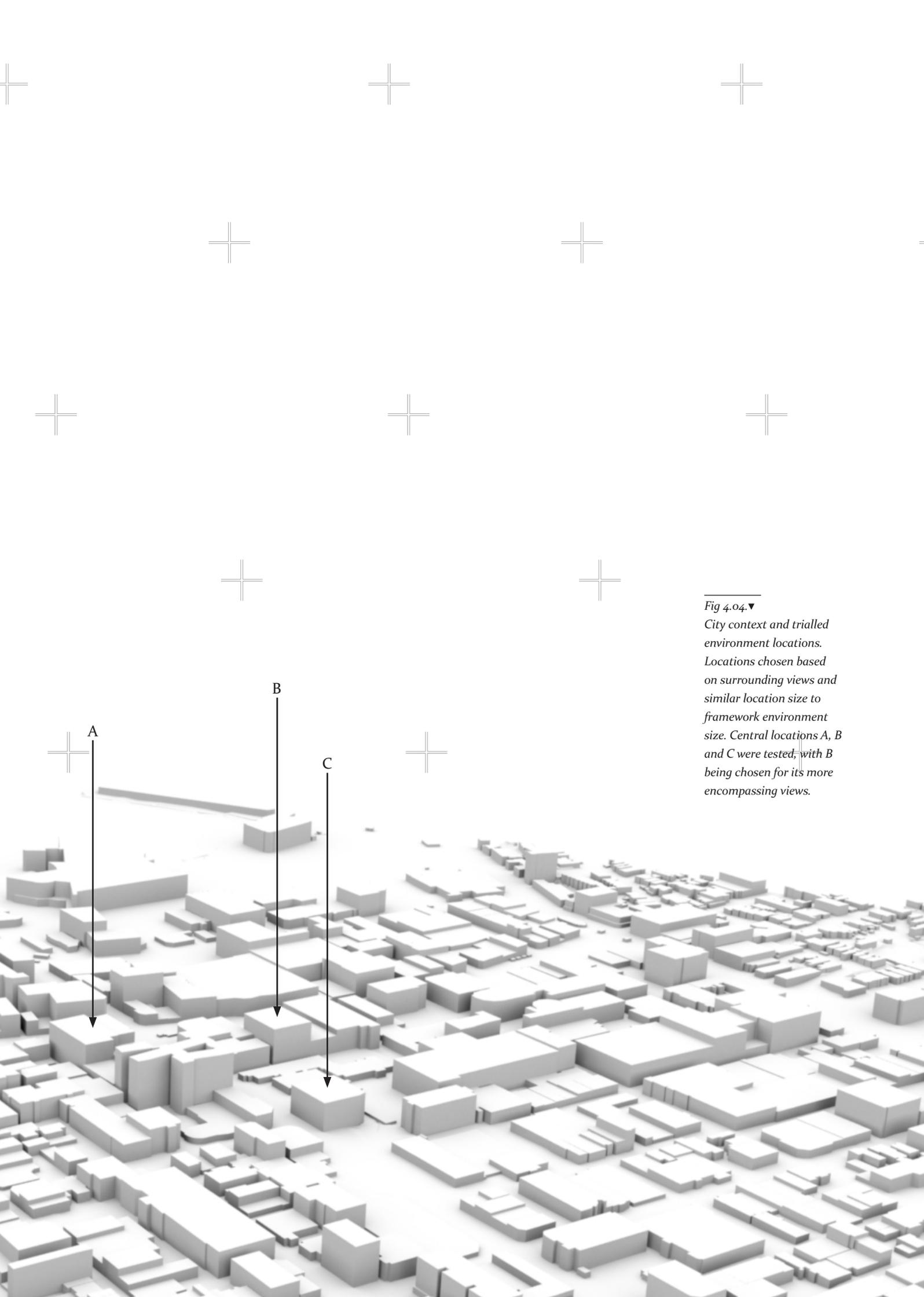
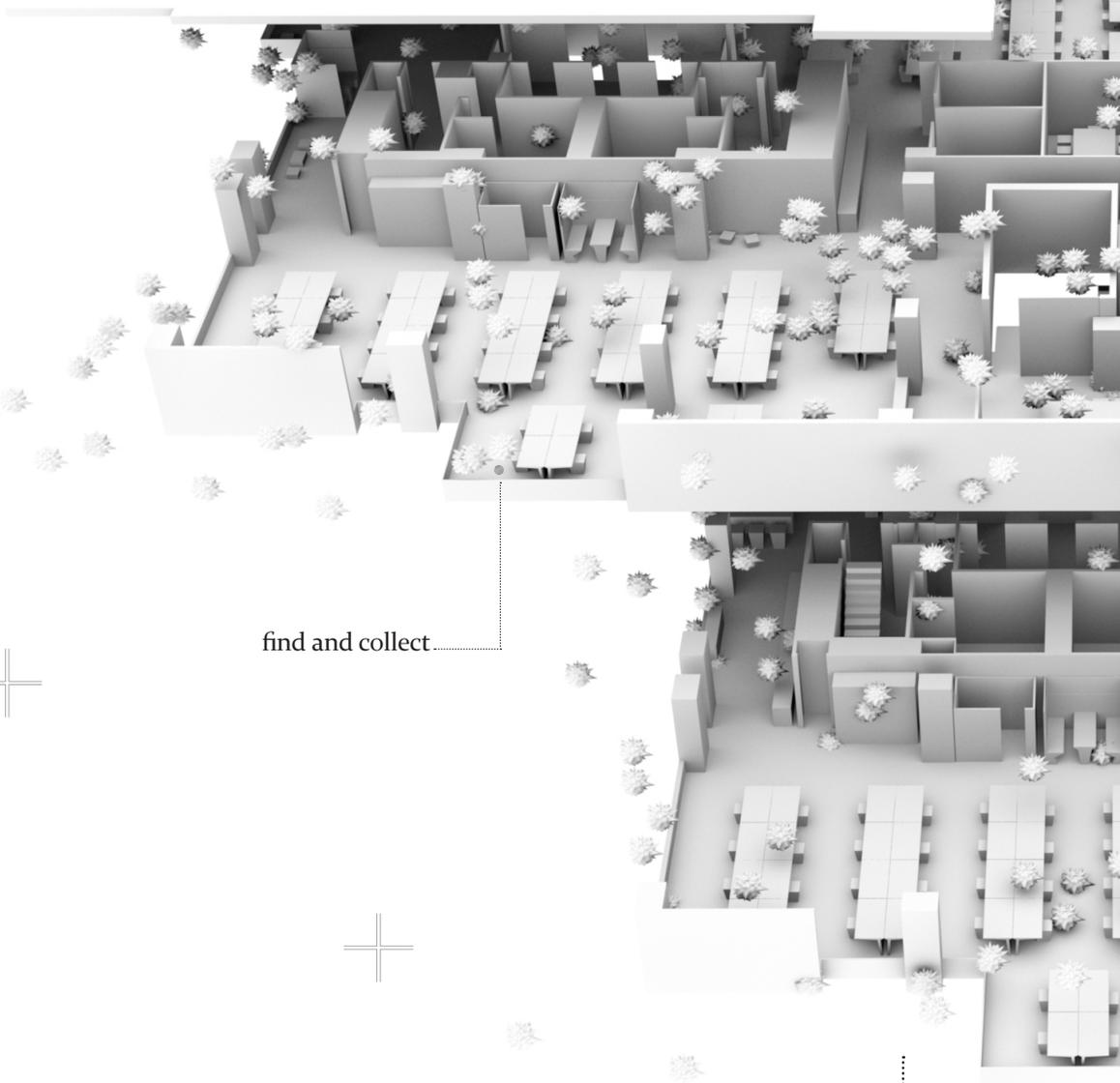


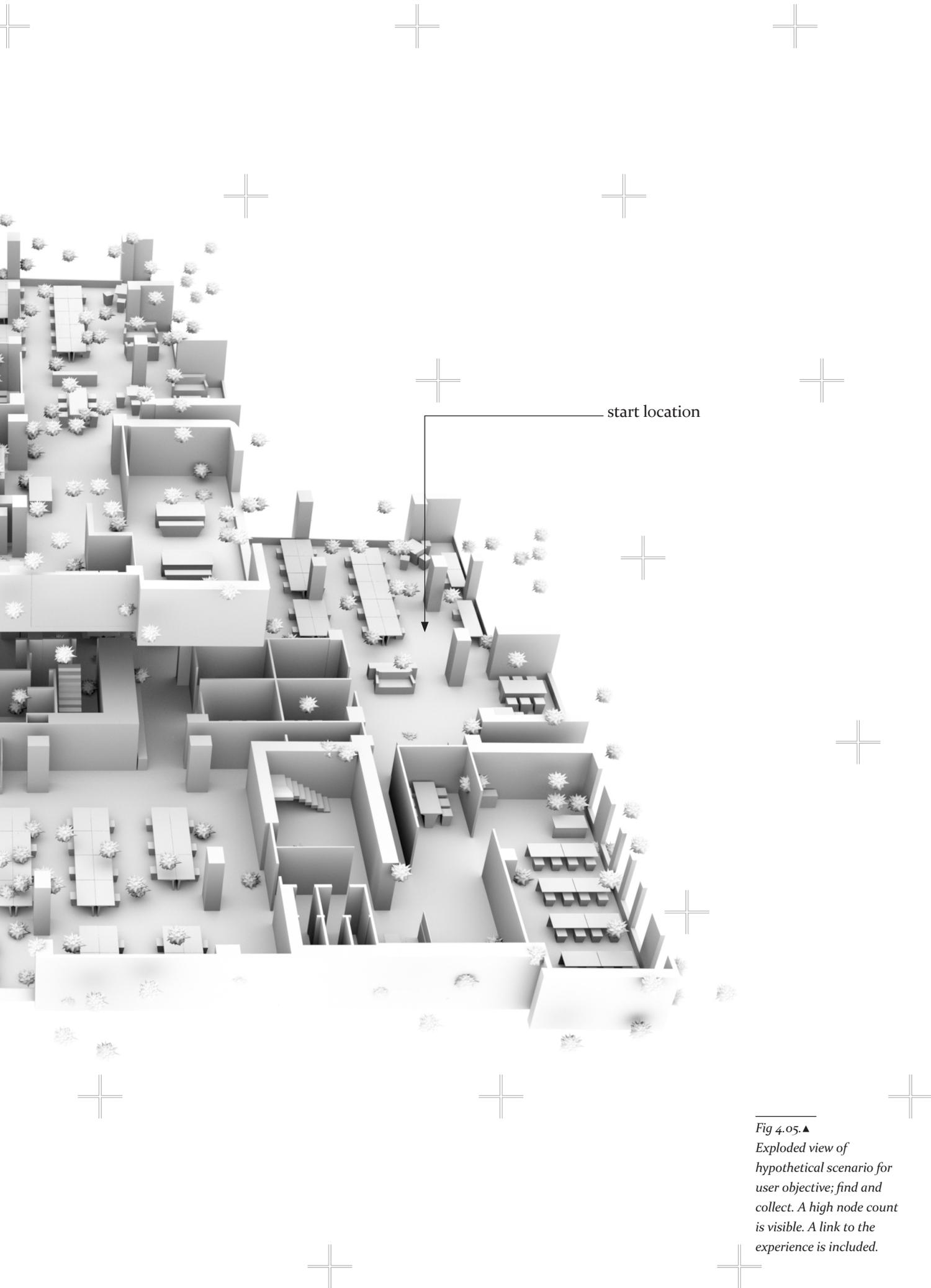
Fig 4.04.▼
City context and trialed
environment locations.
Locations chosen based
on surrounding views and
similar location size to
framework environment
size. Central locations A, B
and C were tested, with B
being chosen for its more
encompassing views.



find and collect.....

task based activities

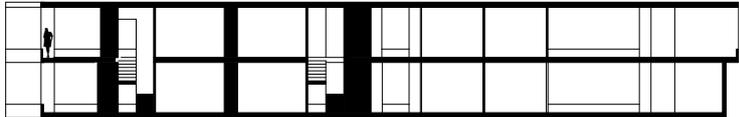




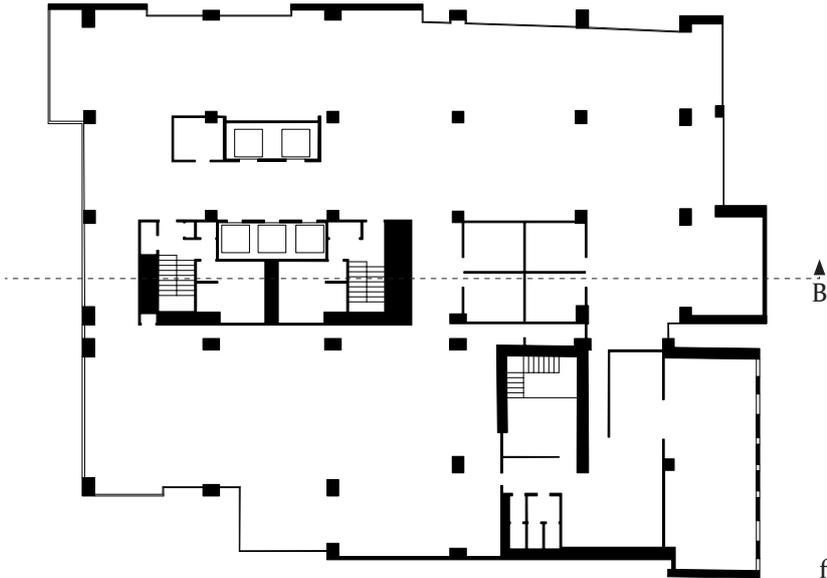
start location

Fig 4.05.▲
Exploded view of
hypothetical scenario for
user objective; find and
collect. A high node count
is visible. A link to the
experience is included.

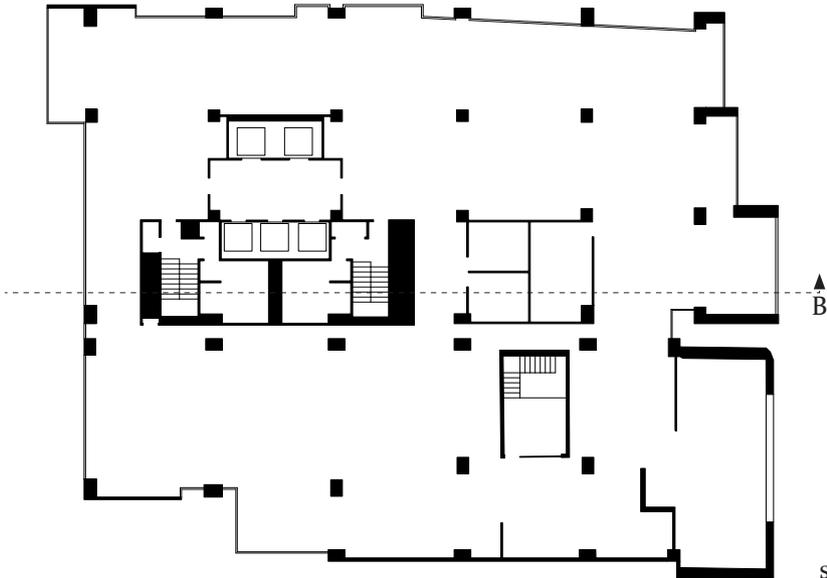
experiment space #2



section B



first floor



second floor

The environment was developed into a two-story building based on a generic floor plan, see Figure 4.06. This included structural elements, meeting rooms, lift shafts, stairways and a more complex layout with a range of wider contexts trialled across a basic city model, see Figure 4.04. As the environment comes to resemble the form users expect, the experience becomes less jarring, allowing users to become immersed in the task at hand.

