Accessible Design for Varied Sensory Wayfinding in Virtual Spaces

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Declaration, Publications, Funding & Awards

The work presented in this thesis is my own and has not been submitted in substantially the same form for the award of a higher degree elsewhere. To the best of my knowledge, it does not contain any materials previously published or written by another person except where due reference is made in the text. It does however contain research funded, published and awarded in other forms as detailed here:

Section 1 contains images and information adapted from the exhibition Mason, Z. (2020) 'Machine Learnt Landscapes', *Multimedia Encounters: Experimental Approaches to Ethnographic Research.* UCL Media Anthropology Lab. https://www.uclmal.com/exhibition

As well as information included in Green, D. P., Lindley, J., Mason, Z. & Coulton, P. 2022. 'A Design-Led Exploration of Material Interactions Between Machine Learning and Digital Portraiture', *[ ] With Design: Reinventing Design Modes, IASDR 2021*, Springer, Singapore. https://doi.org/10.1007/978-981-19-4472-7_211

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Zach Mason

Acknowledgements

I would like to begin by expressing how the journey of my PhD documented in this thesis has been so incredibly enjoyable, while deeply challenging. I have so many people whose help I've been so deeply thankful for along the way, but I would like to keep this acknowledgement short and sweet, and leave the rest for when we see each other again.

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Abstract

The research within this thesis is, in of itself an example of the power of Research through Design (RtD). It began as an introspective exploration around how virtual wayfinding systems could provide an enjoyable sense of togetherness during the COVID-19 pandemic, evolving into an exploration of others, considering how designing wayfinding experiences with their unique needs in mind can provide far greater accessibility, legibility, togetherness, and immersion. This research, enacted through the process of designing and redesigning, is a window into the research process I began long before my PhD, and one I intend to continue after its concluding statements.

Researching 'Accessible Design for Varied Sensory Wayfinding in Virtual Spaces', this thesis unearths that while legibility and accessible design are inherently intertwined, universal legibility in virtual wayfinding is never truly achievable due to people's varying sensory bandwidths, digital experience and intended usage. This research is both an exploration of wayfinding, and a wayfinding journey itself, demonstrated through its intentional drifting methods and wayfinding focused research aims respectively. Conveyed across three specific sections – focusing on over-specificity, ambiguity, and legibility through accessibility – this thesis uses wayfinding games as a vessel for research exploration throughout. Section zero lays the foundations of this research journey, outlining the methods, epistemologies and designs which inspired and were enacted throughout the three following sections. Level 1 is often where games really begin (after the tutorial). To pay homage to this and highlight that section 1 is where my data chapters begin (and that the section before is really the foundations to it) I labelled the preceding section to it as 0.

Section one focuses on over-specificity and documents a process of learning how to design virtual spaces that involve wayfinding, before highlighting that its largely game-centric underpinning would benefit from broader consideration of people and their understandings of virtual spaces.

Section two extends this thinking by exploring the design of virtual public spaces intended for general audiences, created during the pandemic. It looks at how game-like interactive systems collide with design patterns from general purpose video conferencing to create ambiguous and hard to navigate spaces, especially for those with visual impairments.

The third section explores legibility within virtual wayfinding, using the design and development of an audio-only game to uncover how accessibility might improve virtual wayfinding more generally and what the limits of non-visual wayfinding are within generically designed hardware. The final concluding section questions what this explorative journey has taught me, and what within it might be of use to others.

Finally, it examines how future research might begin to erode the limitations of non-visual virtual wayfinding caused by generic hardware's sensory bandwidth limits. These sections can broadly be broken down into these research questions:

0. *How can we unpack the history of virtual wayfinding design?*
1. *What is the design of virtual wayfinding spaces with current tools like?*
2. *How do we design virtual wayfinding spaces for maximum accessibility?*
3. *How could virtual wayfinding spaces be made more accessible?*
4. *Is equitable access to virtual space fixable by hardware redesign?*

Intended Audience

Before getting any further into the thesis, I would like to briefly acknowledge three groups which make up the intended audience. Firstly, I wanted to tailor this thesis to future Research through Design PhD students. Because of this, my thesis is predominantly chronological account of undertaking a PhD in this field. I have also tried to be as authentic as possible in my lived experience of researching, both desk and field research. This is one reason why the thesis does not focus on specific engine details when making virtual spatial experiences, instead choosing to focus on the processes and drifting that happen within a PhD authentically. It is also why I provide a history of wayfinding centric games near the start of the thesis.

Secondly, I wanted to write this in a way that is approachable for UX Designers in industry and academia alike. From personal experience working as a UX Designer in an industry setting I have realised the frequency with which user research is the first part of the UX process to be scrapped under time constraints. Because of this, I see it as extremely relevant to document my journey from self-focused design to accessibility orientated design for others to highlight the improvements it can have upon the overall design usability, quality, user satisfaction and engagement.

Finally, furthering the industry accessibility above, I wanted it to be approachable for game developers who often act as UX Designers and coders. This industry approachability is a significant factor for why section 0 of this thesis is titled as 0 (rather than 1), enabling industry designers and developers to skip straight to the design work I undertook to gain insights which might improve accessibility and usability in their everyday work. It is also why I do not go into detail about engine limitations and usage, as game developers and designers work with many different engines which are rapidly updating. Instead, I focus on the user experience, designing audio only games and how this is adaptable to accessibility features in wider games. I believe this is more useful to a wider audience, showing them how accessibility can be deeply imbedded through listening to users and validating hunches with them.

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0a. Introduction

0a.1. Situating Virtual Fascination

Digital interactions are something which have fascinated me for as long as I can remember. Although I grew up in the early 2000s, both my parents were digitally cautious, causing our family to lag behind others on home computer innovations. For example, we would still have a dial-up internet connection that would cut out when someone phoned the house as late as 2014 due to our rural location. Regardless, games consoles played a key role in my youth, and I enjoyed video games with my brother and friends in-between an active and adventurous childhood. This mixture of physical and virtual interactions, alongside nurture from two parents who were both 3D art and design teachers, led me to consider the relationship and space between objects in my physical environment carefully.

This consideration could be described as a 'spatial regard', and is something which has never left me, becoming central to my undergraduate degree which ended with my trying to rationalise links between physical, virtual and mental spaces. This thought process was somewhat disrupted by the COVID-19 pandemic causing our end-of-degree in-person exhibition of work to be replaced by a website where we could post a video and three images. This felt incredibly underwhelming, causing several students at the Glasgow School of Art (including myself) to begin work on a virtual spatial representation of how the exhibition would have been physically manifested with just a little virtual embellishment. Once this was completed, we had many issues distributing it due to file size, its poor ability to run on people's computers and incompatibility with various operating systems. While I undertook much of the task of optimizing this so it would be downloadable and usable for many more people, even this improved version had many limitations and was confusing to navigate.

The bad taste left in my mouth after this experience of trying to reclaim the physical presence in space, which the pandemic had taken away, is what led me to pursue research which has a focus on creating virtual spaces that provide an enjoyable sense of togetherness to all kinds of user. Being forced to move back in with my parents after graduating left me with a desire to claim ownership of some semblance of space, fuelling the exploration of wayfinding and spatial design described in the first data chapter (1b). I was fascinated with both the idea of making virtual experiences which could be accessed easily by anyone who wished to and how wayfinding design for virtual spaces varies from that of physical spaces. When referring to virtual space I am adopting Char Davies' definition that "when I say virtual space, I am referring to immersive virtual space, i.e., a computer-generated artificial environment that one can seemingly, with the aid of various devices, go inside" (Davies, 2004, p. 69). It is also key to mention that when I refer to virtual space, it is something which sits within digital things and therefore is a subsection of the digital space.

Throughout the thesis the meaning of access and accessibility depends on context. Sometimes the terms are a bit fluid and require interpretation based on situation, referring to general access, and other times referring to peoples' specific needs requiring accessibility design. This concept is something I will explain more deeply within the forthcoming literature review (0b.5) and continue to discuss where relevant. Because accessibility is different for everyone due to the way they experience the world (both in their sensory feedback and subjective mental perspective), it cannot be a universal practice and isn't finite, meaning that we can always make things accessible in different ways by making design choices. To exemplify this point, in this thesis you will notice that all diagrams are monochromatic. This choice means that colour blind people will not struggle more than those with typical colour vision to read diagrams due to the colours appearing differently for them. However, it does mean people with typical colour vision may struggle more than if the images were coloured. In digital applications this option could be toggleable, but for the purposes of constantly reminding the reader of the kinds of struggles truly accessible design must overcome, this thesis is fixed in a monochrome state. I do acknowledge this design choice may also reduce legibility for low vision readers, but with the addition of alt text on all images, alongside the increased awareness this choice brings into the fabric of the thesis itself, it seemed a worthwhile design choice to adhere to. Before going any further with the concept of accessibility, I will clarify my definition of wayfinding. This clarification will lead me on to explain why computer wayfinding games (mainly referred to as 'games' in the rest of the thesis) have been so integral to my exploration of and contributions to wayfinding.

In *Wayfinding: A simple concept, a complex process*, Anna Charisse Farr characterised wayfinding as "the process of finding your way to a destination in a familiar or unfamiliar setting using any cues given by the environment" (Farr et al., 2011, p. 2). In *Wayfinding: A broad view,* Janet Carpman defines wayfinding as "how living organisms make their way from an origin to a destination and back" (Carpman & Grant, 2002, p. 1). For the purposes of this research, I consider wayfinding as knowing your position in, and continuing to plot a course through, a space. While Carpman qualifies wayfinding as being only relevant to living organisms I do not make that distinction as even though most of the research in this thesis focuses on living organisms (namely humans) wayfinding through digital space this often replies upon non-living digital entities (e.g., avatars) or points of interest to facilitate that process. Because of the interplay between physical and digital I deliberately do not make the distinction between organism and non-organism because as non-living agents within virtual space become increasingly common, the line between living and non-living entities is reaching a point of imperceptibility. For example in *Fortnite* (Epic Games, 2017) games, in a 100 entity lobby, the living to non-living entity ratio can vary from 10 to 90 humans to bots in low skill lobbies, all the way to 90 to 10 in high skill lobbies. This practice is becoming increasingly common, facilitating enjoyable, accessible play for those involved, and relying on non-living organisms which can instantaneously adapt to living organisms' behaviour, just as other living organisms would. I believe it is ill informed to argue that this demonstrates non-living organisms are only relevant to lower skill wayfinding as OpenAI were able to train Dota AI (OpenAI, 2019) agents to play at a professional level within a rich wayfinding environment, beating the best pro team in the world at the time across multiple matches. This showcases the rich wayfinding non-living entities can exhibit in virtual spaces, alongside their increasing similarity to living organisms which is enabling more accessible play for all, leading me to not make the distinction between them in virtual wayfinding space.

I choose not to use the word path to avoid conflicting with *pathfinding*. In virtual spaces paths (and by extension pathfinding opportunities) are often easy to spot and follow, while finding the correct way without them is much more challenging. While pathfinding focuses on trying to cut through the environment to navigate it efficiently, wayfinding is intertwined with the nature of the space itself, regarding the landscape as a three-dimensional space in which to find a multitude of possible ways through.

Throughout the thesis I use wayfinding games extensively, both as literature to draw upon, and as the platform for exploration for the research itself. While the digital revolution has resulted in a cornucopia of software – from word processors to business management tools to 3D design packages – games have been the preeminent type of software that incorporates concepts of space and wayfinding. I align with Tim Germanchis' standpoint that "advances in games and digital entertainment has been swifter than multimedia tools." (Germanchis et al., 2005, p. 2). Since I embarked on this research, the gap between games and multimedia tools has only increased. The number of people exposed to games has increased dramatically. Germanchis' asserts that 75% of under 30-year-olds have played games at some point, whilst 40% of the world population and 88% of 16-24 years olds in the UK are playing games regularly (Baker, 2023). It is reasonable to claim that games are one of the main ways that 'space' is created digitally, with most examples of digital space being games.

There are many practical advantages and relevance to working with games when exploring wayfinding in virtual space. Because games are so good at creating digital spaces, other non-game software has started to adopt ideas from games (this is evidenced in various ways throughout (2a) and (2b)). Moreover, there is a great baseline of familiarity because many people play games, games are widely available and their design language well developed. Beyond even this widespread familiarity and rich design history games have, it is also easier to do research looking at virtual spaces using games because of how easy it is to access tools to edit and create them.

Before moving on to the outline of the sections within this thesis, I would like to clarify the way I have approached the research and the first-person style it is presented in. Research through Design (referred to as 'RtD' from now on) is the methodology which scaffolds all the other sub methods used to underpin this research and is concerned with the pursuing:

> "some variation on user-centred design… that some contact with the potential audiences for the things we make is desirable before, during or after design work itself… that exploring a wide space of potential designs, whether through sketching, scenarios, narratives or design proposals, is crucial in achieving a good outcome. Most of us appreciate the value of craft and detail in our work. Most fundamentally… that the practice of making is a route to discovery, and that the synthetic nature of design allows for richer and more situated understandings than those produced through more analytic means" (Gaver, 2012, p. 942).

RtD has been described in terms of "drifting by intention", leading to a research practice where "what the study loses in relevance it gains in depth" (Krogh & Koskinen, 2020, p. 62). This type of RtD requires a high level of interpretation and reflection, justifying wayfinding as both a method and subject within this thesis. Drifting with intention is about exploration, as is wayfinding. Thus I use drifting as a methodological wayfinding, creating a thesis where wayfinding is both method and topic. Due to the subjectivity and personal nature of interpretation and reflection, I decided that the thesis would benefit overall if I allowed the writing style to sometimes take the form of a personal narrative. I will further unpack how and why the drifting interpretation of RtD is a valid and robust approach when discussing the methodology in sections (0c.11) and (0c.12). Reflecting a contemporary commentary on RtD, this thesis is not a quest, but a journey, and in this it becomes complex and redefines the questions it seeks to answer throughout. Using "emergence as a feature of practice-based design research" (Gaver et al. 2022) my research constantly questions and requestions itself, and "instead of valuing projects that adhere to the theories, methods, procedures and predicted outputs they started with", it embraces the unexpected findings and directions that emerge through RtD.

0a.2. Outline of the Thesis

Moving on from the introduction where I defined my usage of concepts including wayfinding and virtual space, as well as my rationale for employing games so extensively and my varied meaning for the term accessibility, I am now able to define the main aim that drove the research in this thesis.

This research is concerned with designs that facilitates movement through virtual space for different user groups and how this can be enhanced to provide more equitable virtual spatial experiences. It aims to find patterns and guidance for designing virtual spaces, especially when considering their wayfinding and accessibility affordances. The thesis takes the shape of a sandwich. In the middle of the thesis is the 'filling' of the three main sections (1, 2 and 3). These focus on the topics of over-specificity, ambiguity, and legibility, respectively (visualised in figure 1). Sections 1, 2 and 3 are sandwiched by the introductory section (0) and concluding section (4). Each of these sections contains multiple chapters that are signified by letters (e.g., 0**a**, 0**b** and 0**c**), and the smaller subheadings within these sections are continuous throughout the entire section (e.g., 0a.**1**, 0a.**2**, 0b.**3** and 0b.**4**) rather than just in the chapter itself due to the continuous nature of each section between their literature review (part **a**) and data chapter (part **b**). To help clarify this further I've included a map of the sections as well as an explanation of their purposes.

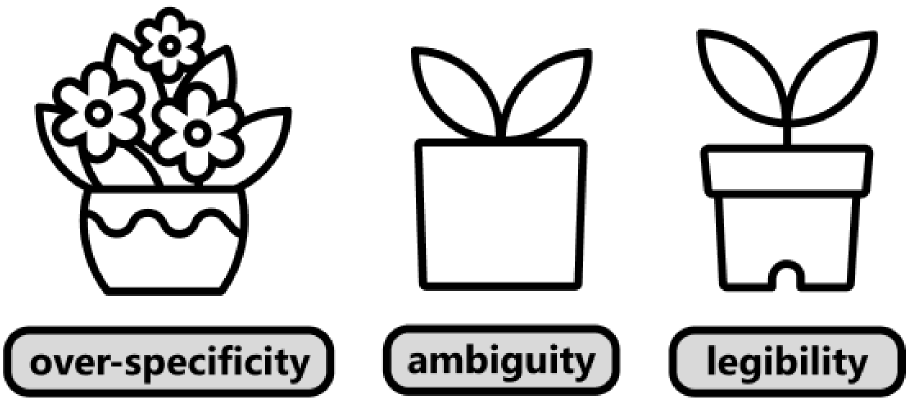

Figure 1. Note: Over-specificity, ambiguity and legibility in design. Reprinted from *Dribble*, n.d., Retrieved February 7, 2024, from https://dribbble.com/shots/2106737-Iconwerk-Aha-2

Section 0 can be considered the foundation of the thesis, laying the underlying structure which section 1 begins from with big 'R' Research through its data chapter. It contains this introduction, a literature review, and the methodology. The introduction and outline (0a) explain the background, stylistic choices, and overview of the thesis. The literature review (0b) unpacks previous related research, explains the gap the research seeks to address, and grounds the subsequent sections in relevant literature relating to wayfinding, accessibility in design for virtual spaces, and games. The methodology chapter (0c) explains how various methods are used in the practical projects that follow, establishes the epistemology of the work, and articulates how the research is, overall, framed as RtD.

Section 1 is the first of the three main sections and explores the concept of over-specificity within virtual space through a literature review chapter (1a) and a RtD exploration chapter (1b). Each of the second parts of sections 1-3 (1b, 2b and 3b) is often referred to as a data-chapter throughout this thesis. This aims to denote the fact that these chapters focus around 'Research' I myself have done, rather than the work of others. This section exhibits the drifting quality of RtD, wayfinding through several different topics. Unifying these topics is the aspiration to closely represent the real world in a digital form. While the section is eclectic and jumps between different concepts rapidly, it creates a scaffold which allows section 2 and 3 (focused on ambiguity and legibility) to begin to tackle specific issues around accessible virtual wayfinding.

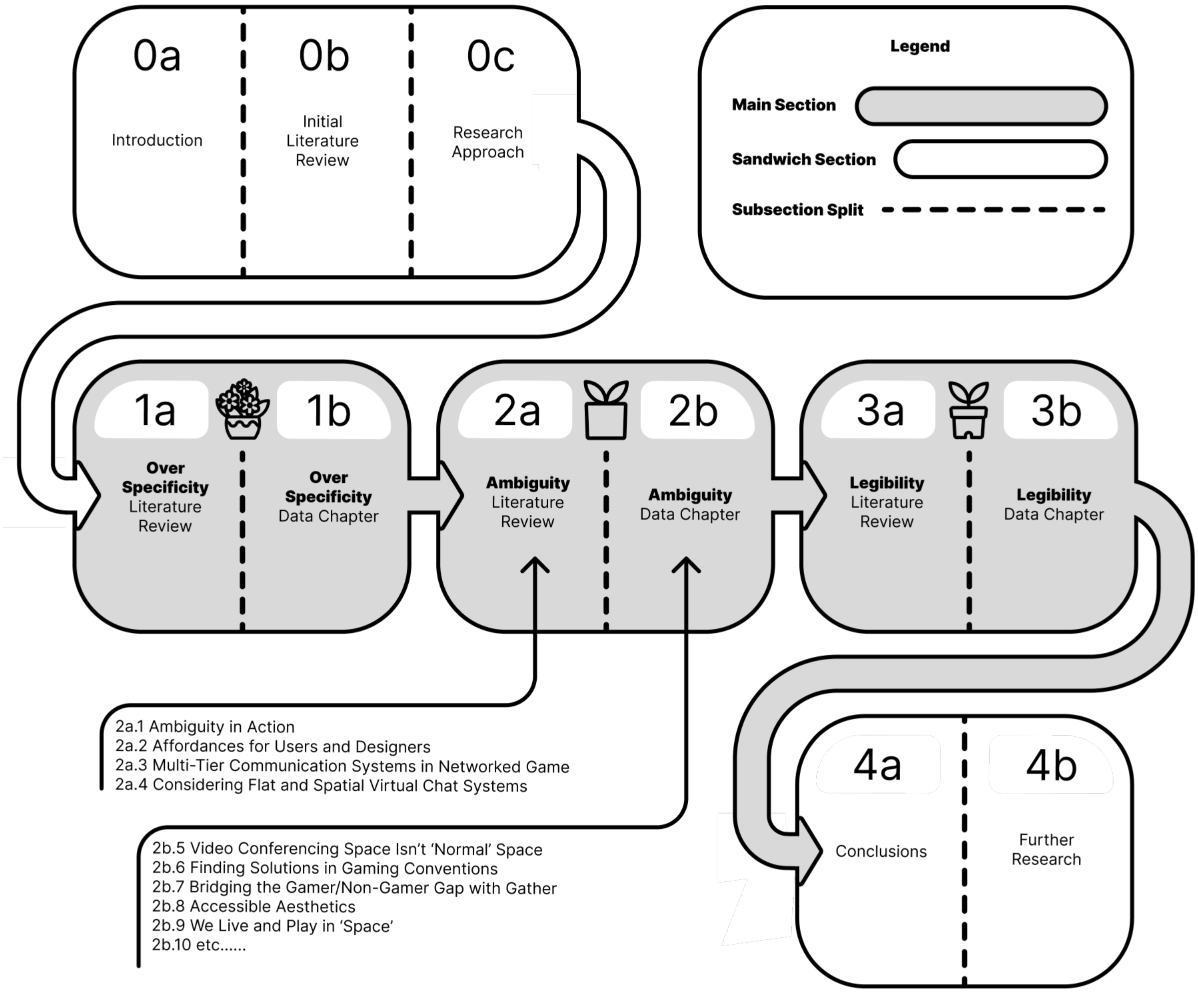

Figure 2. Map of Thesis.

Section 2 include a literature review (2a) that explores ambiguity. 2b is an RtD reflection on a series of spaces designed in *Gather* (2020). Gather is a two-dimensional spatial web conferencing system we used to explore user interactions through varied kinds of virtual space design. This chapter considers the risks of creating designs that are too simple and abstracted (expecting users will translate knowledge from game wayfinding they may not have even experienced). "Ambiguity is not only a trait of visual communication, but also a characteristic of communication in general: a message always has (although to different degrees) multiple and sometimes even conflicting meanings, depending on the interactional context in which it is communicated" (Eppler et al, 2008, p. 392). Because this risk of ambiguity is always present, as in the case of figure 1 (implying flowers when the intent was a general plant), finding the right balance to create legibility is vital.

Section 3 seeks to find balance between the research in sections 1 and 2. It aims to rhetorically frame how to design for legibility through a focused literature review (3a) and then documents the process and findings from a co-design workshop exploring a non-visual audio-only game for a marginalized group (visually impaired people) (3b). It treads the fine line between 'over-specificity' and ambiguity, highlighting that accessibility is for everyone, as wayfinding requires universal access to be legible. This section continues to unravel virtual wayfinding, and in doing so leads towards design for accessibility as a solution to achieving this balance.

Section 4, the final section in this thesis, covers conclusions and reflections (4a). It also includes a discussion around the limitations of the research and explores possible directions for future research (4b).

0b. Literature Review

0b.3. Balancing Virtual Accessibility

While this research did not set out to focus on accessibility, it nonetheless became as integral to the research as wayfinding itself. To be able to discuss accessibility unambiguously, it is important to clarify my framing of the concept. Accessibility's dictionary definition is "the quality of being reachable or entered" (Oxford University Press, 2024). The factors that influence accessibility are variable for each person, but certain broad measures can be taken to reduce access issues for most people who need them. To mitigate the effect of different designers interpreting accessibility needs in varied ways, "international standards groups such as the World Wide Web Consortium (W3C) have created design checkpoints and standards for developers to use when creating their site content." (Kuzma, 2010, p. 141).

Certain governments have integrated these accessibility guidelines into regulations. For example, the UK government requires that public sector websites' "accessibility regulations build on your existing obligations to people who have a disability under the Equality Act 2010 (or the Disability Discrimination Act 1995 in Northern Ireland)" generally aiming to facilitate accessibility when it is a reasonable accommodation (Central Digital and Data Office, 2023). The European Commission also has a directive which effects products including "consumer general purpose computer hardware systems and operating systems for those hardware systems" which are "placed on the market after 28 June 2025" (European Parliament, 2019), stating they should be designed in a way to maximise their accessibility, doing "so via more than one sensory channel; this shall include providing alternatives to vision, auditory, speech and tactile elements" (ibid).

If we focus specifically on video games, accessibility is rarely if ever 'enforced' due to the lack of any relevant legislation. Although not legally protected, colour-blind modes, controller remapping, subtitles and dyslexia friendly fonts are relatively straightforward to implement. "Inability to follow a storyline… Unable to complete a puzzle or task… Unable to determine how a game is played" (Bierre et al., 2005, p. 23) and even repeated player deaths are often unavoidable when a player is unable to access information either through exclusively audio or visuals means due to a particular impairment making some senses unavailable. The reliance on exclusively sight and sound is not only problematic for video games, but also all virtual spaces and digital experiences. This reduced virtual sensory bandwidth is vital to consider before being able to improve virtual accessibility and wayfinding beyond the existing common place accessibility features mentioned previously. To help to understand the kinds of accessibility issues which may be commonplace in digital software and virtual spaces, I will look at these spaces in terms of the sensory ‘bandwidth’ that is available.

0b.4. Virtual Sensory Bandwidth

Sensory differences between physical and virtual spaces make virtual accessibility which works for all users’ needs complex. In part, this is due to a lack of smell and taste sensory information in virtual spaces, a reduced ability for touch-based information to be utilised, and two-channel stereo (usually through headphones) becoming engrained as the most common and consistent way of listening to audio information in games. However, it is important to note that game engines do include audio systems which are able to spatialise this audio further, even though only two speakers, enabling this audio to feel like it is surrounding the player. Furthermore, outside of game engines, operating systems can have their own spatialisation systems such as Dolby Atmos or Windows Spatial Sound which aim to create this spatial effect on any audio. Alongside this, some headphones have smaller additional speakers in each ear or other hardware solutions to get closer to a surround sound spatial audio. Finally, it is worth noting some players do use home cinema systems such as Dolby Atmos setups with more than 2 speakers spread throughout the room (commonly known as 5.1, 6.1 and 7.1 for their respective number of speakers). The variety of ways in which we can sense information about the world by splitting the information into different sensory channels to make the data less overwhelming and more digestible is extremely useful in interaction design. To consider how this differs in physical and virtual spaces, we need to first look at the difference between physical and virtual sensory/perceived bandwidth.

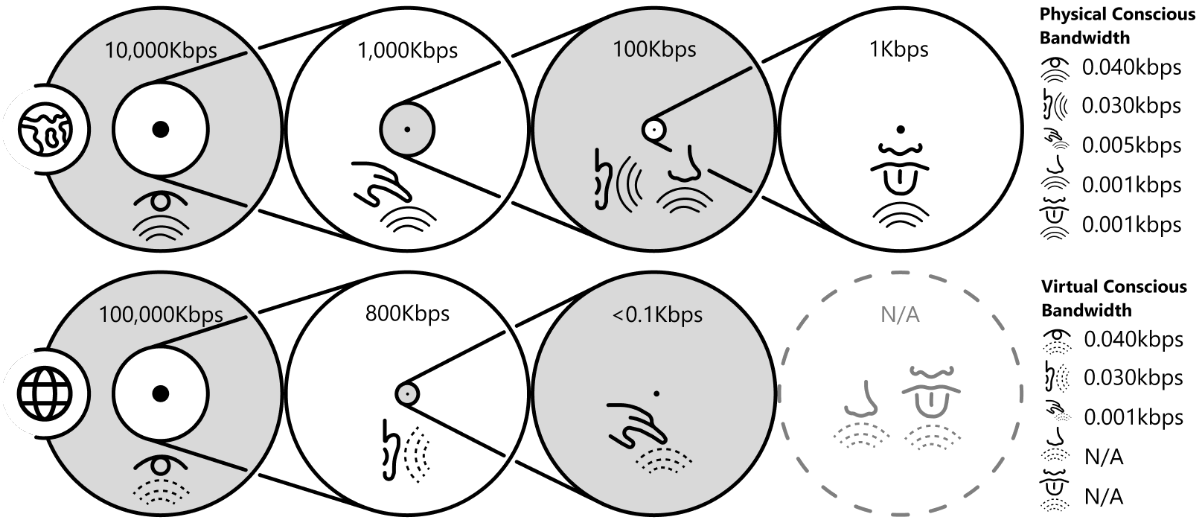

Figure 3. Note: Physical and Virtual Sensory Bandwidth. Adapted from *Sensory Art and Design* (p. 201), by P. Coulton, 2020, Routledge. Copyright 2017 by Paul Coulton. Adapted with permission.

Figure 3 visualises the difference between sensory and perceived bandwidth, showing that we sense much more than we can mentally attend to, and highlights that virtual spaces are limited in the information they can provide to our range of senses compared to physical environments. For example, even though in physical space touch provides more raw data, the perceived information from this is less than that from hearing. In virtual space this gap in conscious sensory bandwidth is widened due to a distinct lack of consistent rich haptic (touch based) interfaces, leading to computer systems which often omit its usage entirely.

While haptic interfaces do exist for digital devices, and controllers like DualSense (Fahey, 2020) are aiming to standardise its inclusion, even with such aforementioned 'haptic rich' semi-commonplace devices, sound still provides more information through conscious sensory bandwidth. Because of this lack of standardised haptic interfaces, virtual spaces are almost entirely designed for dual sensory interactions (sight then sound). Visuals are designed to function alone in most cases, with sound often merely providing immersion or ambience for those that want it. Whilst this is accessible for deaf users of digital devices, it offers nothing for blind users, or people with low vision. Because of this, the design and affordances of virtual spaces has developed differently to physical spaces. This is considered further in the subsequent section.

0b.5. Accessibility and Affordances

Affordances are a concept originally proposed by James J. Gibson (1977) to denote the "actionable properties between the world and an actor (a person or animal)" (Norman, 2004, p. 1). For Gibson affordances are not linked to awareness or usefulness but comprise the ways a person could interact with said object. Norman adds to this concept in the space of design with the notion of 'perceived affordances', which relates to our awareness of how we can interact with something. "Touch sensitive screens often make their affordance visibly perceivable by displaying a cursor under the pointing spot. The cursor is not an affordance; it is visual feedback" to illustrate the action of touch is possible. This key concept is important in interaction design, as designers must be aware of how to make intended interactions evident to the user. This challenge is even more important when considering the accessibility needs of an individual since perceived affordances may differ wildly on a per-user basis. Perceived affordances can also provide false positives, meaning there is an assumed affordance due to surrounding information, and such ambiguity should be removed to improve usability.

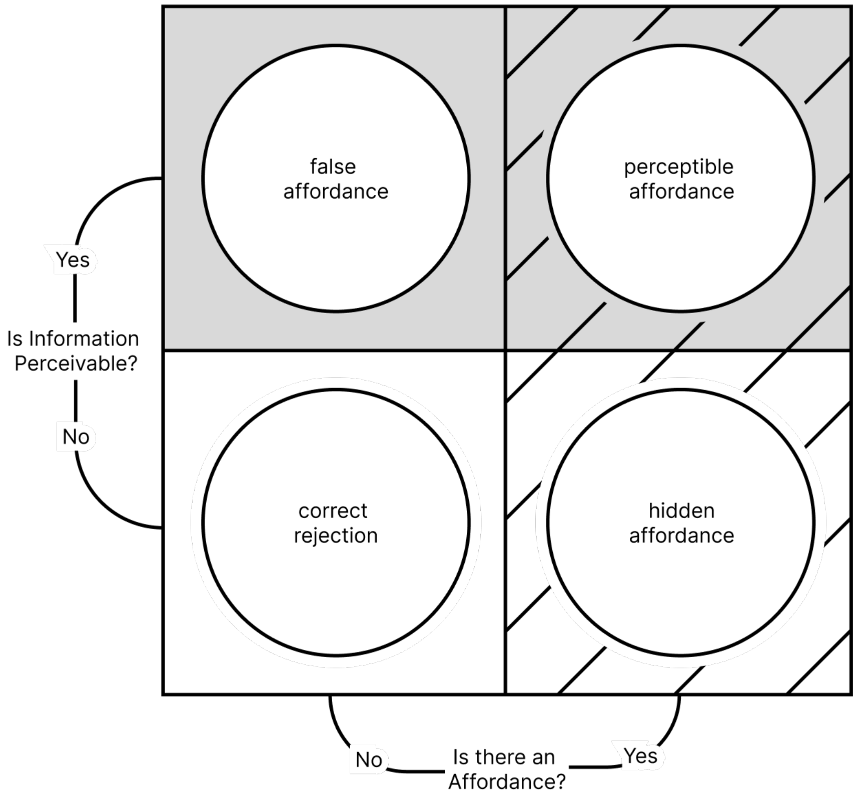

Figure 4. Note: False and Perceived Affordances. Adapted from "Technology affordances," by W.W. Gaver, 1991, *CHI '91: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, p. 80.