A furniture layout was also included based off the four main types of Activity Based Working spaces, abstracted from Francis Duffy's four main places of work (1997).

4.12 interactivity

Two forms of interaction were developed to test the framework. The first activity was a basic wayfinding test where the participant would be placed randomly within the environment and asked to find a series of different locations. As the node count grew within the space the user's ability to navigate within a denser space as assessed.

A secondary task-based interaction form was devised that tested an occupants ability to locate an object within the space. The user was given the task of finding a special node that had a different shape and size to those used to portray environment density. Once found the object would disappear and reappear elsewhere within the space and the user would have to find it again. The user's ability to find the node as quick as they were able was recorded, and the time it took was compared against the density node count.

Fig 4.06. ◀

A floor plan and section of experiment space two, based off a more complex two-storey office plan. This environment improves user immersion through the use of a more realistic space.

4.2 results

The goal of this stage of the research was to continually develop the framework system as part of an iterative design process. Users reported that an increase in the level of complexity of the model represented a significant increase in the levels of immersion they felt, in particular the addition of a wider city context to the model gave them a much better sense of existing within a 'real' location.

The tasks devised were an improvement on the Generate interaction form, users reported; largely due to their more complex nature. However both the Wayfinding and the Find and Collect tasks were still quite abstract tasks and users found them hard to engage with. It was suggested, by users, that a more appropriate task for the office environment would help improve user immersion.

4.3 limitations and scope

A major limitation to these forms of interaction is the inability to accurately simulate others in the space and by extension the 'true' office density (and all associated movement and noise) that is likely to have a large impact on individual tolerance levels for dense environments.

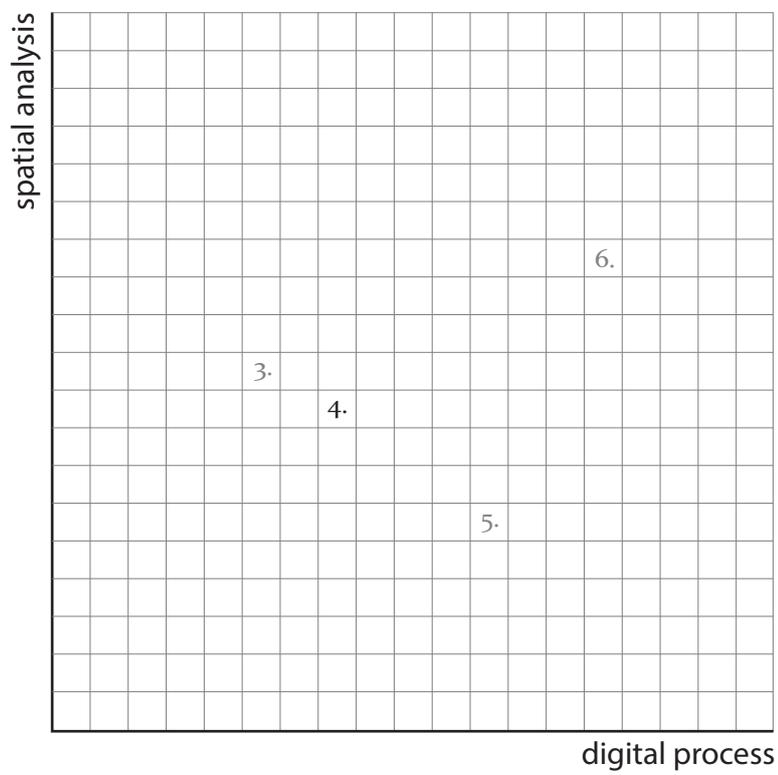


Fig 4.07.▲
 A context grid situating
 this chapter, across both a
 spatial analysis and digital
 process scale, in comparison
 to the other chapters within
 this research.

4.4 conclusion

This chapter developed the framework by improving the physical environment and trialling two new task-based interaction forms. It was found that higher levels of environment complexity, in particular the addition of wider context and furniture, gave the users a greater sense of immersion within the environment. The accurate use of physical scale proved important, as occupants displayed an inherent ability to detect slight inaccuracies in scale, and would show this by performing actions such as measuring desk widths and commenting on door heights. By ensuring that the model was based off a more developed office floor plan and utilising a wider city context model the environment gave a more 'natural' feel and thus improved immersion. Users were no longer lost immersion due to low levels of environment complexity and slight scale inaccuracies.

The developed task-based forms of interaction improved immersion, however the most common feedback was that the 'node count' density system was too far abstracted from the sensation of 'real people' in the space. This created a break in user immersion.

phase one reflection

Phase one developed a digital environments framework, tested it, highlighted areas that required development and implemented changes. Chapter 3.0 created a digital environmental framework and conducted test as a proof-of-concept. Chapter 4.0 improved user immersion by increasing the complexity of the environment and forms of interaction.

The main weakness of phase one was the inability to produce a sufficient approximation for density within the environment. The node-based system created in chapter 3.0, and adapted for chapter 3.0, gave a rough indication of how the framework would function as a testing environment; however it did not provide a natural sensation of people density within the environment. This difference was less pronounced in the experiments conducted within chapter 2.0 as the whole environment was intended as a more abstract proof-of-concept, however in chapter 4.0, where the under-developed sections of the framework were improved, the node-based system began to feel too abstract to the users and had a sense of novelty to it.

phase two

Phase two introduces virtual reality into the framework established in phase one. This phase improves immersion levels by introducing virtual reality specific interaction. An experiment is then conducted within this framework that seeks to gain a better understanding of spatial impacts on participant mood and provides a precedent for a spatial analysis survey methodology.

This phase does not address the problems found with the abstract 'node-based' density system, identified previously, as this framework is intended as a general framework and the density system is an experiment-specific variable.

5.0

VR framework integration

Users found the task-based interaction forms too abstracted from the office scenario, which reduced experiment immersion. This chapter focuses on the development of more natural forms of interaction within the digital office environment. The primary form of interaction within this chapter is a question-and-answer User Interface (UI). Virtual reality was integrated at this stage and required a shift in various elements of the framework. In order to ensure immersivity the participant must feel that the various forms of interaction within the digital environment feel natural.

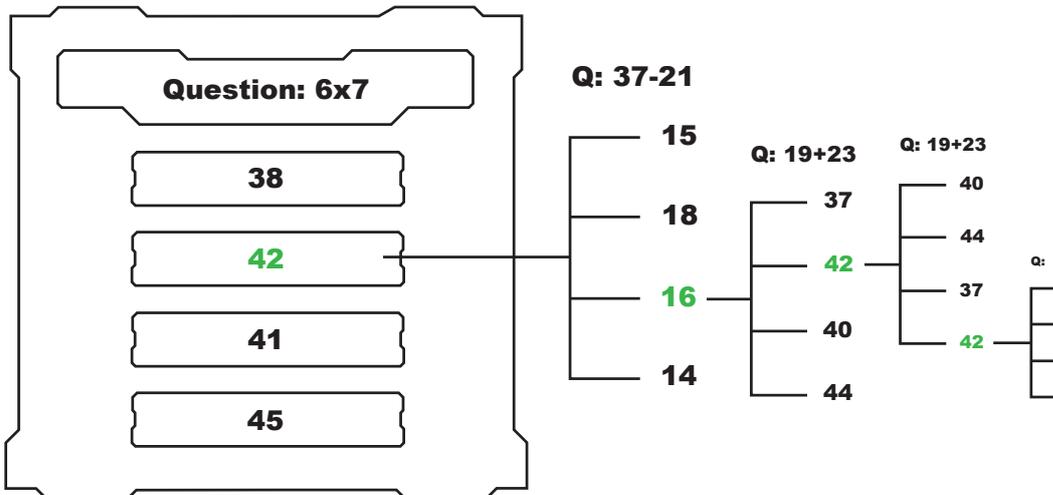
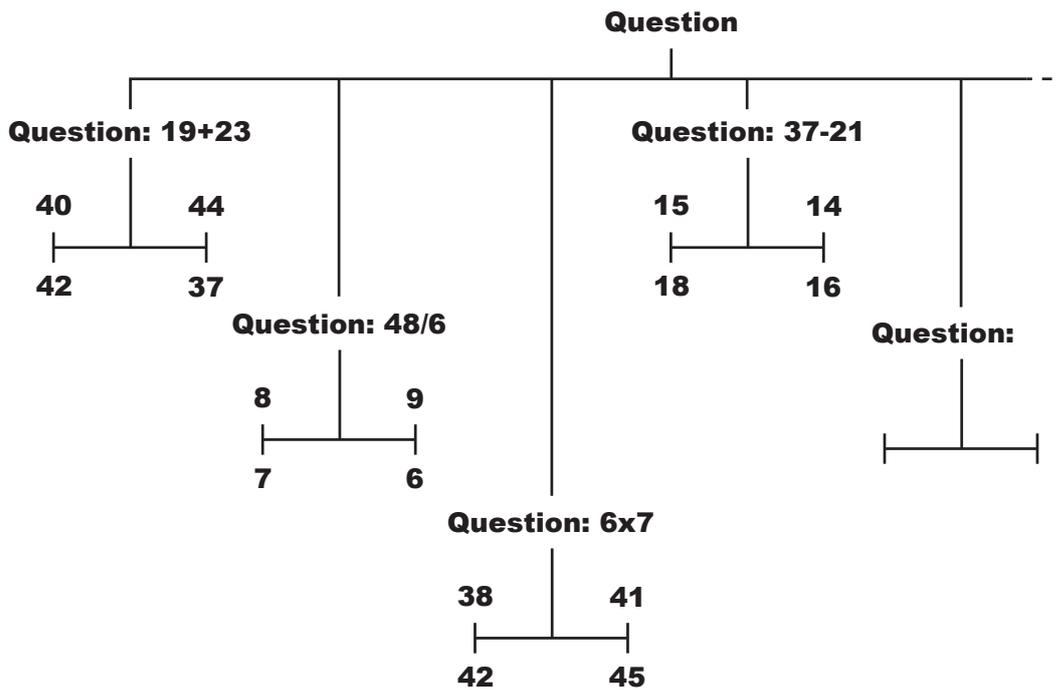


Fig 5.01. ▲
 The question and answer tree system (above) illustrating four questions and their corresponding pre-programmed answers. This system allows for any number or type of questions to be included.

Fig 5.02. ▼
 The question allocation visualisation (below) illustrates the UI menu and the question and answer tree. As the user selects the correct answer a random question from the set is displayed next with its answer set arranged in a random order. The total number of correct answers is recorded for each experience.

5.1 framework development

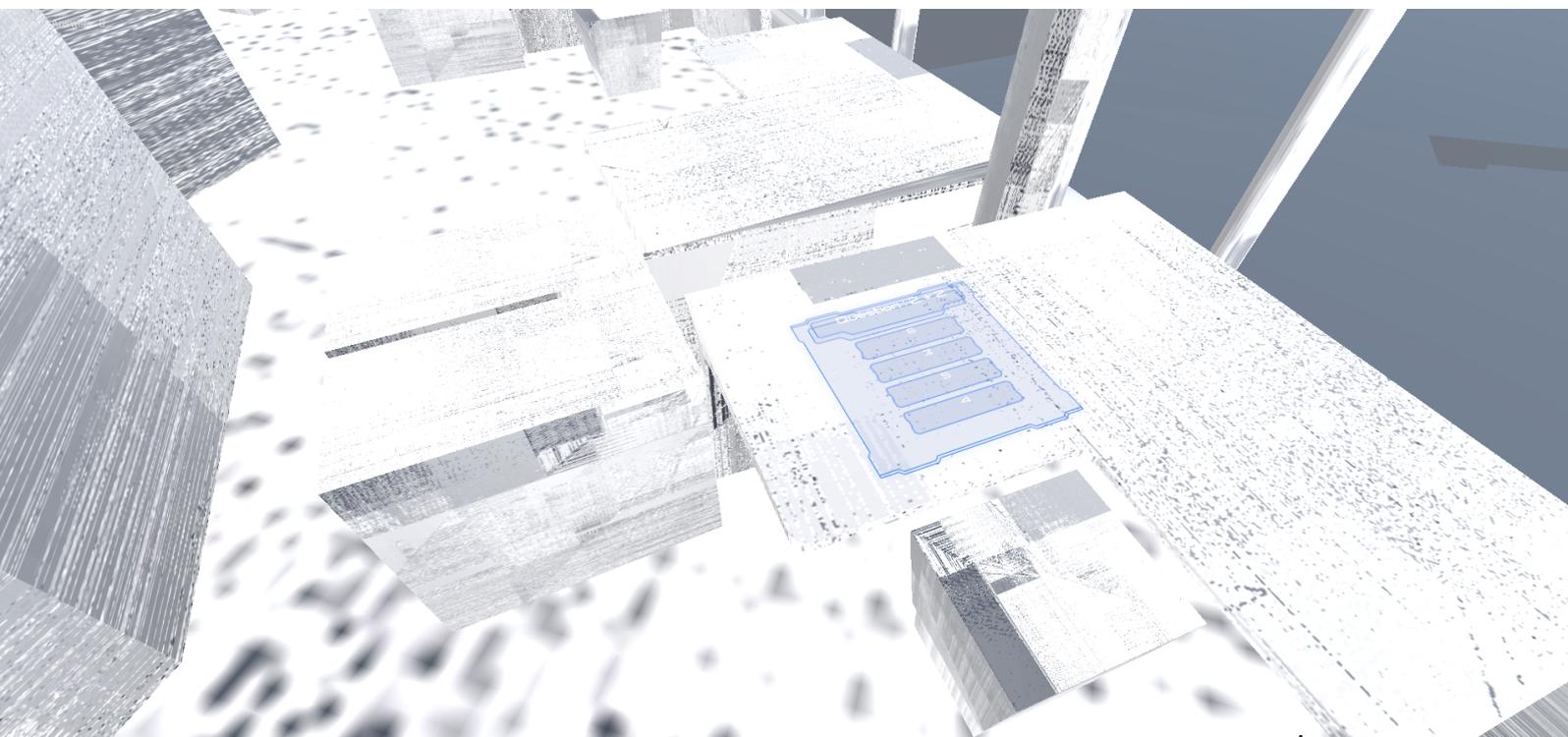
Through an iterative participant tested process, a UI system is implemented that allows users to feel more immersed.

5.1.1 interactivity

To create more immersive interaction within the framework a task was needed that required user engagement without making the task arduous. A simple series of mathematical questions was devised where the user was asked a question within the internal UI system and given four potential answers, see Figure 5.01. Once the correct answer was chosen a new question would appear, see Figure 5.02. This system prompted constant user engagement without creating a task the user found too difficult that would trigger the user to disengage with the environment. This made it possible to retain user immersion for longer.

The VR UI was used to improve immersion through a more organic form of interaction. Immersion within VR is important in order to ensure the occupants behave 'realistically', a part of this involves integrating the UI in a way that feels natural despite the inherently unnatural nature of UI. Initial concepts included creating in-game 'screens', however it became apparent that the resolution of the VR system made small UI systems such as an in-experience computer hard to interact with, so the UI had to be enlarged to fit across a work station within the environment.

The question panel itself consisted of four 'answer' buttons and a 'question' panel. Once the correct answer had been selected then the question panel would display a new question and a new set of answers, this avoided repetition and the subsequent loss of focus. When selected, buttons would 'emboss' slightly to let the user know they had been selected, this improved user focus on the task. A physical UI system was chosen over a fixed UI (that would move with the players head) as it was disorienting and made the player sick. The physical UI system also allowed the user to locate themselves spatially whilst answering questions, giving the ability for spatial factors to impact their ability to answer questions.



UI experiment

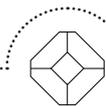


Fig 5.03.▲

Screenshot of part of the development process for the UI, showing the UI system being tested on a table (in blue). Visible are the question and answers. The environment texture was experimented with then abandoned later, as it reduced immersion.

5.2 limitations and scope

One limitation is that, with the introduction of VR, participants enjoy a sense of novelty with this new technology and report positively across all factors being tested. However as those framework components being tested were tested in comparison to previous iterations of these components and the impact of the novelty of VR is expected to be minimal.

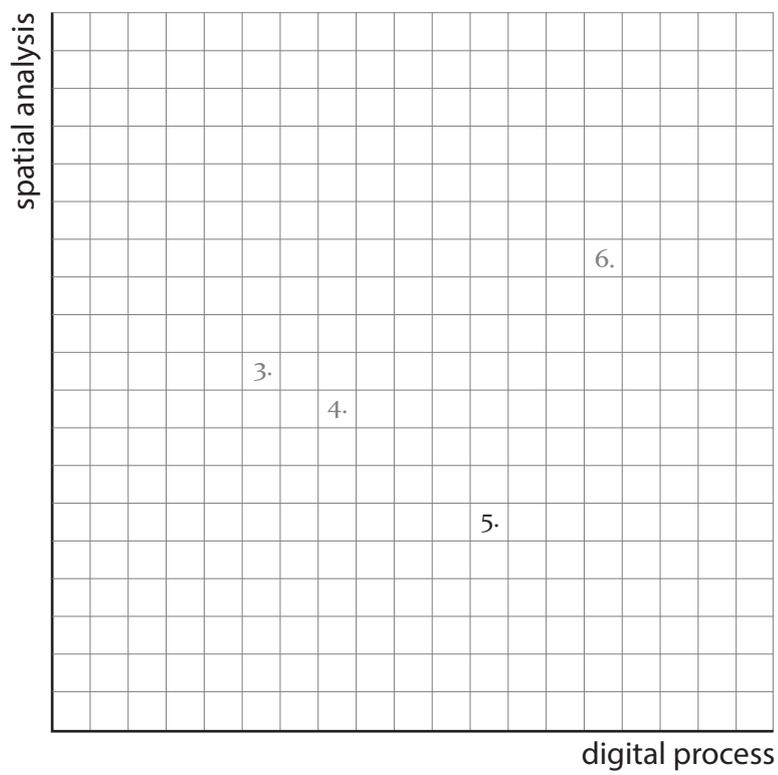


Fig 5.04.▲
 A context grid situating
 this chapter, across both a
 spatial analysis and digital
 process scale, in comparison
 to the other chapters within
 this research.

5.3 conclusion

The interactive systems that worked best were simple in nature and responded naturally to player's gestures. After an initial period where the user familiarised themselves with the controls, most users felt comfortable using the UI system and reported high levels of immersion. When the UI system shifted into a physical system, when it introduced a cycle of different questions (over just the one) and when button feedback was added, users reported higher levels of immersion.

Aydin and Schnabel (2015) use the term 'ambivalence of gamers' to describe the innate ability for those who have grown up within this digital age to quickly grasp and intuitively use mechanics given within digital space. The objective of this chapter was to anticipate and develop systems that capitalised on this ambivalence, developing a more immersive framework for the creation of VR experiments. The integration of strong and 'natural' UI is a core part of immersive environments. With the advent of VR, these will experience further development as former barriers between the physical device interface and the user are removed.

6.0

spatial analysis and data collection

The goal of this chapter is to test whether certain mood related characteristics can be isolated as predominant within different pre-existing VR experiences, and analysed. This represents an initial study in the area of digital spatial analysis and is indicative of a research methodology to be used in conjunction with the framework.

It is important to understand how different spatial factors influence the user within a VR environment. This chapter seeks to understand how various VR experiences influence player behaviour based on four pre-existing case studies and two control environments. Surveys were carried out by 30 people across five different virtual reality experiences. Using the data collected, an analysis was conducted on which spatial factors had the largest impact on user emotion. This provides an example study to improve understanding of a more sophisticated integration of intrinsic VR elements into a digital environment.



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The five environments tested were as follows;

Irrational Exuberance: Prologue (Buffalo Vision, 2016)

A space based experience chosen for its ability to promote ‘awe’ based emotions. It involves a high level of interactivity and has no clear objective.

The Lab: Longbow (Valve, 2016b)

An archery mini-game that was chosen for its high level of interactivity and its similarity to more traditional ‘game-based’ experiences.

Destinations: Talos Principle (Valve, 2016a)

A realistically textured environment of an abandoned castle. Chosen for its relaxed, self-directed nature.

The Cubicle (van Beek et al, 2016)

Satire of a cubicle style office; this experience was chosen for its ‘edgy’ take on a traditional environment and its relevance to office environments.

two control environments

The first control environment was an empty room where the user set a baseline for their moods pre-VR and the second control environment was a blank room within VR (the default HTC Vive screen).

Fig 6.01. ▲

Screenshot of *Irrational Exuberance: Prologue*.

Fig 6.02. ▼

Screenshot of *The Lab: Longbow*.

Fig 6.03. ◀

Screenshot of *Destinations: Talos Principle*.

Fig 6.04. ▶

Screenshot of *The Cubicle*.

Fig 6.05. ▼

Screenshot of the VR control environment.

phase two

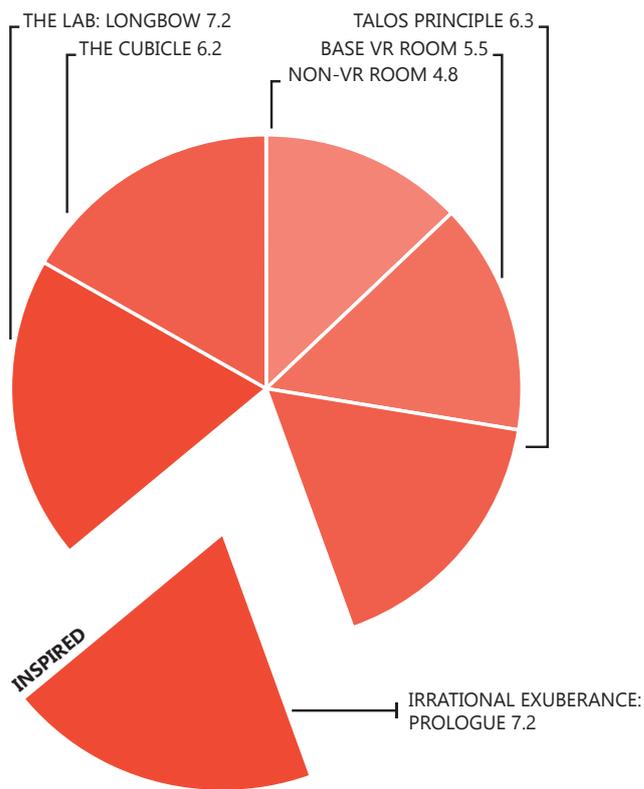


Fig 6.06.▲
 Breakdown of the 'Inspired'
 mood score across each
 experience. Irrational
 Exuberance: Prologue had
 the highest overall score
 of 7.2, joint with The Lab:
 Longbow.

The four chosen experiences represented an active environment, a calm environment, an unfamiliar 'awe' inspiring environment and a familiar environment designed to make the participant uneasy; these were chosen for their diversity and spatial nature. After data was collected from these experiments, two spaces were created based on factors that had an impact on participants in the experiments. These spaces were created as extreme examples of how this process could be used in conjunction with the digital environments framework.

6.1 methodology

Thirty participants were tested across four different virtual reality experiences in order to gather data on the impact various spatial characteristics had on participant's moods. Two control environments were also used to set a base mood for both pre and post-VR.

6.1.1 data collection

Each participant was given a survey that they completed throughout the experiment. Observational notes were also taken. The survey (Appendix 02) was derived from a short form of the PANAS mood survey (Thompson, 2007), the MSAQ motion sickness survey (Gianaros et al, 2001) and an immersivity study conducted by Singer and Witmer (1998). Results from the PANAS section of the survey provides feedback on each user's moods. A short form of the survey was chosen as it reduced experiment time thus preserving participant immersion and increasing the possible sample size. A range of surveys were considered (Ekkekakis, 2013) but ultimately the PANAS short form was chosen for its non-specificity and widely accepted use. The motion sickness and the immersivity tests were conducted to start collecting general data on virtual reality for later research.

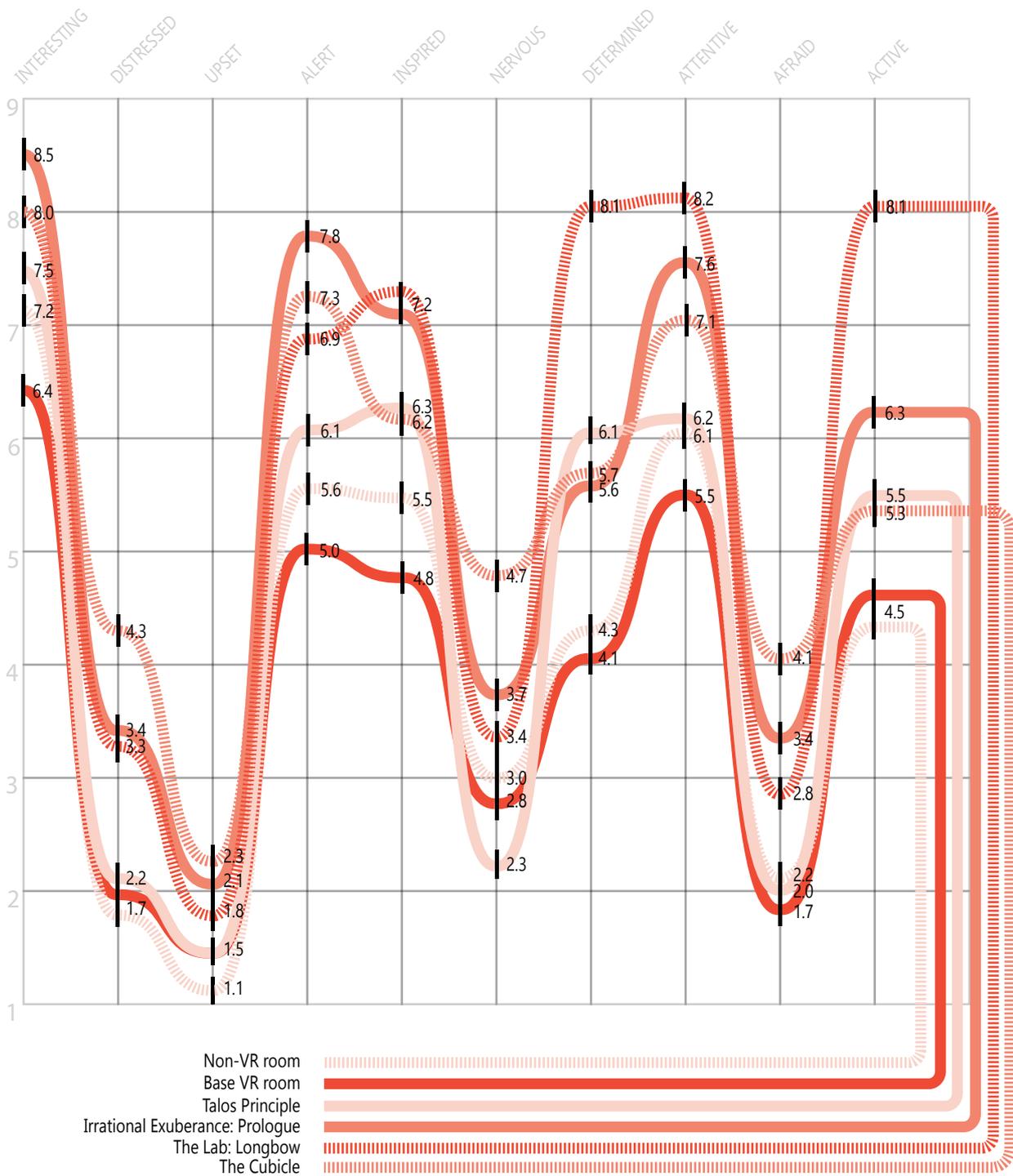
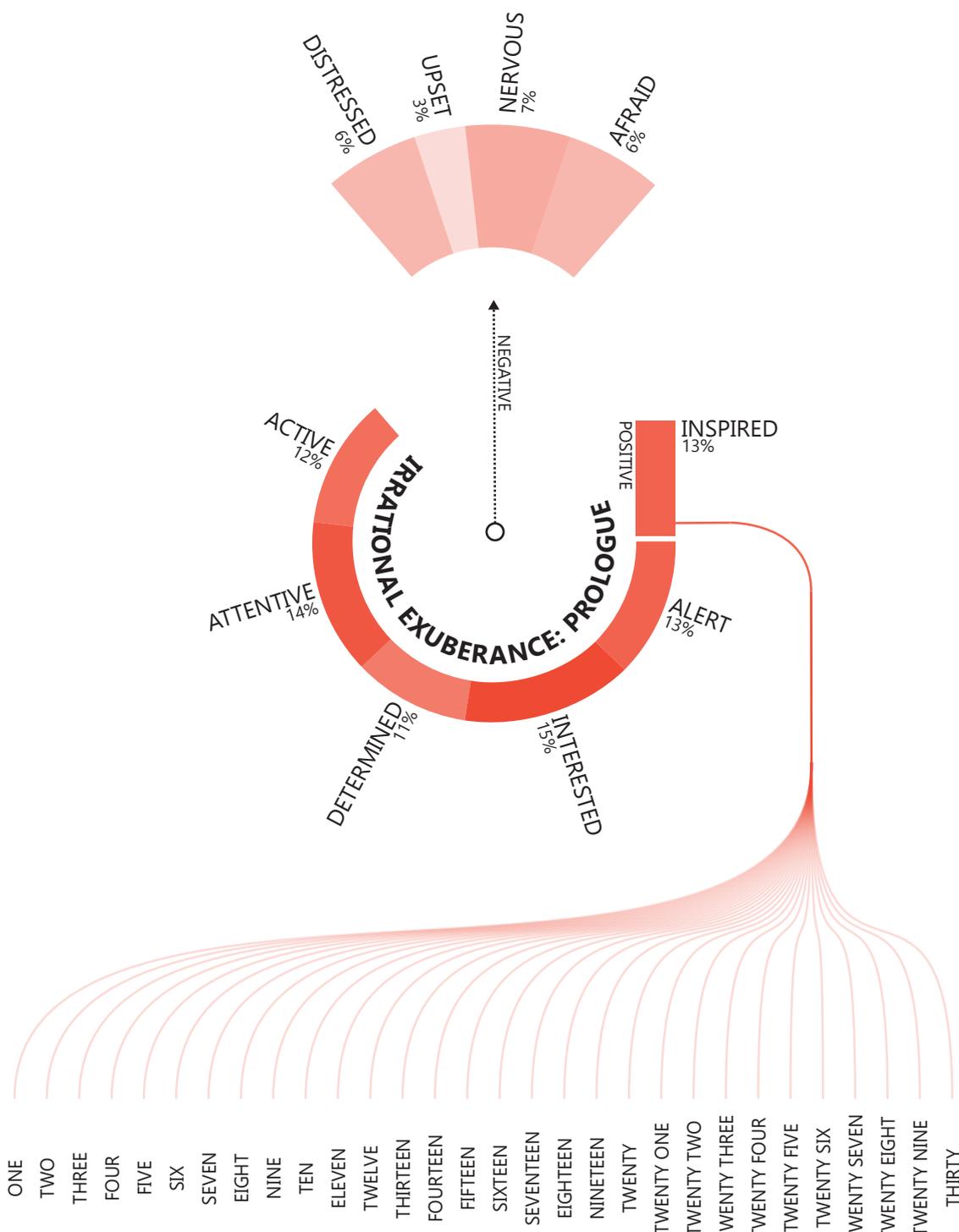
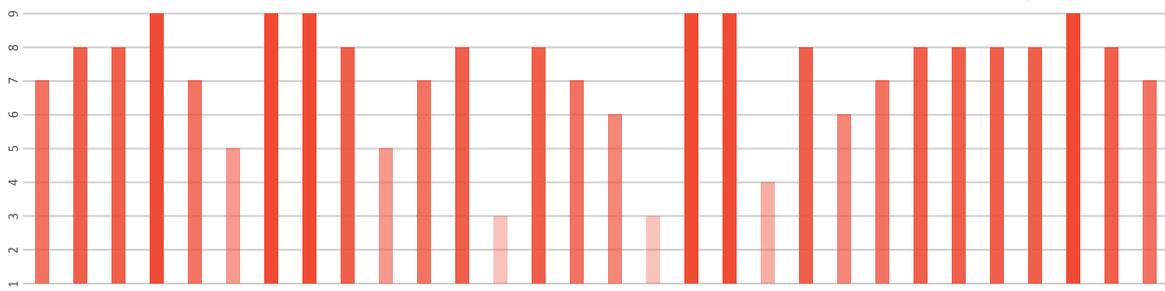