To illustrate this issue Norman highlights "none of us see doors as menacing obstacles, yet we have all experienced difficulties in knowing whether to push or pull and on the right or the left". According to Norman, this information should be built into a well-designed door (Norman, 1988, p. 141). Having a flat large panel on the push side, and a large obvious handle on the opposite pulling side is a key example of how this may be achieved. The modern manufacturing trend to put a handle and panel on both sides to reduce costs produces the need to add signs saying 'push' or 'pull'. For this research, we need to understand how these same concepts translate to on-screen interactions. Bill Gaver delves deeper into this concept of perceived affordances as shown in figure 4 stating, "affordances exist whether or not they are perceived, but it is because they are inherently about important properties that they 'need' to be perceived" (Gaver, 1991, p. 80). Gaver also introduces the notion of sequential affordances in which subsequent interactions flow naturally from one to the next. Perceived affordances are often implemented in both video games and digital interactions through 'skeuomorphs' which are designs meant to mimic or emulate "the reality of the objects themselves" (Mullaly, 1998, p. 13) such as floppy disks' likeness being used for digital save icons. Skeuomorphs are prevalent within virtual designed spaces due to their ability to create visible affordances very quickly (this was especially useful during the advent of digital technology when people were unaccustomed to using digital devices).

Affordances are closely associated to cultural conventions. “Over the last decade, the design of graphical user interfaces has seen several changes relating to its visual appearance. Skeuomorphism is being increasingly replaced by minimalist user interfaces” (Urbano et al., 2022, p. 452) and flat design as interactions become more commonly understood. Because of this acclimatisation, users can perceive more of the affordances allowed to them which previously had to be represented through skeuomorphs, limiting designs in many ways. These notions are something which I will return to throughout my thesis but are especially relevant when designing for audio accessibility where there isn’t a richer history of skeuomorphism to draw from.

0b.6. Early History in Virtual Wayfinding Design

To understand and talk about designs, and their perceived affordances (both correctly perceived and false affordances visualised in figure 4) for wayfinding in virtual spaces, it is important to first look at the history of wayfinding in such spaces. Virtual wayfinding has existed for as long as there have been computers and their associated storage of information. Hyperlinking, a concept introduced by Ted Nelson in the 1960s, has become the main method to navigate virtual sites. Now known commonly as ‘links’, “Hyperlinks introduce discontinuities of movement to 3D virtual environments” (Ruddle, 2000, p. 551) which make wayfinding in virtual space less predictable and continuous than in physical spaces. These links enable moving between pages on the internet in non-linear ways to support faster and more tangible movement between knowledge points which the user is interested in. They have many purposes and provide a universal system for virtual navigation. This invention was vital for websites to be considered as virtual ‘space’ as they lacked many of elements of physical space which help us way-find.

> “Structuring and identifying the environment is a vital ability among all mobile animals. Many kinds of cues are used: the visual sensations of color, shape, motion, or polarization of light, as well as other senses such as smell, sound, touch, kinesthesia, sense of gravity, and perhaps of electric or magnetic fields... Despite a few remaining puzzles, it now seems unlikely that there is any mystic ‘instinct' of way-finding.” (Lynch, 1960, p. 3).

The lack of varied and unique objects to enable wayfinding in virtual space (such as intertwining trees and potholed paths which help us so greatly in physical ones) leaves a requirement for the previously mentioned hyperlinking. Rather than being physically bound, in virtual space we can teleport, which is extremely important to provide a different kind of structure and identity to that mentioned by Lynch. Rather than each door needing a distinct look for us to maintain our bearing, we can simply teleport to the door (or website) which provides what we are looking for using varied search systems. Because we can navigate individual websites in this way and move between different sites by typing in their URLs the internet maintains a distinct lack of rich wayfinding. Digital file structures are similar in structure to hyperlinking on the web, with shortcuts enabling movement in non-linear ways as hyperlinks do.

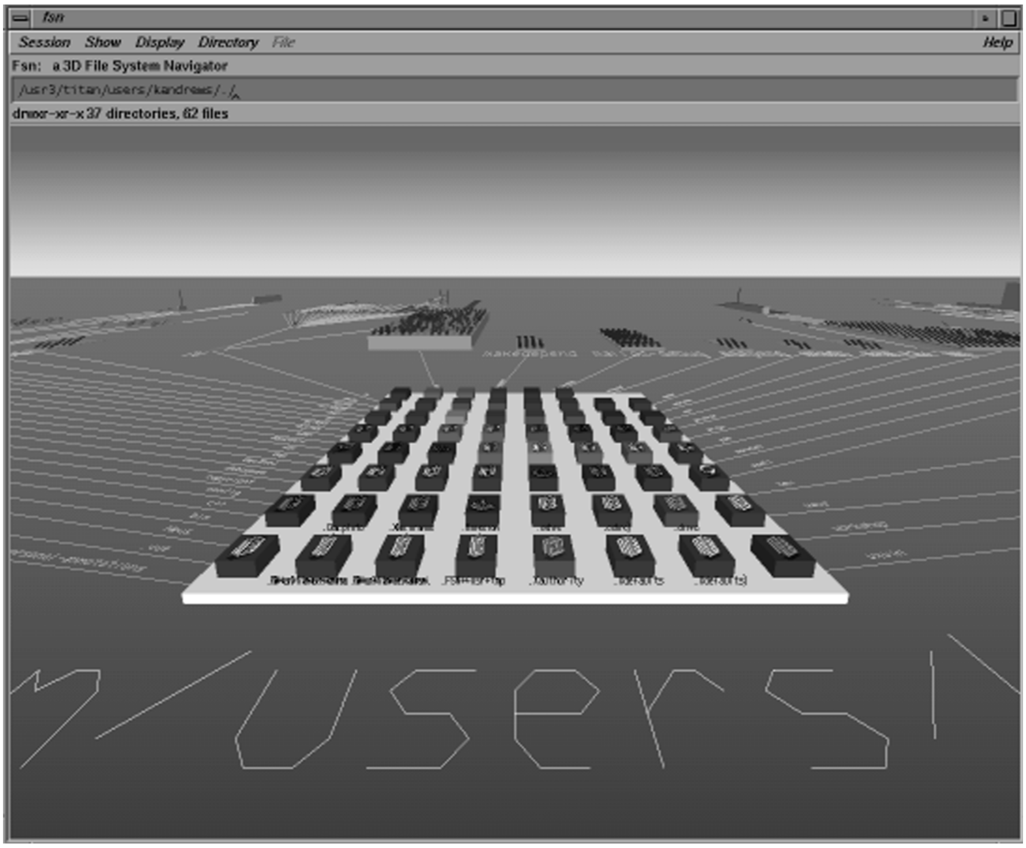

Figure 5. Note: Fusion File System Navigator. Reprinted from "Constructing cyberspace: Virtual reality and hypermedia," by K. Andrews, 1993, *Virtual Reality Vienna*, p. 5.

3D Spatial file navigation systems have been attempted, such as Fusion. "The File System Navigator (FSN or 'Fusion') written by Joel Tesler and Steve Strasnick at Silicon Graphics [TS92] visualises a Unix file system as an information landscape. Directories are represented by blocks laid out on a plane, their height representing the cumulative size of the contained files." (Andrews, 1993, p. 4). Despite being featured prominently in popular media at the time, such as in the film Jurassic Park, it failed to gain traction because people did not perceive enough benefit over existing file navigation systems and instead opted for visually flat hyperlinking systems.

While some other spatial systems for different purposes did exist within early virtual design, such as 3D scene viewers where users arriving from some "other node in the hyper media web are presented with a 3D representation of the scene", these remained non-mainstream due to plug-in and specific browser requirements. The Virtual Reality Markup Language (VRML) was aimed at bringing 3D graphics to the World Wide Web, but "unfortunately didn't gain the broad adoption its supporters had hoped for." (Parisi, 2012, p. 7). This was due to the sheer complexity in coding for it, as well as the limitations on it due to being bound to OpenGL API's fixed function graphics pipeline. This made it impossible to add visual effects beyond those in the original API. WebGL was eventually able to leverage the power of OpenGL differently using hardware acceleration (Leung & Salga, 2010). However, by this point file storage systems had already become skeuomorphs of physical file storage which users had become accustomed.

Jumping forward from these early file and information navigation systems, I want to consider more recent virtual 'spaces' which are immersive. Davies "thinks of virtual space as… spatio-temporal" (2004, p.69-70). His view of virtual space is that it must be "in three dimensions and be animated through time". I agree with this and believe that games are arguably the primary virtual spaces to do this both successfully and consistently. I have taken concepts from and used simplified versions of different game controls and visuals in all three of my data research chapters (1b, 2b and 3b), just as developers of non-game virtual space are currently doing with *Gather* and *Mozilla Hubs*.

Non-game virtual spaces common referred to as "Social Virtual Environments" offer users "interactive 3D settings where people are represented by virtual characters that inhabit… artificial environments." (Hagler, 2022, p. 19). These systems offer information and file navigation in very similar ways to the early Fusion File System Navigator. These systems leverage a rich history of both solo and multi-person spatial virtual experiences in new ways taking from Fusion and game design alike. Because games have proven to be enjoyable, accessible, and navigable for a reasonable subsection of society, the assumption that their control schemes and design languages can be re-used in non-game settings seems logical.

In the 65 years since *Tennis for Two* (Higinbotham, 1958), arguably the first ever video game, games have been refined to incorporate many lessons learned about accessibility, navigability, affordances, and control systems. Hence, by looking at their past successes and failures, arguably we may find productive inspiration to begin redesigning improved virtual non-game spaces for the modern world.

0b.7. The Origin of Video Games

By using an oscilloscope to display a ball and then using a knob and button as controls, *Tennis for Two (Higinbotham, 1958)* - which, incidentally, heavily resembles *Pong* (Atari, 1972) meets many of the basic requirements to be defined as a video game. First, "video games are, before anything else, games" (Frasca, 2004, p. 1), and second, a "video game is a game which we play thanks to an audiovisual apparatus" (Esposito, 2005, p. 1). While there were earlier attempts to create what could be defined as video games, these often-required physical objects to make sense of events taking place in the computer, such as the *Draughts Program* (Strachey, 1952), and were focused on technical demonstration rather than being designed principally as a game. *Tennis for Two's* popularity was very localised due to the inaccessibility of the devices it could run on. *Pong* however proved *Tennis for Two's* mass viability as a game when it was released over a decade later through more attainable hardware but largely similar mechanics.

Aptly named when considering this thesis, the first commercially available video game was *Computer Space* (Nutting Associates, 1971), recreating an earlier game *Spacewar!* (Russell, 1962) for the much larger arcade audience. *Computer Space*, like many games at the time was distributed within specific hardware due to it being more economical, meaning it could have bespoke interfaces and controllers if required. While affording the player the ability to move within space, reaching the edges of the screen transports you to the opposite side, and with no obstacles to avoid, and all 'space' being always visible, wayfinding was likely a minor consideration here. Due to its arcade genre, it prioritized simplicity and fun mechanics over vast explorable worlds.

Video games were boosted in the 70s when "advances in semiconductor technology make it practical to integrate complex digital computers onto a few chips suitable for use in a variety of consumer-oriented applications such as video games." (Mazor, 1977, p. 1). While early home video games were made possible due to the forementioned chips, they also benefited from advances in TV resolution and colour. They were still simpler than the most advanced games that could be played at arcades, where more expensive and powerful hardware was available (but taking up much larger physical volume). Numerous other games followed on in similar fashion alongside *Pong* and *Computer Space,* with most games in the following decades being of similar style with little wayfinding needed, and locations rarely being returned to, removing the need to feel familiar in them and begin to know them.

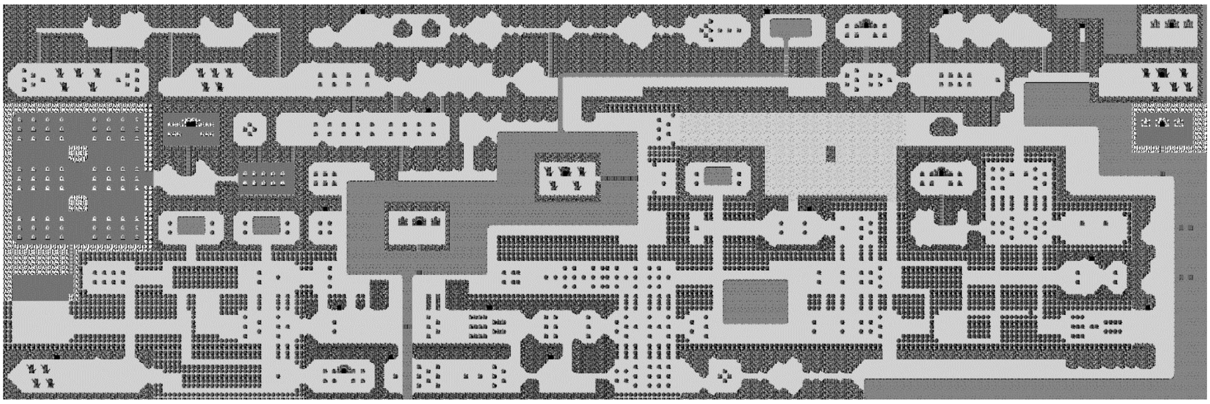

Figure 6. Note: The Legend of Zelda Overworld Map. Adapted from NES Maps, by R. N. Bruns, 2009, from https://nesmaps.com/maps/Zelda/ZeldaOverworldQ1.html. Copyright 2009 by Rick N. Bruns.

Jumping beyond this initial potted history, a familiar game to most, *The Legend of Zelda* (Nintendo, 1986) (heavily inspired by *Ultima* (California Pacific, 1981)) started a franchise which continues to push the boundaries of virtual space and wayfinding to this day. While MUD games (encompassing Multi-User dungeon, domain and dimension games which are usually text-based) did exist prior, their lack of movement and visuals makes them non-video games even if they play a significant role in digital game history having their own wayfinding language.

> "Text adventures render their setting and their spaces as language. This may seem like an unnatural mode in which to understand something spatial, but text adventures can represent space effectively, even portraying spaces in figurative or unusual ways to create interesting puzzles for the player." (Montfort & Bogost, 2009, p. 45).

While there is significant value in this alternative style of wayfinding, for the purposes of visual wayfinding (the most common wayfinding in modern video games), *Ultima* was the first game to include an 'overworld', a term in video games used to denote a space which is in some sense a hub. It connects various other spaces attached to it such as dungeons, other dimensions, levels, or any other location. Usually, a safer space than those connected to it, overworlds are common in adventure, RPG, dungeon crawler and multiplayer games (where they may be called a hub world instead and serve as a restocking and questing hub). Overworlds are a space within games rich with wayfinding, often connecting quite linear locations together as a non-linear explorative place. Because of this I will consider the invention of overworlds as the beginning of significant wayfinding alongside open-world video games.

0b.8. Wanderlust and Disillusionment in Open-Worlds

Now we have established where both open-world and overworld concepts in games came from we can begin to analyse their usage and successes and failures in their implementations. "Open-world digital games pose significant challenges for game designers. Open-world games' emphasis on player autonomy is at odds with game designers' focus on crafting coherent storylines" (Min et al., 2016, p. 2590). Because "it is difficult for game designers to craft compelling stories if they do not know, in advance, what actions the player is going to take next" there are two main approaches for achieving convincing open worlds.

The first approach is to metaphorically hold the players hand and create systems that prevent them from deviating from the main narrative path. This requires making certain areas impassable until items or objectives are achieved. This can be achieved through severe weather, experience levels, artefacts or almost any other manner, and can be suggestive (meaning the player can deviate but with significant resistance) such as "drawing the eye to an item of interest, and narrowing physical spaces/architectural pressure to channel the player" (Nisbet, 2016, p. 23), or finite (meaning the player simply cannot access said area). This kind of system can be rewarding, giving players some sense of achievement in an otherwise directionless game, but also can remove from the sense of discovery if barriers are completely impassable and the rational for this impassibility is not convincing (either mechanically or narratively). This kind of system is implemented most in games where quests have specific locations and worlds are non-generative, but also works well when these locked off sections are dungeon-like and the main 'overworld' is explorable and free to roam very early on, such as in *The Legend of Zelda: Breath of the Wild* (Nintendo, 2017) or *World of Warcraft* (Blizzard Entertainment, 2004). *Breath of the Wild* does this exceptionally well, with its sequel furthering its innovations by taking many common place tropes in open world games such as map de-fogging (the process of making the map's objectives visible through exploration), barrenness and travel across overworlds and turning these weak points of most open world games into arguably the most enjoyable sections.

The second approach for creating convincing open worlds is to have objectives tied procedurally to the world. Games such as *No Mans Sky* (Hello Games, 2016) and *Minecraft* (Mojang Studios, 2011) are good examples of this. Each time the player starts a new save, they are placed in either a specific world in an essentially infinite universe (*No Mans Sky*), or a randomly generated world from essentially infinite options (*Minecraft*). In both these game systems' actions cannot be tied to one specific location due to the sheer scale of the environment. It would be impossible to journey around them, even in a full human lifetime. Because of this, quests and location access need to be tied to more procedural events. In *No Mans Sky* small clusters of planets have 'Space Stations' which provide marketplaces and missions with similar hubs existing in *Minecraft* called 'Villages'.

> "The downlights illuminating the path to the right and those illuminating the path to the left had an equal level of illumination, 69% of the people went to the right. Whereas when the path to the left had a higher level of illumination, 75% of the people went to the left. The study found that basically people are like moths—attracted to brightness." (Ginthner, 2002, pp. 2-3).

Both previously mentioned games include many more types of generatively placed structures which provide wayfinding opportunities in moments where a good wayfinding aim would otherwise be unapparent. All these structures are lit to highlight them significantly (especially at night when the landscape itself becomes less clear). In *Minecraft* this is done when there is little else to do above ground and in *No Mans Sky* this is useful in the void of space when the player wants to seek refuge and save the location for later access. Ginthner highlights the idea that game developers can rely on the fact that humans are somewhat like moths, which are attracted to light. However, it is also important to realise that when options might seem equal as a designer, humans may have ingrained habits which lead them to pursue a specific path more commonly, such as the 69% of people choosing the right path when both are equally illuminated. This issue can be counteracted in video games with rewards prescribing the value of wayfinding goals to the player. This phenomenon is an important aspect of games which can translate poorly to non-game virtual environments such as Gather, as explored further in section 2 (2b.12).

In both types of open world game (generative and curated), movement generally accelerates as the player continues through the respective game. 'Tower' systems (where a player climbs, powers or completes a puzzle around a usually tall structure in order to reveal more objectives around the nearby map) multiply this increased movement speed by providing in game systems to map locations and teleport to. *Breath of the Wild* succeeds in fusing some of benefits of both above approaches by opening-up the options for achieving objectives by providing many pathways to success in most questlines or player defined obstacles. This progression of open world games begins to blur the line between the two main types and is leading towards a new paradigm for open-world game design. It is no surprise that 'openness' is a key factor in designing enjoyable open-world games. While in the past it may have needed to be faked, procedural systems have come a long way and game tropes have expanded to the point where many simpler concepts have become subconscious allowing game developers to build more complex systems on top of these subconscious ones which the player can comprehend. It is also key to note that a sense of wayfinding mastery is also important in open world games. Having devices 'unlock' in-game often makes this progressively easier by increasing the player's sense of understanding of their virtual environment. The opposite can occur when concepts like 'Change Blindness' are introduced, gradually reducing the obviousness of in-game wayfinding markings at a rate where the player gradually becomes oblivious to them. This provides a consistent sense of wayfinding by counteracting the players increased understanding of the game with reduced queues to detect information (Nisbet, 2016, p. 38).

Physical Barriers or Choke Points, Lights and Path Highlighting, Colour, High Ground, Sound and Motion all play roles in wayfinding in games. This wide range of visual and spatial queues means that "perceptual and environmental psychology, fine art, architecture, urban planning, and design all contribute valuable information to creating immersive game wayfinding cues." (Nisbet, 2016, p. 33). The same therefore also applies to wayfinding in other virtual spaces which draw from game design tropes. While there is much more to game wayfinding design, I believe the basic explanation of how open-world games achieve enjoyable and understandable overworlds above is enough grounding to validate considering wayfinding in virtual space through mixed academic fields in the subsequent pre-data-chapter literature reviews. Beyond what is happening in-game, it is also vital to virtual spatial wayfinding that we consider the controllers and interfaces which provide access to input and output information enabling us to navigate and comprehend these virtual spaces.

0b.9. Controllers and Sensory Output in Games

Sensory output (usually facilitated through screens, speakers, and controllers) is an essential component of interactive games. Information must be bi-directional for the user to react and play in response to the game's mechanics. As I mentioned previously (0b.7), early games had more autonomy as to how a controllers should operate and react largely due to the lack of interoperability between consoles, and also the rapid acceleration of video game development. This often made it cheaper to produce specific hardware for each game, rather than using something generic (especially in the arcade context) (DeMaria & Wilson, 2022). As players had little experience and thus expectations for controllers changing them for each game was seen as normal. While some controller innovation does still occur, it is diminished in variety and scope. Looking back at historic examples of controllers will shed some light not only on how games evolved, but how future games might benefit from some of these learnings, especially when considering accessibility needs. When we consider controller history alongside the games they were built for, we can regard game wayfinding design from a more holistic perspective, considering the physical and digital aspects which limit their usage and understand their interaction design more thoroughly.

While very early home systems – such as the Atari Home Pong (Montfort & Bogost, 2009, pp. 10-24) - only allowed a single game to be played, Atari soon realised devices like this would not scale as consumers would be very unlikely to want bunches of them around the home. Instead, they opted for separate wired controllers and pluggable game cartridges (which contained the games) to go alongside a standardised console such as the Atari VCS Paddle Controller, which meant different controllers can be swapped in for different games. "The first gamepad (also known as a joypad) arrived with the Atari 7800, but it was with the Nintendo Entertainment System (NES, that it was used to its full potential." (Cummings, 2007, p. 3).

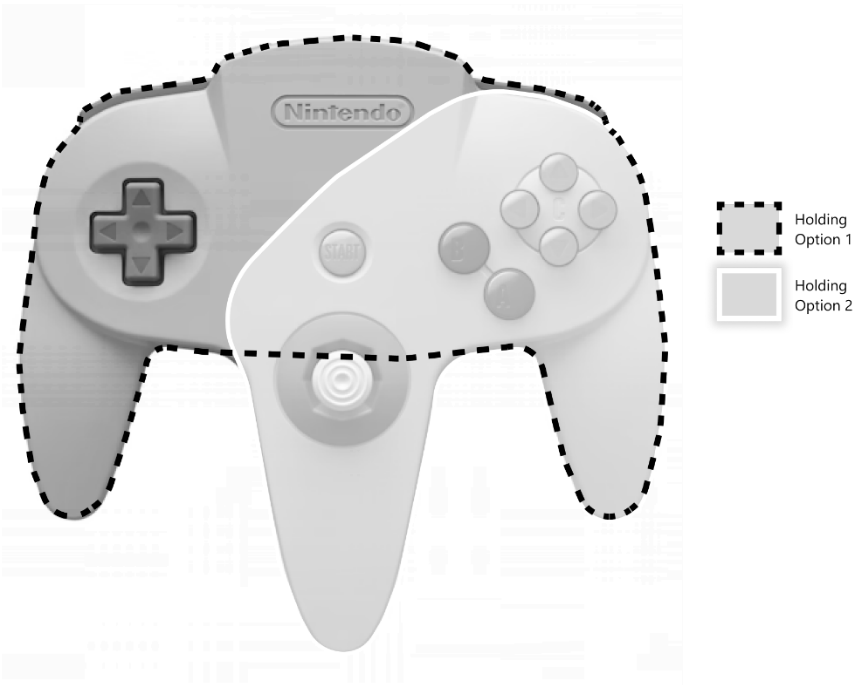

Figure 7. Nintendo 64 Controller Holding Options.

The conflict between joystick and joypad existed for many decades until joystick accuracy surpassed joypad reliability around the advent of the original PlayStation and Nintendo 64 (N64) consoles. The N64 "controller included an analogue stick, a small joystick-like device that enabled the user to provide a vector as directional input. The stick can be pushed in any direction and does not have to be pushed all the way out (hence providing a size of the movement)." (Cummings, 2007, p. 4). While this controller was designed to be held in several ways to enable gameplay and design variety, it was generally held on the centre and right handles, leading for later controllers to only ship with these handles. The controller was specifically designed to work well with 3D games, especially Mario 64 – the console's flagship title. "During the development of this game, the hardware and software developers worked together to discover what was necessary from a controller for a 3D platform game. Prior to the start of Mario 64's development there had been few 3D and no 3D platform games." (Cummings, 2007, p. 4). This analogue stick innovation allowed control of both the player character and camera, even if the camera's movement is notoriously clunky compared to modern titles (due to it being split into snap rotations). "The Playstation Dual Analogue controller added 2 analogue sticks, giving it the… means to control the camera in games more accurately". (ibid, p. 5).

Figure 8. PlayStation Controller 1994 (Left) DualShock 1997 (Middle).

PlayStation released their debut console 2 years prior to the release of the N64, drawing inspiration from Nintendo's previous console the SNES (Super Nintendo Entertainment System) for its controller design, with movement on the left and action buttons on the right. A year after the N64's release, PlayStation briefly released a dual analogue controller for use with specific titles - likely in reaction to the success of *Super Mario 64* (Nintendo, 1996) - followed swiftly by the DualShock controller. This had four iterations before becoming the DualSense. To this day, any game purchased on a PlayStation 5 can be played with the DualShock 4 controller, which functions in entirely the same way as the original DualShock from 1997 besides gyroscope, rumble and trackpad functionality. Each of these are non-essential to almost any modern game released.

This settling in controller design reflects a settling of sensory input within games design which occurred around the 1990s. While motion controls and VR systems have existed since (with Nintendo continuing to push controls more exploratively) these have come and gone, with the dual-analogue scheme becoming standard amongst all console developers, forcing game designers to follow suit. Games on PC are no different with RTS (Real Time Strategy) titles being generally restricted to mouse and keyboard input, and first person shooters adopting mouse and keyboard control schemes through *Quake* (GT Interactive, 1996)

> "Quake added a control option known as Mouse look. This is the ability to use the mouse to control where the player is looking at in the game, rather than using keyboard buttons for this function. A side effect of this was that the now redundant turn left and turn right buttons became strafe (sidestep) left and strafe right. This control system was superior to using the keyboard to look due to the ability to change the vertical angle, increased accuracy, and increased speed."

These became the default controls in *Quake 2* (Activision, 1997), with this control style persisting to this day across all first person games played with mouse and keyboard.

The combination of dual-analogue sticks being tacked onto existing controller design being the most usable console control scheme for 3D games, in tandem with mouse and keyboard usage being even more effective (with mouse and keyboard being designed for entirely non-game purposes) puts into question all design for game control input. If the two most common place systems which exist in modern games were stumbled upon and work (with little attempt to challenge them), is there not an extreme likelihood that better control systems could exist? The fact that these controls systems became normalised at a time where controls schemes were becoming much more standardised and widespread may be their primary reason for success. Because of this, there is a strong argument for alternative designs for controllers (or at least adaptations of existing ones), especially when regarding accessibility. This is something I will explain more deeply in the subsequent literature reviews, but for now the point remains that wayfinding in virtual spaces is likely constrained by the input modalities which we access them through. While there have been several forays into more dynamic types of game controller (especially with the generation of consoles released post 2005 as games were becoming extremely mainstream and exercise was seen as key selling point) from Nintendo's Wii remotes, to PlayStation Move and Microsoft Kinect (Scheer et al., 2014), we have now settled on a games era where dual joystick controllers are the norm across Xbox, PlayStation, and Nintendo consoles due to the cross-released nature of games. PC games are principally controlled using mouse and keyboard which heavily mimic and can emulate the outputs of a controller consistently and mobile games are either using touch controls bespoke to the game, or also emulating dual joystick controllers on their touchscreens.

It could be argued that Virtual Reality (VR) offers the best chance at breaking away from the norm we have developed in controllers, as well as the standard sensory outputs we have begun to see focused on visual only (higher resolutions and refresh rates). VR "presents unique opportunities for the implementation of audio feedback congruent with head and body movements, thus matching intuitive expectations" (Bosman et al., 2023, p. 1). However, the importance of improved spatial audio does not need to be tied into VR to make it useful. VR is expensive, and therefore inaccessible for entry level virtual wayfinding in terms of cost alone (not to mention common issues with motion sickness when using it). Standard controllers are accessible, well documented, and have familiar conventions to work from. While there is no doubt that revisiting game controller design from the ground up would be beneficial for users, due to existing controllers' widespread familiarity, it is more useful for the purpose of this research to focus on how to make accessibility work through existing interfaces first. Therefore, for the purposes of the research within this thesis, while input and output are highly relevant, I do not intend to reimagine their designs, but rather reconsider how their designs can be used to provide improved accessibility through greater heterogeneous sensory wayfinding in virtual spaces.

To begin attempting this improvement process it would be tempting to look towards existing research, games and software which has attempted to deviate from normal sensory outputs in the design of wayfinding for virtual spaces.

> "If you are designing a new version of something that already exists, 'state of the art' is the most useful starting point. The chance to set a precedent with something completely new is rare. In most cases you are designing a new version of something that is already there, so you can research what has been done before, learn the lessons from previous attempts, discover guiding principles, and extract knowledge from the precedents." (Moggridge, 2007, p. 726).

However, as explained previously with the sensory bandwidth diagram, users of digital virtual spaces are usually only afforded visual and auditive sensory interactions. While there may be some haptic inputs through controller or mouse movement, outputs for this are not common and so audio and visuals are the main senses we can use to explore virtually. Therefore, for the subsequent literature reviews before each data chapter, I will focus on alternative designs for legible wayfinding that use standard interfaces and hardware. Through analysing these sensory experiences, I aim to situate my own research within relevant work and identify gaps I see within it to give my lines of enquiry clear origins.

0b.10. Summary

To recap this preliminary literature review, considering the fine balance between ambiguity, legibility, and over-specificity in the wayfinding of virtual space has identified a need for more general accessibility. Through this need for accessibility in wayfinding I have considered the impact of an altered sensory bandwidth within virtual spaces (essentially cutting off all senses besides sight and hearing) and how this differs from physical space where touch, smell and taste is prevalent. This altered sensory bandwidth causes a shift in both perceived and actual affordances, which is further altered when the accessibility needs of blind, visually impaired, and deaf users are considered. By exploring the history of virtual wayfinding design to better understand how we might make it more inclusive, a distinct lack of widely adopted virtual spaces was identified beyond game spaces. This led to the investigation of video game history through the lens of wayfinding. Open-world games play a significant role in the development of this virtual wayfinding due to their reliance on exploration and therefore they also needed to be analysed. To consider the play of these types of games better, their input systems, or controllers needed to be examined as well. Probing controller design history, it is reasonable to suggest that they have become homogenized, and therefore when designing virtual spaces of the future, it is necessary to design for these dual-analogue stick controllers when considering accessibility.

This summary aims to situate the subsequent sections in a broader wayfinding legibility analysis. Each data chapter considers a different approach to sensory design for legible and accessible wayfinding (1b, 2b and 3b) which is sub-situated through research and games analysis around its topic (1a, 2a and 3a). Each data chapter maintains the narrative established here whereby widely available hardware (computers, controllers, and other peripherals) are used to conduct research which intends to have tangible effects on changing or creating real software which people can use. While the following research questions have been superseded by more specific ones related to each chapter which I outlined at the end of the abstract, they succinctly ground the initial direction of this research:

- *What is Legibility in Virtual Spatial Wayfinding?*
- *How Can We Improve it?*
- *When is a Virtual Space Over-Specified?*

0c. Research Approach

0c.11. Drifting and Flow in Design Practice

In this chapter, I aim to describe my research Epistemology, Theoretical Perspective, Methodology and Methods. I will consider my research perspective holistically by looking at the methodology and methods I practice and connecting these to ontological positions and other epistemological theories. By rationalizing my methods, including describing the relationship between thought-experiments, individual prototypes, and fully-fledged projects, I hope to shed some light onto how the research within my thesis evolved through time. Before I get into the messier part of this chapter, I would like to make it clear what my Epistemology, Theoretical Perspective, Methodology and Methods are.