Fig 6.07.◀

Shown are the individual mood scores for each VR experience across all of the mood categories. Scores are on a scale from 1 to 9, with 1 being 'Not at all' and 9 being 'Extremely'.

Participants were taken through each experience one at a time with no audience allowed; to ensure authentic behaviour. A brief introduction sheet was given to the participants alongside the ethics information (see Appendix 04). After filling out a control set of questions for non-VR rooms, the participants had the equipment explained. Once the headset was fitted and comfortable the participants were given five minutes within an empty VR space (the default HTC Vive room) to become adjusted whilst the format of the test was explained further to them. The two different control environment were used to collect data both before and after the VR environments. In later comparison it was found that the VR control environment worked as a better control, as user's pre-VR often rated their emotions highly but once inside a VR environment this subsided. Each of the four subsequent experiences was given to the participants in a randomised order, with each one briefly explained beforehand and mood questions collected verbally upon the completion of each experiment. Upon the conclusion of the final experiment, the participants were required to complete a second set of motion sickness questions and a set of questions on immersivity. Observational data was recorded throughout, as users responded to various aspects of their environments. The observational data was made up predominantly of erratic movement and user speech.



1. **Interacted heavily with environment.** Initially remained stationary.
3. Jumped at explosion.
5. **Quite active.** Scared of heights.
7. Loves 'outer space'. Jumps at explosion.
11. Clings onto shard.
12. **Interacted heavily with environment.** Initially remained stationary.
15. **Interacted heavily with environment.** Wished 'chaperone' system could be turned off.
19. **Very active.** Moved away from shooting stars and jumped at explosions.
20. Laughed a bit.
22. Made noises of amazement. Hid from explosion.
23. "Cool". Jumped at explosions.
27. Noticed red cube.
28. **Quite active.**
29. "Amazing". Scared of explosion. Not heeding 'chaperone' system.



Fig 6.08.◀

Mood percentage scores for Irrational Exuberance: Prologue, with the most predominant category (Inspired) broken down per individual on a 1 to 9 scale.

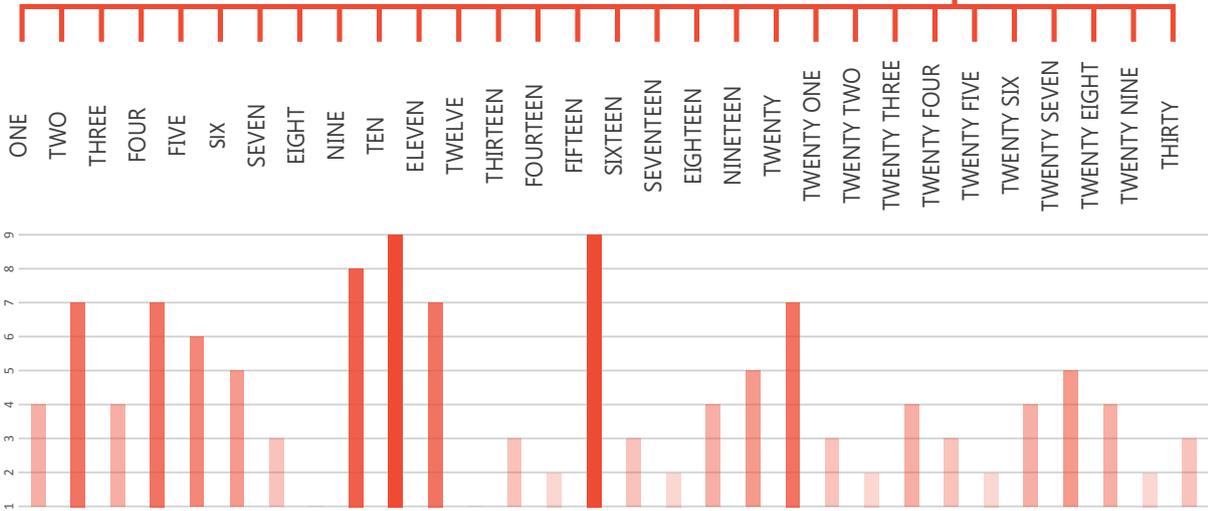
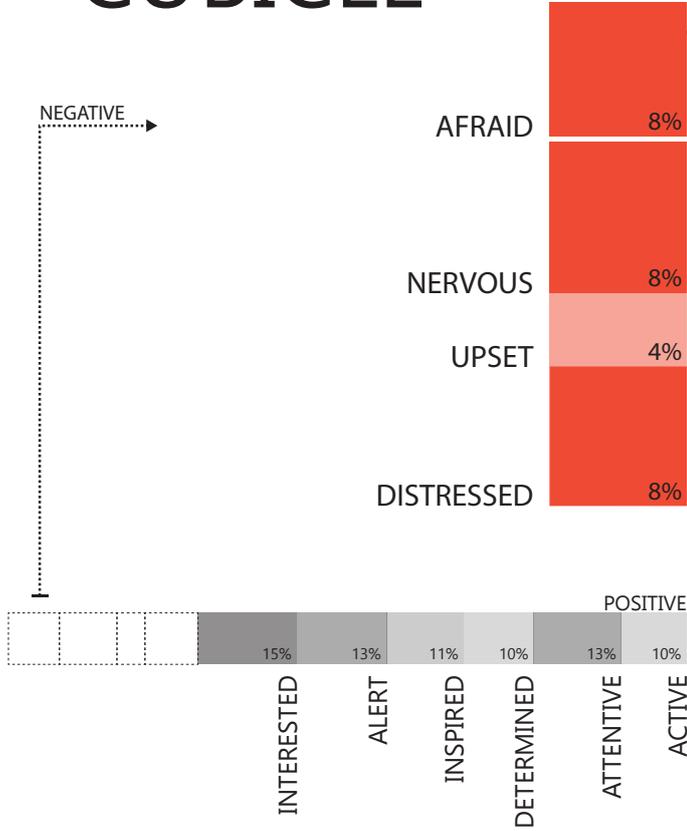
Fig 6.09.▲

User comments and observational data recorded for Irrational Exuberance: Prologue. Comments in bold are those that mention interaction, as this is linked to the heightened mood in this experience.

Fig 6.10.▶

Visualisation of an 'inspiring' environment based on those qualities emphasised within Irrational Exuberance: Prologue.

THE CUBICLE

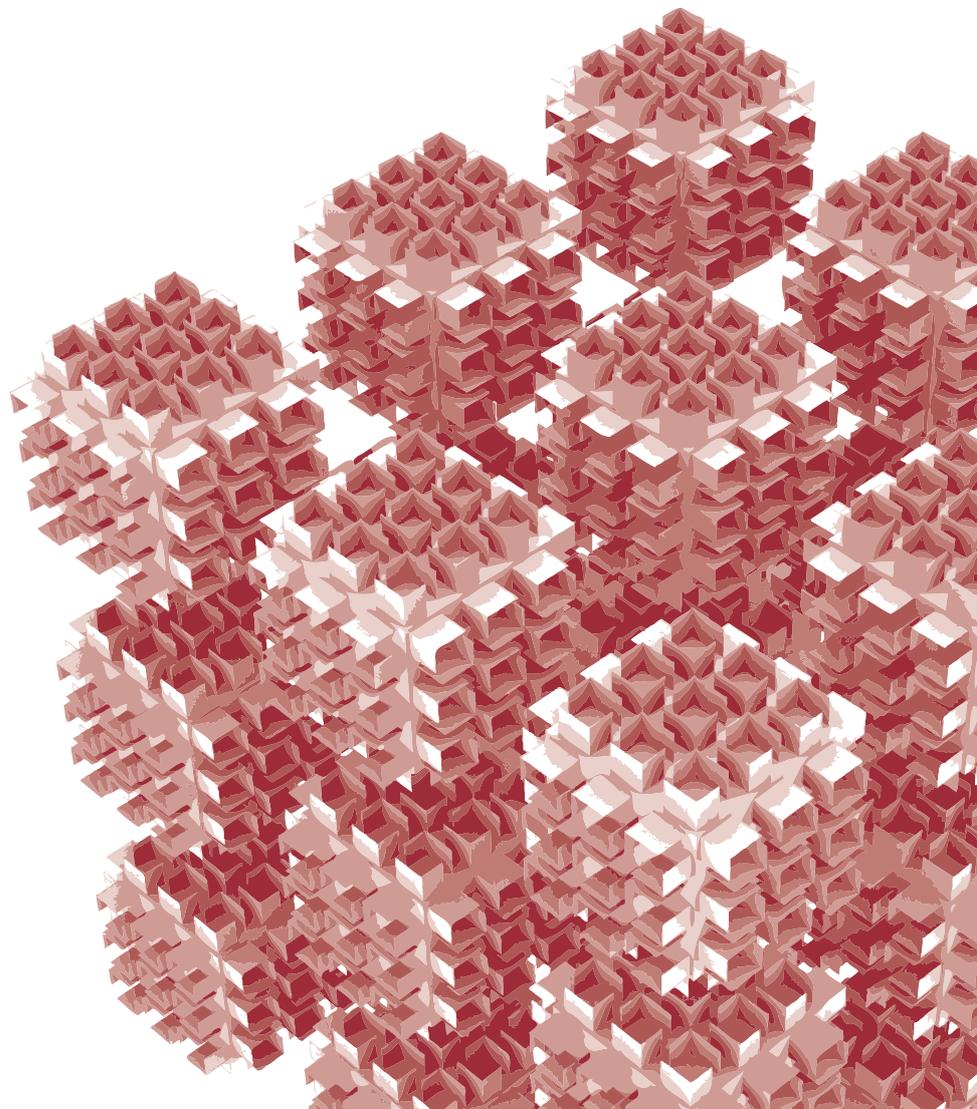


5. Lacked focus.
8. “Mean”. “Home time..”. Low focus and talked a lot.
9. Sways with motion. **Afraid of edges; “can’t move”.**
- 10. Scared of movement; distracted self by doing things.**
12. Had to restart experience. Sorted files on top of cabinet.
13. Vocal. **Unnerved; particularly by the ‘rings’.** Bit of motion sickness.
16. Efficient. Peered over edge.
17. Chose wrong cabinet to start with. Picked all the folders off the floor.
18. “I feel so sick”.
19. Using left hand. **“Creepy” and “no way out”.** Controller disconnected from body at the end is ‘creepy’.
22. “Weird”. Laughed.
23. “Cool bro”. **Took big breaths at rings.**
26. “So cool” comment at interaction. **Alarmed at floor moving; generally excitable.** Had to restart. **Alarmed at rings.**
27. “Holy ****” comment at the file interaction and floor movement. Enjoying throwing objects around. Generally really excited. Had to restart. Looks over edge when falling; “ground’s still moving”.
29. Tried to use phone.

Fig 6.11. ◀
 Mood percentage scores for The Cubicle, with the most predominant category (Afraid) broken down per individual on a 1 to 9 scale.

Fig 6.12. ▲
 User comments and observational data recorded for The Cubicle. Comments in bold are those that mention a reaction to unexpected environmental changes, as this is linked to the heightened mood in this experience.

Fig 6.13. ▶
 Visualisation of a ‘scary’ environment based on those qualities emphasised within The Cubicle.



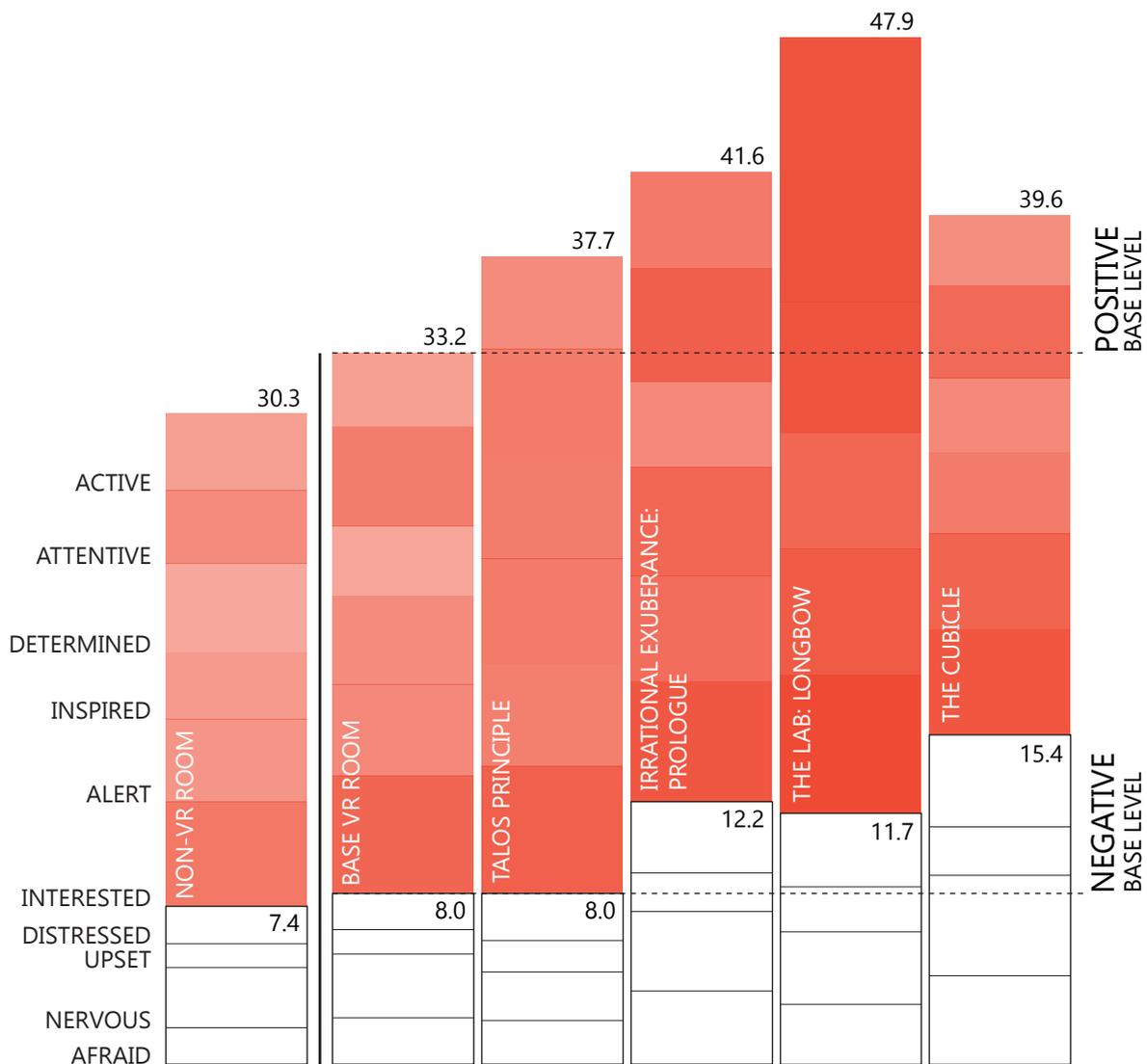


Fig 6.14. ◀

Each bar shows the overall positive and negative mood scores for a specific VR experience. In addition each mood type has been broken down within each bar, with darker shades highlighting the experiences that scored higher. The average for both negative and positive score is shown as a dotted line.

6.2 results and data

While the motion sickness data wasn't analysed fully, basic analysis and anecdotal evidence suggest that there was little motion sickness induced throughout the test, with only a few participants reporting a low level of motion sickness.

The recorded data (see Appendix 03) showed that the highest mood scores emerged from those experiences that required constant action and user focus. The higher the level of user interaction, the greater each mood score was. The Longbow experience produced overall high ratings for all categories and anecdotal/ observational data suggests this was due to a high level of physical activity, this was excluded from later testing as the experience wasn't inherently spatial. Both The Cubicle and Irrational Exuberance: Prologue produced high scores in 'Afraid' and 'Inspired' respectively; these two experiences were chosen for further analysis as a result.

In Irrational Exuberance: Prologue users had to constantly interact with their immediate environment. The experience contrasted the small scale of the asteroid the user was standing on with the vastness of space around them. To emphasis this the user was required to continuously interact with small space 'objects' found on their asteroid. Particle effects and background noise further added to the ambience. This produced high emotional scores in the 'Inspired' category for the majority of users.

In The Cubicle, participants reported equally high levels of Afraid, Nervous and Distressed. Similarly this experience contrasted the small scale of the users interactions with an increasingly vast abstracted office space. In addition the environment introduced each scale change in an unexpected way (i.e. the floor receding) which created a building sense of suspense for the user. This resulted in high scores in the 'Afraid' category for the majority of users.

Both experiences used a difference in scale between the users interactions and the wider environment to immerse the user before introducing other spatial factors to alter the users mood.

6.3 designed response

This section produces an abstract designed response to the factors highlighted within the data.

In Experience One an office was warped and skewed within space to induce the feeling of 'awe', see Figure 6.15. The scale of the 'mountain' section is chosen to contrast with the office space.

In Experience Two a sense of claustrophobia and uneasiness is created through the contrast in scale from the office cubicles to the floating cubicle cubes, see Figure 6.16.

These are not intended as a finalised designed outcome. Instead they are physical manifestations of the data; they are digital folly's.

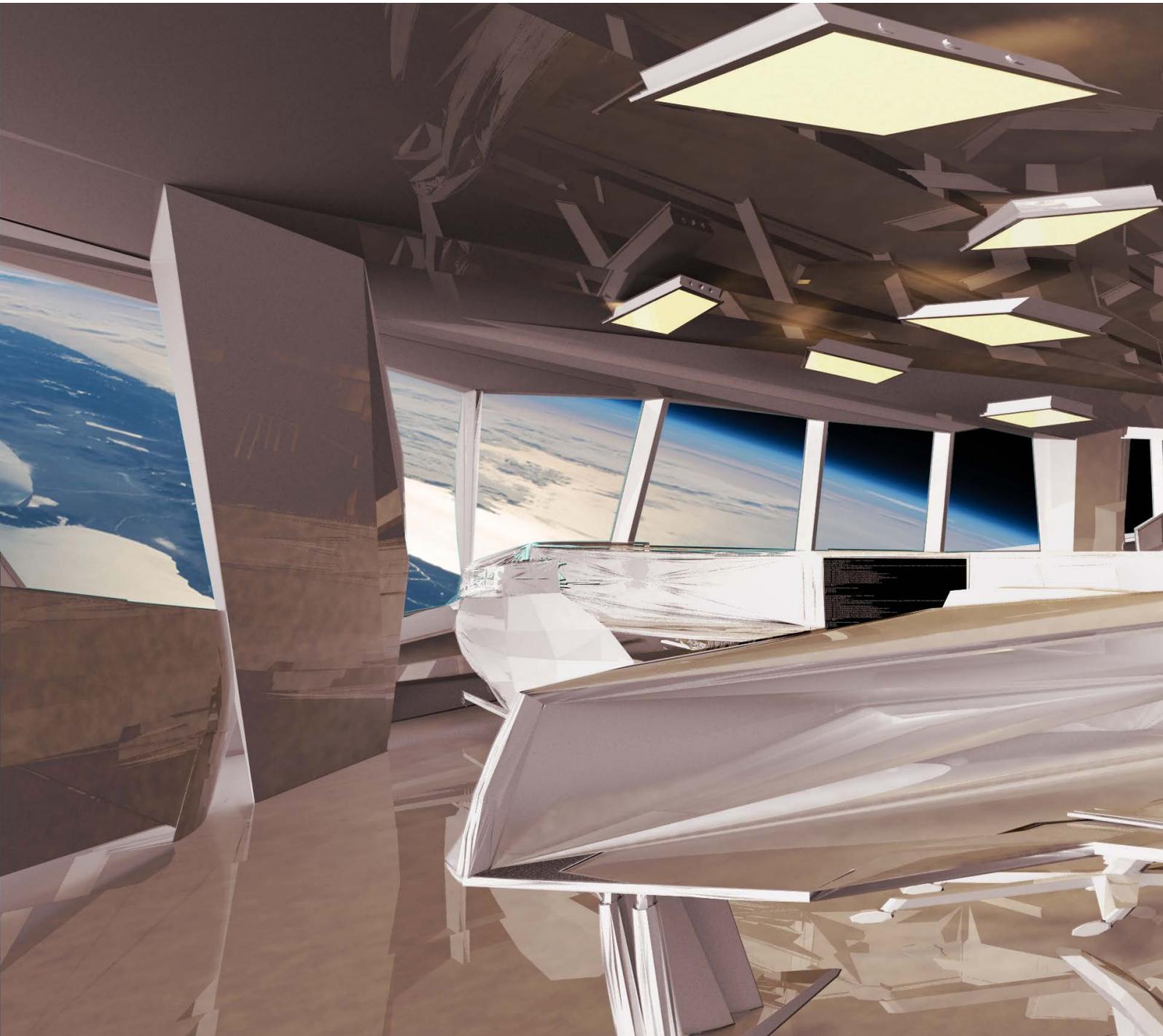


Fig 6.15. ▲
An abstracted office
environment based on
the 'inspired' spatial
characteristics found within
Irrational Exuberance:
Prologue.



experience one



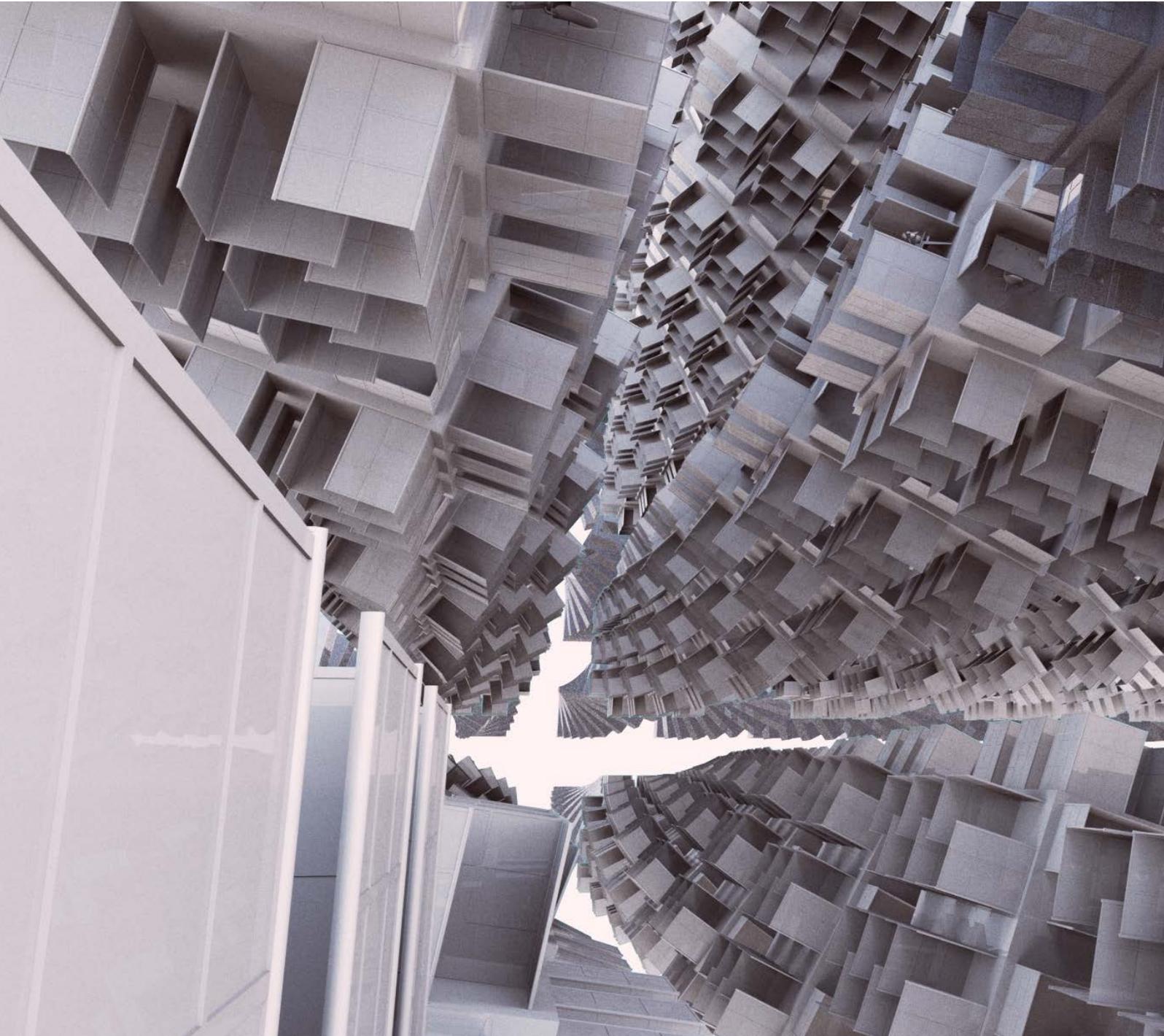
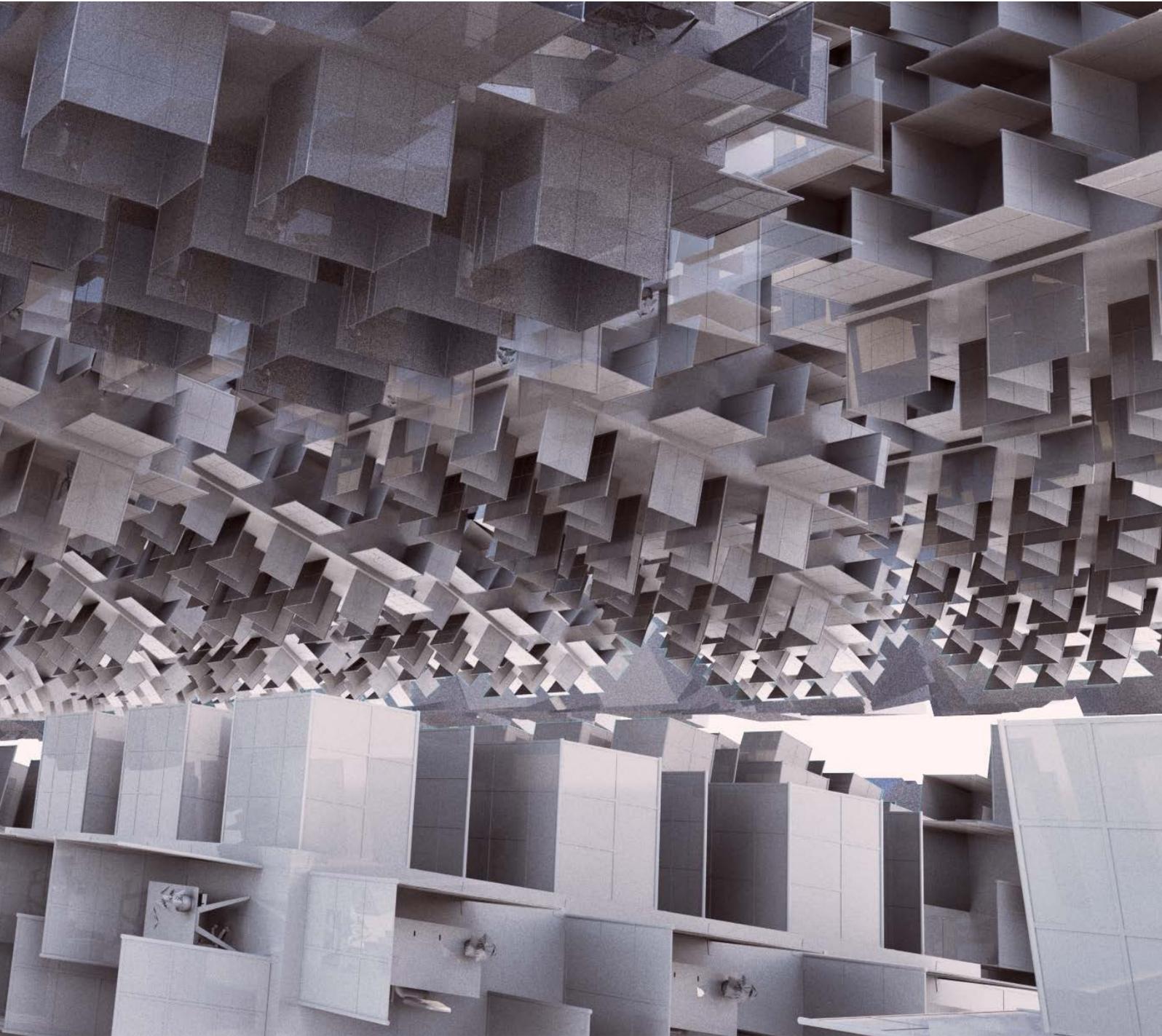