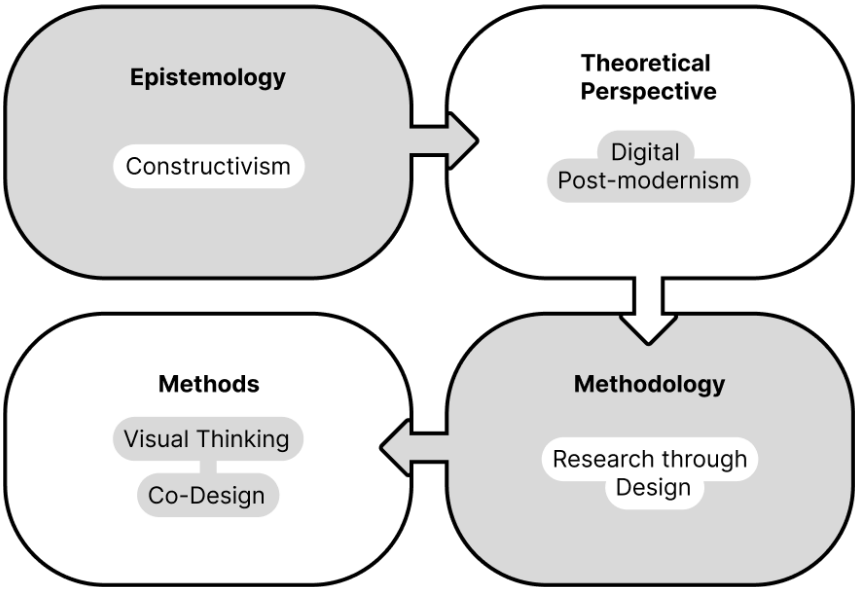

Figure 9. Epistemology, Theoretical Perspective, Methodology and Methods.

As the branch of philosophy concerned with the study of knowledge, I would consider Epistemology as the foundation of any research approach. Whilst my overall approach is shown in figure 9, and further reasoning will be explained throughout this chapter, to summarise it Constructivism is an Epistemology that resonates with my research due to its subjective nature which emphasizes that knowledge as a "constructive activity occurs as the cognizing individual interacts with other members of a community" (Fosnot, 2015, p. 37). social influence and multi-perspective value. Drilling down slightly further into my Theoretical Perspective, Digital Post-Modernism is integral to my thought processes due to its focus on remixing media into new forms and its emphasis on Hyperreality, where people have become "self-aware of their backgrounds as digital natives, accept technology as a default part of contemporary human existence, and are interested in mining digital vernaculars for novel potential" (MacDonald, 2019, p. 95). RtD (Research through Design) is the Methodology I utilize to achieve my research. It complements the subjectivity of Constructivism as well as the remixing and remaking processes within Digital Post-Modernism. The Methods which enable this RtD Methodology vary throughout this thesis based upon situational need. In the beginning I focus inwards through my own reflection and Visual Thinking, while at the end of this thesis, it transitions into Co-Design concerned primarily with the views of others. This varied use of research methods is rationalised throughout this thesis and comes full circle back to Constructivism's ideas of multi-perspective and Active Engagement through a messy heterogeneous approach, but generally causes this thesis to contain both opinion and evidenced ideas.

The pathways, which I follow through my messy heterogeneous research, are non-linear and certainly chaotic, like open world games. Sometimes the threads appear detached, but by following them to natural endpoints, I can weave them together to form tangible ideas and grander projects down the line. From personal working experience and cultural exposure, its apparent that digital development and design more generally also often suffer from (or are bestowed with) this same messiness as my personal research practice. This chaos is a core part of design as indicated by Fullerton's advice.

> "Learn to program. You don't have to be ace, but you should know the basics. In addition to a solid technical foundation, get as broad-based an education as you can. As a designer you never know what you're going to need to know- behavioural psychology will help you immensely, as will architecture, economics, and history. Get some art/graphics experience, if you can, so you can speak intelligently with artists even if you lack the skills to become one yourself." (Fullerton, 2014, p. 24).

This requirement for seemingly chaotic knowledge acquisition applies heavily to virtual and game design more specifically (and by inheritance, virtual wayfinding design), allowing virtual spaces to be just as fluid as any other form of design, only without the physical restraints of the physical world. The research in this thesis began in 2020 during the COVID-19 pandemic, and ended in a world largely restored to normality which enables it to exemplify ideas about constantly adapting to the world which is changing around it through the messy and drifting processes of RtD.

John Law affirms these notions talking about how "research needs to be messy and heterogeneous. It needs to be messy and heterogeneous, because that is the way it, research, actually is. And also, and more importantly, it needs to be messy because that is the way the largest part of the world is." (Law, 2007, pp. 595–596). Finding order within this sense of disarray can be useful, but purpose can be found without the end-product, even if the reason is merely to make, reflect and re-make within this state. My personal methodologies heavily reflect this principle, and my own moments of clarity come through at moments which others may deem completely unimportant. This style to my research as well as my seemingly eclectic process is extremely important to me and is what allows me to enter a flow state which can be described as an ability to focus exclusively on a given task often described as being 'in the zone'.

While achieving flow state is extremely personal, as designers, drifting in our creative process often facilitates flow state successfully, allowing for organic wayfinding processes to occur. "Some people can experience the flow state in virtually any activity, whereas others can enjoy and get absorbed in leisure but find it hard to enter the flow state at work." (Tse et al., 2022, p. 2520). I have commonly entered a flow state at times when within game experiences (such as video games, board games, role playing games and game design) also described as immersion. Because of this, I have used games throughout my PhD Research both in recreational time, and as vessels to develop new design ideas (although I would consider these as a homogenous experience). "It is not easy to transform ordinary experience into flow, but almost everyone can improve his or her ability to do so." (Csikszentmihalyi, 1997, p. 83).

> "Gradually I learned to be indifferent to myself and my deficiencies; I came to centre my attention increasingly upon external objects: the state of the world, various branches of knowledge, individuals for whom I felt affection" (Russell, 1930, p. 6).

I concur with this statement from Russell, finding it easier to enter a flow state when the concerns and needs of others are in question, rather than my own needs. This outlook seems to align heavily with ethical design intentions. Designers should be concerned with the needs and useability of their designs for the intended user and should be able to distance their own desires from the artifact. It makes sense that games would facilitate this same flow as I easily become disinterested when the pursuit of new knowledge is unavailable in virtual game spaces unless the game enables teamwork or working collaboratively is a core aspect of its play. "Flow is a state of peak enjoyment, energetic focus, and creative concentration experienced by people engaged in adult play, which has become the basis of a highly creative approach to living." (Csikszentmihalyi, 2000). This emphasis on flow and adults allowing themselves to play is something my methodologies revolve around and lead my research to drift heavily into mixed methods whenever it allows the continuation of personal flow.

‘Drifting’ intentionally is a process I enact through this thesis, which I am using to refer to the process of allowing one research idea to sidestep or flow into the next and gradually form a basis for a more focused research question further down the line. This process is wayfinding in method, and so both drifting and wayfinding are often used synonymously when referring to this methodological approach. I firmly believe that “drifting is typical in design and cannot be avoided in it” (Krogh & Koskinen, 2020, p. 1) forming the method element of wayfinding in this thesis. In a scientific research setting, a deep specific study might focus in on one small aspect of data, “what the study loses in relevance it gains in depth. The increasing depth of knowing derived from every experiment is iteratively build (layered, stacking) into the next generation of the same version” (Krogh & Koskinen, 2020, p. 62). Drifting by intention in design takes the opposite approach to that described by scientific research allowing context and relevance to remain which is often vital in Co-Design and accessibility aims. In the physical sciences, unexpected data may lead to the reformulation of hypotheses or the discovery of new phenomena” (Gaver et al., 2022, p. 518) and this unintentional drifting can be just as prevalent but often comes at the end of research rather than during. Intentionally using this drifting approach aims to broadly explore many avenues, with the links between each becoming clear over time. These ‘paths of desire’ often end up being more efficient, more used and provide more space for new branching threads to grow from and thrive, only then to be delved down deeper further on. These desire paths could be considered as RtD in action and often exist in research where the journey is more important than the outcome itself such as this thesis. This process can be described as wayfinding, exemplifying why wayfinding in this thesis occurs both in method and research topic.

0c.12. Making Sense of research and Research

To be able to explain what RtD is, it is first important to understand the difference between ‘research’ and ‘Research’. Frayling describes the difference between ‘Research’ and ‘research’ through their Oxford English Dictionary Definitions with lowercase ‘r’ research being the “act of searching, closely or carefully, for or after a specific thing or person” (Frayling, 1994, p.1). This might be described through the acquisition of knowledge or skills new to the person themselves, but already known within the wider field. Uppercase ‘R’ Research on the other hand, is intertwined with new or ground uncovering knowledge. Deviation from the standardised path is required. Whilst ‘research’ might follow relatively new desire paths, ‘Research’ includes the first trampling of the thick grass, even if only for a few steps, before returning to previously trodden areas. While this is movement “directly towards innovation” (Frayling, 1994, p.1), it is important to clarify knowledge acquired through (big R) Research can lead to a very similar outcome to that from (little R) research, but the intent and methodology are interwoven with aiming to uncover new knowledge where possible. Within this thesis, I will be focusing on the big 'R', due to it being a cornerstone of both design research and academia.

Within the field of research and art, Frayling unpacked three main categories within which research took place. These methodological approaches are broken into: research 'into' art and design, research 'through' art and design and research 'for' art and design. These, in a sense, follow a progression. Research 'into' Design (RiD) is commonplace within design research academia. This approach primarily aims to add context to design and its relationships to the world it fits within. It considers the history and theory of art and design practices and situates them as a field of study.

RtD is about action! It is concerned with the material qualities of both the world around us, as well as the designed artefacts situated within it. Making is a core part of RtD with it being both a vessel for thinking and an output for ideas. Essentially, the idea is to apply theories in the real world to understand them more deeply. Research 'for' Design (RfD) can be seen as the final artifact. It is the output which encapsulates all other research and learnings. The artifact is deemed as the result to embody the whole process and the research is done for the design.

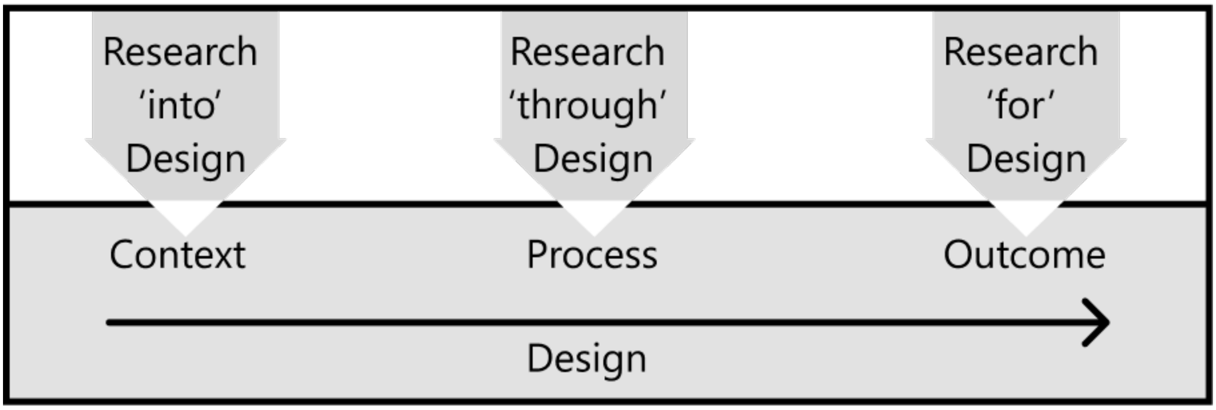

Figure 10. Note: Design research categories. 'into', 'through', 'from' Research Design. Adapted from "It's research, Jim", by M. Press, 1995, in Proceedings of the European Academy of Design Conference, p. 3.

In the above, I have adapted Press's diagram, which was aiming to visualize the process of design research and separate it from the scientific method to avoid adopting its properties. Drawing from the diagram, when referring to my own work in this thesis, and when considering it from an academic position, RtD is the most focal part of this process. When considering the knowledge produced through my research and through the lens of these subsections of design research, it is RtD, which encapsulates the method, production and reflection of my work and generally has a focus on tacet knowledge producing processes even if at points it is more concerned with the emphasis on tangible outputs that Research for Design is focused on.

RtD has and will continue to represent a cross-disciplinary group within design research. Because of this, it is tempting to define it within constraints to give it some agreed forms (Zimmerman, Stolterman & Forlizzi, 2008). This thought rests on the idea that if we do not do this, we risk leaving its intangible boundaries even more open to criticism from the wider research community than they already are. However, I would like to take the standpoint that:

> “The reason that research through design is not convergent is that it is a generative discipline, able to create multiple new worlds rather than describing a single existing one. Its practitioners may share many assumptions about how to pursue it, but equally, they may build as many incompatible worlds as they wish to live in. We may wish to improve the standards of research within the field, but from this perspective we should realise that what we mean by 'improve', what criteria we propose, even the assumption that shared standards are necessary, possible or desirable, are potentially repressive acts of ontological politics” (Gaver, 2012, p. 943).

Within RtD, researcher and designer are often one holistic role which can lead to personal biases or opinions heavily influencing the direction and outcome of research projects, especially when outcomes are qualitative in nature. While this could be seen as a major flaw within RtD practice, Gaver’s position on this lack of convergence instead highlights it what I perceive to be an essential part of the method.

“Designers look at the material world, compare their observations with their value preferences on how the world should be, and propose material changes” (Press, 1995, p. 6). When we consider any design challenge, as simple as it may be, a variety of different designers are likely to have completely different solutions and aesthetic preferences towards the end-goal. If we were to take an example where several designers were tasked with creating a series of simple wooden chairs alongside a dining table, while we might expect that each would incorporate standard ergonomic principles and places for sitting and a large enough surface area to eat from, the variety in structure of everything else would be reasonably noticeable (especially regarding ornamental sections purely for visual detailing). Because design is inherently human, life experiences vastly change design values. This bias isn’t unwarranted as “design is for human consumption and not bounded by the quantifiable ‘certainties’ of the physical world” Swann (2002, p. 51).

Something which is contested in design research is the desire for design practice to provide scientific research results (which wider design does not necessarily need). Savic & Huang (2014, p.14) argue that “the outcome of research design practice does not appear as a final product, if it ever does, before it has been repeatedly demonstrated to different expert audiences." However, the question of what is the final product or design 'artifact', and how many of these exist within the process of producing 'the' final product is very open. I think this is important due to iteration being a key element within design practice, and unintentional drifting being vital to most great outcomes. Often as a designer we may prize one specific artifact we have created, while others may focus in on elements of the design process along the way. This difference in how we perceive the value of the journey and the outcomes within RtD is what makes it so powerful. If I were being idealistic, I might leave this research's explanation of methodologies at this vague point, however I realise that to situate the research within the wider field, it is important to situate my methods around existing paradigms. These paradigms are identifiable by their ontology, epistemology, and methodologies.

0c.13. Constructing Ontology and Epistemology

Ontology can be best described as the study of being or the "nature of reality" (Hudson & Ozanne, 1988, p. 509). It looks at what kinds of things exist in the world around us. Epistemology is more about the nature of knowledge, connecting with ontology by analysing how we know and learn about what exists. Personally, I want to get as close to reality as I can in my design process, viewing research as a vessel to achieve this goal. Often research can distance us from practical applications and gaining balance between business and research (academic) projects helps to clarify our epistemological stance. "Ontology is concerned with identifying the overall nature of existence of a particular phenomenon… Epistemology is about how we go about uncovering this knowledge… and learn about reality… Epistemology is internal to the researcher. It is how they see the world around them." (Edirisingha, 2012). From my perspective (or epistemology), ontology is more concerned with an a consistently provable sense of truth amongst many, whilst epistemology is bespoke and subjective to the beholder.

Epistemology and ontology are directly related to research methods. I believe we cannot wholly pursue objective truth through design research. Others might go further arguing that the world is holistically subjective or even disagree entirely and claim for objectiveness. RtD sits in the space between many paradigms, and through this, also bridges across and takes from many different epistemologies and ontologies. Sometimes it is vital to "blend elements of one paradigm into another, so that one is engaging in research that represents the best of both worldviews" (Lincoln & Guba, 2000, p. 174).

While its almost inarguable that "subjective thought and the object of that thought are interlinked… Constructionism suggests that there is no true or valid interpretation of the world" (Rodriguez Ramirez, 2009, p. 6). I agree with this philosophical paradigm that Ramirez discusses. Viewing most things as subjective is useful, but I also think there is value in making objective statements within design so we can focus on other aspects of it. To position this with an analogy; when designing an audio game (which is explained later in this thesis) I chose to assume that currently designed controllers are objectively good at certain points to allow myself to focus on other aspects of the audio game. Later in research I did flip-flop back and forth on this rational, enabling me to hone-in on specific problems in my area of research. These 'constructs' which I create are fleeting, but useful to my research. The pragmatism of this process is that even the user does not have to believe their own constructs but can simply use them as tools to achieve more clarity even if only momentarily.

Employing this kind of rationale enables the designer to separate themselves from their research and then at different moments consider each viewpoint as equally valid. To return to defining the difference between epistemology and research paradigms, even just regarding constructivism can be quite vague as Crotty (believing constructivism to be an epistemology) states "the terminology is far from consistent" (1998, p.57). I want to take the standpoint that constructionism is "design research in which construction - be it product, system, space, or media - takes centre place and becomes the key means in constructing knowledge" (Koskinen et al., 2011, p.5). This is the most relevant factor to my research and defines the methods I employ later. Constructivism and constructionism put the researcher or individual at their centre in a rather post-modern way, characterising themselves with ideas of self-consciousness and distrust as well as decentralising knowledge.

"Often used interchangeably" (Lindley, 2018, p. 46), Constructionism and Constructivism have quite a large amount of overlap. "Constructivism centres around the notion that reality, knowledge and meaning are all constructed cognitively within an individual's mind. And, while internal reflection is still a crucial part of Constructionism, it focuses more on how knowledge is constructed through social, direct, and tangible engagements with reality." (Stead, 2020, p. 75). While there is significant crossover between both Constructionism and Constructivism, I agree with both Lindley and Stead on their bias towards Constructionist philosophy due to its more tangible nature (especially regarding making actual artifacts). Ramirez's statement which I drew upon earlier transcends both Constructivism and Constructionism and is added to by Gradinar stating modernism "means that the individual voices and local stories give way to larger trends" (2018, p. 19). Post-Modernism rejects this future "In this way, local takes precedence over global (and to some extent, a total rejection of global) … Postmodernism accepts a worldview where everyone’s voice is as equal as anyone else’s, an epistemological plurality which naturally implies an acknowledgement of multiple sources of knowledge creation.” This decentralisation is critical to my research perspective, and I will continue to talk about it in other methodologies I employ such as Co-Design and Participatory Design, taking the standpoint that multiple opinions on one topic will help to produce more generally useable qualitative data. However contrary to this de-centralisation, Digital Post-modernism is reliant on central systems due to the medium it resides in. Because of this I choose to quantify my Theoretical Perspective as Digital Post-modernist because while post-modernism’s multi-perspective concern is highly important to me, the digital space my work resides in has to tread carefully to maintain this in practice.

0c.14. Research through Thematic Action

Ensuring we understand what drives our research by establishing grounding through existing epistemologies, ontologies and methodologies is vital to continue it with strong direction. This is exemplified by distinctions such as the one I just made between Digital Post-modernism and post-modernism. This process of defining can be simplified into a need for us to understand what we are researching within context as it is extremely important for designers to be able to situate themselves. My own method of researching heavily leans towards a childlike sense of exploration. I make things because they interest me and I believe they will either improve my life, or the lives of those around me (even if this pleasure is quite fleeting). The things I make piece together like LEGO when they have coherence into grander projects to be refined. I will continue to associate the way I research with play throughout this thesis, but for now, I will aim to rationalise this methodology with existing academic theory.

Through my research, I have touched on the use of Grounded theory due to its qualitative research approach (as well as its aim to understand phenomenon within real world context). Conducting interviews or personal observation is often a key part of this kind of research. “Interpretations made from given perspectives as adopted or researched by researchers - and therefore fallible - is not at all to deny that judgements can be made about the soundness or probable usefulness of it” (Strauss & Corbin, 1994, p. 279). However, when many perspectives begin to reflect in similar ways on relatable observations, and these observations lead to the design of useful artifacts, then methodologies like grounded theory begin to prove themselves viable. Generally, my research is ‘Emergence-friendly’ meaning “it is responsive to external influences, material potentials, new learning, ideas and inspirations or any developments in the world of virtual wayfinding design. Methods, understandings, outputs, even overall topics are all left continually in play, and at their extremes can stray more or less completely from the originally intended course." (Gaver, 2022, p. 518).

The grounded nature of grounded theory is the main aspect I take from it, using it to focus my research on real world applications rather than lab-based viability. I conduct research with real people in realistic non-controlled spaces and I am open to the straying, drifting and change this might leave it susceptible to. This same rational could be used to associate my process with Thematic Analysis or Interpretive Thematic Analysis "which involves immersing oneself in the data in order to identify common ideas or themes that emerge based on the phenomenon under investigation and that resonate with the research question(s) posed in the study" (Peterson, 2017, p. 1). Thematic analysis is both inductive and deductive and having been developed across disciplines remains loosely defined and broadly useful (Mihas, 2023, pp. 302-305). Games design (and virtual wayfinding design by inheritance) works incredibly well with Thematic Analysis as the designer should be immersed in play, before during and after designing their own game systems to best design for the player and understand their struggles and enjoyment of games in a deeper way. The key rationale for associating myself with and partaking in these methodologies is to seek immersion in the research I undertake (both in games and virtual accessibility) and surround myself with the habits they induce fully.

Even after many affirming opinions are layered within one idea, research produced using grounded theory or Thematic Analysis should be open to criticism. As personal subjectivity comes into it heavily, it is vital the researcher includes positioning on their design process and rational. "Flexibility in the methods of research, a focus on defining the researcher and on insights brought up by the stories from the people researched take on greater importance. Such stories are not only from the people researched, but also from the own experience and cultural background of the researcher" (Rodriguez Ramirez, 2009, p. 7). By conducting user testing, running co-design workshops, and using participatory practices in RtD we can strengthen this openness to criticism of grounded theory and diversify and amplify the voices of those we aim to design for. "If all the participants are actively involved in the projects, they are thus contributing to the production of knowledge and invariably influencing the overall outcome of the research. In acknowledging this point, the participatory paradigm is a good fit since we are looking at a participative reality, a co-created subjective objective one, based on the shared knowledge and understanding of the work undertaken for the whole duration of the project" (Gradinar, 2018, p. 21). I agree firmly with Gradinar's perspective on this, and his continued narrative afterwards. While RtD enables open and exploratory research, combining it with other methodology to provide more benefit for both the researcher and the user.

Bottom-Up and Top-Down are possibly familiar concepts. Top-Down seeks to break apart something from above, finding nuggets of usefulness within a larger idea. Bottom-Up builds from nothing. By gradually adding towards a bigger idea, it seeks to find usefulness in smaller things and combine them together rather than assuming anything is inherently useful within the concept to begin with. Bottom-Up Analysis through Design is the method I generally use, and as with RtD can lead to similar outcomes to other research around the same subject, but tying it within grounded theory, when these outcomes materialise very similarly, it only further validates the original research which validates itself in turn.

In large scale team projects in software development, Top-Down design is employed my managers and team leads to plan out roadmaps, while Bottom-Up approaches are taken by individual developers who design specific functions. This double approach is effective, but when working on such small scales as with my PhD research, I believe Bottom-Up is the better approach to produce research and design which authentically reacts to idea generations from Participatory and Co-Design methodologies. Bottom-Up methodologies and the idea of clustering from software architecture design not only applies to the software I've designed through this PhD, but also the methods through which I relate and understand design projects I have documented. "Clustering will group data into similar categories where the number of categories has not been predetermined. Data points, often referred to as records, that are similar are grouped together." (Wirsch, 2014, p. 10). This clustering provides a method for grouping and relating important elements or variables to one another.

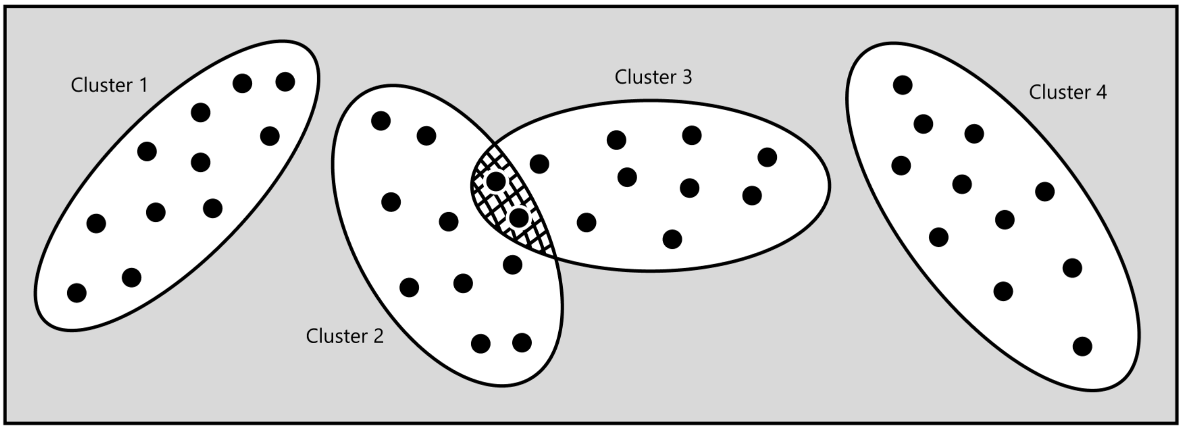

Figure 11. Bottom-Up Analysis Clustering.

These correlations are visualised as round shapes or clusters, and when they are close to each other, or provide many linkages, they may have significant overlap. Once we reach this point, we can begin to "reduce and separate the variables. Not all variables may be needed. At this step variables that are not required are removed from analysis. The more variables are included the more CPU time will be required for processing" (Wirsch, 2014, p. 12). This notion of viability or importance is key and

‘CPU time’ can be considered as human time for reflection and processing. When conducting initial research, we may take more of a scattergun approach, but as we refine, the areas of most overlap, or where most mini projects are leading to similar outcomes are the ones we pursue. For example, this directly applies to the audio game, and virtual web conferencing research within this thesis. While both were intriguing, the common area of research interest between them was in spatial audio systems and so other variables, or research topics were dropped in favour of these more ‘CPU worthy’ processes. These overlapping clusters, form a new ‘mega-cluster’ which then becomes an entire sandbox field of research once more, and the clustering process restarts.

While the research I conduct throughout this PhD all strives towards better understanding for people using virtual spatial environments, accessibility is a focal factor that came about by using clustering and Bottom-Up approaches, alongside other methodologies described here. Once the need for accessibility to be a core factor in this thesis became apparent, the methodologies I employ became much more grounded and concerned with the perspectives of others (even though I maintained a Bottom-Up approach). This is already something I was exploring through informal game play analysis, which led me down the route of participatory and co-design methods.

0c.15. Action, Participatory and Co-Design Research

Kurt Lewin believed that “research that produces nothing but books will not suffice” (1946, p. 35) leading him to propose “an iterative approach to solution driven problems where both the researcher and the client would benefit.” (Gradinar, 2018, p. 21). This notion led to the creation of Action Research as a methodology which Lewin tested through several community experiments in America (Kemmis & McTaggart, 1988, p. 6). Action research could be described in a similar way to trial and error. We use what we already know and attempt experimentally towards our outcome leading to a reality where “action researchers have large and complicated stories to tell.” (Avison. 1999, p. 96). If the desired outcome is attained, we are successful and we use this method several more times, if during which it is repeatedly reliable, we deem it a true success, and if it isn’t consistent, we try variations on it until it is, or something outside of our control is confirmed to be the cause of the unreliability. This process can be broken down into as many stages as necessary to approximate variables and maintain controls as with the simple scientific experiments we conduct in school. This method of iteration enables comprehensive understanding of a situation (or something close to it). “When action and reflection take place at the same time they become creative and mutually illuminate each other.” (Baum et al., 2006, p. 856), intertwining new discovery, failure, and reflection in a unified process.

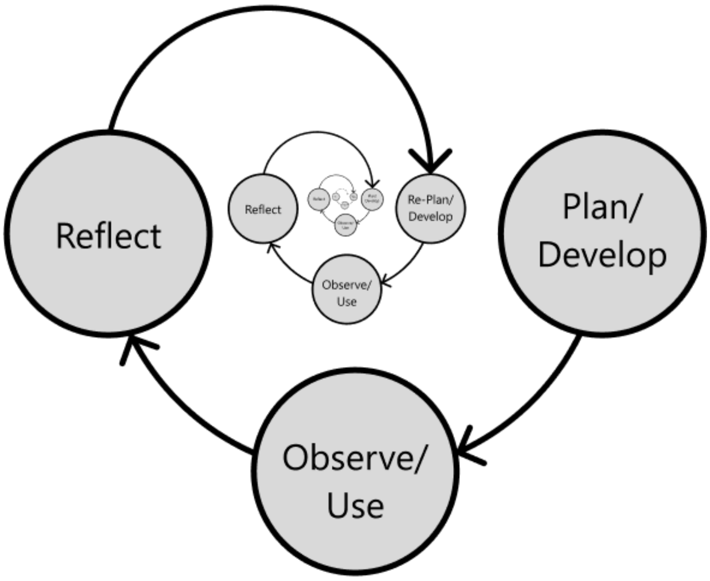

Figure 12. Action Research Process.

Simply described, action research is “an approach in which the action researcher and a client collaborate in the diagnosis of the problem and in the development of a solution based on the diagnosis” (Bryman & Bell, 2011, p. 414). Action research broadly encompasses both participatory and co-design principles through this definition, both of which I have taken from to gain qualitative data for my research. Participation is focalised more in Participatory Action Research (PAR).

> “PAR draws heavily on Paulo Freire's epistemology that rejects both the view that consciousness is a copy of external reality and the solipsist argument that the world is a creation of consciousness. For Freire, human consciousness brings a reflection on material reality, whereby critical reflection is already action. Freire's concept of praxis flows from the position that action and reflection are indissolubly united” (Baum et al., 2006, p. 856).

My own choice of methodologies would insinuate that I also believe Freire’s position that action and reflection are tied completely together. This action might be through the form of personal action research or working alongside people to enact participatory or co-design workshops. Regardless of the actioner in the research, the need for action alongside reflection is paramount to my own methods.

From personal experience using co-design, it happens similarly to action research, but emphasises the others involved in the research over the researcher themselves. Distilling its workings into phases, beginning with development or planning, new concepts or features are created which aim to cause a certain change in the general outcome or usage of the idea. From this, we give the changes to a range of people, often including ourselves in earlier cycles. During this usage, we observe and use it in a similar vein to general purpose user testing. From this, we reflect on the benefits and disadvantages which may have been caused by the changes. From here we re-iterate, plan, and develop continuing this cycle somewhat indefinitely (Kemmis & McTaggart, 1988, p. 8). The benefits of this iterative approach are numerous. Not only does it facilitate continuous re-evaluation of the design, but it allows it to be improved at each point and re-tested in its new state. This re-testing and re-evaluation is integral to RtD as a whole, but co-design is relevant to my specific angle of game design just as much as action research is. In a book focused on game inventors, Tinsman recalls one relevant interview with a game designer Reiner where they discuss the requirements for appropriate game design practice.

> "Well, you can't always start at the same corner, or you'll always end up in the same corner. That's the problem with game design – there is no consistent approach. Taking the same approach goes against creativity. Game design really is an art, not a science. You can't always apply the same methodology or you'll come up with the same type of game." (Tinsman, 2008, p. 21)

This thought process not only advocates for the use of mixed methods throughout the design of games or virtual wayfinding systems, but also for remaking and rethinking whenever possible. This re-doing process mitigates the likelihood of a design which has become distanced from the needs of its intended user and is integral to action research. This avoidance of distancing is what makes co-design such an appropriate methodology for the research I undertake, especially in the later parts of thesis when accessibility becomes the core focus.