Fig 6.16. ▲
An abstracted office
environment based
on the 'afraid' spatial
characteristics found within
The Cubicle.



experience two



6.4 limitations and scope

A limitation was the use of a mixed gender of students aged between 17 and 35. It was decided that participants within this age bracket would be receptive to VR technology and would lose the 'wow factor' quicker, allowing for 'truer' responses. An older/ less digitally able person may spend longer adjusting and not experience as high a level of immersion. Though gender was unlikely to cause any bias, an equal amount of male and female participants were used.

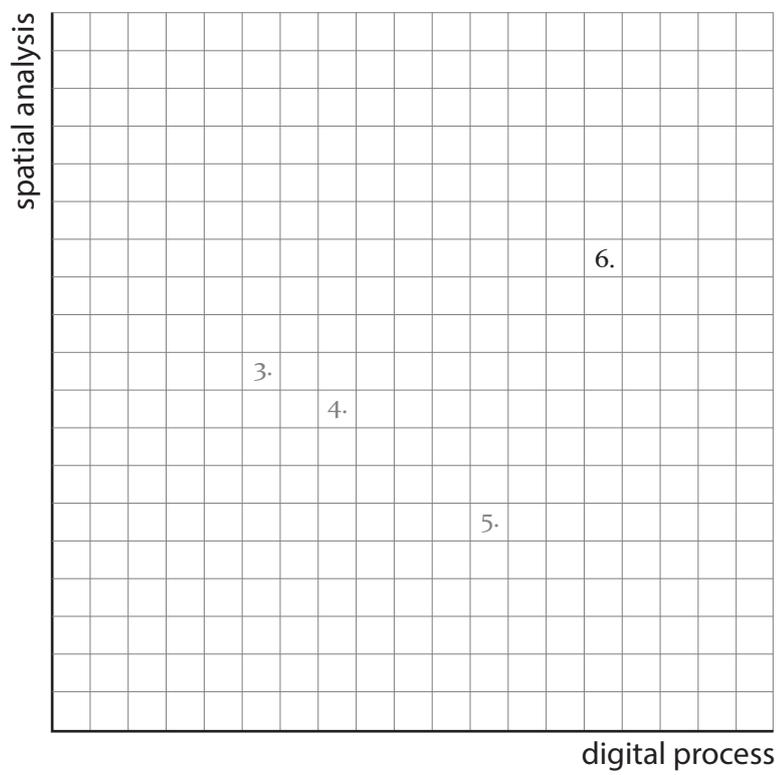


Fig 6.17. ▲
A context grid situating
this chapter, across both a
spatial analysis and digital
process scale, in comparison
to the other chapters within
this research.

6.5 conclusion

Both *Irrational Exuberance: Prologue* and *The Cubicle* successfully induced consistently high mood scores in users. This was due to the contrast between the human scale of the users interaction and the vastness of general environments, which created strong levels of user immersion. Each experience took advantage of this immersion to then induce emotion.

The survey methodology produced user reported, anecdotal and observational data, which were used to draw conclusions on spatial factors within the two experiences. This functions as a proof-of-concept for the collection of experience-based data from a digital environment. The survey process, coupled with the developed framework, provides researchers with the ability to both create an experiment and collect spatial data from within a virtual digital environment. This extends the application of the digital framework to allow for greater levels of feedback between iterations within an architectural design research methodology.

phase two reflection

Phase two introduced virtual reality functionality into the digital environments framework. An analysis into impactful spatial qualities found within existing VR experiences was conducted as a means to inform further development of the framework and to provide an example study. The success of a space is not a purely visual thing, and relies heavily on conscious and subconscious cues from the environment. Building users expect the toilets in a restaurant to follow certain spatial rules, supermarkets and shopping malls follow a logic to keep people buying things; and digital environments generate a similar set of rules. Phase two presents an early engagement with this logic and ideals.

Chapter 5.0 demonstrates that a more organic UI and interaction system improves user immersion; this includes spatial cues within the UI system.

Chapter 6.0 demonstrates how a survey-based testing system can be used to analyse a digital environment and identify cause-and-effect type relationships between different user moods and the space they are in. Using a contrast of scale between what the user is interacting with and the wider environment proved effective at increasing user immersion, which in turn allowed for each digital environment to more easily alter the users mood.

A more 'typical' environment (i.e. an office space) may not show high mood results like those tested. This should be accounted for in future experiments with a specific set of environmental tools that are tailored to the environment being analysed.

7.0

conclusion

This research set out to develop a digital environmental framework that could be used to understand the impact of the digital environments architects are creating, on their users. This digital instrument would be used in conjunction with those currently used by the architectural profession. Through the use of the framework developed by this research, a greater understanding of the impact of different spatial factors on an occupant can be achieved. The design of this framework constitutes the design research within this thesis.

Chapter 3.0 introduces a screen-based digital environments framework and conducts initial tests. It was found that after a certain level of environment density that users chose to leave the experiment. This demonstrated a proof-of-concept for the framework and prompted its further development. Users suggested that the experiment environment and the forms of interaction hindered their sense of immersion.

Chapter 4.0 used the feedback from the previous chapter to develop the environment and the forms of interaction within the environment. The complexity of the environment was increased and a wider city context was added. The forms of interaction were also increased in complexity and the player was given a more focused objective, however users stated that with a more advanced environment that the interaction forms, whilst better, were too abstract for the scenario. Both of these developments proved effective at improving user focus and immersion. In particular it was noted that the wider city context gave the users a much more grounded experience. Users displayed an inherent ability to pick up small inaccuracies in environment scale, which would disrupt immersion.

Chapter 5.0 integrates virtual reality into the framework. This was done to try and improve user immersion within the experiments. By integrating a visually responsive UI task-based interaction system the users reported higher levels of immersion than previous

forms of abstract interaction. The UI system was developed to be as organic as possible through the introduction of a physical UI system (as opposed to a heads up display/ visor), responsive buttons and a cycle of questions. It was found that more natural UI created increased levels of user immersion

Chapter 6.0 establishes a survey methodology to be used in conjunction with the framework, and tests this on a range of pre-existing VR experiences. Users reported higher mood scores on those experience that had a high degree of interaction. When broken down further it was found that the scenarios that created the highest mood scores produced a strong sense of immersion by contrasting the scale of the users interactions with the wider environment. This allowed for those experiences to then start to effectively influence the users mode. The survey methodology proved overall successful as it allowed for data to be collected both qualitatively and quantitatively; with high correlation between the observational and question-based data.

The developed framework is intended to be used within a design research iterative process as a means by which to test a space. Test parameters are subject to the requirements for the space and could include both physical and perceptual factors, as demonstrated through both the 'node' system and the mood based PANAS tests. By allowing greater flexibility to test within digital spaces the architectural design process becomes more finely tuned to the physical and emotional requirements of its occupants.

Future research could develop upon this framework and create more robust in-built testing functions, more advanced interaction forms and mutiple test environments. As understanding improves, so too will the versatility of the framework. The ultimate goal of future research should be to remove the knowledge barrier surrounding the use of these instruments entirely, so that they become widely accessible to architectural and non-architectural disciplines alike.

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interactive experience links

Fig 3.15

Raycast Create - <http://www.jamesholth.com/interactive-1/#/interactive/>

Raycast Spawn Distance - <http://www.jamesholth.com/interactive-1/#/interactive-2/>

Raycast Shape - <http://www.jamesholth.com/interactive-1/#/interactive-2-1/>

Generate - <http://www.jamesholth.com/interactive-1/#/interactive-2-1-1/>

Fig 5.02

UI experiment - <http://www.jamesholth.com/interactive-1/#/office-experiment-2/>

Fig 6.14

Experience One - <http://www.jamesholth.com/interactive-1/#/new-page-2/>

Fig 6.15

Experience Two - <http://www.jamesholth.com/interactive-1/#/new-page-2/>

software used

Block'hood - <http://www.plethora-project.com/blockhood/>

Minecraft - <https://minecraft.net/en-us/>

Polyomino -

<http://plethora-project.com/completeworks/2015/07/20/polyomino-2/>

Wireflies -

<http://plethora-project.com/completeworks/2014/10/27/bpro-logo/>

Reon - <http://plethora-project.com/completeworks/2014/10/25/reon-academic-research/>

Journey - <http://thatgamecompany.com/games/journey/>

The Cubicle - <http://store.steampowered.com/app/452490/>

Fuzor - <https://www.kalloctech.com/>

Unity 3D - <https://unity3d.com/>

Rhinoceros 3D - <https://www.rhino3d.com/>

Grasshopper 3D - <http://www.grasshopper3d.com/>

Maya - <http://www.autodesk.com/products/maya/overview>

Irrational Exuberance: Prologue - <http://irrationalexuberancevr.com/>

The Lab: Longbow - <http://store.steampowered.com/app/450390/>

Destinations: Talos Principle - <http://store.steampowered.com/app/453170/>

appendices

Chapter 2.0 Methodology

The pilot study used to test the proposed framework involved users navigating through a simple ‘workplace’ environment whilst a range of visual, aural and movement based nodes manifested in the environment. The user’s reactions to an increasingly dense configuration of nodes were used to draw initial conclusions about the impact various combinations of visual, aural and movement based distractions had on occupants of workplace environments. The key components of an IVE research framework are the environment, the variables and the level of interactivity between the user and the variables. All three of these factors are highly interrelated, making the user feel a part of the ‘system’ they’re placed within; if they don’t then they risk losing immersion and the experiment loses validity (Slater and Sanchez, 2014). Immersion ‘level’ is a subjective trait, but through a combination of observation and post-experience analysis a user’s level of immersion can be fairly well established.

2.1.1 Environment

In this research, a typical open-plan ‘office’ environment was created as the combination of homogeneity and familiarity allowed the occupants to become focused on the changing spatial characteristics without being distracted by an overload of other new information. This gave a more immersive experience to the occupants despite the relative simplicity of the digital model.

The environment consists of a typical office floor layout with two core blocks, perimeter columns, spandrels and a ceiling height of 3.0m. Though there are windows there is currently no exterior view, showing instead a grey background, this prevents exterior distractions from impacting on user behaviour. In early stages of the project a basic single story space was used, whilst in later stages a more developed model is created that looks at multi-level spaces and a more complex layout.

2.1.2 Variables

The major variables being investigated are those most closely related to perceptions of dense space; physical, aural and movement based distractions.

Octahedron shaped nodes of various sizes represented physical distraction and density of space. Their homogenous form allows the sensation of density to occur through their massing rather than a specific architectural form or spatial dimension.

A second node was used to represent both aural and movement-based distraction. These nodes consisted of red particle clouds that emitted a dull 3D background noise of a typical office space. The spatialised sound allowed for proper orientation within the space and had a cumulative effect when multiple nodes manifested themselves near each other. The particles within a node create, move on random paths, and finally disappear. This created a sense of peripheral movement within the space without drawing the users focus to a specific point.

The nodes create at a rate of one node of each type per second, this rate doubled every five seconds until the user opts out or is unable to move due to completely obstructed pathways. Through analysing what actions the users take in order to try avoid/stop the nodes, and at what point they become agitated, conclusions are drawn regarding an overall 'density threshold'.

2.1.3 Interactivity

As Slater and Sanchez (2014) describe, in order to be fully immersed the user must have an exchange of information with the environment. This exchange may be the ability to physically alter the environment, or it could be the ability to affect how the user interacts with the environment. In this experiment physical interaction was implemented, as system based interaction requires more sophisticated setup than used in this pilot study.

As a method to mitigate the increasing amount of nodes within the space the user was given the ability to remove nodes. This ability worked on a cool-down (usable once every few seconds) allowing the user to craft a path through the nodes without being able to totally remove them all. This forced the user to weigh up moving to less densely populated areas, and risk getting trapped on the way, versus attempting to clear the area they were in.

2.1.4 Sample Group

In the initial stage of this project a small sample group of students was used. This group consisted of ten architectural Masters Students aged between 18 and 25 and of a mix of genders. In latter stages a larger sample group of students, office employees and architects are used in order to eliminate random variance and establish a more comprehensive data set.