Gradinar defined 2 key aspects to Action research. Firstly, that a "close relationship between gaining knowledge and action" (2018, p. 24) which I also believe is vital as a usable output or visible improvement are vital for proper iteration. Secondly that "Action research is a participatory process between a research group (or individual) and an external partner (client) where the results are shared amongst all participants." This joint interest where both parties have different use cases for the information gained, and different perspectives is incredibly useful in providing less subjective and more holistically useful data, but it also leads to research which is useful outside of academic settings (something which I move further and further towards through the process of this thesis). Co-Design sits within this space of action research (as does participatory design) and is a method I continue to employ with my research as it fulfils many of the same criteria as Action Research but puts the needs of the co-designers first.

RtD and Action Research both are focused on looping processes and iteration, something which is also vital for proper co-design. I found that choosing methods to suit the aims rather than being philosophically bound to them (being non-dogmatic in my methodologies) was extremely beneficial. Drifting into mixed methods touching on some HCI (Human Computer Interactions) and game playtesting methods alongside this RtD focused approach produced useful data. Games Design Research (or more generally virtual spatial wayfinding research) through Game Design Practice is one such example of this drifting method. “Practice-based design research is arguably underrepresented in the games research community.” (Coulton & Hook, 2017, p. 97). While this is underrepresentation is shifting it is still important to rationalise why this shift should continue.

> “Any forms of research in which the experience of the researcher is at work, such as design, can stray towards subjective evaluation, which can lead to criticism that it is not a valid form of knowledge creation. However, RtD has established a number of approaches that help ensure it is not performed through a designer's personal and privileged perspective, or that it does not reflect either design scholarship or design practice. One of the important facets of RtD is that it both includes, and is included, in the contextual world of design knowledge by being developed with influences from design scholarship and from an acknowledgement of everyday design practices.” (Coulton & Hook, 2017, p. 191)

Continuing from Coulton’s vital rational for RtD’s inclusion in Game Research, it could be further argued that Design Research Practice is ideally suited for gameplay as games themselves are systems for play where the player is designing their own experience as they go. This on-the-fly experience where players find themselves designing “meta-processes of… setting up, (dis)engaging with, and configuring the total play situation which could not have been observed in a laboratory study, as the experimental control of conditions would have prevented it by definition” (Deterding, 2016, p. 3940). This process of gameplay analysis from a RtD perspective is something I enacted in the later parts of research through Co-Design workshops and enabled the research to consider both the physical practicalities of starting a game, and the virtual experience of playing it as one all-encompassing experience.

0c.16. Justice and Non-Tokenism in Interaction Design

Physical-digital duality in any interactions bound to virtual space are important to outline to further my explanation of Action research. “On one hand, any interactions with the Internet, in whatever form or shape that might be, have a digital component which can be associated with a digital environment, a digital world in which the Internet is situated. On the other hand, the final product will ultimately have a physical presence, a tangible object, represented by the embodiment of the actions and decisions taken during the design process.” (Gradinar, 2018, p. 25). When looking at these interactions through the lens of Co-Design we may group them as one holistic experience, however the design processes for each are vastly different.

> “Haptic interfaces, environmental interactions, internet of things, smart objects, ubiquitous computing, augmented, virtual reality and the 3-dimensional evolution of interactive experiences are opening new possibilities to a multimodal and spatial aesthetic involving a multi sensorial-interactions.” (Bollini, 2017, p. 99)

While we can tweak and alter aspects of virtual space in much more fluid and rapidly increasing ways, the outputs afforded to us through common place devices severely impede what we can achieve through physical input and output limiting the variety of designed software or experiences. “There would be no point in designing anything which sits outside of human benefit; art appeals to feelings, design to use!” (Gradinar, 2018, p. 25). To keep pace with the rapid growth of digital possibilities, we must consider the physical aspects of these processes which ground them in our realities.

For the purposes of my research, I am concerned with this realm directly in between virtual and physical space and the space close to this on either side which could be characterised as points of interaction (or touch points). As physical technology evolves, this liminal space changes in turn, but when designing these physical technologies, companies generally focus their designs in-line with normative sensory experience to maximise their sales and profitability. Accessibility is already so complex to both design for, and pinpoint. While accessibility generally revolves around giving more people more access to the things we create, it is impossible to perfect.

> “Design in its most general sense is a process practiced by virtually every profession. Two of the most commonly thought-of professions are engineering and architecture. However, universal design for learning is an example of the spread of universal design beyond its traditional disciplines… As universal design and its close first cousin, accessible design, evolve and their influence spreads, society changes its collective conceptions about human functioning. This process is driven by a collection of dynamic feedback loops among societal element and design activities… Universal design provides a broader, yet complementary, approach to design. Universal design has evolved from ethical and market-driven pressures, particularly the pressures of global competition. The Council of Europe has passed resolution seeking to have universal design principles and methods incorporated into all training and educational programs dealing with design.” (Erlandson, 2007, pp. 1-20)

Universal design is really an extension of accessible design. Universal design considers accessibility needs as mainstream needs, and fixing designed issues which exacerbate them as a necessity that benefits everyone, rather than an accessibility feature which should be added for inclusive purposes. This justice orientated mentality, providing equality by fixing the system rather than providing specialised equipment is more sustainable long term. Creating an analogy around Michael Jordan’s lucrative basketball career, Sandel explains justice quite aptly.

> “No matter how hard he has worked to develop his skills, Jordan cannot claim credit for his natural gifts, or for living at a time when basketball is popular and richly rewarded. These things are not his doing. So it cannot be said that he is morally entitled to keep all the money his talents reap. The community does him no injustice by taxing his earnings for the public good.” (Sandel, 2010, p. 69).

This system is an attempt at justice in action, as the money Jordan received through his mixture of genetics, luck and personal hard work is taxed to benefit the many with widespread systematic changes. However, accessibility, although usually aiming for equity rather than justice, only seeks to provide more access, which is generally positive and shouldn’t be deterred when done correctly.

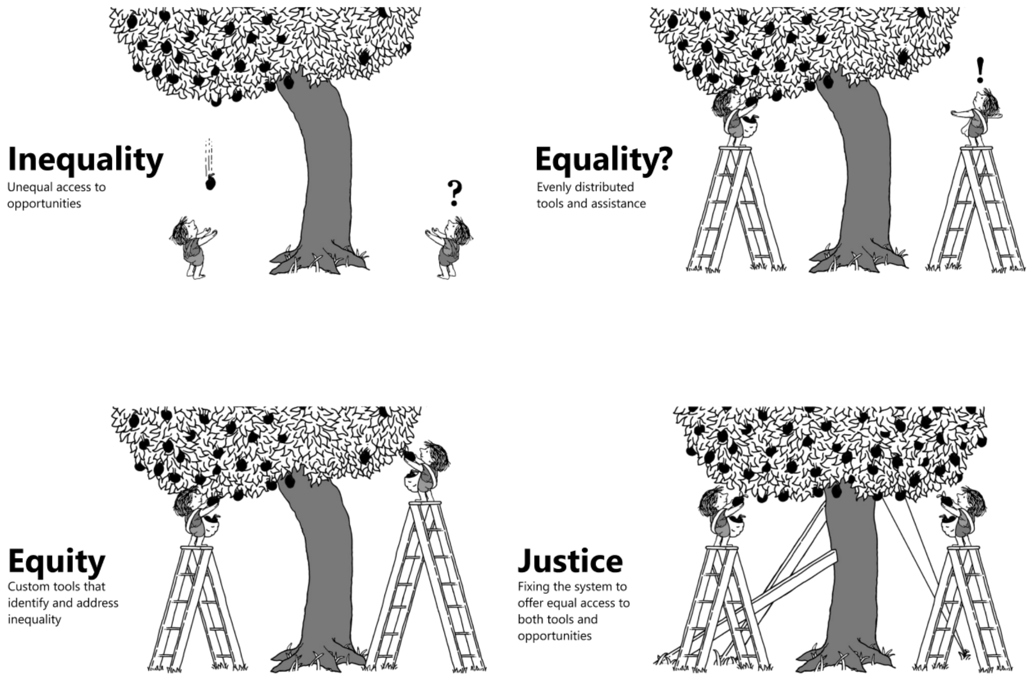

Figure 13. Note: Inequality, Equality, Equity and Justice. Adapted from “Digital Divide to Digital Justice in the Global South: Conceptualising Adverse Digital Incorporation”, by R.Heeks, 2021, p. 773.

Adding more customisability to our interfaces will allow more users to make the system work for them but will increase the complexity and learning curve for those same users. Because of this, generally as designers we aim for simple general-purpose artifacts which work for the most users possible. We can then aim to make rich accessibility features which are optimal for those marginalised in the original design. This retroactive approach can be detrimental to those most in need of accessibility causing clunkiness in usage and exclusion from default users. While I will go into this further through my thesis, I want to establish now that while I may address physical and digital aspects of interaction design separately at points, I see them as one holistic experience intertwined and reliant on one another. In doing this, I aim to propose and design solutions for the future which incorporate accessibility more subconsciously without the need for retrofitting and adaptation. This approach aligns better with the notions of justice, striving towards systems which are equitable by default, and aiming towards true justice within the systems they target.

The characteristics or "perceived affordances" of an object (Norman, 2013, p. 29) are defined by what a person perceives an object is capable of, and the properties it possesses (what it affords the possessor). This idea is obviously perception and perspective based, meaning each person may have different understandings of what a single artifact affords them. This is an important concept to this thesis which I explained in the initial literature review, especially when regarding accessibility. Affordances not only vary by life experience, but also by sensory experience and physical capabilities. What I mean by this is, while a larger foundation of knowledge will enable a wider range of affordances to be perceived from an artifact, a visually impaired person with no sight will perceive an entirely different series of affordances from a computer than a deaf user with no hearing. This variation in perceivable affordances when considering people with accessibility needs is vital to my research when framing it around interaction design and requires physical and digital design to be considered together. It also again ties into aims for justice over equity, as assuming a 'normal' within affordances leads to equity not justice.

If we are aiming to design the most accessible computer, both in software and hardware for a non-sighted person, we could clearly state that the display resolution is unimportant, and therefore so is the animations which appear on it. However, when thinking about sound, if we were only to look at the types of sound we produce, and not how it might fit into the sound range of a standard pair of headphones (or set of speakers) we would not be designing properly for accessible needs. It is also important to highlight unnecessary costs such as an expensive display would also be reducing the monetary accessibility of the device for the same user. I will go deeper into this notion of varying affordances due to accessibility needs later in the thesis, but for now the key point is that both co-design and interaction design require affordances to be considered both continuously and focally to be successful, but this tailored affordance approach can take us further away from justice if we do not intend for the accessibility features to be core features (meaning they could be turned on by default like subtitles are in recent years in games).

"Becoming virtuous is like learning to play the flute. No one learns how to play a musical instrument by reading a book or listening to a lecture. You have to practice. And it helps to listen to accomplished musicians, and hear how they play. You can't become a violinist without fiddling." (Sandel, 2010, p. 197).

I am taking the stance that interaction design is inherently tied to this same concept. To be able to design great games, we need to play games, or have others playtest them and understand what makes them fun. A great example of this in action is Microsoft's development of "the RITE method during the development of Halo I. In RITE when a player identifies a problem, the developers address the problem immediately before testing the game further" (Choi et al., 2016, p. 255). Accessibility features require similar processes; we can imagine how to design a good website, but it's likely to fail if we only use a screen reader once the site is fully formed. Instead, we should be using technology like screen readers as we design the site, and this will enable the site to work well with screen readers, and very likely the user flow will be better for all users in turn.

"Findings from interview participants maintained that it was difficult to retroactively address accessibility issues mid-cycle, particularly for large-scale projects and teams. We believe that preparing students to handle accessibility issues amidst the development cycle is as important as exposing them to accessibility concepts." (Patel et al., 2020, p. 6)

I would again like to iterate many diverse voices and perspectives lead to more valuable information and using co-design to gain data from these voices, alongside interaction design goes a long way to achieving the multifaceted perspective required. Co-designers are likely limited by their skillset, and however much we do to include them in the design process, this will reduce their design impact. Due to this, designers and developers should immerse themselves in accessibility software as part of their methodologies to enact universal design, something which I continue to practice.

Interaction design can be as simple as "design for people" (Verplank, 2003, p. 2) but it is also incredibly complex. It aims to meet humans needs, both physically and emotionally, slotting into their ergonomic requirements and mental states. Mental states are extremely important to consider when designing due to the unpredictability introduced if they are not properly considered. Therefore, interaction design must account for stress and mitigate the stress the design itself creates. "Designs intended for stressful situations have to particularly account for matching the needs of the users, for making appropriate actions salient and easy to apply. In other words, the principles of good human-centred design are especially important in stressful situations." (Norman, 2002, p. 41). While causing stress in some users may be unavoidable, making the design of anything usable while in stressful situations is never a bad thing, with it only proving the durability of the design in question.

> "Differences between designer and user perspectives of the same product are particularly evident with respect to the role of emotions. The designer may intend to induce emotions through the design, but because emotions (which are a special, but particularly salient form of affective reaction) reside in the user of the product rather than in the product itself, the emotions the user experiences are not necessarily the same as those intended by the designer." (Norman, 2003, p.2)

While many of the preliminary segments of this thesis are quite introspective, this enabled me to find and understand what I valued in my methodological approach. As I continue to build my research and design understanding, I continuously reevaluate the importance of the voices of others, realising their significance increasingly as usable data to provide diversity in perspective and to improve the reliability of the things I choose to design. Norman's above quote about emotions in design are important to consider in this methodological progression as we as designers are always distanced from the effects of our designs (especially in regard to human emotions), usually concerned with intent. Having a greater awareness of people as flux-like in nature is something I now see as integral to proper interaction design. Taking physical, virtual, and mental spaces into account equally enables the most holistically aware interaction design for virtual wayfinding with a heightened likelihood to work well for more people.

Interaction designers, whatever their area of expertise need evidence of users' needs. This can be achieved in many ways, but co-design and participatory design are the method I have gradually shifted towards through my research projects due to their ability to provide qualitative data through repeated user testing throughout the design process. Separating itself from Participatory design, co-design aims to be more thorough in its inclusion of participants returning to them throughout the design process, and because of this, I see co-design as something that can stem from Participatory design with enough rigour and iterations in the design process.

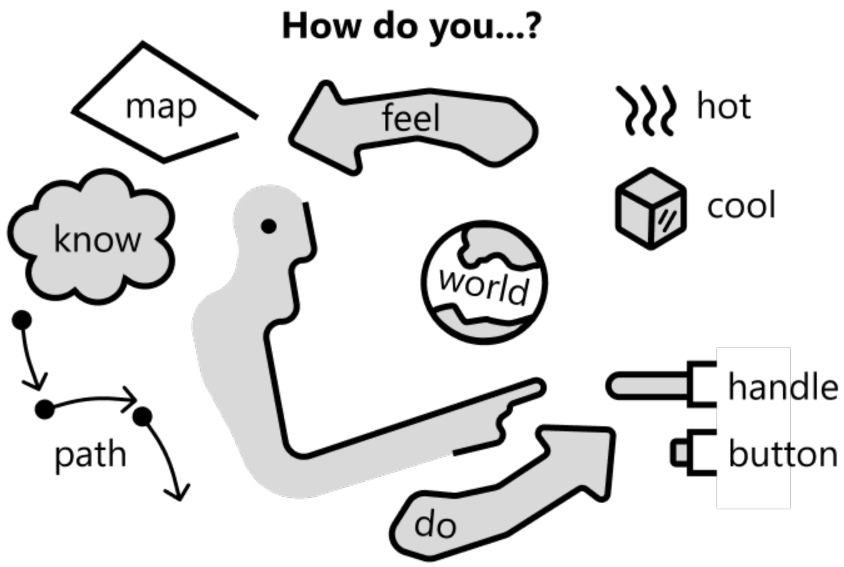

Figure 14. Note: Interaction Design. Adapted from "Interaction design sketchbook", by B. Verplank, 2003, p. 5.

Verplank states Interaction design is concerned with answering three questions, "How do you..." do, know, and feel? (2003, p. 7-8). 'Doing' is explained through the handle and button "A handle allows continuous control both in space and time. When I press a button (e.g. ON) the machine takes over." Considering how a person will interact and continue to interact with the things we design is made apparent through this idea. As people become experienced, the ways they do will change, and making these interactions have comfortable learning curves at all stages of their design is key for rigorous interaction design.

I see it as highly relevant to my thesis to include a discussion about interaction design, primarily focused around Verplank's perspective on it due to how his rational revolves around the world at its centre. My shift from incredibly introspective research to almost the opposite where research is led through others in co-design focuses on this realisation of understanding doing, knowing, and feeling within the world. While all parts of my research focus on the individual and their needs as design for accessibility should, it also centres around the different effects the world can have on that experience, especially in designed interactions. Accessibility needs are different for everyone which I visualised through the sensory bandwidth diagram, with this bandwidth being altered further in virtual space. However, the key aspect of virtual space which makes Verplank's ideas even more compelling to refer to are the heightened levels of adaptability that a virtual space or world can afford due to its non-physical state. Rebuilding a city overnight in a virtual space is entirely possible, while the same is impossible with modern technology in physical space. As sensory experience is different for every person, as well as the experiences perceived through those senses, this in turn effects the knowing, doing and feeling that happens on a per person basis. Virtual space affords those who design within it the ability to rebuild spaces for everyone, enabling signs to have different colours for colour blind users, while remaining unchanged for those who do not need it. This core realisation is integral to my thesis, and its shift towards multi-perspective design. Even the experiences of two blind people (for example one who became blind at 20, and another who was born blind) can be vastly different. The only universal thing is the physical world at the core of interaction design, and even this can be perceived in different ways due to all the doing, knowing and feeling that takes place within it.

'Feeling' is determined by our sensory experience and indicated by hot and cold. This is always important, but especially relevant for my research due to the unique sensory experience or "Information Bandwidth" (Gullick et al., 2015) many of the people I aim to design for possess. In Sensing Atoms and Bits Coulton writes about the variation in actual and conscious bandwidth (Coulton, 2020, p. 201) but the key factor here is the example of temperature. While Verplank takes this notion from McLuhan who uses "hot" and "cold" to mean absorbative and participatory (McLuhan et al., 1995), I think this use of temperature can also provide further meaning. Water has states and flows between these, even moving through sublimation to jump from extremes. Feelings act in a similar way so it is key to account for this when creating experiences which cross multiple senses or use senses in ways users may not be accustomed to. To avoid rapid changes in state, we need to use interaction design in ways that reinforces this sensory flow and allows the user time to adjust to their new sensory environments.

The final sections of Verplank's interaction design diagram we need to concern ourselves with when using interaction design methodologies is the act of knowing. Verplank uses maps, and paths, which to me asks us to consider how we allow our users to build up knowledge. Tuan questions the idea of human knowledge building by comparison to animals stating "most mammals, soon after birth, gain a sense of orientation by taking a few steps after their mother. The slow-maturing human child must acquire this skill more gradually." (Tuan, 1977, p. 20). This knowledge basis based more on experience than pure instinct means that humans can evolve quite rapidly in a technological and societal sense, especially when considering them generationally. Something else which I regard as central to my research exploration but also to both Tuan and Verplank's theories is the link between knowing and space. "Space is experienced directly as having room in which to move. Moreover, by shifting from one place to another, a person acquires a sense of direction." (Tuan, 1977, p. 12) This sense of direction not only gives people a purpose to the knowledge they are acquiring, but also a link to space which means they can re-visualise their progress through it at a later stage (just as I am aiming to do in this thesis).

0c.17. Space in Co-Design

> "The confusing streets of Venice become traversable after one or two experiences, since they are rich in distinctive details, which are soon sequentially organized. Less usually, landmarks may be grouped together in patterns, which in themselves have form…The city is not built for one person, but for great numbers of people, of widely varying backgrounds, temperaments, occupations, and class. Our analyses indicate a substantial variation in the way different people organize their city, in which element they most depend on, or in what form qualities are most congenial to them" (Lynch, 1960, p. 102)

These associations between physical space and the ways we know are important to all interaction design, but are hyper-relevant when considering spatial, virtual, and digital design either together or separately. Open world games as well as many other games are great examples of this idea I'm attempting to illustrate. They themselves have (mini) maps to guide the player and modern titles provide systems for players to map their own routes and denote their own landmarks (Such as The Legend of Zelda: Tears of the Kingdom). Towards the end of this thesis, I will talk more about mini-maps and their accessibility problems, but the key factor here for talking about these virtual space navigation systems is in trying to represent virtual space better (and the non-linearity it provides or presents individuals) without touch or sight. In the previous chapter, I explained how touch and sight provide the highest potential sensory bandwidth, but with current hardware for non-sighted users in virtual sensory bandwidth sound provides the biggest potential to make games more accessible non-visually. To explore the limits of this in space making terms, co-design and participatory design are vital methodologies I employ throughout my research both subconsciously and actively. The research I enacted sits at the margins between participatory and co-design due to the limits of current accessible technology for game design even though forays such as *AudioQuake* have been attempted. *AudioQuake* which enabled some systems for editing and creation of 3D game levels for blind and visually impaired people alongside an altered version of *Quake* is described below.

> "Other research being undertaken in parallel aims to allow users to edit their own game levels. This represents the last major barrier to blind people being able to produce complete games for both themselves and the sighted. The work is being carried out with generalisation in mind and has the further objective of making viewing and editing other types of 3Dstructures accessible in the future." (Atkinson et al., 2006, p.22)

“Co-creation practiced at the early front end of the design development process can have an impact with positive, long-range consequences. This mirrors Jungk’s observation that ‘participation at the moment of idea generation’ is an important place to be practicing participatory design.” (Sanders & Stappers, 2008, p. 9). The way in which we consider our designed artifacts changes the ways in which we see those involved. If we see our research as finished product, then people providing idea generation through workshops will always be participants in participatory design. If we inverse this and consider each stage as a part of a grander project, then the entities involved with it are co-designers generating ideas and making decisions along the way. As I do not consider my research around accessible games complete, and the voices of workshop co-designers continue to dictate the direction of what we produce, I think the line between Co-Design and Participatory design is very unclear, and generally for the purposes of the research, if we continue to involve the same people throughout the design process, they are co-designers in it, existing somewhere on a gradient between co-design and participatory.

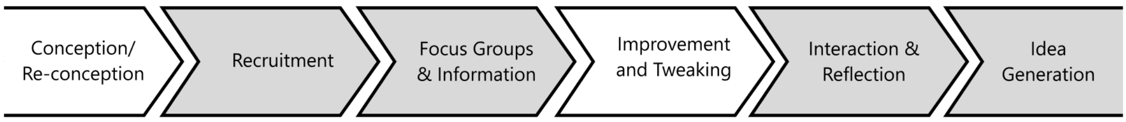

Figure 15. Note: Co-Design Process. Adapted from “A Participatory Design Approach to Creating Echolocation-Enabled Virtual Environments,” by R. Andrade et al., 2019, ACM Trans. Access. Comput. 15, 3, Article 18, p. 5.

In the above figure, we can see two lightened stages of the process added from Participatory Design. The inclusion of iteration and improvement throughout the process is integral to it being Co-Design. In my chosen methodology, it also relies on cycling this same process many times, similarly to Action Research, but with an emphasis on idea generation and improvements coming from several others rather than the those leading the design (such as designers or researchers) to improve the diversity of perspective and design in collaboration with the intended user (who the design is made for). Aside from being established research methods, using Co-Design or Participatory Design avoid making “disability dongles” (Jackson, 2019) (“contemporary fairy tales that appeal to the abled imagination by presenting a heroic designer-protagonist whose prototype provides a techno-utopian (re)solution to the design problem” (Jackson et al., 2022)). “Participatory design, with its strong emphasis on learning from users, provides an approach that allows us to move away from a discourse of normalisation and towards a discourse of empowerment” (Andrade, 2022, p. 20) which was key to Andrade’s research but also that within this thesis.

I would like to make it clear at this point, that while involving those we worked with (sight loss charities and 12 blind and visually impaired collaborators) as far as possible within the design process (both in idea generation and reflection), with the current state of virtual accessibility tools, it was not possible to do this throughout the entire process of game development. The software currently available does not afford this access, and due to this, later parts of this thesis become concerned with how we might rectify this to enable more holistic Co-Design. "During co-creation end users are involved as experts of their experiences not as game designers. Most people are not actively aware of their experiences." (Kuiper-Hoyng et al., 2011, p. 2). This regard to co-design and co-creation taken when designing Wii games with blind children is extremely transferable to how I used co-design through my research with adult groups. None the less I believe for our purposes we were as inclusive as viable within our research scope and whether the reader regards our methodology as Participatory Design or Co-Design when enacting workshops, the outcomes are useful and non-tokenistic and provided all the useful insights for accessibility design that fuelled the continued development of my research.

0c.18. Visual Thinking as Method

As a final section within this methods chapter, I would like to end where I intend to begin with describing my projects in the next sections. Visual thinking can be described as an "essential designer's tool for capturing preliminary observations and ideas" (Verplank, 2003, p. 2), and it "generates alternatives, which in turn lead to multiple prototypes to be tested in order to define a principle." (Gradinar, 2018, p. 34). Visual thinking is usually synonymous with sketching or drawing, and while I have no distaste for the word 'sketching', it is inherently linked to pencil and paper (or other more analogue mediums). I would like to take the standpoint from here on, when referring to 'sketching', that any process using tools where the tooler is in close to full control, or where the tool does not provide creative limitations is in fact sketching. Any digital software from Figma to Mudbox or even PowerPoint or Paint can be viable, and the definition of sketching is only defined by the users' capabilities in their sketching environment and their intent for said environment. Many younger people are much more fluent when creating digital sketches than when using more traditional methods such as pencil and paper. Much of my initial research within this thesis has evolved from such digital sketches, and the only prerequisite for digital sketching over more general digital design or art is an emphasis on rapid idea visualisation rather than detailed final graphics. "We conclude Digital Sketch Modelling does combine affordances indicating its potential benefit in use between sketching and CAD" (Ranscombe et al., 2019, p. 309), and if the users' abilities in digital sketching are significantly heightened, and their physical sketching lacking, the choice seems clear. If the aim of the sketch is to visualise thoughts and connect mind to paper, why not do this in the most natural way for oneself?

"Where seeing and drawing overlap, seeing facilitates drawing while drawing invigorates seeing." (McKim, 1972, p. 9) and with each other relation between 'Imagining', 'Seeing' and 'Sketching' the same occurs as shown in the below figure. When these all combine through my methodology, a flow state, usually only attained through games or play is achieved through visual output. While these sketches may be useless to others, they enable thoughts rich with ideation and the ability to lead to more rigorous prototyping and grander projects. This 'visual thinking' makes up many of the preliminary projects in this thesis, and while some of these reach into the prototype territory, these are grounded in the existence of these original sketches.

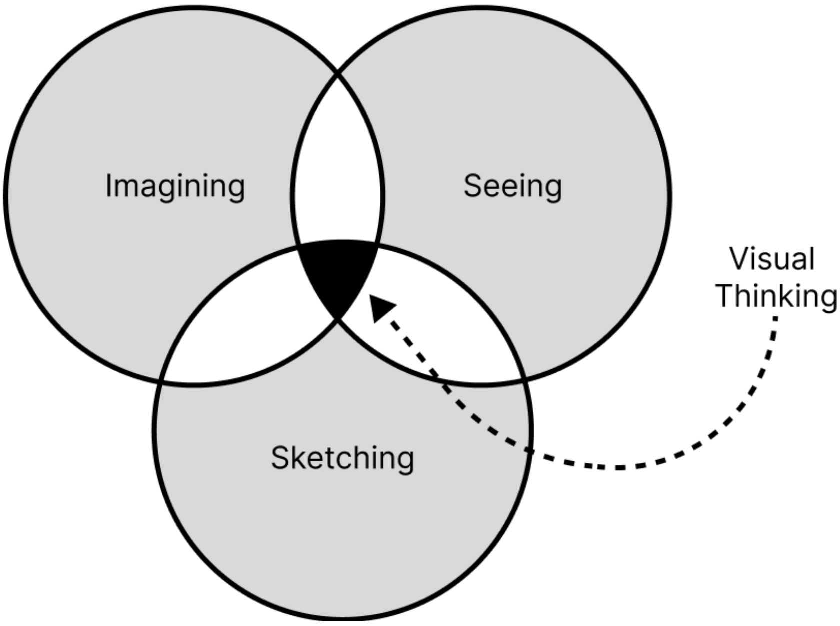

Figure 16. Note: Visual Thinking. Adapted from "Interaction design sketchbook", by B. Verplank, 2003, p. 4.

Using visual thinking as a method comes from a childhood of 'draw it for me' moments. In younger years I played repeatedly with LEGO branching out into more diverse making methods until finding digital sketching to be my home. During this time, especially in younger years, it was hard for me to formulate these ideas into objects. Having two parents who were both art and design teachers allowed me access to technicians vastly superior in physical craft to myself, but both requiring sketches to share in my ideation process and help produce the artifacts I was imagining. As I gained access to my first computers, this process gradually shifted towards 3D modelling and then 3D printing, but the ability to create extremely rapid ‘sketch’ 3D models was inherited from this hand drawn sketching in my formative years. I would attribute my association between thinking and sketching to this childhood experience which occurred commonly to me.

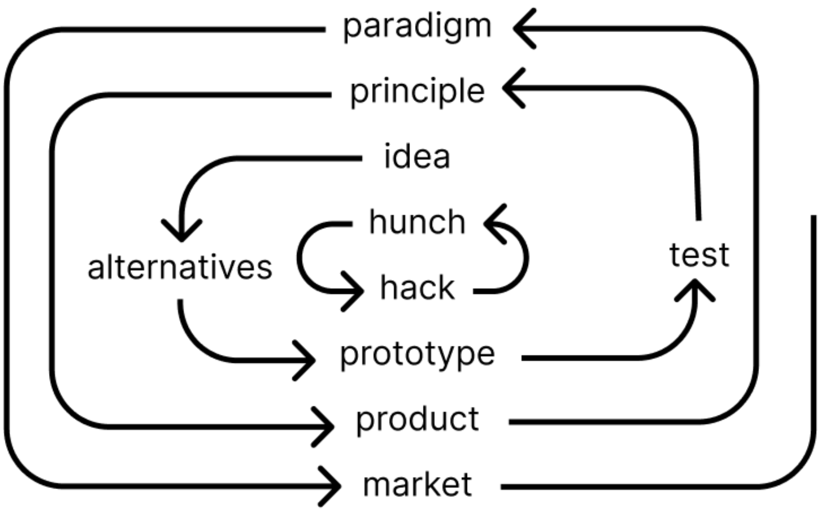

Figure 17. Note: The Design Process. Adapted from “Interaction design sketchbook”, by B. Verplank, 2003, p. 3.

Verplank defines the Design Process very clearly in his diagram which I’ve adapted. “If you are only working on one design at a time, comparisons are never drawn, criteria are never challenged.” (Verplank, 2003, p. 3). This could be categorised as ‘visual thinking’ which is very similar to the ‘hunch’ and ‘hack process in Verplank’s diagram, a vital stage for exploring creative avenues. I believe that the hunch and hack happen at all stages of the design process, be it at market, idea, or prototyping and is what largely mitigates the risk of an unchallenged design being bad for users. The childhood process I previously described made up of ideation and sketching occur before the prototype stage, and this process is something which I have continued to enact through this thesis and exploration of virtual accessibility.

Gradinar is “mostly concerned with the top part, which defines the principle and the paradigm” (2018, p. 35) when considering himself a researcher and the bottom half when seeing himself as a designer. When considering these same sections, I see my entire thesis as a processing through this cycle as one holistic role of researcher and designer as shown in the above figure. Rather than seeing each part of this thesis as a small facet or project, I see each as interconnected and flowing towards a product and market. Many prototypes were designed to challenge the paradigm, and then each retested and accessed for its merits. Once many stages of this occurred, I began to more formally produce a product which is marketable and user centric and striving towards a much more accessible future.

0c.19. Game jams as Method

While constant parallel designing should never cease when trying to make designs best for users, it is important to reduce it as projects evolve, instead refining the design of a specific selected artifact. At some stage we as designers need to decide which ideas are more viable, and which should be forgotten, or banked for later usage. However, before reaching these later stages of design refinement, parallel design is a more than suitable method to strengthen design robustness. Game jams are a notorious digital prototyping method with many valuable takeaways. Game jams could be regarded as game design's equivalent of visual thinking and have many benefits, even beyond the ability to test and refine designs. Game "jam events seem to be important for learning rapid prototyping technologies and working with according tools. The potential for industry partners (networking, recruiting, publicity) is also mentioned several times." (Pirker et al., 2016, p. 3).