An Exploration into the Psychological Impacts of Growing Density

James Holth, Victoria University of Wellington

Mood Survey:

Experience Non-VR Room

Using the scale below, indicate to what extent you feel this way currently:

	Not at all	1---2---3---4---5---6---7---8---9	Extremely		
1. Interested	()			6. Nervous	()
2. Distressed	()			7. Determined	()
3. Upset	()			8. Attentive	()
4. Alert	()			9. Afraid	()
5. Inspired	()			10. Active	()

Experience Base Model

Using the scale below, indicate to what extent you felt this way during the virtual reality experience:

	Not at all	1---2---3---4---5---6---7---8---9	Extremely		
1. Interested	()			6. Nervous	()
2. Distressed	()			7. Determined	()
3. Upset	()			8. Attentive	()
4. Alert	()			9. Afraid	()
5. Inspired	()			10. Active	()

11. How much a part of the experience/ environment did you feel? ()

Experience ()

Using the scale below, indicate to what extent you felt this way during the virtual reality experience:

	Not at all	1---2---3---4---5---6---7---8---9	Extremely		
1. Interested	()			6. Nervous	()
2. Distressed	()			7. Determined	()
3. Upset	()			8. Attentive	()
4. Alert	()			9. Afraid	()
5. Inspired	()			10. Active	()

11. How much a part of the experience/ environment did you feel? ()

Experience ()

Using the scale below, indicate to what extent you felt this way during the virtual reality experience:

	Not at all	1---2---3---4---5---6---7---8---9	Extremely		
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2. Distressed	()			7. Determined	()
3. Upset	()			8. Attentive	()
4. Alert	()			9. Afraid	()
5. Inspired	()			10. Active	()

11. How much a part of the experience/ environment did you feel? ()

Experience ()

Using the scale below, indicate to what extent you felt this way during the virtual reality experience:

	Not at all	1---2---3---4---5---6---7---8---9	Extremely		
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3. Upset	()			8. Attentive	()
4. Alert	()			9. Afraid	()
5. Inspired	()			10. Active	()

11. How much a part of the experience/ environment did you feel? ()

Experience ()

Using the scale below, indicate to what extent you felt this way during the virtual reality experience:

	Not at all	1---2---3---4---5---6---7---8---9	Extremely		
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2. Distressed	()			7. Determined	()
3. Upset	()			8. Attentive	()
4. Alert	()			9. Afraid	()
5. Inspired	()			10. Active	()

11. How much a part of the experience/ environment did you feel? ()

Comments

An Exploration into the Psychological Impacts of Growing Density

VR Experience Survey:

James Holth, Victoria University of Wellington

Gender

Age

Motion Sickness (Pre-Experience)

Using the scale below, please rate how accurately the following statements describe your current condition:

	Not at all	1	2	3	4	5	6	7	8	9	Severely
1. I felt sick to my stomach	()										()
2. I felt faint like	()										()
3. I felt annoyed/ irritated	()										()
4. I felt sweaty	()										()
5. I felt queasy	()										()
6. I felt lightheaded	()										()
7. I felt drowsy	()										()
8. I felt clammy/ cold	()										()

9. I felt disoriented	()										()
10. I felt tired/ fatigued	()										()
11. I felt nauseated	()										()
12. I felt hot/ warm	()										()
13. I felt dizzy	()										()
14. I felt like I was spinning	()										()
15. I felt as if I may vomit	()										()
16. I felt uneasy	()										()

Focus

How physically fit do you feel today?

Unfit 1 2 3 4 5 Fit

How good are you at blocking out external distractions when you are involved in something?

Poor 1 2 3 4 5 Excellent

Are you easily disturbed when working on tasks?

Easily disturbed 1 2 3 4 5 Not easily disturbed

Gaming

How many hours a day do you play video games?

Immersion and Involvement

Do you ever get extremely involved in projects that are assigned to you by your boss or your instructor, to the exclusion of other tasks?

Not often/ At all 1 2 3 4 5 Often/ All the time

Do you ever become so involved in a television program or book that people have problems getting your attention?

Not often/ At all 1 2 3 4 5 Often/ All the time

Do you ever become so involved in a movie that you are not aware of things happening around you?

Not often/ At all 1 2 3 4 5 Often/ All the time

How frequently do you find yourself closely identifying with the characters in a story line?

Not often/ At all 1 2 3 4 5 Often/ All the time

Do you ever become so involved in a daydream that you are not aware of things happening around you?

Not often/ At all 1 2 3 4 5 Often/ All the time

How well could you examine objects from multiple viewpoints (from different angles in the room)?

Not well 1 2 3 4 5 Well

How realistic and natural was your sense of moving around in the virtual environment?

Unrealistic/ Unnatural 1 2 3 4 5 Realistic/ Natural

Control Factors

How quickly did you adjust to the virtual experience?

Slowly 1 2 3 4 5 Quickly

How much were you able to control events?

Not much/ At all 1 2 3 4 5 A lot

How responsive was the environment to actions that you initiated or performed?

Not much/ At all 1 2 3 4 5 A lot

How natural did your interactions with the environment seem?

Unnatural 1 2 3 4 5 Natural

How much did your experiences in the virtual environment seem consistent with your real-world experiences?

Not much/ At all 1 2 3 4 5 A lot

Distraction Factors

How distracting was the control mechanism (the remote control device)?

Not much/ At all 1 2 3 4 5 A lot

How aware were you of events occurring in the real world around you while in the virtual environment?

Not much/ At all 1 2 3 4 5 A lot

Motion Sickness (Post-Experience)

Using the scale below, please rate how accurately the following statements describe your experience:

	Not at all	1	2	3	4	5	6	7	8	9	Severely
1. I felt sick to my stomach	()										()
2. I felt faint like	()										()
3. I felt annoyed/ irritated	()										()
4. I felt sweaty	()										()
5. I felt queasy	()										()
6. I felt lightheaded	()										()
7. I felt drowsy	()										()
8. I felt clammy/ cold	()										()
9. I felt disoriented	()										()
10. I felt tired/ fatigued	()										()
11. I felt nauseated	()										()
12. I felt hot/ warm	()										()
13. I felt dizzy	()										()
14. I felt like I was spinning	()										()
15. I felt as if I may vomit	()										()
16. I felt uneasy	()										()

User #	Gender	Age	Motion							
			1	2	3	4	5	6	7	
1	M	22	1	1	1	1	1	1	1	2
2	M	22	1	1	2	3	1	2	1	1
3	F	22	1	1	1	1	1	1	1	1
4	M	24	1	1	1	1	1	1	1	1
5	M	23	1	2	1	1	2	2	3	3
6	F	23	2	2	2	2	1	1	3	3
7	F	23	1	1	1	1	1	1	1	1
8	M	23	1	1	1	1	1	1	1	1
9	F	22	1	1	1	1	1	1	2	2
10	M	22	1	1	1	5	1	1	1	1
11	F	23	1	1	1	1	1	1	1	1
12	F	25	1	1	1	1	1	1	1	1
13	M	23	1	1	1	2	1	1	3	3
14	F	22	1	1	1	1	1	1	1	1
15	M	24	1	1	1	1	1	1	1	1
16	F	33	1	1	1	2	1	1	1	1
17	M	23	1	1	1	1	1	1	1	1
18	F	23	1	1	1	1	1	2	4	4
19	M	23	1	1	1	2	1	1	1	1
20	M	20	4	2	1	2	2	1	3	3
21	M	23	2	2	1	2	2	1	1	1
22	F	22	1	2	1	3	2	2	3	3
23	M	22	1	1	1	2	1	2	2	2
24	F	22	3	1	1	1	2	2	1	1
25	F	22	1	1	1	2	2	1	3	3
26	F	23	1	1	1	1	1	1	1	1
27	M	22	1	1	1	1	1	1	1	1
28	F	25	1	1	1	1	1	1	1	1
29	M	23	1	1	1	2	1	1	1	1
30	M	23	1	2	1	1	1	3	3	3
			1.23	1.20	1.07	1.57	1.20	1.27	1.67	

Sickness (Pre-Experience)

	8	9	10	11	12	13	14	15	16
1	1	5	1	4	1	1	1	1	1
1	1	3	1	4	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	3	1	5	1	1	1	1	1
6	2	4	2	5	2	2	1	1	1
1	1	4	1	3	2	1	1	1	1
1	1	2	1	1	1	1	1	1	1
1	1	3	2	1	1	1	1	1	1
1	1	2	1	1	1	1	1	1	1
1	1	9	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	3	1	2	1	1	1	1	1
1	1	2	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	3	1	2	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	7	1	3	2	1	1	1	1
3	1	3	1	2	1	1	1	1	1
2	1	6	3	5	2	3	2	1	1
1	3	1	1	2	2	1	1	1	1
1	1	3	1	2	1	1	1	1	1
2	2	2	3	3	3	2	1	1	1
1	1	4	2	4	1	1	1	1	1
1	1	4	1	6	2	1	1	1	1
2	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	4	1	3	1	1	1	1	1
2	1	7	2	5	3	1	1	1	1
2	1	4	1	1	1	1	1	1	2
1.40	1.13	3.17	1.27	2.43	1.33	1.13	1.03	1.03	

Mood: Non-VR Room

	1	2	3	4	5	6	7	8	9
5	1	1	5	4	2	2	4	1	
7	6	2	6	8	2	7	6	2	
5	1	1	1	2	2	2	3	1	
9	1	1	5	6	2	1	8	1	
8	2	1	5	6	3	3	8	2	
3	1	1	4	3	4	2	2	2	
9	1	1	7	2	1	1	8	1	
6	1	1	4	4	1	1	5	1	
2	1	1	5	2	8	5	8	8	
2	1	1	5	4	1	5	5	1	
8	3	1	8	9	6	6	8	4	
8	1	1	4	5	1	1	5	1	
8	2	1	6	5	3	5	6	1	
9	1	1	7	8	4	7	7	2	
8	1	1	8	8	1	7	7	1	
7	2	1	5	4	3	6	7	1	
2	1	1	3	3	1	2	4	1	
5	3	1	4	5	1	7	6	1	
7	2	1	7	5	3	4	7	1	
8	4	1	5	5	6	8	4	2	
8	1	1	2	6	3	4	4	2	
9	1	1	6	6	6	6	6	2	
6	4	2	5	3	2	6	6	2	
9	1	1	4	7	6	6	6	3	
7	1	1	7	6	1	6	7	1	
2	1	1	1	1	1	1	2	1	
7	3	3	8	5	2	2	3	1	
6	1	1	4	5	4	4	5	1	
8	2	1	8	5	2	5	6	2	
5	1	1	2	1	2	1	1	1	
6.43	1.73	1.13	5.03	4.77	2.80	4.10	5.47	1.70	

Mood: Base Model									
10	1	2	3	4	5	6	7	8	
2	6	1	1	5	4	1	4	5	
4	8	3	2	7	7	2	7	6	
2	5	1	1	2	3	1	5	4	
9	9	1	1	9	9	5	5	8	
4	6	2	2	7	7	4	5	5	
4	7	2	1	6	7	1	4	6	
2	9	1	1	8	1	1	1	5	
4	9	1	1	3	8	1	3	3	
2	6	2	1	5	3	7	3	7	
7	5	2	1	7	2	3	5	7	
7	9	3	1	9	9	7	7	9	
5	9	1	1	4	7	1	2	5	
6	8	1	1	6	7	2	5	9	
6	8	1	1	4	6	2	4	6	
5	9	1	1	9	7	5	9	9	
5	5	2	1	6	2	4	2	4	
2	4	1	1	1	1	1	3	6	
1	7	1	1	5	5	1	6	6	
7	8	1	1	8	6	3	4	5	
7	9	4	2	8	5	4	4	9	
6	8	1	1	4	5	4	3	2	
4	9	1	1	7	7	4	6	8	
6	2	2	2	5	3	5	5	7	
5	8	2	1	5	6	4	3	5	
8	8	1	1	7	7	1	4	8	
1	8	1	1	5	6	1	5	7	
5	8	1	1	5	6	1	4	8	
1	9	7	1	7	7	6	7	7	
7	9	2	1	2	8	5	2	5	
2	2	1	1	2	3	2	1	3	
4.53	7.23	1.70	1.13	5.60	5.47	2.97	4.27	6.13	

									Mood: Exp
9	10	11	Exp Type	1	2	3	4	5	
1	1	4	I	6	2	1	7	7	
3	7	6	T	8	1	1	7	7	
1	5	8	A	7	2	1	6	4	
1	7	7	A	9	2	1	9	9	
3	4	3	C	7	6	4	8	6	
1	4	3	A	8	8	4	9	7	
1	2	3	I	9	4	1	9	9	
1	3	4	C	9	1	1	8	9	
9	2	2	C	9	8	5	9	7	
2	3	8	A	9	4	2	8	8	
6	9	9	A	9	1	7	9	9	
1	4	1	I	9	1	1	5	8	
1	7	5	A	9	3	2	6	8	
1	5	9	I	9	1	1	6	8	
5	9	6	A	9	4	4	9	9	
3	3	4	C	7	3	1	7	7	
1	2	4	C	8	2	1	6	5	
1	2	7	A	9	5	3	7	7	
1	4	7	I	9	3	1	8	9	
2	5	4	A	9	6	2	9	9	
1	6	6	I	9	3	2	6	8	
2	5	6	C	9	2	1	8	7	
2	2	1	I	7	4	2	8	7	
1	5	4	I	9	2	1	5	8	
1	8	2	T	8	1	1	6	7	
1	2	4	C	9	4	1	7	5	
1	6	6	T	8	1	1	8	7	
5	5	5	I	9	6	1	7	9	
5	6	2	I	9	1	1	1	8	
1	2	5	T	6	1	1	5	7	
2.17	4.50	4.83		8.37	3.07	1.87	7.10	7.50	

Experience A								
6	7	8	9	10	11	Exp Type	1	2
1	6	7	2	6	9	T	7	3
2	8	8	3	7	7	I	8	5
3	6	5	1	7	8	C	8	4
4	9	9	3	9	7	I	8	3
6	5	7	5	5	7	I	7	5
8	8	8	8	9	8	I	7	8
6	6	9	4	8	8	A	9	1
3	8	9	4	8	8	I	9	2
8	8	9	8	5	9	T	9	5
4	7	8	3	9	5	T	7	4
3	9	9	3	9	9	C	9	7
2	2	7	1	3	5	A	9	7
2	8	8	1	5	7	I	7	2
1	4	6	1	6	8	C	8	2
9	9	9	3	9	7	C	8	9
4	8	8	3	5	7	A	5	2
1	4	8	1	5	7	A	8	1
5	7	9	5	8	9	C	4	4
3	5	8	3	4	8	T	9	1
2	9	9	2	9	9	C	9	7
2	6	6	3	8	7	A	9	4
3	6	8	4	6	8	I	8	1
4	8	8	3	6	7	C	8	4
1	3	5	1	6	8	C	9	3
1	8	7	1	8	8	I	9	2
4	7	8	4	4	9	I	9	3
1	6	8	1	8	7	C	9	5
5	7	9	3	7	9	C	9	4
1	9	9	1	8	8	C	9	2
3	2	4	2	2	8	I	6	2
3.40	6.60	7.73	2.90	6.63	7.70		8.00	3.73

Mood: Experience B									
	3	4	5	6	7	8	9	10	11
1	6	6	3	6	6	1	6	7	
2	6	8	5	6	7	5	8	8	
1	8	2	5	3	9	4	5	9	
1	9	9	6	5	9	4	6	9	
3	8	7	3	5	7	2	7	8	
7	9	5	9	7	9	9	8	8	
1	9	7	2	9	9	1	8	7	
1	9	9	4	8	8	2	9	9	
1	8	9	3	9	9	5	9	7	
4	5	4	1	6	6	1	3	4	
3	9	9	8	9	9	5	9	9	
1	6	6	3	6	6	2	7	6	
1	4	3	2	6	5	1	7	4	
1	8	7	2	8	8	2	8	9	
5	9	5	6	5	9	5	5	8	
2	7	6	4	8	8	3	7	7	
1	9	4	1	7	8	9	6	7	
4	6	4	8	2	4	4	4	9	
1	7	8	2	6	6	2	6	6	
3	9	6	9	4	6	8	4	6	
2	7	6	2	6	7	2	9	8	
1	7	6	1	7	7	1	6	7	
2	8	7	7	8	8	5	7	7	
1	6	8	2	4	5	2	5	8	
1	9	8	1	5	9	2	8	8	
1	7	8	7	7	8	7	4	8	
1	9	8	4	6	9	3	6	7	
1	9	9	4	7	4	3	7	9	
2	2	7	3	9	9	3	7	9	
1	5	7	4	5	8	2	8	9	
1.90	7.33	6.60	4.03	6.30	7.40	3.50	6.63	7.57	

Mood: Experience C								
Exp Type	1	2	3	4	5	6	7	8
A	7	4	1	8	6	2	9	7
A	8	6	5	5	4	6	8	8
T	9	1	1	3	5	1	3	3
C	9	7	1	9	7	6	3	7
T	8	6	4	8	7	6	9	9
C	9	5	3	8	7	6	5	6
C	5	3	1	9	3	2	2	8
A	9	4	1	9	9	2	9	9
A	9	9	3	9	9	8	9	9
I	7	6	5	6	5	6	3	7
T	5	5	2	7	6	4	8	8
C	9	1	1	5	5	1	4	4
C	6	3	1	6	7	2	7	6
A	9	1	1	9	9	2	9	9
T	9	1	1	9	9	7	9	9
T	7	2	2	6	6	2	7	5
I	6	1	1	7	3	1	3	7
T	6	5	5	5	5	3	7	6
C	9	5	3	7	7	6	5	6
I	5	4	2	3	4	4	3	4
T	7	3	1	5	6	1	4	5
T	9	1	1	8	7	1	9	8
T	8	4	2	8	7	7	8	8
T	9	1	1	4	6	1	4	5
C	8	2	1	8	7	3	7	7
A	9	3	2	9	7	2	9	9
A	9	1	1	9	8	1	9	9
T	7	1	1	5	5	1	5	5
A	9	2	2	2	8	2	9	8
A	6	2	1	5	7	4	5	8
	7.73	3.30	1.90	6.70	6.37	3.33	6.37	6.97

9	10	11	Exp Type	1	2	3	4	5
1	9	8	C	7	4	2	6	5
4	8	8	C	8	7	7	6	5
1	5	9	I	9	4	1	9	8
7	4	8	T	6	1	1	6	5
7	9	9	A	9	7	3	9	7
4	6	9	T	8	1	1	7	8
1	4	7	T	5	1	1	6	2
1	9	9	T	8	3	1	8	9
6	9	9	I	7	6	2	8	8
7	2	5	C	8	9	8	8	4
4	7	6	I	9	7	3	9	7
1	3	7	T	9	1	1	4	8
2	1	2	T	5	1	2	5	4
1	9	9	T	9	1	1	8	7
5	9	8	I	9	1	1	9	7
2	4	7	I	7	1	2	7	6
1	4	6	T	5	1	1	4	2
2	3	7	I	9	8	5	9	9
6	4	7	A	9	6	3	8	6
3	2	3	T	7	6	1	5	6
1	5	4	C	9	3	1	6	6
1	8	8	A	9	2	1	9	7
5	7	7	A	9	3	3	9	9
1	5	7	A	9	1	1	7	6
2	9	9	A	9	1	1	9	7
1	8	9	T	8	1	1	7	5
1	9	8	I	8	2	1	6	8
1	4	7	A	9	1	1	7	7
1	8	9	T	9	2	1	2	8
2	8	9	C	6	3	1	5	5

2.73

6.07

7.33

7.93

3.17

1.97

6.93

6.37

Experience D						Focus			
6	7	8	9	10	11	Fit	Ext. Dist.	Disturbed	
3	6	6	2	5	6	3	4	4	
6	3	5	7	3	9	4	3	3	
2	5	8	2	7	9	4	3	4	
1	1	4	1	3	6	3	4	3	
4	9	9	6	9	9	4	4	4	
2	8	7	1	7	9	5	4	4	
1	2	5	1	2	5	5	5	4	
1	8	7	1	8	9	5	3	3	
4	5	8	4	5	3	4	5	4	
8	5	6	9	2	7	3	4	3	
7	9	9	6	9	9	5	3	4	
1	5	6	1	3	8	5	5	4	
1	5	4	1	3	4	4	3	2	
1	7	8	1	5	7	4	4	3	
8	5	9	7	9	7	4	5	3	
1	5	7	3	6	7	3	3	2	
1	5	3	1	5	6	3	4	3	
9	9	9	9	7	9	3	4	3	
5	8	7	5	5	6	4	4	3	
7	5	4	4	5	6	4	3	2	
2	5	8	2	7	8	5	4	2	
4	9	8	3	9	9	4	3	2	
3	9	9	3	8	8	4	4	3	
1	8	7	1	7	9	3	3	3	
2	9	9	1	9	8	4	3	3	
1	5	5	1	1	8	3	3	2	
1	5	8	3	6	7	3	4	2	
1	7	9	1	9	7	2	5	2	
1	9	9	2	8	9	5	4	4	
8	7	7	8	7	8	3	5	1	
3.23	6.27	7.00	3.23	5.97	7.40	3.83	3.83	2.97	

Gaming		Immersion and Involvement							
Hours	Projects	TV	Movie	Char.	Daydream	Viewpoints	Realistic	Adjust	
2	4	3	2	3	2	4	3	4	
3	4	4	4	4	4	4	4	5	
0	4	2	2	5	2	4	5	5	
1	3	3	3	4	2	4	4	5	
0	4	3	3	4	4	4	3	4	
0	4	4	4	3	4	4	4	4	
0	3	2	3	2	2	5	1	5	
0	5	3	4	3	1	4	4	5	
0	5	5	4	5	5	3	3	4	
2	3	2	2	3	3	3	3	2	
0	1	4	3	4	4	2	5	4	
0	4	1	2	2	3	3	3	3	
2	4	5	3	3	4	4	3	4	
0	5	3	4	4	5	4	4	4	
3	5	1	3	3	1	3	3	5	
0	4	2	2	3	2	4	3	4	
0	2	3	4	3	3	4	2	4	
0	3	4	5	5	3	4	5	4	
1.5	2	2	3	3	1	4	2	5	
0	4	4	4	3	4	3	4	4	
0	4	3	3	4	2	3	4	5	
0	4	4	4	4	4	4	4	5	
0	4	2	3	4	2	4	4	4	
0	3	4	3	3	2	3	4	3	
0	4	2	3	2	2	4	3	5	
0.5	4	5	5	5	5	4	5	5	
0.5	4	4	4	2	1	5	3	2	
0	4	4	4	3	3	4	4	3	
0	2	3	3	4	4	4	4	5	
0	5	3	2	2	2	5	4	4	
0.52	3.70	3.13	3.27	3.40	2.87	3.80	3.57	4.17	

Events	Control Factors			Distraction Factors		1	2
	Responsive	Natural	Consistent	Controller	Real World		
3	3	4	3	4	1	4	1
4	4	3	3	4	1	5	3
3	4	4	3	1	1	1	1
4	4	3	3	2	1	1	1
3	3	2	3	2	2	2	2
3	4	4	4	2	3	1	1
2	5	3	1	1	1	1	1
4	4	4	4	2	1	4	2
5	4	3	4	1	2	1	2
3	3	3	3	3	1	4	2
3	4	4	2	1	2	1	1
4	5	5	3	1	2	1	1
4	3	3	3	2	4	1	1
4	4	3	3	2	2	3	1
2	3	4	4	2	2	1	1
3	4	3	3	2	3	1	2
3	4	2	3	3	3	1	1
3	5	5	3	2	1	6	6
4	4	4	2	1	1	1	1
2	4	4	4	1	2	4	2
4	4	4	5	2	2	3	2
5	4	4	4	2	2	1	1
4	4	3	3	2	2	1	2
3	4	4	3	2	2	2	1
3	4	5	4	1	2	1	1
3	4	5	4	1	1	1	1
4	4	2	3	1	2	1	1
2	4	3	3	3	4	1	1
3	3	4	3	4	3	1	1
4	3	4	4	2	1	1	1

3.37

3.87

3.60

3.23

1.97

1.90

1.90

1.50

Motion Sickness (Post-Experience)

	3	4	5	6	7	8	9	10	11
1	1	4	2	1	1	1	2	4	1
5	5	5	3	1	1	1	4	1	4
1	1	1	1	1	1	1	1	1	1
1	5	1	1	1	1	1	6	1	1
	1	1	1	3	1	2	2	2	2
1	1	3	3	1	1	6	6	1	2
1	1	1	1	1	1	1	2	2	1
2	1	1	1	2	1	1	1	2	3
3	3	3	5	3	1	1	7	3	4
3	8	6	1	1	1	5	5	1	3
2	4	1	2	2	2	6	6	2	2
1	1	1	1	1	1	1	1	1	1
1	3	1	1	1	1	2	4	1	1
1	1	7	1	1	1	1	1	1	2
1	5	1	1	1	1	1	5	1	1
1	1	1	2	1	1	3	3	2	1
1	1	1	1	1	1	1	1	1	1
7	6	7	5	1	1	6	6	1	8
2	1	1	2	1	2	3	3	2	1
1	4	4	4	4	4	4	6	4	3
2	2	1	1	1	1	2	2	2	1
1	2	1	1	2	1	1	1	2	1
2	3	2	4	2	1	3	3	2	2
1	2	2	1	1	1	1	4	2	1
1	3	2	1	3	1	4	4	3	1
1	1	1	1	1	1	1	1	1	1
1	3	1	1	1	1	6	6	3	1
1	1	1	3	1	1	3	3	1	2
2	2	1	2	2	1	1	1	5	2
1	1	1	2	3	1	3	3	1	1
1.69	2.57	2.07	1.80	1.37	1.23	3.33	1.87	1.87	

	12	13	14	15	16
	5	1	1	1	1
	3	3	4	2	4
	1	1	1	1	1
	7	1	1	1	1
	6	2	3	1	1
	1	3	3	1	5
	2	1	1	1	1
	1	3	2	1	1
	5	3	5	1	3
	5	6	1	3	7
	4	2	2	1	3
	1	1	1	1	1
	3	1	1	1	1
	3	2	1	1	3
	1	1	1	1	1
	2	1	1	1	1
	1	2	1	1	1
	6	7	7	6	7
	2	1	1	1	1
	6	5	5	2	3
	1	2	2	1	1
	2	2	1	1	1
	4	5	4	1	2
	3	1	3	1	1
	3	1	2	1	1
	1	2	1	1	1
	1	5	3	1	3
	3	2	1	1	1
	3	4	2	1	2
	1	2	1	1	1
	2.90	2.43	2.10	1.30	2.03

Comments

Fairly typical; headset jumped around.

Punched walls in I. Starts stationary.

Swears a lot in A. Teleported too close to object in T. Scared of edge T. Jumped at explosion I.

Very 'interested'.

Mucks around a lot in C. Kept teleporting past goal T.

Weird' base model. Quite reactive I. Scared of heights I.

Loves 'outer space'; jumps at explosion I. Did much better at A after second try. When she takes her time she is more accurate A. Tried to fall off wall T.

Fucking mean' C. Home time... Mucked around a lot in C. Chatted a lot in C.

Sways with motion in C. Afraid of edges; 'can't move'. Noted that it was more immersive without other people around.

Scared of C; distracted self by doing things.

Liked popping balloons A. Tried to teleport up trees and interact with puzzles I. Scared of walls in I; startled by explosion.

Clings onto shard I. Most people don't practise much A. Had to restart C. Sorted files on top of cabinet C.

Pretty vocal in C and A. Unnerved by C; particularly the 'rings'. Bit of motion sickness.

Punched wall in I. Stand pretty stationary.

Very active. Acts like a gamer.

Pretty efficient C; peers over edge. Practised longer than normal A. Punches everything as per normal I. Wishes chaperone system could be turned off in I.

Chose wrong cabinet to start C. Picked all the folders off the floor C. Did some practise in A.

"So buzzy". Excited. Quite vocal and excited in A. "I feel so sick" in C. Seems lost/ agitated in I. Punched wall; very active in I. Moved away from shooting stars and jumped at explosions in I.

Headset heavy/ worried about cord. Laughed a bit in I. Couldn't see self, 'weird'. Teleporting in I 'weird'. Played with force fields T. Scared when suddenly next to edge T. Using left hand in C. C is 'creepy and there is 'no way out'. Controller disconnected from body at end of C is 'creepy'.

Scared of heights T.

Makes noises of amazement I. Take cover from explosion I. Tried interacting with puzzle elements T.

Fucking weird' C; laughing. Didn't practice long in A.

Cool bro' C; big breaths at rings. 'Sick' T. No practice in A.

Explored instead T.

A bit reluctant to walk around. Explored mostly; attempted getting higher T. Rushed into A; couldn't hear me.

So cool' tiles interaction C. Alarmed at floor moving; excitable C. Had to restart C. Alarmed when HMD reset; and at rings C. 'Cool' in I, jumps at explosions. Vocal in A.

Predisposed to motion sickness in VR. 'Oh my lord' I; tried stepping off edge. 'Holy heck' at the tile interaction and floor movement in C. Enjoying throwing objects around C. Generally just really excited C. Had to restart C. Looks over edge when falling in C; 'grounds still moving'. Much better at A after round 13. Excited at I; 'holy shit'. Noticed red cube in I.

Some hearing issues. Quite reactive in I. 'Cool' in T. Vocal in A.

Amazing' I; scared of explosion. Not really heeding chaperone system. Tried to use phone C.

Prior experience.



Phone 0-4-463 5205
Email stephen.marshall@vuw.ac.nz

MEMORANDUM

TO	James Holth
COPY TO	
FROM	Dr Stephen Marshall, Acting Convener, Human Ethics Committee
DATE	19 June 2016
PAGES	1
SUBJECT	Ethics Approval: 22966 Dense: An Exploration of the Psychological Impacts of Growing Density

Thank you for your application for ethical approval, which has now been considered by the Standing Committee of the Human Ethics Committee.

Your application has been approved from the above date and this approval continues until 31 March 2017. If your data collection is not completed by this date you should apply to the Human Ethics Committee for an extension to this approval.

Best wishes with the research.

Stephen Marshall,
Acting Convener, Victoria University Human Ethics Committee

MEMORANDUM

TO	James Holth
COPY TO	Prof Joanna Merwood-Salisbury
FROM	AProf Susan Corbett, Convener, Human Ethics Committee
DATE	14 October 2016
PAGES	1
SUBJECT	Ethics Approval: 22966 Dense: An Exploration of the Psychological Impacts of Growing Density

Thank you for your request to amend your ethics approval. This has now been considered and the request granted.

Your application has approval until 31 March 2017. If your data collection is not completed by this date you should apply to the Human Ethics Committee for an extension to this approval.

Best wishes with the research.

Kind regards

Susan Corbett

Convener, Victoria University Human Ethics Committee