While the research within this thesis does not include research from any official game jams, the subsequent literature review (1a) and first data chapter (1b) do lean into many of the techniques which could be deemed game-jam-like (especially the game design upskilling, and short time frames to develop a playable game experience). Because of this I see it as fitting to end this methodologies chapter by briefly explaining the process of Game jams to the reader which likely began in 2002 with the Indie Game Jam.

> "Initially, game jams were widely seen as frivolous activities. Since then, they have taken the world by storm. Game jams have not only become part of the day-to-day process of many game developers, but jams are also used for activist purposes, for learning and teaching, as part of the experience economy, for making commercial prototypes that gamers can vote on, and more." (Lai et al., 2021, p. 1).

Game jams as a method are fundamentally defined by several typical attributes including "time-boxing, a general theme, ad hoc group forming and a communal presentation" (Lai et al., 2021, p. 2), however the general attitude is focused around "an accelerated video game development competition" (Kultima, 2015, p. 2), with the competition element being variably important (meaning some participants see it as important to the Game jam, while others see the competition merely as a tool to fuel direction within creation).

For the purposes of this thesis, I used game-jam-like techniques to accelerate the speed at which I understood game development within general purpose engines. Not only did the notion of Game jams enable me to rapidly prototype several wayfinding based virtual experiences, but it also enabled me to remain distanced from hardware and software constraints in early development (Which was drawn from Game jam's hardware, and software agnostic approach).

> "Many reflections on game studies are still narrow and affected by the personal academic interests of the researchers themselves… The word 'design' is found to be complex in the field of design research in general. As more and more design fields are emerging, it is becoming increasingly difficult to address the area as unified." (Kultima, 2018, pp. 9-15).

This parallel drawn by Kultima between game design and design research is incredibly compelling for this thesis. Within the same book, Kultima also draws attention to the interchangeability of the terms game designer and game developer (which is also generally true for the words designer and developer more generally) alongside taking the stance that "approaching game design as design research changes the way we see game studies". Doing so draws emphasis onto the designer, design, practice, and process which were previously considered as context for the game, play and player (which were viewed as more central). While in the initial data chapters (1b and 2b) of this thesis the focus was more orientated towards game design through a general design research lens, later, through the use of Co-Design, a more balanced approach was achieved (3b), regarding design and play as equally significant to good game development practice and involving the players in the design as far as possible.

"As the digital world becomes part of everyday lives for the larger population, the variety of functions that games are fulfilling and the thresholds of use for digital games also become more versatile. The rise of casual and social game industries indicates transformation in games cultures that embodies this very same development." (Kultima & Stenros, 2010, p. 72) This idea is emblematic of the purpose of this entire thesis. Virtual spatial experiences are no longer simply an escape from the physical world, having expanded beyond the scope of games into the realm of general purpose, virtual social spaces (proven by the explosion of Metaverse spaces developed by large companies). Because of this, games (and virtual spatial wayfinding systems) can no longer rely on the learned experience of dedicated gamers when designing the languages they need for virtual spatial wayfinding. These systems must lower their entry points by simplifying their onboarding processes, improving their mixed sensory tangibility and focusing on accessibility from their earliest development stages. This thesis aims to better understand how to achieve these goals, using drifting between the methods mentioned in this chapter as a design research vessel.

0c.20. What Comes Next?

The next sections of this thesis will be focused on the research I undertook. Each of my three data chapters in each section will aim to segment the work I created into parts which led to the next section and adventure or discovery. At the start each of these sections is a smaller literature review, similar to the one at the start of this thesis aiming to situate each of the chapters directly after them within the wider narrative of wayfinding and accessibility in virtual non-tactile space. I believe it important to represent both sides of this progress to best showcase where accessibility currently is in the virtual landscape. After these sections comes a conclusion, thinking about where I ought to go next, and where others might find interest starting off from when exploring similar research avenues. With each section I will study the research similarly through a form of case study, but I will approach them as personal design projects, each using different approaches and methods which will be more specifically explained in their contexts.

These do not necessarily conform to the definition of a case study, but they aim to explain each segment of the thesis as a project in the clearest way possible, situating each within relevant literature. While each project can be read individually, I do see some significance in reading them as a journey, as this is the path I voyaged, and it may help provide clarity on the entire thesis and rationalise my design pathways. Each is written with my ontology, epistemologies, and methodologies in mind, and I have tried to reflect any adjustments in methodologies as I move through the research and the thesis.

> "Research is often portrayed as a systematic, inquiry-driven investigation of predetermined topics and questions. Our experience as practice-based design researchers, however, is that the reality is far messier. We routinely invent, adjust and reconfigure methods, issues, goals and even topics in the course of our projects. This often leads to outputs that are entirely different (and arguably better) than we imagined when we began." (Gaver et al., 2022, p. 517)

My main aim with this thesis' narrative is to have a recorded log of my processes and mental reflections on these processes, which you the outside viewer can understand. Because of this, messiness is clearly involved as well as some significant drifting by intention. Finally, I would like to say enjoy the journey, I hope it will be much shorter, but just as eye opening for you as it was for me.

1a. Over-Specificity

1a.1. The Rise of Pandemic Virtual Social Spaces

This section is a bridge between the initial literature and the first data chapter. Focusing on the concept of immersion by balancing over-specificity and ambiguity, I will use Gradinar's definition that "immersion can be described as the degree of involvement of a player with a particular game" (Gradinar et al., 2015, p. 1). While this entire thesis looks at immersion, this literature chapter (1a) considers different features of designed virtual wayfinding experiences which reduce or increase immersion through over-specifying.

> "When looking at the features of immersion, there seem to be strong links with Czsentmihalyi's concept of flow, central to flow is attention. Any distraction from the task at hand causes the feeling of flow to be erased. Flow has some parallels with immersion in the fact that attention is needed, sense of time is altered, and sense of self is lost. Also, the use of skill and knowledge is the same in immersion as in flow." (Brown & Cairns, 2004, p. 1300).

Visual fidelity, or VR may be regarded as key to immersion, but I have come to believe that play and interactions are more integral, with graphics merely being a beautifying wrapper. As Brown & Cairns assert, distraction reduces flow and immersion. Therefore, increased fidelity through something like VR is not likely to boost immersion unless the experience is carefully designed around VR's features, and instead may cause more distractions. If someone is already overwhelmed, then adding more information to make it more 'immersive' will not be successful. This thesis' overarching narrative also showcases why my view of immersion moved so heavily towards play.

Before continuing to explore the concept of immersion it is important that I situate this section's research within global events. In the year 2020, I amongst millions of others found myself in seemingly unprecedented circumstances due to the COVID-19 pandemic while finishing an interaction design degree where I used Machine Learning to create self-reflective design pieces. While very accustomed to virtual socialising (through playing online games with friends for many years), those I lived with struggled to enjoy virtual social spaces, trapped by imposed restrictions on their physical world. While not claiming the pandemic did not impact me, the almost immediate drop in social satisfaction I observed in those I lived with made me question which elements of virtual social spaces were not immersive to them.

Realising their ability to be immersed within a virtual space was tied to a lack of familiarly, I felt a need to explore the balance between legibility and over-specificity, which might reduce this inaccessibility they experienced. Familiarity with complex virtual spaces makes virtual immersion easier, and while this does not guarantee more enjoyable experiences, these interactions tend to have more longevity of engagement. In-game social mechanics, out-of-game communities, episodic content, e-sports potential, gambling elements, neurotic addiction, strong stories, replay-ability, and ability to exhibit creativity (Xu, 2016, p. iv) are all identified as factors which increase a game's longevity. "In the few decades since they first blipped their way onto television screens, videogames have become one of the most culturally, socially and economically significant media forms." (Newman, 2012, p. ii). My personal experience with longevity in games links to in and out-of-game social mechanics, frequent gameplay updates, and the surrounding esports scenes. All these aspects provide frequent markers for players to return to the virtual space.

Simpler games, while more accessible, often lack these frequent return markers. Episodic content would detract from their appeal, disadvantaging people who play infrequently by causing them to have to constantly relearn game systems. Their simple nature also reduces esports potential. This is because there is a lower skill ceiling due to their over-specified mechanics. Social circles evolve around these games less due to their other infrequent return markers, and in-game social systems are usually not implemented to increase the simplicity and child friendly play they aim to facilitate. Because longevity of engagement is not always important to a game's design, viewing the difference between these simple and complex virtual spaces as a gradient between over-specificity and ambiguity perhaps describes their intents better. Through the next 2 sections (1 and 2) I will be exploring ambiguity and over-specificity as focal points with the intent to focus on legibility (the balanced space between) in section 3. To situate the over-specificity focused RtD experiments in (1b) it is important to analyse examples of virtual space which attempt to create immersion through over-specificity.

1a.2. Immersing or Immerging in Virtual Space

While all virtual spaces have varied purposes, they are generally designed to be used and useable. Many approaches can achieve this, but in this chapter, I will focus on how over-specificity can compromise or improve usability. Well-designed virtual spaces can teach users their interactions along the way, but greatly benefit from users' existing wayfinding knowledge, which can transfer from virtual or physical experiences. Designing for realism often causes over-specificity, and while this lack of legibility can be deemed as design oversight, understanding the developers' intents for virtual spaces can help identify causes of over-specificity.

Realism may be designed into virtual spaces with the aim to make narratives more believable, increase immersion, or for the user's visual enjoyment, as well as a plethora of other reasons. However, realism can lead to many issues with perceived affordances (if the physical world being emulated would have actual affordances, but their interactions have not been implemented virtually). Accounting for this issue, *Half-Life: Alyx* (Valve, 2020) focused on diverse environmental interactions, making most objects which would usually be static (within other games) destroyable, moveable, and dynamic, and therefore providing more realistic engagement. Ranging from glass bottles to street cones - and even facilitating carrying power-ups inside a frying pan - *Half-Life: Alyx's* wide range of interactive objects allowed many more perceived affordances to be actualised than in most other virtual spaces, largely negating VR control over-specificity (similarly to physical world movement). These optional interactions avoid overcomplicating the play experience, and Valve's vigorous playtesting unearthed many false affordances either removed or made into actual affordances.

Outside of game virtual spaces, where the target audience does not necessarily have familiarity with virtual interaction norms, over-specificity tends to be even more commonplace. However, over-specificity is still prevalent in games when their UI (User Interface) and affordances are not carefully considered.

> "Videogames are created for human players whose commonsense knowledge of real-world objects and interactions (and their familiarity with other games) primes them for successful play. Action games feature recurring formal elements including a directly controlled avatar, moving enemies, resource pickups, and portals to new map areas; mapping these onto culturally significant symbols helps players learn to play quickly." (Bentley & Osborn, 2019, p. 1.).

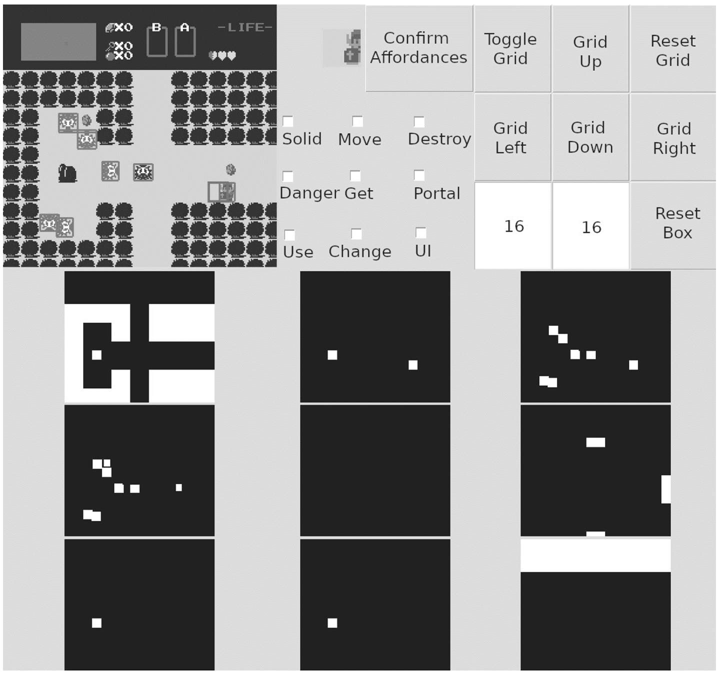

Figure 18. Note: Affordance Annotation Tool. Reprinted from "The videogame affordances corpus," by G. R. Bentley and J. C. Osborn, 2019, *Experimental AI in Games Workshop*, p. 2.

Bentley deduces that games are not consistently able to make affordances perceivable due to their varied genres and art styles. Developing an automated version of Bentley's tool as an assistive overlay could be revolutionary for visually impaired players. Change blindness is essentially the visual equivalent of what a tool like this could achieve. Commonly used in modern games, important affordances are highlighted earlier in gameplay, then gradually unhighlighted with each occurrence as players notice the affordance themselves. This process can be inverted to impede the player, moving objects or rooms when out of sight. When tested "only one out of 77 participants was able to definitively notice that a scene change had occurred while exploring" (Suma et al., 2011, p. 166) in a maze layout virtual environment which changed door locations when they were out of view.

Visual trickery (such as change blindness) is more evident when the player is distracted but relies on unfamiliarity with a location. This familiarity can be extremely useful in other ways, allowing designers to lean on the normal physical space tendencies of people in the virtual space. This effect is strongest when attendees have been in the physical original space together, such as virtual church services, or simple video calls.

> "Virtual services raise many important questions for human and theological geographers. For the theologian, publicly accessible online services challenge the relationship between parish structure and people; the virtual service destroys geography by extending the geographic reach of the parish beyond physical boundaries and existing communities. Nevertheless, they also extend

the congregation; even small churches are seeing online attendances well into the hundreds. Online services enhance inclusivity as the ill, and those who have moved beyond the parish, are able to engage with intersacred space." (Bryson et al., 2020, p. 370).

While these services are geographically subversive, and have intriguingly transferred social wayfinding from their physical counterparts, their movement-based wayfinding is limited due to their target audience's lack of experience with virtual spaces. Virtual spaces incorporating movement and social wayfinding are more likely to facilitate flow state at varied user proficiency levels, using 'affordance-hacks' like change blindness to keep them between anxiety and boredom, maintaining intrigue. The original *Crash Bandicoot* (Naughty Dog, 1996) game notably used a rolling boulder which slowed with each failed escape from its chase.

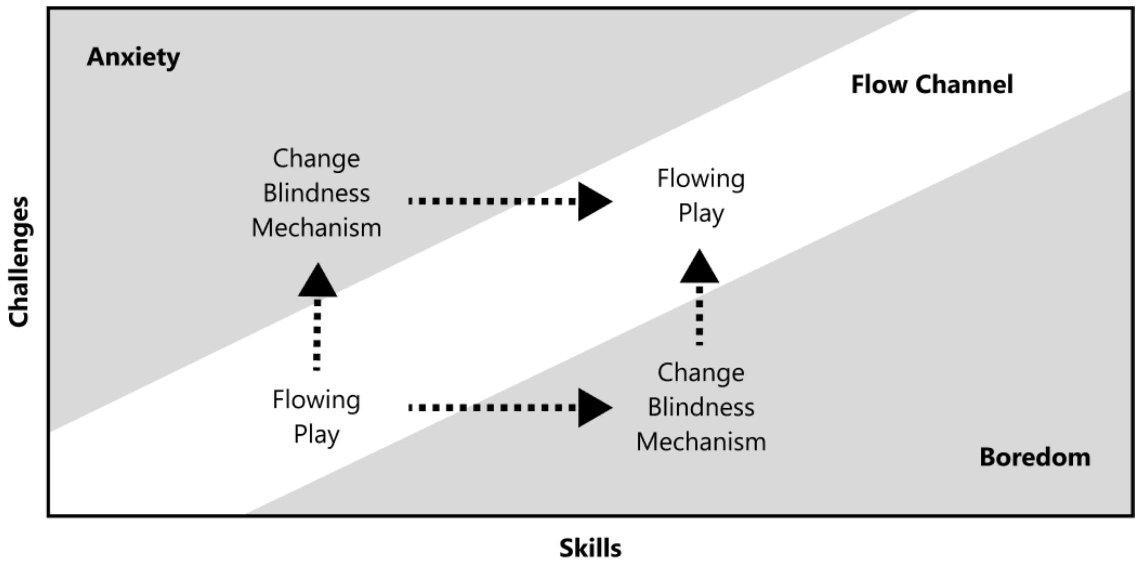

Figure 19. Change Blindness to Maintain Flow State.

Virtual reality experiences provide ample opportunity for immersive wayfinding. "In the 21st century workplace (especially in COVID times), much of human social interaction occurs during virtual meetings. Unlike traditional screen-based remote meetings, VR meetings promise a more richly embodied form of communication." (Osborne et al., 2023, p. 1789). The language of affordances for virtual space beyond games is still very primordial, especially so for virtual reality where there is not a long history of VR games to draw from.

Scale for onboarding:	Spatial	Glue VR	Mozilla Hubs	VRChat	AltspaceVR	Rec Room
Unsatisfied	**40%**	**0**	**0**	**29%**	**17%**	**0**
Neutral	**20%**	**33%**	**0**	**0**	**17%**	**60%**
Satisfied	**40%**	**66%**	**100%**	**71%**	**67%**	**40%**
Environmental Cues:						
Skeuomorphic	**40%**	**0**	**0**	**29%**	**17%**	**0**
Experimental	**20%**	**33%**	**0**	**0**	**17%**	**60%**
Prefabs-based	**40%**	**66%**	**100%**	**71%**	**67%**	**40%**
Total N of Participants	**5**	**9**	**4**	**7**	**6**	**5**

Figure 20. Note: Environmental affordance queues and onboarding metrics in VR systems. Reprinted from "Being Social in VR Meetings: A Landscape Analysis of Current Tools," by A. Osborne et al., 2023, ACM Designing Interactive Systems Conference (DIS '23), p. 1800.

Osborne's findings from considering usage of VR capable social spaces are generally non-conclusive, but do provide the useful revelation that allowing users to bring personal files into virtual space "was the most popular tool our participants used upon its availability across all platforms, including Spatial (100%), Mozilla Hubs (100%), and Glue VR (89%)." This ability to bring files (such as notes, images or 3D models) into shared space creates great opportunity for participants to engage in wayfinding which "video conferencing software does not" (Osborne et al., 2023, p. 1801). This personal connection to virtual spaces is not new, but this self-empathy impacts virtual experience's chance of keeping its users in a flow state by enabling them to personalise their space, and mentally attach themselves to it.

Narrative focused games often focus on creating empathy between the player and their character (self-empathy). This self-empathy reduces the gap between the player and the environment they are present in as with bringing files into virtual social spaces. Self-empathy is in constant danger of becoming over-specificity, leaving players without agency, or ambiguity through vague character motives. This balancing act between anxiety and boredom can be circumvented by giving the user the ability to drive their own narratives through their own ideas and objects as with virtual social spaces. Personal tethering to virtual worlds can also be improved when users are able to recognise other users easily within the space. While microphone and webcams facilitate this recognition, they reduce the prominence of space within shared virtual space. Avatars increase this sense of space alongside the recognisability of other users through embodied presence, and when properly implemented help avoid over-specificity by visualising characters abilities through their physical appearance.

1a.3. Embodied Immersion

Virtual immersion through embodiment is complex due to users not feeling self-empathy when specific characters do not represent themselves, or when virtual narratives are vague to facilitate a user designed avatar. Player avatars provide opportunities for immersion by giving users presence in space but are another balancing act where over-specificity is often the outcome. Immersion within multi-user virtual spaces is reliant on creating a believable sense of space which can be increase through appropriate avatar design. Using self-avatar, face-to-face and no self-avatar as the variants, Pan found that "while participants were cooperating at the same table, we observed several notable differences in participant body orientations. For the face to face condition and the self-avatar condition, participants often stood side-by-side, and tilted their bodies toward each other. However, for the no self-avatar condition, participants seemed more evenly distributed." (Pan, 2017). This study also found several other benefits to self-avatar besides just body language immersion including increasing trust between the participants in general, and heavy benefits to embodiment in virtual environments, both VR and otherwise:

> "Users in the self-avatar condition completed the task more quickly that users in no self-avatar in cooperative tasks; however, embodiment levels had no significant effect in competitive tasks. Additionally, participants completed the task faster in a cooperative style than they did using a competitive style for the self-avatar and the face to face condition. However, interestingly we were not able to find such effect in the no self-avatar condition. Furthermore, participants with a self-avatar showed a significant increase in trust after interaction, compared with participants without a self-avatar" (Pan & Steed, 2017, p. 17).

These findings allude to an increased sense of spatial awareness through this embodiment, likely caused by bodily affordances which users were accustomed to in physical space being transferable when they embodied a virtual avatar.

Avatars can however introduce over-specificity, counteracting positive transferable learnings from physical space. While giving users autonomy over their avatar's appearance is likely to increase self-empathy, it can be misunderstood as also effecting the avatars capabilities, introducing false affordances. Furthermore, not providing users with sufficient tools to design their avatar can be more mentally limiting than a specified character.

> "Players do not always desire a realistic avatar in games, and… they seldom arrive at CCIs with concrete plans for their avatar's appearance… we understand avatars to be the result of a dialogue between user and interface… The issue of social exclusion arises when players who want to recreate

themselves via their avatars are limited by interface affordances. When this happens, games go from being places where we can be who we want to be, to becoming places where we can only be who the developers allowed us to be." (McArthur et al., 2015, p. 239).

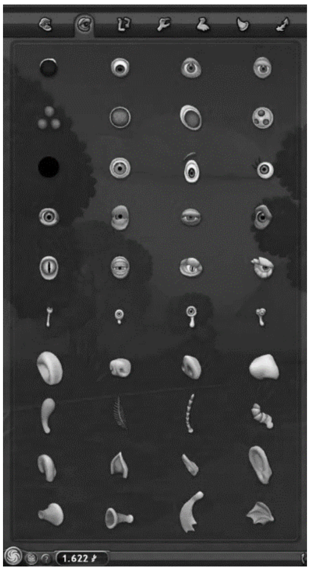

Figure 21. Character Creation Interface in *Spore* (EA, 2008)

Intertwining the avatars perceived affordances due to their visual appearance with their in-game abilities is critical to avoid over-specificity. *Spore* (EA, 2008) ties avatar abilities directly to their creation. For example, certain eyes allow a player to see further, specific noses have more complex smelling capabilities and mouths change the complexity of their spoken language. While this deviates wildly from traditional character creation, tasking the user with balancing their avatar's capabilities through character design it highlights the variety of motives for avatar design which developers may intend, and users may desire. While many people want to play as themselves within virtual spaces, many others may opt to use "generated avatars dissimilar to the user's self to allow for identity play and ameliorated self-representation." (Trepte et al., 2010, p. 172).

Gameplay, player desire to experiment with identity play, trust and embodiment are just a hand full of factors highlighted above which a designer ought to consider when considering how avatars effect immersion. Bartle's taxonomy of play is often used to demonstrate how different user motives orientate within game-space play. While compellingly, it has largely been discounted as overly simple (which this handful of examples begins to showcase) with players often having "different motivations to take on different characteristics at different times and with different games" (Gabriela, 2014, p. 203).

Vandenberghe (2012), a creative director at Ubisoft "proposed that psychology's big five personality traits could easily and accurately predict a player's game choices and that each of the five personality traits (openness, conscientiousness, extroversion, agreeableness, and neuroticism) is related to the motivations that drive behaviour and choices in general" and "that each player mapped onto the domains of play differently… While we cannot always design for everyone, he encouraged designers to think about personality and play style, beyond the demographics (and assumptions) that are often used." (Gabriela, 2014, p. 204).

One thing the above analysis around avatar immersion does highlight is that varied character design systems are enjoyable for different players. AI (Artificial Intelligence) and machine learning systems have the potential to tailor play experiences to a user further, better satiating users in their specific gameplay tendencies. Allowing a user to inject their own identity and play preferences into virtual space through AI generated game elements is one potential avenue to improve virtual immersion which I explore in (1b) through machine learnt landscapes. AI could maximise self-empathy through adaptive wayfinding without introducing the normal ambiguity caused by open ended narratives.

This section feels especially relevant to this thesis around accessible virtual wayfinding design as Machine learning and AI are starting to be used as tools to create NPCs (non-Player Characters) and even character variations for a player to choose from which I elaborate on in (1a.4). Therefore, understanding their impacts in virtual spaces is vital to realising how they can improve wayfinding accessibility in future virtual spaces.

1a.4. Machine Learning in Virtual Spaces

Large companies such as Nvidia, Electronic Arts and OpenAI are investing heavily into AI driven character behaviour and visuals. These developments will be integral to the future of wayfinding in virtual space, especially in relation to assistive functionality for accessibility purposes such as the affordance highlighter theorised in (1a.2). Nvidia, a leading game software and hardware company conclude the following about character driven AI behaviour:

> "Our method learns when and where to transition from one behaviour to another to execute the desired task. We introduced an efficient randomization approach for the training objects, their placements, sizes, and physical properties. This randomization approach allows our policies to generalize to a wide range of objects and scenarios not shown in the human demonstration. We showed that our policies are robust to different physical perturbations and sudden changes in the environment" (Hassan et al., 2023, p. 7).

Systems like this are already being used by game modding communities in titles such as *The Elder Scrolls V: Skyrim.* (Bethesda, 2011), to create conversational NPCs. "AI-assisted game design is a perfect example of hybrid intelligence since it is a process where human expert knowledge and AI techniques together serve the purpose of game design" (Xia et al., 2020, p. 508). This AI assisted design can enable games which simply could not have been made before, opening the potential for even more complex wayfinding. Because of these improved possibilities for wayfinding, there needs to be greater accessibility considerations as games become increasingly less linear and therefore game experiences become less mediated by the designers, vastly increasing ambiguity in player affordances.

RtD (Research through Design) and other design processes are already beginning to use AI during ideation. AI can bring a "perspective that opens up new avenues for artistic expression" augmenting human creativity (Chiou et al., 2023, p. 1941). Self-empathy forms when the player can associate with their avatar (1a.3), and realistic movement helps this association, building immersion. Using AI can enable "both photorealistic and stylized avatars, and the ability to enable mutual eye contact in multi-directional video conferencing." (Stengel et al., 2023, p. 1). Eye contact greatly improves empathy and communication with others, especially for virtual spaces which are intended for people who are unfamiliar with games. Stylising avatars while displaying users' physical facial expressions could improve virtual empathy but risks over-specificity if designed without accessibility consideration. By removing the need for emotes and text communication through voice and facial input, participants within AI-mediated virtual space could focus their thoughts on the natural embodied conversations. The increased similarly to physical interactions people are used to could also reduce false affordances, buttons, and menus, providing accessible interactions enacted similarly to the physical world. While this presents many potential benefits to using AI, mediating human interactions during the design process increases the risk that wayfinding accessibility and legibility are overlooked. Game designers often rely on their predecessors to form virtual wayfinding systems in an iterative way, and non-game virtual spaces take from these same predecessors. AI is trained on data similarly to iterative game design, making it susceptible to accessibility issues which previous game designers overlooked (Hong & Williams, 2019, p. 80). Because of this, moderating AI's inherited bias is vital to the future of legible and accessible virtual wayfinding.

This subsection (1a.4) highlights how AI systems can intertwine us deeply with game worlds, increasing immersion and legibility, but is cautious to advise that AI is a one size fits all solution without the need for human checks. The increased reactivity to our physical selves AI can provide risks a decline into virtual spaces which pander too much to our desires and tendencies for vanity. If everything within a virtual world is responsive to our own sense of self, we risk creating over-specificity through over-compatibility. Being aware of the boundaries between the physical and virtual worlds we inhabit, it is vital to avoid this future. Virtual spaces which are physics subversive can help to specify this boundary, focusing on immersion through mental stimulation and unique gameplay experiences, rather than warping themselves to our own overly specific expectations and desires.

1a.5. Physics Subversive Over-Specificity

Several patterns are noteworthy when considering physics subversive game design. Physics subversive games care little for creating believability in the game universe, instead focusing on the core physics subversive systems' seamlessness through simple narratives which enable users to understand their unusual onboarding. Silent protagonists are usually used, due to developers' expectation that levels will be failed many times (and wanting players to avoid hearing repeat voice lines). Puzzle games core interactions focus on wayfinding, having been proven to improve the problem-solving skills of their players (Pusey, 2018) making them critically important to this research's aims when considering the design of accessible virtual spaces for both non-game and game purposes alike.

For the purposes of analysing these physics subversive game features, I will be looking at *Superliminal* (Pillow Castle Games, 2019), *Viewfinder* (Thunderful Publishing, 2023) and *Portal* (Valve, 2007). Other games such as *The Witness* (Thekla Inc, 2016), *Antichamber* (Demruth, 2014) and *Miegakure* (Bosch, Unreleased) include many of the same features, however *Superliminal, Viewfinder* and *Portal* are exemplary of the genre's common features. All three titles present non-Euclidean physics to the player (a term which when used within game contexts usually refers to the breaking of physical world physics laws). While "we still cannot decide whether the real world is approximately Euclidean or approximately non-Euclidean" (Coxeter, 1998, p. 12), standard game engine physics are Euclidean.

"The experience of disorientation not only shatters the players' fundamental behaviour built by experiencing the physically real but it also becomes the crucial entertainment of such computer games." (Bonner, 2021, p. 9). These shattered expectations within physics subversive games rely on non-Euclidean elements being perfectly polished, allowing players to finitely understand the limits of the physics subversion occurring. Flawless physics subversion bolstered by adequate specificity slowly reduced through change blindness focuses immersion away from the wider game world's believability. *Portal* does this explicitly with bright white panels allowing portals to be placed on them, while darker panels rejecting them, quashing a false affordance before its engrained through distinct visual language.

Viewfinder subverts physics by allowing players to capture photographs which can be reconstituted into 3D objects at will. As with *Portal*, tone is used with vibrant red and blue signifying objects which will and will not show up in photographs. *Viewfinder*, as a "non-action video game" (Oei & Patterson, 2014, p. 218) allows gameplay to be rewound in real time, establishing that failure is a core part of its play by making the usual inconvenience of making mistakes an enjoyable gameplay element. With repeating being core to gameplay, having voice lines repeat after each reversal would be unwise, with game developers unable to account for how many rewinds might take place.

Conversely to *Portal* and *Viewfinder, Superliminal* repeatedly creates intentional false affordances to trip up the player. While amusing the first few times, this highlights an inability for its physics subversion to create genuine challenge, instead focusing on a gradual degrading of space from quite normal rooms into completely abstract voids. This does however highlight that successful physics subversive games depend on perfectly ample specificity during onboarding. *Portal* can always use time to increase challenge, and *Viewfinder* gradually reveals more constraints and tools such as photographs destroying the original spaces they capture, time-based levels and a handheld camera.

These types of games can be complex to grasp and harder to complete, requiring refined abilities to control character movement and look direction. This, complexity requires iterative onboarding throughout meaning linearity is essential, and any narrative must be tied to the completion or beginning of puzzles. Mittell states that:

> "The puzzle genre is frequently hailed as the proof that gameplay trumps story via examples like Tetris, as the compelling mechanics of such games need no narrative frame to engage players. Evoking sports, another frequently cited genre of non-narrative games, Markku Eskelinen (2001, p. 1) famously and provocatively staked out the extreme anti-narratological position by writing, "If I throw a ball at you, I don't expect you to drop it and wait until it starts telling stories." But I would argue that this dismissively pithy phrase captures much of what makes Portal such a compelling experience on both ludo-logical and narrative terms: midway through this puzzle game, the ball starts telling a story. This unexpected shift in Portal is what elevates the game beyond just an engaging puzzler into a landmark of the medium: you slowly begin to realize that the game has been presenting a narrative throughout, even while you were primarily focused on the mechanics and puzzles." (Mitell, 2012, p. 9)

Portal's narrative elements have significant value for virtual spatial wayfinding far beyond the realm of games, let alone puzzlers. As Eskelinen states, *Portal's* story does not begin until roughly half-way through the game at which point its overly specific affordance markers have dissolved through change blindness. Crumbling and half destroyed walls take the place of darker materials where portals cannot be placed, and urgency is incorporated through conveyer belts as real perceived danger to the player. All these escalating mechanics hold more gravitas because of the extended linearity in the earlier sections, presenting a shining example of effective and effortless onboarding for the user. This doesn't require any specific narrative elements to be defined initially, allowing a user to become heavily accustomed to virtual space mechanics first.

To summarise, *Superliminal*, *Viewfinder* and *Portal* highlight that clarifying affordances through extensive onboarding can be enjoyable if the underpinning purpose of the space is deemed worthy to the user. Hunicke identifies "Sensation, Fellowship, Fantasy, Discovery, Narrative, Expression, Challenge and Submission" as a series of very common game taxonomy (Hunicke et al., 2004, p. 3). If these taxonomies are met, there is no need for high fidelity. When designing any virtual space for users who might be unfamiliar with the standard mechanics, physics subversive games can be used as references for interaction design. Linearity and extensive onboarding should be used whenever they increase users understanding of the virtual spaces social and mechanical rules and should be built into the experiences themselves. Physics subversive games focus on voiceless protagonists may not always be relevant to the spaces we design. However, they do show that embodiment is not required if users are already immersed, which opens up virtual spaces for users to imprint their own self-empathy in their experiences.

1a.6. Where does the 'Research' Begin?

To summarise, the literature in this chapter focused on over-specificity, while legibility is a key factor in successful virtual spatial wayfinding, what may initially be deemed as over-specify may be required when onboarding users. Some virtual spaces are intended for vast hours of interaction and others as infrequent short-lived interludes to our physical lives as virtual spaces can be tailored for work, play or anything in-between. Varied virtual spaces different amounts of ambiguity and over-specificity to be legible and immersive to their users. As almost all virtual spaces are designed with an intent for their systems to be as useable as possible, identifying design focuses such as immersivity, embodiment, avatar representation, spatial familiarity and onboarding comprehension enables each to be correctly designed for appropriate wayfinding legibility. The proceeding data chapter (1b) continues to explore the over-specificity issues which are identified here through RtD virtual space experiments. With virtual spatial wayfinding legibility as the key consideration, the following chapter will tackle virtual over-specificity with more targeted experiments around these questions:

- *What is Designing a Physics Subversive Virtual Space Like?*
- *How Does Spatial Familiarity alter Subversion and Immersion?*
- *Can Machine Learning Improve Embodiment in Virtual Spaces?*

1b. Reaching the Problem

1b.7. Beginning [R]esearch

While sufficient research rationale is important, I believe 'Research' with a capital R within RtD is critical, and must be focused on the action of doing, the reflection on the process itself, or the impact the doing had on continued 'Research'. This initial data chapter is an eclectic RtD exploration, drifting by intention in order section 2 and 3 more specific research direction. The previous chapter (1a) ended by considering physics subversive games as this PhD's research stemmed from a fascination with *Superliminial, Portal* and *Miegakure*. While *Viewfinder* was unreleased at this time it continues to explore virtual wayfinding in the same unique way. While considering the similarities between these games, I realised consistent controller design spanned across all games including them. (0b.9) Establishes that game controllers are incredibly standardised, and game designers are forced to conform if they want their games to be successful. While keyboard and mouse allow wider control options and increased accuracy, having been designed for file navigation it is very plausible to suggest their appropriation for gameplay has stunted game innovation.

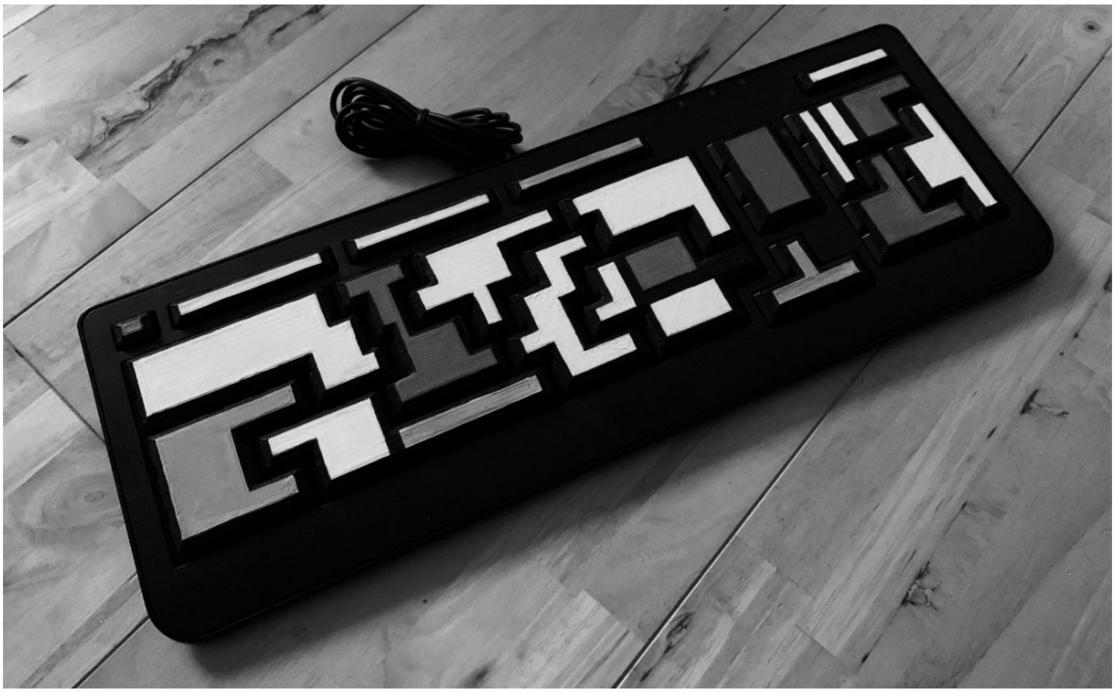

Figure 22. 3D Printed De Stijl Keyboard.

To highlight this design appropriation, I wanted to consider how a keyboard would appear to an alien. "We know that nothing in the engineering of computer terminals requires the awkward keyboard layout known today as QWERTY" (David, 1985, p. 332). Considering this, I decided to create a De Stijl (White, 2003) inspired keyboard using a 3D printer playing on De Stijl's strict ruleset to highlight the inappropriate restrictions a keyboard forces game designers into. Making this keyboard furthered my awareness of virtual spaces reliance on physical controllers which is why it is both the first (1b.7) and last (4b.6) piece of 'Research' in this thesis. Noting that I had initially been drawn to consider the physical aspects of virtual experience which are so much less likely to be changeable by a single research thesis, I instead focused the rest of this initial RtD research exploration within virtual design. This physical protrusion of virtual space is arguably the least significant part of the immersive wayfinding design I aim to target in this thesis.

Considering the unconscious practice I had begun to develop collecting 3D scans of places I had lived in, I reflected on this transposition of sentimental physical spaces into artifacts. Being able to distort scale, texture and colour spaces felt closely tied to my fascination with physical subversive games (1a.5), and my own form of materialism. I decided to delve deeper into this practice I had developed during the isolating times of COVID-19, document my thoughts around the objects I chose and the subversions I applied to them. Talking to my father about a crocodile skull which had always intrigued me in my parents' home - where I lived for several months in the pandemic - I discovered it had been a gift from his father-in-law. The idea that someone could be expected to enjoy the material qualities of bones made me consider my own attachment to virtual objects.

Figure 23. Original African Crocodile Skull next to 3D printed miniatures.

I distinctly remember my father asking me what the purpose of transposing these objects was, due to his lack of understanding for my attachment to the virtual objects and an inability to visualise the strands which link these RtD artifactstogether. Often feeling similarly at the time, when I look back through my RtD artifacts chronologically, the progression through each new artifact (as written through this chapter (1b)) becomes a quantifiable design journey.

Continuing to digitise physical objects and 3D print copies, I realised this process applied similar knock-on effects to the keyboard, locking objects in their 'specified' physical state and constraining new designs reliant on them. People who inhabit spaces can completely redesign the space's usage, but the walls, doors and windows constrain these redesigns heavily. Trying to explore the liminal area between physical and virtual space made me realise that physical interfaces connecting to virtual space (such as controllers, touchscreens, and keyboards) have the same effect on virtual experiences. Because of this, I decided that staying digital in my RtD ideation going forward would draw the focus of this research away from the over-specificity which physical interfaces bring to potentially fluid virtual space.

1b.8. Staying Digital to Avoid Over-Specifying

Recalling a visit to the 'Crazy Horse' monument (Newton, 1994), I planned to use Google's 3D data over the past 2 decades to make a 3D timelapse of the monument's progress. Upon seeing the lack of progress my focus shifted to representing longer term effects of time such as erosion.

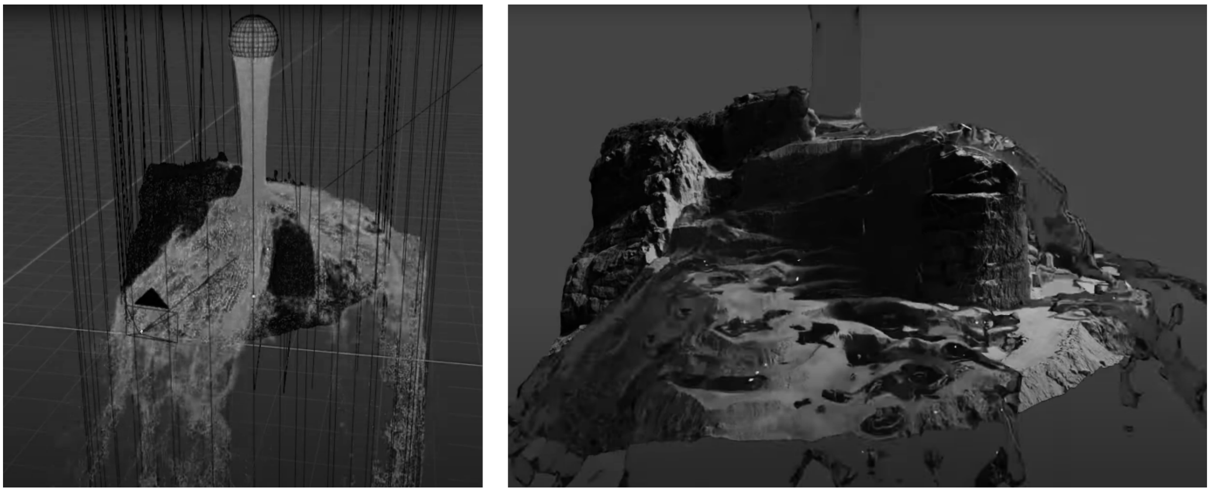

Figure 24. In Software (Left) and Photographically Rendered (Right) Liquid Simulations of Crazy Horse Monument.

I began to consider the self as something which, while physically temporary, could be virtually longer lasting. Most of the digital objects which I had collected were closely tied to my sense of personal identity, and upon realising this, I decided to fully embrace and investigate self-empathy through a self-avatar made from a 3D scan of myself.

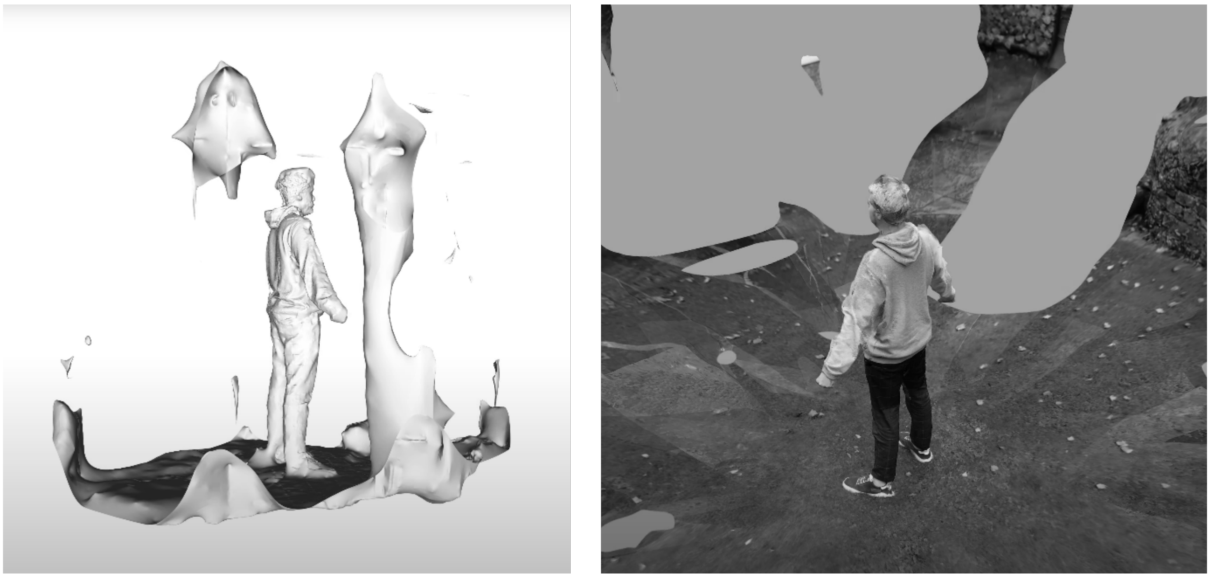

Figure 25. Topology (Left) and Textured (Right) Photogrammetry Self Portrait.

Embodied Immersion (1a.3) explores how avatars link to self-empathy, and wanting to personally explore this process to its fullest I used photogrammetry (a process which transforms many 2D images into 3D models through geometry calculations (Remondino, 2011, p. 1110)) to model a digital version of myself which could be used as a game character. From this model I began to explore what space I could situate myself in virtually. As themes of subversive physics and digital materialism had been focal to my exploration of immersion so far, I decided to continue this with a museum of collected and generated digital artifacts. This virtual RtD artifact allowed me to learn the basics of setting up a game engine, as well as the complexities of the overly-specific space only relevant to myself.

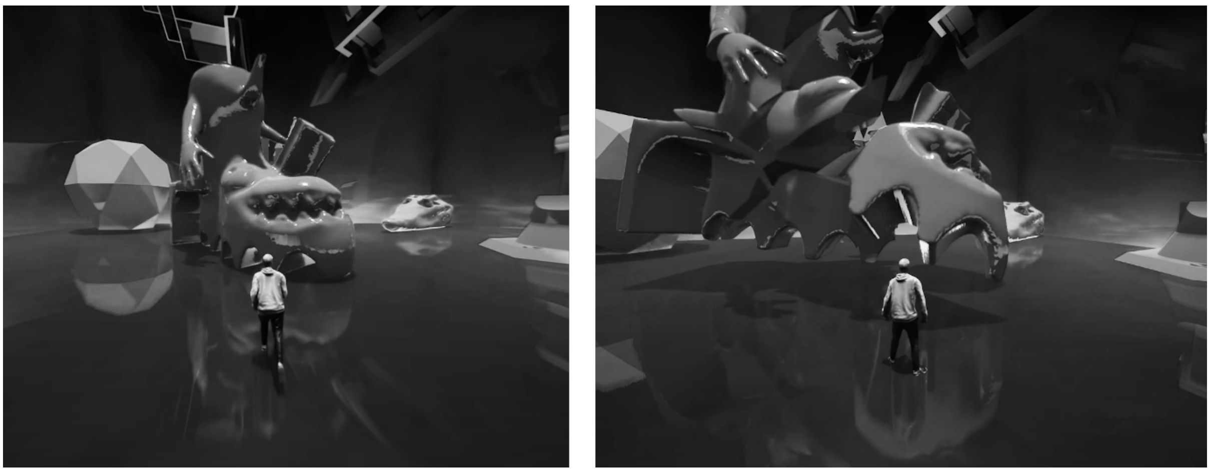

Figure 26. Pre/Post Shattered Object in Please Do Not Touch the Exhibits.

Titled 'Please Do Not Touch the Exhibits', the space aimed to create physics subversion from expectations of physical museums, as when you touched the artifacts the pieces shattered in slow-motion. Furthering my aims to immerse through subversion, the virtual space allowed users to rewind any damage -glorifying the destruction and 'mistakes' similarly to *Viewfinder* and *Portal* as explained in (1a.5). This experience is extraordinarily over-specific (being tailored only for my enjoyment). Realising it would only present immersion through self-empathy to me had huge knock-on effects for the rest of this research. We as designers can often make this 'mistake' in much less noticeable ways, and thinking back to the plant icons for over-specificity, ambiguity, and legibility we can see how personal design choice directly impacts false affordances, reducing legibility and accessibility.

Having realised the vanity through over-specificity which this artifact created, I wanted to intentionally consider self-empathy through vanity using machine learning GANs (Generative Adversarial Networks). Having begun to consider how machine learning and AI are likely to be used extensively in the future of virtual wayfinding (1a.4) to improve immersion, I wanted to explore how this could affect self-empathy. Retraining a GAN on images of my face, I wanted to consider how procedural landscapes could be created through images of the user rather than the avatar itself. In (0b.8) I discussed how procedurally generated game spaces are designed to constantly maintain the user's attention and AI's rapid absorption of digital ecosystem design is very likely to become a major part of this procedural virtual space generation in the future. When we consider that games like *Crash Bandicoot* (1a.2) have already been adapting themselves for player enjoyment for several decades, and game modders are already editing NPCs in games to allow player interaction through AI models (1a.4), hypothesising and prototyping virtual spaces that can adjust to keep players in immersion or flow states (1a.1) is highly relevant to the future direction of accessible design for virtual spatial wayfinding.

Figure 27. Self Portraits from Retrained Face Generation GAN.

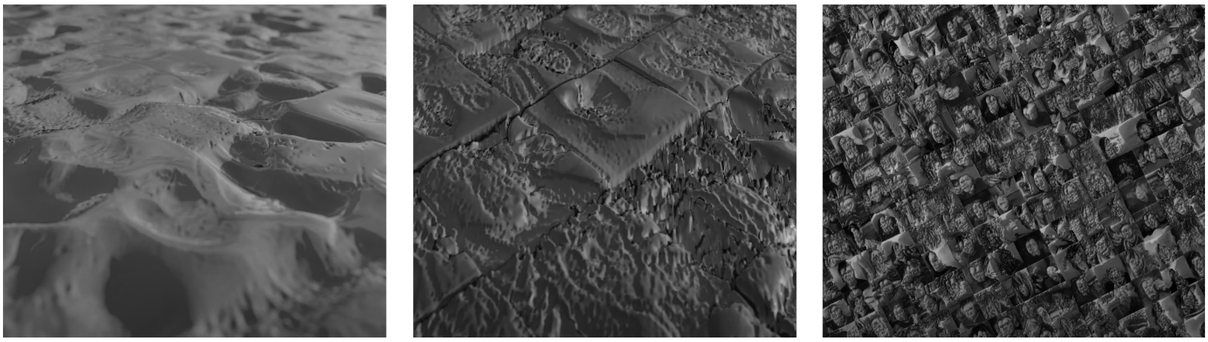

Figure 28. Stills from Animation Showings Transformation from Desert Landscape to GAN Image Grid

I used Blender (a free to access 3D animation and modelling software) to convert my GAN generated images into a prototype machine learning procedural landscape. Generating over 1000 images from my GAN, I randomised them into a tile layout, experimenting with parameters until it was traversable by a game character as a desert dunes landscape. This landscape styling sufficed as its training data was not immediately obvious, it could be more or less untextured, and did not need trees or rocks to make it more realistically game-like.

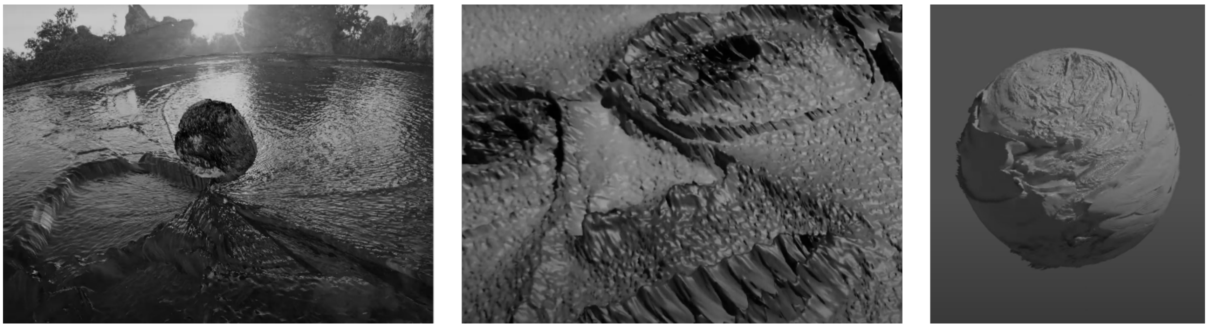

Figure 29. Pre-Prototype Outputs for Landscape Generation from GAN Images.

This environment was accessible through an animation to visualise the image to model pipelines, and unreal engine virtual space which was ported to Mozilla hub web environment for online access by a much larger audience as part of a virtual exhibition by UCL's Media Anthropology Lab. While this experiment taught me a lot about game engine development, it also further cemented the notion that passing too much of the design processes onto AI or machine learning risks lifeless and over-specificity without accessibility (as outlined in (1a.4), and possibly both at once. While this experiment does not fully explore if using machine learning can improve legibility, it certainly alludes to the idea it may have a positive or negative effect depending on usage. As designers we should be continuously wary of this risk of over-specificity (or ambiguity) automating virtual spaces can bring. For the same reasons I deviated at the start of this chapter away from physical interface design for virtual spaces (1b.7), I want to base the rest of this chapter on virtual space design elements which can be better designed to improve immersive wayfinding.

1b.9. Playing with Immersive Data

From the crocodile skull to the self-imaged landscapes, each RtD artifact I created so far has grappled with immersion. While I established in (1a.1) that I did not believe that graphical fidelity (such as that brought about by VR) was the key to immersion, I had begun to see that the immersive control capabilities that VR afforded users could potentially contribute to increased immersion (such as through games like *Half-Life: Alyx's* (1a.1)). While VR does not automatically provide immersion, Nilsson highlights that presence relates "to the sensation of being in a given virtual (or unmediated) environment." (Nilsson et al., 2016, p. 129). If presence is considered as user feeling based upon immersive technical elements, then it is reasonable to deduce that using the human body as the controller is likely to reduce the sense of mediation, and therefore increase immersion. 3D printing the crocodile skulls aimed to increase their immersion through presence, just as importing myself into a virtual landscape did. If VR has the potential to further this presence through immersion, this research certainly could benefit from experimenting with it, even if it deviates into the territory of non-accessible hardware.

This chapter aimed to document: *'What is Designing a Physics Subversive Virtual Space Like?'* As I had begun to see the shortsightedness of designing introspectively in (1b.8), and all the previous RtD artifacts had been focused on my own perspective, I realised the next virtual space which I begun to make needed to be more accessible and legible to others to be immersive. This realisation marks a turning point in this research, with all subsequent designs considering the use cases of others. Wanting to learn how to make a basic virtual reality space, I began trying to emulate a childhood pastime for many, playing with wooden blocks and stacking those into innumerable structural forms. This experience proved surprisingly immersive due to its inherent lack of specificity.

Figure 30. VR Cube Playground Playtesting Version 1 (Left) and 2 (Right)

This intuitive VR experience proved to be an ideal playtesting environment with my parents. As I designed new interactions which added physics subversion into the space, my parents found it easy to understand these gradually increased mechanics as a form of onboarding. While my parents were unable to play conventional games with dual joystick input until a later experiment which I outline in (2b.13), they found VR both intuitive and immersive. As complete newcomers to game space I was able to observe their interactions, understanding which affordances were not perceivable without game experience. Refining gameplay to be as intuitive as possible lead to the incorporation of physical concepts such as having tables react to player height for ergonomics. Inversely, oversized cubes which would not fit in a human hand worked better with unreliable collision boxes, increasing play fluidity even if reducing believability. Other quality of life features included a rapid sun-cycle for a sense of time within otherwise time locked space, allowing users to phase through the tables to reach blocks, as well as being able to reset them into neat rows at will. Informal playtesting as established through this RtD experiment became integral to this research’s focus on usability, legibility and accessibility as keys to immersion, instead of believability and replication of physical reality.

When beginning to implement physics subversion into this experiment, I took inspiration from portal's use of tone to signify affordances (1a.5), adding cubes with varied physical properties (such as mass and gravitation speeds). These were chosen to provide interesting subversion in the weightless space of VR, with many of their affordances going unnoticed (such as the heavy cubes being indistinguishable unless thrown towards other lighter cubes). Realising the intrigue these cubes could provide, I began implementing all manner of subversions, including rotational and directional energy, low friction, and non-collision cubes, all of which could be transposed into any other type of cube by the user.

Figure 31. VR Cube Playground Playtesting Version 3 (Left) and 4 (Right)

1b.10. Immersing Together, Remotely…

This cube RtD experiment made me realise any commonplace experience could be subverted through virtual wayfinding’s unique capabilities. These experiences provide adults with many of the childlike joys we had once revelled in. As I began to consider the fact that all these experiments had been forced to take place in my childhood bedroom due to the global pandemic, I also realised their potential to achieve these joys remotely.

My first thought leading on from this revelation was to attempt to augment my room to be more enjoyable for myself through virtual subversion. With my room having become a place I associated with isolation, I decided to connect with one of my closest friends to explore ways of alleviating this feeling.

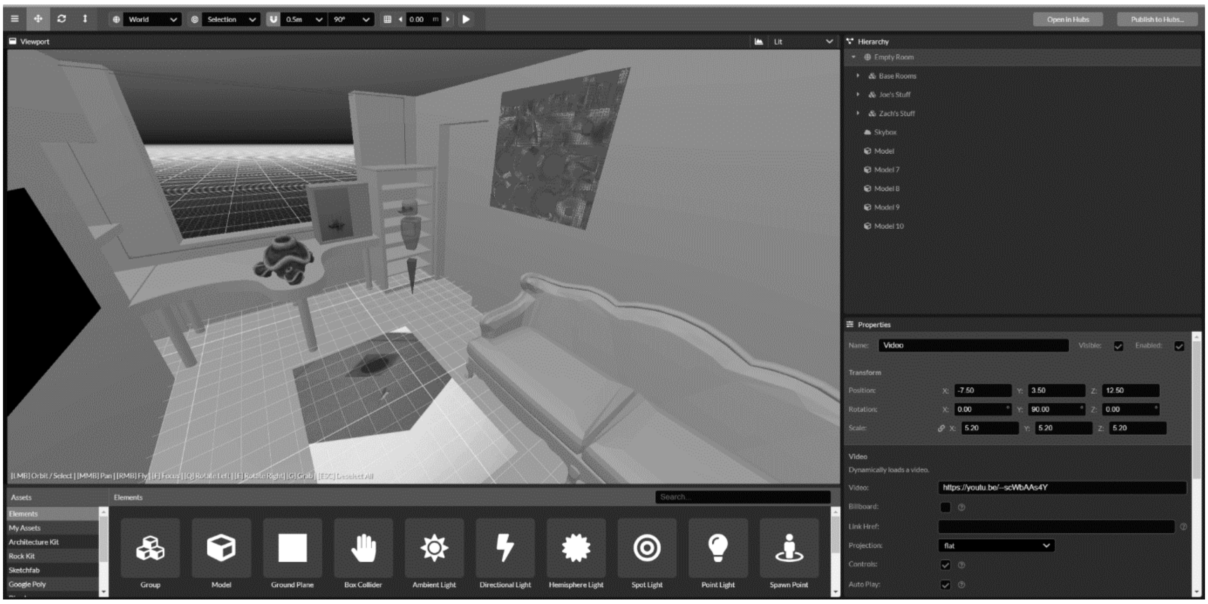

Figure 32. My Room as a Shared Mozilla Hub Space in Editor Mode.

Sending them a link to a Mozilla hubs editor which allowed adding objects into my virtual room, we would take turns to add objects into the space. As we had physically lived and designed our home together before, I wanted to test how similar a virtual version of this could be. Having played games and created digital artwork together many times I expected that they would be capable of collaborating in this space.

The enjoyment we found in designing physical spaces and cohabiting them was not found in this virtually copy we created. We often found that we would only cohabit the space in the allotted time we designated. Although we met much more often, we usually did this in other virtual spaces. Games were used as the virtual space and traditional calls for talking. While Mozilla hubs editing was easily accessed compared to testing with its competitors with similar features at the time, we still found dissatisfaction with the complexity of its space-design systems.

Even with larger group meetings, which benefit more from the spatial features, we quickly found our friends wanting to move to traditional video calls for simplicity over realism. My personal desire to understand what was failing to immerse my friends within non-game virtual space fuels section 2 of this thesis. This leads the next section to focus on virtual systems designed for meetings and conventions. Before moving onto this section, it is important to consider the outcomes of the RtD artifacts in this chapter.

1b.11. Cohesion after Drifting by Intention

Drifting through many RtD artifacts, this chapter's research has uncovered that interfaces like keyboards can limit virtual experiences through engrained overly specific design when normalised for purposes beyond intended use case. Seeking to focus on designs for accessible wayfinding, which are not as limited by engrained interfaces, I directed this research towards virtual space software approaches. Exploring self-empathy - through photogrammetry and machine learning prototyped procedural landscapes - I began to see the benefit of designing from an extrospective approach to allow the virtual spaces I continued to make to be less specifically tailored for my taste. I found it beneficial to playtest further experiences within VR due to the legibility of both the camera and handheld controllers. This is also because user input devices are a barrier to immersion. Finding immersion for my parents in VR, I began to make a usable physics subversive virtual space which found a sense of balance between over-specificity and ambiguity through repeat playtesting. Due to this artifact's success in my eyes, I decided to attempt a similar space (also based upon my bedroom) to facilitate togetherness remotely. Using Mozilla hubs, I was left with a sense of disappointment as my friends could not find enjoyment within its virtual spaces.

All the RtD artifacts in this chapter led to a focus for this thesis around balancing legibility, and extrospective design to avoid false affordances. Considering the first question posed at the end this section's literature review '*What is Designing a Physics Subversive Virtual Space Like?'* Through creating one, I have realised their simple visual design, and narratives pull the focus onto their subversion and reduce the risk of over-specificity caused by their complex mechanics. Playtesting is paramount, not only when making physics subversive virtual space, but in all extrospective design.

Addressing the second question '*How Does Spatial Familiarity alter Subversion and Immersion?'* I found that while familiarity is useful to build immersion, it cannot be relied on for wayfinding. This was realised by my father frequently walking into walls during playtesting of my VR game and defined social space not transferring successfully to virtual ones when testing in Mozilla Hubs. This question around familiarity is continued with my exploration of Gather (a spatial web conferencing platform) in section 2.

Considering the final question *'Can Machine Learning Improve Embodiment in Virtual Spaces?'* it has potential to vastly improve many features of virtual space. However, this potential is entirely dependent on designer's intent and proficiency with AI and machine learning. While it can rapidly accelerate many stages of the design process, it is simply another piece of a large toolkit. Calculators help us do large sums, but we still learn how to do them by hand, so we are to fact check machines. Machine assisted processes will never deviate from this truth, as without human checks, automation is always likely to create false affordances in the things we design.

Finally, it would help to explain the connection between section 1 and 2. This chapter's unresolved exploration of virtual togetherness through Mozilla hub spaces appears to be a closeable gap between the success of virtual spaces for games, and the failings of those for other intents. Virtual wayfinding in non-game contexts needed much more exploration. While Mozilla hub is arguably a much richer wayfinding space than Gather, this richness creates over-specificity, often during interaction before wayfinding has been allowed to occur, reducing legibility and user immersion (cementing Gather's importance throughout the second section of this thesis). This is a shortcoming of many of the experiments within this chapter, causing immersion to fail due to over-specificity in interactions. This stifling of immersion before wayfinding leads this chapter to at times appear more focused on interaction due to it being the gates of virtual wayfinding. I believe immersion is more of a quality of an experience rather than something you can just manifest by increasing fidelity. Removing the requirement for users to operate within a 3-dimensional space, Gather allows for spatial wayfinding design in more accessible 2-dimensional space, reducing barriers to interaction and onboarding. Assuming the familiarity of its visuals are more likely to be understandable, the proceeding literature review will aim to situate this rational further through a series of experiments using Gather to test this hypothesis.

2a. Ambiguous Comms

2a.1. Ambiguity in Action

To begin to situate Gather as a viable vessel to explore how ambiguity through assumed design may impede user experience in virtual wayfinding space (especially regarding communication with others) I believe it is important to clarify the kinds of ambiguity I am looking at. Ambiguity can be caused by over-simplicity, but I also acknowledge that it can be a requirement in a designed artifact to give users freedom. Online virtual wayfinding systems usually incorporate person-to-person communication systems in their designs. Because these communication systems tend to introduce ambiguity, analysing this ambiguity around virtual wayfinding felt incredibly relevant to my research. A great example of how ambiguity can be useful when people communicate is demonstrated through a diagram and explanation in a paper about using implied language when referring to shapes. Their diagram referred to red and blue colours, but I will change these to black and white to align with this thesis' lack of colour to highlight accessibility needs.

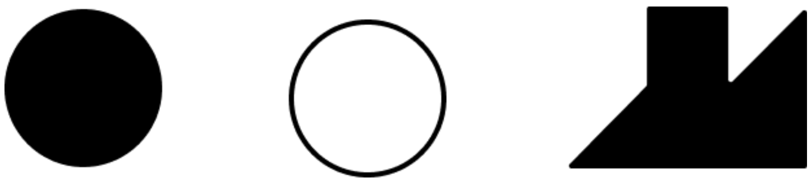

Figure 33. Note: Beneficial Implied Language. Adapted from "Communicating with Cost-based Implicature: a Game-Theoretic Approach to Ambiguity," by H. Rohde et al., 2012, ***Proceedings of SemDial 2012*****, p. 1.**

When referring to these three shapes, Rohde states that saying 'Look at the circle' "In a context with all three shapes, a more specific referring expression - such as 'black circle' – is required to unambiguously indicate that same item. However, if it is necessary to draw attention to the third item, the speaker may need to accept either inefficiency or ambiguity. Since there is no efficient label (e.g., 'circle') for the third item's unique shape, it is costly to unambiguously refer to it in the context" (Rohde et al., 2012, p. 1). "The [black] thing" or "the [black] shape" may successfully make sense to another person when used, but less efficient statements like "the triangle-and-square thing" or "the [black] shape that's not a circle" may have a higher success rate even if more time consuming to convey. In this example it seems not overly cumbersome to use the latter longer statements, but there are plenty of examples within virtual wayfinding (especially in high pace game environments) where shorter statements, which are implied and require more inference, may be better suited. Unique game-specific acronyms and dialect are often naturally formed around these exact principles by game-players, but, as is evident from this example, enabling this ambiguous language leaves systems open to misinterpretation or abuse by malicious users.

This chapter takes this principle and explores several systems for virtual communication, which introduce ambiguity in their designs, as well as looking at literature which researches similar areas of ambiguous design. Coming from the opposite angle to the previous pair of chapters (1a and 1b), this next section explores ambiguity as an edge of effective flow state in virtual wayfinding experiences. In doing this, it hopes to create a channel between over-specificity and over-simplicity in which effective design can take place and lead the final section which includes a data chapter working through this channel into an applied design output. To situate the next data chapter and enable it to flow into the final section most focused on accessibility, this literature review will explore 3 main areas. The first area is focused on affordances and how they relate to ambiguity due to their artefact and practice levels (referring to the designer and user perspective on these affordances). The second section is based around in-game chat systems and how these are often circumvented by private party chats on all platforms. To highlight and explain why these systems are so often circumvented, I will analyse *Dota 2's* (Valve, 2013) systems for communication considering how they grapple with ambiguity and toxicity to provide a useful user experience. This will also enable me to talk about the different kinds of 'chat' available to users online and their impact on play, and the richness of communication they afford by looking at their ties to user communication ratings. The final section of this chapter explores two extremely different modern video conferencing systems which are commonly used by different groups of people online (Microsoft Teams and Discord) looking at how they design for conversations in different ways through their interface languages in order to situate an exploration of Gather (which is a more recent video web conferencing system which takes an extremely spatial approach).

2a.2. Affordances for Users and Designers

To start this first section, I want to begin to further dive down into the ways I will use affordances within this chapter and going forward. Affordances are something I have already begun to unravel in my initial literature review and methodologies chapter where I discussed perceived, false, and actual affordances. The language used around affordances can often be distinctly tied to a visual perception (although I will use it to refer to hearing and other senses throughout this thesis as my approach to accessibility is based on perception from multiple senses and the ways altered sensory experiences changes perceived affordances). Affordances were first proposed by Gibson and brought into design and HCI by Norman to try to clarify and rationalise the differences between perceived and actual interactions or properties of a thing. When "affordances are taken advantage of, the user knows what to do just by looking: no picture, label or instruction is required" (Norman, 1988, p. 423). Bærentsen & Trettvik note that the "term has since become a buzzword used by almost anybody to describe anything ... and is in risk of losing contents altogether." (Bærentsen & Trettvik, 2002, p. 52). Vyas iterates on Bærentsen's thoughts around usage of the term affordances suggesting that in their research, 'Affordances in Interaction' (which they use interchangeable with affordances) "are not the properties of the artefact but a relationship that is socially and culturally constructed between the users and the artefact in the lived world." (Vyas et al., 2006, p. 92). This aligns rather well with what I've suggested earlier where perceived and actual affordances shift as a user engages with an artefact but is especially relevant to re-iterate in this section which is about ambiguity in interface language.

Affordances work on two levels from my understanding of them, and I will continue to use the term affordances when referring to either, due to their intertwined nature. The first level of affordances is what we assume a user will themselves assume when they interact with what we design. Processes like co-design can fall victim to the fact that even if we integrate our intended users completely throughout the design process, their heightened awareness of the systems they are interacting with (due to their involvement throughout the systems design) can cause them to recommend or design unperceived or false affordances. Because of this, user testing is often implemented as another important stage in designing a thing while aiming to alleviate this misalignment of actual and intended perception for the user.

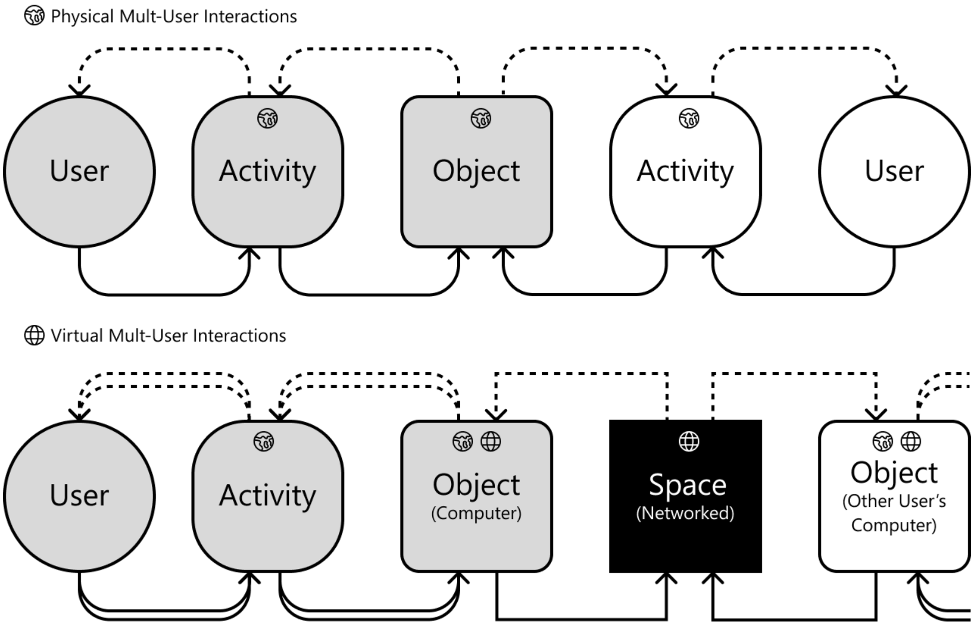

Figure 34. Note: Virtual Multi-User Interactions. Adapted from "An activity theory approach to affordance," K. B. Bærentsen, J. Trettvik, 2002, Proceedings of NordiCHI, p. 53.

"It is not the unmediated 'stimulation' of the senses, that informs the organism about the world, but cognitive or perceptual activity … establishing contact to objects, and the influence of the objects on this activity … that informs … the organism about the characteristics of the objects." (Bærentsen & Trettvik, 2002, p. 53). Within virtual, spatial, online, multi-user interactions this 'object' can be considered as the computer, and a further 'networked space' as the location which is being accessed. Because of this, within virtual multi-user spaces, the user complexity increases as some times they are affecting the object itself (the computer) and other times they are affecting the networked space accessed through the object as visualised in my adapted diagram. While often from a technical perspective they are always interacting with the networked space, from a user perspective, many changes they make only impact them locally (such as choosing to turn on an accessibility setting in an online game). Because of this, they should be regarded differently from a design perspective. Physical interactions on the other hand can be regarded as much simpler in comparison, due to multiple people effecting a singular object and the object not having to grapple with having both physical and virtual presences.

Going back to the idea of communicative ambiguity, this choice to delineate things the user does between having single-user and global effect can be quite confusing. This is something I will further discuss in this chapter with examples such as 'muting' another user appearing to come under single-user effect while often actually effecting how others continue to interact with them. This is due to the ambiguity of social constructs within games and other virtual spaces meaning that another user may or may not become aware that the original user has chosen to mute them. On the other hand, systems some networked games have - such as 'like' and 'dislike' systems - only make 'likes' apparent to the user they are expressed towards because the designers are aware of the ambiguity this can cause and seek to promote positivity in the playful experiences they design. All these design decisions are highly impactful on users and effect the perceived affordances players have on their usage. Because of the richness even just one of these communicative systems has, I feel it highly relevant to dedicate the next section to them.

2a.3. Multi-Tier Communication Systems in Networked Games

As this chapter has been constantly re-iterating so far, it focuses on the ambiguity that can be introduced through systems designed for voice, and/or video chat through the internet. Even though the next chapter will predominantly focus on spatial wayfinding ambiguity (meaning the confusion users may experience when moving through spaces), the ambiguity introduced through conversational tendency expectations from the physical world is largely at fault. Limitations on virtual conversations, due to the technical design of their systems, will be highlighted in the next chapter (2b) on Gather as a platform, but for now I want to focus on ambiguous expectations of conversations in a game called *Dota 2*.

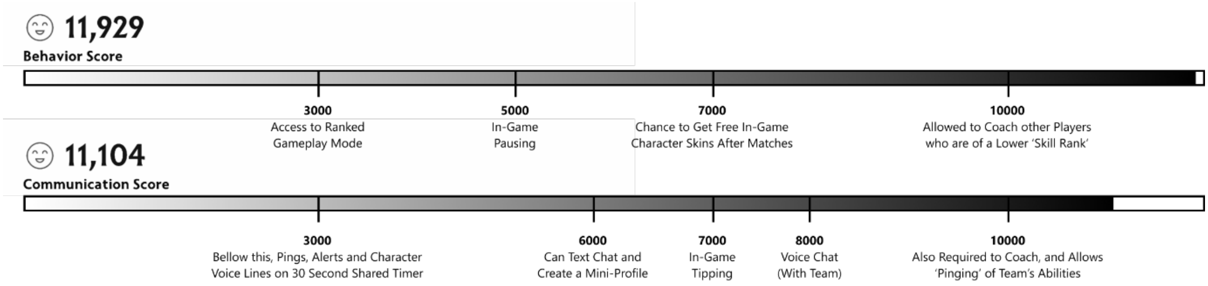

Figure 35. Behaviour and Communication Score Access Scale in Dota 2.

The figure above visualises two score metrics in *Dota 2* (which I will refer to as Dota from here onwards). While Dota, like many other player versus player games (commonly referred to as 'PVP') has a traditional ranked system based on in-game skill, it also recently implemented a complex social behaviour and communication score system split into two categories. Both scores are designed so that they gradually go upwards with most players sitting between 6,000 and 10,000 in behaviour, and 9,000 and 11,000 in communication. This system was vastly expanded from an existing system which combined both with a rating of 10,000 at its max to form the new categories which cap out at 12,000 to give players who gained erroneous reports from bad actors the ability to continue to coach others. The separation of communication and behaviour is interesting as both form social communication, but behaviour is positional and spatial language predominantly, and communication is textual and vocal (with the added ability to 'ping' spots on the map for a plethora of different purposes). The main reason for discussing this system is to consider ambiguity in gameplay communication systems from a gamers perspective before going deeper into more commonly used software such as Discord which exists externally from the game itself, as well as considering the different systems a website like Gather has simplified which may otherwise go unnoticed as a user.
The ways in which a player can communicate in Dota can be categorised as follows (with global meaning heard by both teams): 1. Voice chatting (team), 2. Text chatting (global), 3. Pinging or drawing with mouse cursor in game-space or on team-mates abilities (team), 4. Character voice lines (global), 5. Tipping (global), 6. Pausing the game (global), 7. Emoting with character (global), 8. 'Griefing' (global) 9. Liking or disliking another player's performance (global), 10. Reporting (potentially global). As this shows, the variety of ways in which players can communicate is incredible wide, largely due to the competitive nature of the game.

This plethora of ways in which players can convey information enables quicker communication with lower chance for ambiguous understanding causing misinterpretations and 'mis-plays'. Voice chatting is generally the preferred method of communication and is used widely in professional play alongside Pinging to reduce ambiguity by highlighting specific parts of the map the player is referencing. However, these methods of communication, though highly useful, are also the most susceptible to abuse by bad actors or toxic players (players who act in negative ways to others). The developers of the game also realise that only players with very high scores in both ratings should be able to help other players (through coaching) because of the potential negative effects this system could have on a player desiring coaching if used by a toxic player. Other systems such as tipping and character voice-lines are allowed to be enacted by and onto both teams, with this feeding into character role playing and atmosphere in professional play for live viewers. Tipping is often used in rather toxic ways, even by professional players due to the incredible ambiguity 'giving someone a thumbs up' has even in the physical world. Voice lines which can be heard by both teams play from audio files in the voices of the character you play as, or specific notable celebrities (players or commentators) in the Dota scene. Other communication systems such as 'Pausing', 'Griefing' and 'Emoting' are essentially non-existent in professional Dota but play significant roles in casual network play.

Pausing the game is an action allowed for each player every 5 minutes and can be un-paused by either team with these same 5-minute restoring tokens. This means a maximum of 10 pause, or un-pause actions can happen every 5 minutes. Un-pausing is prohibited for a short 30 second duration if the pause occurred whilst an enemy player is disconnected, but allies of the disconnected player are not limited by this prohibition meaning toxic team-mates can negatively impact their own team. Griefing, "which in online communities loosely means unacceptable behaviour" (Chesney et al., 2009, p. 526) can be described in Dota as the action of intentionally causing damage to your own team in almost any way to the benefit of the opposing players and could be exemplified by the action of un-pausing on a disconnected teammate, or by intentional dying to the enemy team, giving them gold and experience. Emoting, while significant in many other online games plays little part in social interplay within Dota although automatically occurring when significant actions take place. This could largely be attributed to the plethora of other ways to communicate socially with others, and the fast paced and often confusing nature of the game making emotes harder to notice. The same could potentially be said for Gather, where the layers of communication systems combined from game and video conferencing make avatar emotes go largely unnoticed both as a user looking for them in the interface, and a participant engaging in conversation where they are being used by others.

"Initially the only medium for player-to-player communication in virtual worlds was text, a medium well suited to identity-play and asynchronous communication, less so to fast-paced coordination and sociability among friends." (Wadley et al., 2014, p.336). Because of this, the voice communication systems afforded to users in Dota are seen as worthwhile to keep access to when playing with randomly match-made players and therefore reward good behaviour, especially in the ways we communicate, but also in how we play. 'Good behaviour' may be more complex to characterise in less goal orientated games, but these other games often have communication systems with complexity not too dissimilar to that of Dota. MMORPGs (Massively Multiplayer Online Role Playing Games) like *World of Warcraft* have many of the same systems as Dota with the addition of textual chats based on location in game and the server a player is connected to. Regardless of their differences with in-game systems, players of most games are more likely to communicate through external voice or messaging systems than those available within game. This practice is common likely because it removes the need to learn new communication systems for each new game a player wants to engage with, but also because they allowed persistent chat even when not connected to the game, or even when players are away from their computers. This is often the case even in games with directional or spatial audio voice chat where players will remain in Discord calls, muting themselves to use the in-game spatial audio only when it directly adds to the experience, or is available (for example they are not in a loading screen). This practice is persistent across most gaming platforms with both PlayStation and Xbox having their own external systems for groups of players to voice and text chat outside of their games.

Because this is such common practice for gamers, it seems incredibly relevant to analyze usage of these kinds of software in the next section through comparison between systems or programs like Microsoft Teams which have extremely similar features but are instead designed for work purposes. Because both PlayStation and Xbox are sealed ecosystems (meaning users largely are unable to choose which voice chat software they would prefer to use), it seems most fitting to analyze Discord's usage by PC players as it was adopted by choice, rather than forced upon users.

2a.4. Considering Flat and Spatial Virtual Chat Systems

To begin to understand Discord as a piece of software, a brief history of how it came about is important. Before Discord became part of gaming space in 2015, most players were split between using Skype and TeamSpeak, or a little of both. This was not due to players liking using them, but due to a desire to chat with their friends beyond the bounds of the game communication systems. Many users actively disliked both systems due to either their intensive computing cost, high latency in voice, low quality, or lack of cohesive management server systems (meaning spaces for specific groups of friends). Because of all this distain, Discord's founders had a perfect opportunity to get users moved over to their platform. By rebuilding their software several times in the early months to improve efficiency and reliability, and introducing simple moderation features for server owners, Discord optimised its own success, due to the failure of existing systems to keep up with modern demands. With its slogan, 'It is time to ditch Skype and TeamSpeak.' Discord exploded in popularity due to clean interface design, reliable features, and a targeted user as well as some help from the COVID-19 pandemic. "Discord is a platform that was born solely with text and audio communication features, but in 2017 video calling and screen sharing features were integrated. It is considered an application for gamers, although there is a growing number of servers that are not gaming-related." (Mora-Jimenez et al., 2022, p. 2). Discord was not simply a replacement for its predecessors, but also positioned itself as a third space, designed to create a sense of community.

"Bodies exist in space and time, forming relationships and eventually communities through the everyday uses and practices the bodies undertake together, whether they exist in third spaces like Discord or in physical spaces." (Hull, 2020, p. 14). Virtual third spaces inside systems like Discord have become much more socially acceptable since the global pandemic due to the blurred lines between physical and virtual social spaces that it caused. It could be considered that systems like Gather play upon this notion of a third 'space' even further and therefore provide even more avenues for exploration. However, before delving deeper into Gather's design, comparing features and tendencies between Discord and Teams may help to highlight whether it is the features or social expectations that cause Discord to feel so communal when compared to Microsoft Teams.

	Discord	**Microsoft Teams**
License	Free	Paid
Multiple Shared Screens	Yes	No
Chat Persistence	Yes	Limited
Role Assignment	Yes	Limited
Customization	High	Very Low
Call Participant Limit	25 (video) 50 (screensharing) 500 (audio)	300
Built - in Call Recording	No	Yes
Login Requirement	Yes	Partial Access
Video / Screen Watching	Action Required	Automatic
Individual Volume Adjustment	Yes	No
Bot Integration	Yes	No
Built in file sharing	Yes	Limited

Figure 36. Note: Discord and Microsoft Team's Compared. Adapted from "Using Discord as an Extension of the Emergency Remote Teaching Classroom during the COVID-19 pandemic", by G. Moro et al., 2021, *IEEE Frontiers in Education Conference,* **p. 6.**

Considering this table comparing Microsoft Teams and Discord adapted from Moro et al.'s paper we can already begin to see how their approaches to virtual togetherness differ. Firstly, Discord is completely free to use while Microsoft Teams is a paid service making it more likely to be used by companies for work, and therefore its design better suited to this usage style. Secondly, Discord's capability for call participants to share multiple screens at once vastly enhances the communal feeling of its usage, allowing users to compare their work in a classroom setting or share their in-game perspective when using for play. Its capability to share 50 screens but only allowing 25 video feeds is also somewhat telling of its usage intentions where it prioritises virtual embodiment over tethering them to their physical presence.

Communal screen sharing and webcam-video being the least supported medium are features which I have vast amounts of personal experience with enjoying in Discord but disliking in Microsoft Teams often finding myself wanting to both share and view screens while working and playing games, or feeling there is social expectation to turn my webcam on to participate in Teams based conversations.

Discord's lack of built in call recording furthers its perceived sense of community by removing the feeling of speech being monitored. It instead adopts an unspoken internal self-regulation process without the need for outside intervention. While this has caused controversy for Discord in the past (due to it enabling certain radial groups), it is no different from the kinds of behaviour a physical space can facilitate. The lack of recording also reduces the feeling of calls being meetings, allowing users to flow in and out at will unlike systems such as Teams which are "built around the idea of discrete virtual meetings" (Moro et al., 2021, p. 3) furthered by Discord labelling these perpetual voice calls 'rooms' (which are always open). Volume adjustment at the user level also plays into communal activity, allowing different users to engage with the same conversation in unique ways depending on how they want to position themselves within it by reducing the volume of those less engaged in their specific conversation while still wanting them in the background of their communal activity. Bot integration, file sharing, login requirements, high levels of customisation and role assignment all play further into Discord server owners' ability to create unique third spaces which foster a plethora of social interactions depending on their intent. Teams' much more rigid structure, while being better for new users, does not enable the kinds of diverse communities that Discord is so readily able to foster.

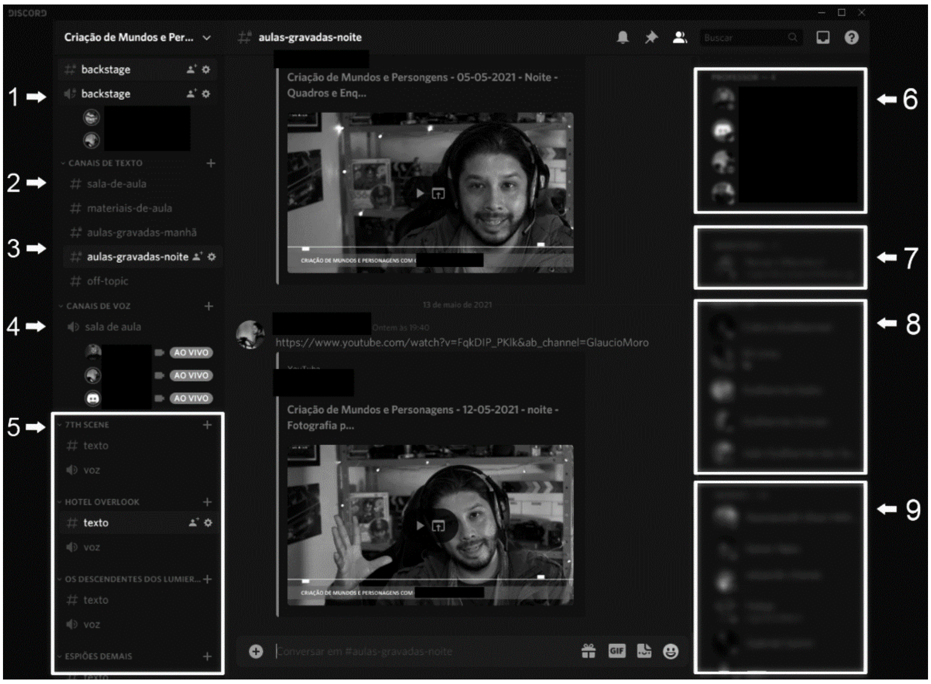

Figure 37. Example of Discord Server Layout. Reprinted from "Using Discord as an Extension of the Emergency Remote Teaching Classroom during the COVID-19 pandemic", by G. Moro et al., 2021*, IEEE Frontiers in Education Conference*, p. 3.

Discord's ability to foster functional communities is further visualised in the above figure showing a university course's Discord structure with: (1) Moderator channels for server organisation; (2) Text Channels for class related material; (3) Text Channels for supplementary material, such as recorded lectures; (4) Audio channel used during live classes; (5) Examples of different text and voice channels created for different students teams; (6-9) Users online grouped by their different Discord tags. While all these features are rather compelling, when considering Discord, it is important to note that it is primarily "used for social activities and humans are social beings. Also, Discord is strongly tied to gaming and therefore to entertainment. Microsoft Teams [is] … mainly used for education and work-related activities which are not always as stimulating, motivating or interesting as social interactions and video games." (Mora-Jimenez et al., 2022, p. 8). Due to this, many of Discord's features feel reliant on certain kinds of social behaviour, and when used for more conventional work-like structures, they tend to function to a lesser extent. Discord aims to situate everything within a single server stylistically on one page, while Microsoft Teams instead separates smaller group chats to function better for smaller working team structures and improved confidentiality.

Discord's distinct stylisation allowed it to become the predominant system for online social communities (especially those focused-on gaming) during the COVID-19 global pandemic. Because of this Gather appears to have attempted to iterate on Discord's successes to a greater extent by furthering the premise of a spatial layout represented through its interface to a point where the user controls an avatar to mingle in and out of conversations which occur in visualised rooms, rather than merely persistent calls titled as such. It does this with varying degrees of success, but certainly expands on customisability for the server owner, as well as spatial premises. From my research perspective, Gather is the perfect vessel for this next section of research due to its position between games and web conferencing systems and its extremely specific art-style choice allowing for lower entry point but increased susceptibility to ambiguity in its user experience. The following chapter (2b) takes Gather specifically, and through design of a variety of spaces within it aims to uncover if the expanded spatial presence it provides adds to the experience of the third space as it is intending to or merely corrupts the clarity of the user experience within, highlighting deeper issues around accessibility in the design of virtual wayfinding. With this in mind, I would like to present these clear questions which the next chapter aims to tackle:

- *Where does Gather's sit in Video Conferencing and Game Space?*
- *What are Best Practices for Designing Spaces for Virtual Togetherness in Gather?*
- *Does Gather Address the Disconnect People Often Feel with the Video in Video Conferencing?*

2b. A Gather-ing Problem

2b.5. Video Conferencing Space Isn't 'Normal' Space

As I discussed in the previous chapter, the way people used digital space changed drastically and rapidly during the COVID-19 global pandemic, with video conferencing becoming a core system in attempting to achieve co-presence, aiming to facilitate the vast array of activities we previously enjoyed face to face. Video calls often give the experience of being talked 'at' rather than being part of a natural conversation. In my view this can result in a joyless experience. O'Toole suggests this is because of "the impact of bad design... multiplied across the billions of people striving to flourish online" (O'Toole & Warburton, 2020). This is especially true when they constitute a major part of your daily activities. During the COVID-19 global pandemic the sudden uptick in the number of hours spent on video calls highlighted, for millions of people, the undue strain our mental capacity of what became known as "Zoom Fatigue" (Bailenson, 2020, p. 1). When considering the negative impacts of video conferencing systems, it is notable that they often fail to achieve the kind of interaction they aspire to because the more users expect from remote communication, the more they note that "mediated" (Nowak et al., 2017, p. 1) interactions (ones carried out using communication technology) fall short. These mediated interactions never tend to be on par with face-to-face interactions due to a plethora of small in-person dynamics which are skewed virtually; an obvious "example is the eye contact problem associated with video conferencing systems." (Hollan & Stornetta, 1992, p. 124). This chapter considers the underlying causes of video conferencing's shortcomings as virtual space. I will discuss that some of video conferencing's limitations are due to ambiguity in the interfaces it presents to its users. The chapter explores how the world of video games may provide us with metaphors and heuristics to reduce the ambiguity in the affordances of virtual spaces and in turn help us create virtual environments which support more productive co-presence (Bulu, 2012) in virtual space. This chapter does this primarily by looking at Gather (http://gather.town) with the intent to improve immersion and understanding of the affordances it presents. The chapter has two key contributions. First, I explore how Gather's successes may be transferable to other contexts. Second, the chapter highlights how, by assuming users will be aware of interaction affordances, Gather's ambiguous design causes issues with users who are unfamiliar with virtual spatial wayfinding.

2b.6. Finding Solutions in Gaming Conventions

While the COVID-19 pandemic forced many of us into an online existence heavily mediated by virtual interaction, arguably "the rise of games as a dominant form of recreation and socializing" (Johannes et al., 2021, p. 1) did this long before the COVID-19 global pandemic. Networked games, where players inhabit a shared 'space' and "the idea of socialising in a game is not new at all" (Lufkin, 2020). The interactions that are normal for gamers, and are enjoyable, are extremely similar to those that can result in Zoom Fatigue. Why is it that what gamers enjoy is an unpleasant experience for so many others? I think this issue is worthy of great consideration. It is not the winning or losing which makes gaming with others enjoyable, but rather the sense of being together (Jia et al., 2015, p. 22). With this in mind, I consider both the conventions that game designers rely upon, and the habits that gamers as a social group have developed. Together these explain attributes which may underpin virtual existences which have the potential to be fulfilling to a wider audience. By analysing such conventions, we may identify processes, mechanics, and design heuristics which can inform the design of more enjoyable forms of accessible and digitally mediated co-presence while avoiding ambiguity in their design.

While this chapter suggests gaming conventions may offer useful design inspiration, it is also worth mentioning that game spaces are by no means a perfect template to adapt from. Gamers "have shown statistically significant gains in problem solving, spatial skills and persistence" (Barr, 2017, p. 87). Because game designers are catering for this group with a higher than average ability in virtual spatial, game spaces can often be inaccessible for novices. Some gamers' level of digital literacy and experience comprehending virtual realms as spatial environments is likely to be significantly higher than that of an average member of the public, but this will not always be the case. While video games designed for the purpose of player entertainment "were found to be positively associated with cognitive functions (e.g. attention, problem solving skills", this enhancement is limited to tasks or performances "requiring the same cognitive functions." (Choi et al., 2020, p. 1). This positive "enhancement" achieved through play of games only transfers to tasks requiring similar cognitive functions.

Gather's systems are purposefully similar to popular game space, and therefore it is reasonable to assume that experience in many different game types would benefit its users. However, because of the cognitive skill gaps created between those who frequent more complex games and those who do not, we need to carefully consider when game techniques are transferable for wider audiences, and when game concepts are niche ideas. This consideration helps avoid creating ambiguous experiences where those who have played less games cannot correctly perceive the available affordances. A simple example is the use of WASD keys (Wilde, 2016) for 'up, down, left, right' movements or the spacebar for 'jump'. Such conventions are completely ubiquitous to the desktop computer gaming audience, yet almost entirely unknown to non-gamers and likely hit-or-miss for games console users. There are potential benefits to adopting gaming conventions, but in doing so we need to consider adopting their onboarding systems too in order to bridge the gap between different experience levels to make virtual spaces without comprehendible and welcoming in the onboarding we provide.

2b.7. Bridging the Gamer/Non-Gamer Gap with Gather

> "We as humans have developed a broad range of mechanisms for social interaction, which seem to meet well our needs for initiating and maintaining friendships and working relationships, for discussing, negotiating, planning, and all other types of social interactions. These are known to be complex processes, and ones which physical proximity facilitates." (Hollan & Stornetta, 1992).

Gather is a platform that aims to alleviate some limitations which occur when using other video conferencing systems by incorporating several gaming conventions, aiming to better facilitate these complex social interactions. The previously discussed shortcomings of video conferencing e.g., fatigue (Bailenson, 2020) contribute towards a reality-expectation gap attached to digitally mediated interactions (where users expect diverse interactions similar to those enabled by physical proximity, when in reality video conferencing is much more discreet). Running in a web browser, Gather is a video conferencing system that uses a spatial design metaphor to initiate calls. In a 'normal' video conference call users on any given call are arranged into a grid (e.g., as is the case with Microsoft Teams, Zoom or other similar platforms). Gather spaces are presented to users as two-dimensional rooms which are rendered in a pixel art style. Any user present in the space can explore it by moving their avatar using WASD keys. When two or more users' avatars come into proximity, a traditional call is established on-the-fly, allowing them to converse as they would via any other video-conference platform (including the ability to share screens and send chat messages). Once the avatars move apart, the call cuts out allowing them to move elsewhere in the virtual environment and seek out others they may wish to speak to.

In short, Gather's functionality is a standard video and audio-conferencing system overlayed on top of a simple game environment. By moving avatars around this environment, users can dynamically start and end individual video conference calls. The result is an unusual, liminal space which is game-like yet achieves what we would expect from a traditional video conferencing platform. This system's design attempts to emulate physical space more closely in how it feels, both through the variety it gives the designers of its spaces, and the movement it affords to its users. This has the potential to facilitate the wider range of activities desired through online systems such as meetings, lectures, and workshops. A specific example of where it really furthers the concepts of video conferencing space by adding spatial elements is a virtual party. Breakout rooms are nothing new to those accustomed to virtual workshops or meetings, but in Gather, the users can physically break apart into smaller mingling groups, and mingle between these groups as they wish through a spatial UI. All these types of social gathering are possible within Gather but can causes ambiguity in its spatial design when its affordances are not made sufficiently clear to its users.

2b.8. Accessible Aesthetics

The visual style Gather uses is arguably part of its charm. Drawing inspiration from early versions of games like *Zelda*, this top-down aesthetic is so ubiquitous amongst games that it should be recognisable to many non-gamers (although this kind of assumption is what causes ambiguity to be a large issue in accessible virtual wayfinding). While this potential familiarity may encourage a sense of ease for some users, it is plausible that for others the design being similar to game space may be alienating and cause people who design spaces within it who are familiar with similarly styled games to create interactions which are ambiguous to those who are less familiar due to their unperceived affordances. Furthering this, the 2D camera removes the need to control a camera-perspective (something which is commonplace in modern 3D games), and while this makes control simple, it makes some objects' appearance more abstract and harder to distinguish their purpose.

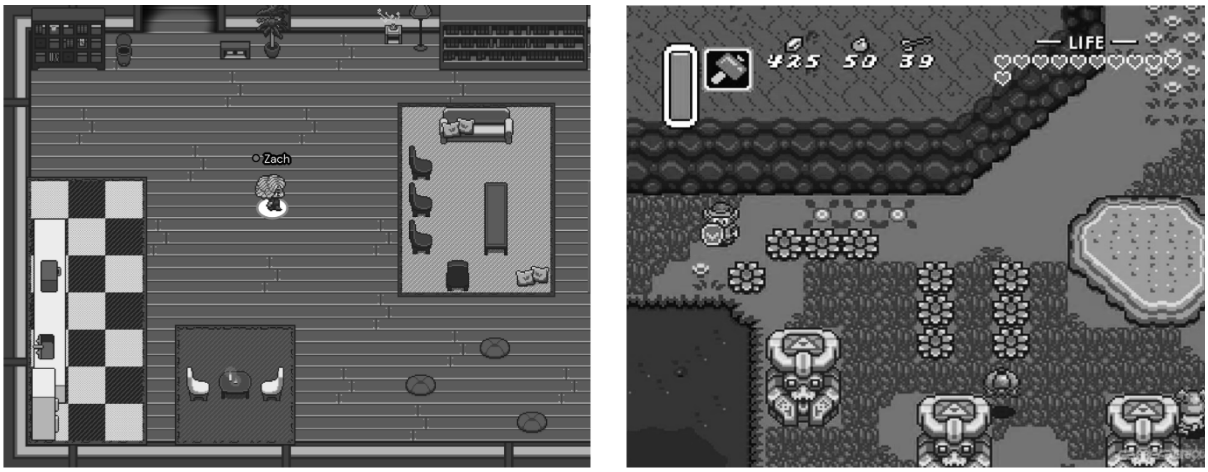

Figure 38. Left, Gather (http://gather.town) Home Space. Right, Video Game ***The Legend of Zelda: A Link to the Past*** **(Nintendo, 1991).**

The 2D graphic style has been adopted in many recent ‘indie’ games (Fiadotau, 2018) such as *Enter the Gungeon* (Devolver Digital, 2016) and *The Binding of Isaac* (McMillen, 2011), and while being visually pleasing and nostalgic to many, it can also be simpler to work with from a technical and authorship perspective than 3D high-resolution styles. In Gather, this simplicity means that spaces can be customised or adapted with simple graphic tools, and it is easy to create diverse virtual environments, including imaginary spaces, or those based on real physical places.

This aesthetic extends to how user avatars appear. Once again cues are taken from the gaming world. When connecting to a Gather space, users are given the choice of how they wish their avatar to appear. “Self-avatars are important, and … animation of the avatar can improve the effect of the self-avatar for most cooperative tasks within the virtual environment” (Pan & Steed, 2017, p. 3) which is something Gather incorporates into its non-game context as a system designed around co-habitation and co-operation. The character editing system in Gather arguably boosts connection with self-avatars further as well as reducing the ambiguity of the avatars abilities by including the player in the design of their character and heightening their awareness to the purely cosmetic nature of their personal design choices. The Gather avatar customisation system is akin to that of *Stardew Valley* (ConcernedApe, 2016), with features such as hair, torso, legs, shoes, and accessories each having around 10 options, leading to the ability to create significant visual differentiation between users.

Figure 39. Character Editors for Gather (http://gather.town) Left, *Stardew Valley* (ConcernedApe, 2016) Right.

This, alongside the ability to emote creates further connections to the characters that users play as well as clarifying to the user which character they are embodying in the virtual space they see onscreen. Emotes are an integral part of online games, enabling short animations to be enacted by the players avatar to represent emotions. They are similar to emojis which non-gamers may recognise, but are much more vivid in their detail, enabling strong signalling when verbal communication isn't used, or to add to a voice conversation in a visual way as video calls are rarely used for online games. This improves embodied presence within the virtual environment, allowing users to understand where they are situated when looking at rooms in Gather and enables them to identify others in order to approach them and start conversations which feel spatial. These emotes are paired with emojis in Gather's interface which seemingly aims to reduce the ambiguity for both the person emoting, and other people in the virtual space when they are enacted, relying on the understandability of emotes for gamers and emojis for the wider public. This spatial embodiment is something video conferencing platforms tend to lack. Instead, they present a flat 'wall' of faces, which can leave users unsure where to look, and stifling opportunities for dynamic spatial conversations. As with Gather's emoji emote pairing, users can also feel unsure whether to regard the avatar or the video feed of the person as their virtual embodiment. This is likely to cause a sense of spatial disconnection because Gather wants to maintain tropes from both games and video conferencing. Because this is such a relevant point, I will go into it in more depth at the end of this chapter in Video is the Elephant in Video Conferencing Space (2b.14), but for this next section, I will be focusing on living and being embodied in 'space'.

2b.9. We Live and Play in 'Space'

Our embodiment and participation, as humans within spaces, is something we took for granted before the pandemic, with the ability to experience immersive, interactive, and social moments in physical space seeming effortless: "The flow and changes in interpersonal distances between individuals in a shared space is an integral part of nonverbal communication." (Williamson et al., 2021, p. 4). Our relationship with movement, the way it allows us to situate ourselves mentally and physically, and how these factors impact our relations to each other, pose a complex challenge for designers wishing to represent these aspects in a virtual environment. One driver of this may be the long tradition of using skeuomorphism, which I first mentioned in Accessibility and Affordances (0b.5), where we retain ornamental or functional aspects of non-digital versions of things in their digital counterparts. Popular terms like Desktop, Recycling Bin, and Wallpapers are all of skeuomorphism in the design of computer operating systems. While those examples echo pre-digital office environments and have had a long time to separate their new digital meanings from their pre-digital versions, in a similar vein video conferences are the descendants of telephone-conferences. As well as being adopted in a much shorter timeframe, their design cues are skeuomorphs of telephones including terminologies and features such as 'call' and 'mute' (which appear on telephones as physical buttons). While the reason for this lineage makes sense, it does not necessarily follow that using these terms to describe features in video conferencing makes for a good experience. Spaces like Gather are descendants of both video conferencing and games, which makes their systems even more susceptible to the ambiguity caused by false and unperceived affordances. The Gamer-centric videoconferencing platform Discord avoids this issue of skeuomorphs by using the term ‘channels’ rather than ‘calls’, with the intention of facilitating different types of discussion in each channel. Discord channels naming encourages users to jump dynamically between different conversations seamlessly for more fluid discussions across them in a process of what we might call discourse.

The spatial nature of digital environments is not understood equally by all users. The notion of physical presence within a digital landscape can be confusing to many owing to the need for systems like Discord. Game designers have sought ways to heighten spatial usage since the earliest games. By focusing users gaze towards the environment, rather than the interfaces on top of them, immersive tendencies can be suggested as immersion cannot be forced. For example, game designers encourage users to centre their focus on the middles of our screens in ‘first person view’ games through a crosshair, or by having a prominent avatar to constantly ground us in ‘third person view’ games.

During conversations, we make eye contact intermittently, and this same physical need is often replaced with looking at our own video feed in video calls because of the feeling of being unsure where to look, which in turn creates its own issues relating to personal image and interface ambiguity. Taking cues from the ‘closeness’ which game environments offer to their players, platforms like Gather leverage avatar proximity to make up for the lack of eye contact. This conversion of a physical space concept allows us to more easily approach others virtually, affording more natural conversations. When we are instead forced to focus on webcam feeds from others, the sense of spatial presence and interaction created quickly fades, leaving the same shortcomings that exist across video conferencing platforms, and increasing the ambiguity with which we expect to interact with their systems.

As a reoccurring theme throughout this chapter, considering and implementing physical space conventions is key to grounding virtual immersive experiences. While gamers may be used to open world exploration in virtual spaces, users of spaces like Gather may need more careful balancing between linearity and the ability to explore to keep them within their flow state. In the following section I will describe several Gather experiments. I consider each of these as an RtD study as described in Making Sense of research and Research (0c.12). By describing and dissecting these designed studies for different purposes, I aim to better understand how to design to avoid this ambiguity. Reflecting on the design of these Gather spaces aims to look at improving the next generation of video conferencing systems with a focus on spatial approaches and accessible virtual wayfinding.

2b.10. Playing with Liminality

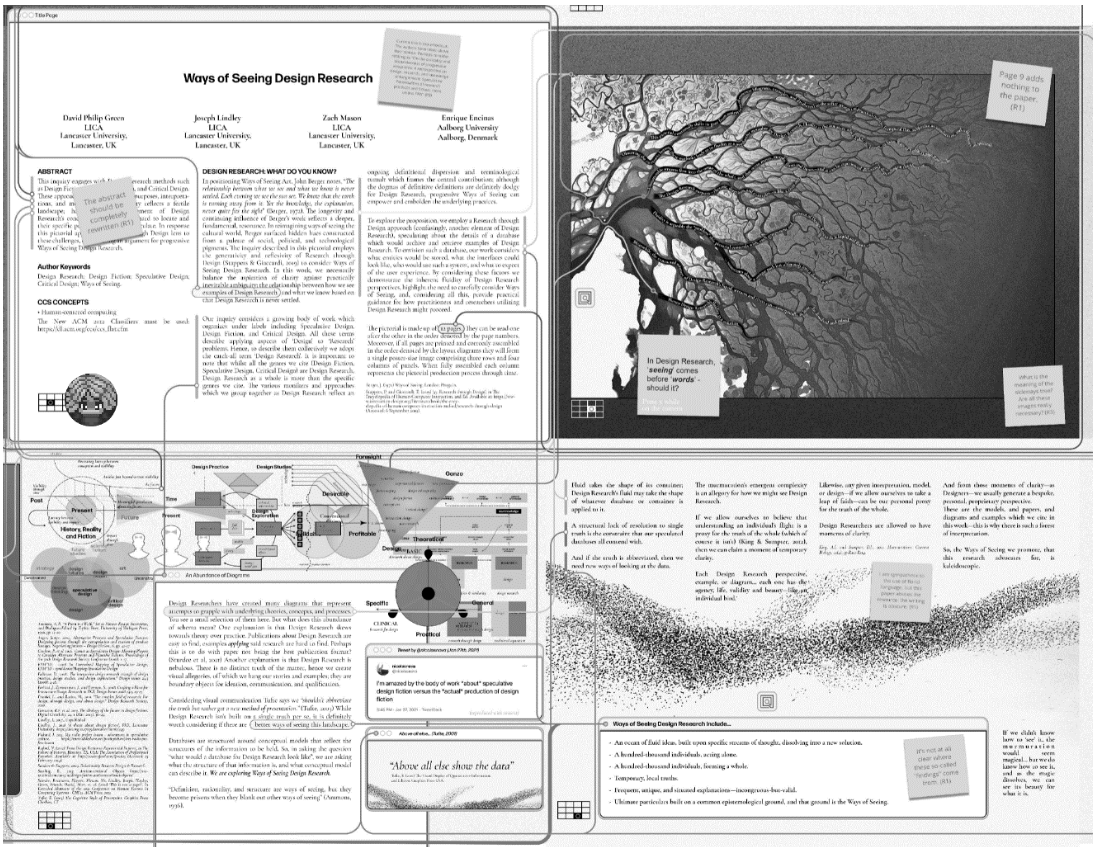

Figure 40. Gather: Ways of Seeing, section of mini-map 4 pages of 12.

In one of the first Gather experimental explorations I designed entitled *Ways of Seeing* (which was adapted from a paper pictorial which was never published, and later documented in 'Ways of seeing design research: A polyphonic speculation' (Green et al., 2023)), I opted for an open-world style map as shown above, which would be familiar to players of *Stardew Valley* or *Zelda*. This open-world style was chosen due to the open-world-ness of the original pictorial, which aimed to explore "the challenge of representing the field of Design Research in an interactive repository" (Green et al., 2023, p. 3), which in many ways was an experiment in wayfinding itself. Almost everything was accessed through the main overworld reached after a short introduction. This was intended to give users the options to explore the overall space, testing how an open environment may change user interaction, allowing them to create their own pathways. While this openness was meant to provide varying pathways and freedom of movement, when testing these spaces with users, myself, Joseph Lindley and David Green found it led to confusion due to unsureness as to where users were intending to get to. Already having been placed in a new piece of software, our potential users would be trying to come to terms with the controls, video conferencing elements, and our open landscape all at once, creating confusion as to what would need their attention first. Usually Gather mitigates this confusion by starting its participants in a small boxed in room or pixelated public park where they can quickly come to terms with the navigation and communication systems without the landscape also providing problems. This need for mechanisms to be gradually revealed isn't new, with games having tutorial segments for as long as they themselves have existed. But, because with an increased number of mechanisms, the need for eased entry becomes increasingly important, simplifying introductions is vital, especially with use cases like this that emulate a workshopping environment where conversation and notetaking takes place in a nonlinear fashion. Because of these issues, myself, Lindley and Green decided I should implement a tutorial section, but afforded users the ability to skip in case they had visited before. Because we allowed skipping, we found almost everyone we encountered who was confused about how our navigation system worked hadn't completed the tutorial, expecting that they would be able to understand the system without it. This lack of need for a tutorial is something which is commonplace in general purpose software, but not always in games. Games account for this by having different tutorials for different types of users with more rich tutorials for newcomers, and simpler ones for those who have interacted with similar games before that merely highlight the mechanical differences that the current game affords from those which are standard in the genre.

2b.11. Conventions from Physical Space

In stark contrast, the Lancaster Design Studio Gather space combatted this foreignness more fluidly. Having been designed for students at Lancaster University, its users started within a space they were very familiar with by copying the studio and building layouts from the physical namesake they had previously inhabited. Thus, this mirrored existing spatial movement patterns from the outset, with students able to employ their complex habits from the real world, focusing on interaction with the virtual environment, having "evolved an exquisite sensitivity to the actions and interactions of others" (Erickson & Kellogg, 2000, p. 60) from the physical version of the space.

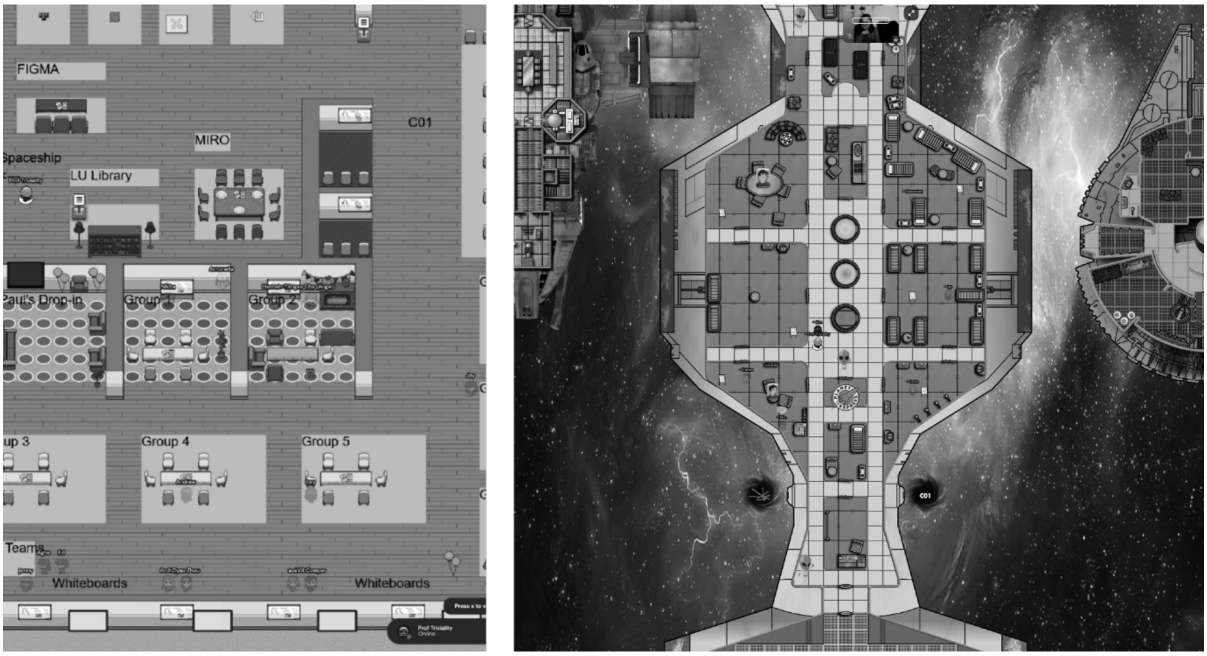

Figure 41. Gather: Lancaster Design Studio for students with attached spaceship section accessible through portal.

This type of Gather spatial layout emulates any standard group meeting or discussion space which would have previously taken place in physical space, demonstrating how by recreating a known space, habits from the original physical environment can be inferred. Copying over the interactive habits from physical space enables a quicker understanding of the virtual Gather as a spatial environment. Attached to this space was a series of portals to other related, but different, Gather spaces. Portals can be represented visually in any way the designer deems suitable, from doorways to spiralling wormholes which allows each Gather space to feel unique but sometimes requires onboarding to make this affordance apparent. The portals in this space transport you to a series of conjoined spaceships the users could explore. While this environment is more foreign than the building you arrive in, when accessed after the initial learning of Gather's mechanics, it appears more spectacular due its departure from the limitations of reality applying a playful subversion to the normal physical spaces people inhabit due to the pre-established expectations of a reality-based virtual environment. The foreignness of these portals within a space the users already knew otherwise reduced the ambiguity they feel when seeing them and highlights the kind of interaction a user can expect when colliding with them.

2b.12. Balance and Chaos

Moving within the environment helps to build engagement through spatial presence, which in turn can build towards immersion (Pasch et al., 2009, p. 173). Once the user has been encouraged to explore the environment, even on set paths, they will feel a greater willingness to deviate from defined routes as they see its design as less ambiguous. Giving users options within virtual spaces is important to enable a certain level of confusion, limited to avoid absolute chaos, creating intrigue, and keeping “players inside the Flow Zone” (Chen, 2007, p. 33). Finding the correct balance between chaos and boredom sparks a human sense of discovery when exploring a physical or virtual space, which boosts creative thought processes as described in previous chapters (0c.11). I experienced this lack of confusion when designing the Imagination Lancaster Gather space alone by trying to make something which was highly accessible and visually understandable without prior experience with games or virtual wayfinding. Created as a space to showcase current research projects to outsiders, rather than copying physical spaces (which may have allowed non-linear navigation to be inferred) I decided to have pathways through a spacewalk, hoping to allude to the vast open design issues Imagination Lancaster is aiming to solve. Each space deviates from a hub page which is displayed as a constellation in the sky, with green icons going forwards, red backwards, and purple being external interactive links (although this colour choice without icons to also differentiate was poor looking back in hindsight with a greater consideration for accessibility needs).

Even though the visual language was extremely clear, it led to an experience where nothing is left to be uncovered. While users could choose not to use the paths, they marked the most efficient way to move through the space and access the information within it. In my efforts to create an extremely understandable environment, I had removed all elements of discovery (even if it was less ambiguous), creating a design which would effectively encourage users not to deviate from set paths which is important in creating natural spatial feeling in game space. Even if users want to stick to pathways, the option to explore things in the wilderness either side of them creates a sense of openness, potentially making these inhabitable spaces more inviting. The complete lack of ambiguity I designed into this space in an attempt to avoid the confusion we (myself, Lindley and Green) caused in the previous spaces we experimented with caused it to sit firmly in the boredom zone of almost all user’s flow experience.

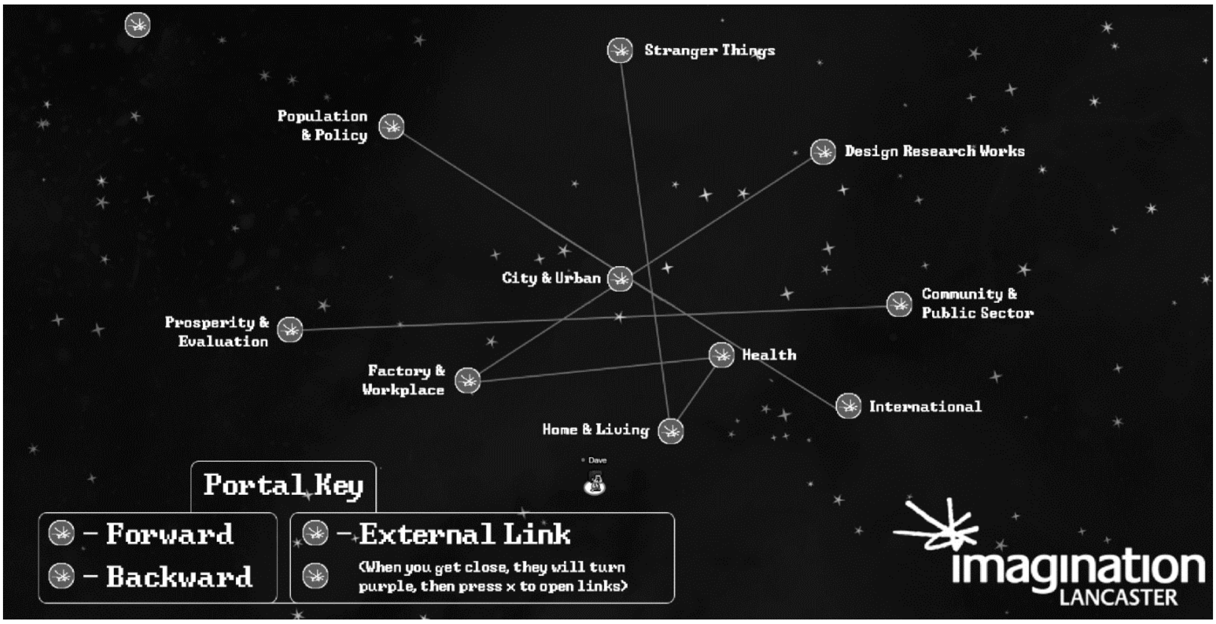

Figure 42. Gather: Imagination Lancaster Gather Exhibition hub room.

The visual language of virtual space is important, with rooms and sections needing unique themes and design choices to help users not only differentiate between each room within one Gather, but between separate spaces they connect to. Visual variety enables people to feel separation between the spaces they inhabit in physical space, translating this to virtual realms can help to create immersive tendencies. With standard video conferencing, the wall of faces is persistent regardless of if the call is for work purposes, socialising, or something otherwise, meaning the ability for the users to feel separation between the groups they connect with is heavily diminished and their mental attitudes become blurred and fatigued. Gather spaces can be designed for different degrees of openness or varied purposes in a similar way to game genres. Some spaces may suit a confusing style of non-linear narrative, while others may need a thin direct path to quickly convey a message. These can connect in a sublime way to one another within one Gather space to help guide narratives, but also be used to create mental contrast for users across a range of spaces built for purpose. Some events need a clear start and end point, while others are a gradual in and out flow of people mingling and generating conversation. Gather can support each of these somewhat naturally if its spaces are designed correctly.

The Egg, a highly experimental use of Gather designed in our university department helped me learn how to design these spaces for specific kinds of experiences. By making confusion a key factor, the feeling of being lost as a user didn't feel so daunting. As it was clearly an intended part of the experience, being named after the *Easter Egg* tropes of game culture (although it is noteworthy that this may go unnoticed to non-gamers), it created a sense of mysticism, inviting users to explore its rooms without fear of becoming lost. Varied colourful segments were designed to help users recognise and distinguish different places, reducing ambiguity as they jumped between them and reducing the chance of forgetting if a space has been visited before.

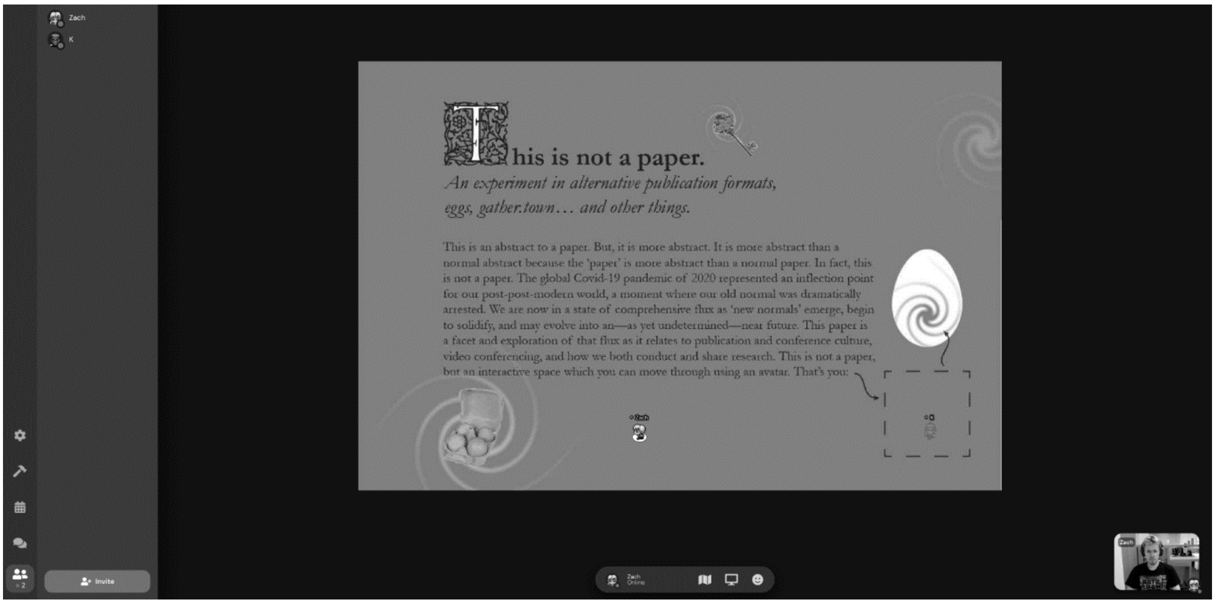

Figure 43. Gather: The Egg, an experiment in alternative publication formats.

Balancing accessibility and ambiguity for a variety of users can be hard. With *The* 'Egg', because there was no clear goal, some may feel lost while others revelled in its halls depending on their ideal balance between boredom and chaos in flow state, even if the design merely intended users to wander within it. As with the idea of 'Easter Eggs', different tiers of challenge can be created, some which may remain unnoticed to many users, only aimed at those most entangled in the workings of virtual environments and their systems, and even the term 'Egg' may have created ambiguity for those unfamiliar with game 'Easter Eggs'. The potential ambiguity caused by foreignness within these spaces needs to be considered repeatedly, and to do so means to also create divergent paths for those who are struggling to find purpose within. If a Gather space's purpose is only to create a replica of a virtual office, then most of these issues need not be considered. In this instance, the conversation becomes the primary provider of enjoyment, people only need the ability to immerse themselves within the digital environment. However, if the space aims to expand on our previously inhabited physical environments, then the additional elements or rooms need to diverge slowly from physical space norms to allow users to maintain understanding of the purpose of the space they are within. This gradual onboarding shifts from physical space understanding into virtual space subversions is a clear best practice when designing spaces for virtual togetherness. This segmented learning, where familiar space, but unfamiliar controls are present certainly helps people and possibly answers the second question posed at the end of the first half of this section (2a) around best practice for virtual spatial design in Gather.

2b.13. Learning Through Play

Segmenting the learning processes within virtual spaces can help to ease loss of interest due to lack of comprehension. For example, while teaching my parents (aged 60 and 73 at the time) to play a modern, open world game *The Legend of Zelda: Breath of the Wild* (Nintendo, 2017), I realised that even the buttons on the controller itself, and the icons displayed on them caused confusion. With my parents having little previous experience in digital interfaces beyond sending emails and editing a brief PowerPoint, segmentation of the game mechanics was vital to avoid ambiguity through design reliant on assumed knowledge. It became apparent that by separating the tropes of an adventure game, and the controls of a 3D game, the ability to engage was greatly improved. The control of 3D player perspective was practiced through *Superliminal* (Pillow Caste Games, 2019), a slow-paced puzzle game which inspired some of the earliest stages of this thesis. The tropes of adventure games was learnt through *The Legend of Zelda: Link's Awakening* (Nintendo, 2019).

Figure 44. Stills from Games, left to right: *The Legend of Zelda: Breath of the Wild* **(Nintendo, 2017),** *Superliminal* **(Pillow Caste Games, 2019),** *The Legend of Zelda: Link's Awakening* **(Nintendo, 2019).**

Combining the skills acquired from each game was simple when returning to the original title after separated practice, and a usually subconscious game learning experience for children had been segmented for a less malleable adult mind. This highlights how maintaining simple mechanics often seems easier than attempting to teach users complex interactive systems when avoiding ambiguity in affordances and options for players. Poorly considered onboarding can block inexperienced users from being able to interact and understand more deeply engaging virtual worlds through a lack of practice. This common oversight discourages them from attempting to learn to play games in the first place and reduces how ambiguous games can be with their onboarding segments and tutorials in the future. In the case of Gather, stripping away any mechanism that does not either provide utility within the interactive systems, or enjoyment, could heavily alleviate this issue. With general use software, mechanisms are copied from existing programs under the presumption that they have significance to their usage. The clear example of this within Gather is video, stemming from videoconferencing where webcams feeds have been treated as an essential part of the experience. Games, and communication software used by gamers rarely implement webcam feed systems as core affordances to their experiences, and instead focus on avatars within the spatial environments they create to embody the players and focus their attention to avoid ambiguity in where they should be directing their attention.

2b.14. Video is the Elephant in Video Conferencing Space

By analysing varied usage of Gather in the various experiments described above I have demonstrated a flexible and powerful way to transcend the trappings of video conferencing. While making significant advances in its attempts to spatialise the environment for its users, many of Gather's features are transported from the assumed norms of video conferencing systems. Those in turn are skeuomorphs of teleconferencing and telephones. Why though would Gather, or other internet-enabled videoconferencing systems, need to inherit these design assumptions at all?

In the case of Gather, the craft and detail that has gone into the design of the spatial systems and avatar design is overridden by the disconnected assemblage of video windows popping up as people come into proximity with one another. When exploring on our own, myself, Lindley and Green found ourselves enjoyably lost as users, entranced by the visual diversity of the space and the ability to spatially navigate it through our self-designed avatar. However, when bumping into others, we often found our escapism challenged due to the abrupt need to visually present ourselves through webcams, perhaps due to transferred judgement or even ridicule of those who do not turn their cameras on in standard video conferencing programs, but also our engagement in the virtual space is disrupted by a need to re-identify with the physical. This need for video is being negated with upcoming systems like *Meta* and existing online virtual social spaces like *Second Life* and suggests that in consideration of the first question posed in this section's literature review, that Gather really does not fit well within video conferencing space at all and would be better further intertwining itself with game systems. Attempting eye contact with the faces that appear in our screen corner and finding a constant urge to check our own appearances on camera to make sure we are presentable creates additional unnecessary mental barriers to immersion, all while sat in our homes, a place usually free of physical judgement. This unnecessary ambiguity that video brings to a system like Gather not only focuses our attention back onto the flat representation of the physical world but adds more complexity while providing less clarity to how people should interact with it. Furthermore, it reduces accessibility for visually impaired people compared to traditional video conferencing without providing any advantages.

The addition of video to communication systems was intended to be used with close family and friends, conversations for mainly personal reasons which generally benefit from the increased vulnerability that a video feed presents, and almost always in much smaller groups. Audio provides a great means of communication, used across game space, and has enabled gamers to communicate effectively and comfortably while completing tasks in a similar manner to our work lives. When considering CI (Collective Intelligence), "…contrary to popular belief, the presence of visual cues surprisingly has no effect on CI; furthermore, teams *without* visual cues are more successful in synchronizing their vocal cues and speaking turns, and when they do so, they have higher CI Bandwidth…" (Tomprou et al., 2021, p. 1). This is something I've personally experienced when developing software solutions in industry with other people familiar with online social scenarios, such as games, who all choose to avoid turning the webcams on except on rare special occasions. While audio uses little data, video can cause major issues for weaker connections, and having only the transfer of audio allow Gather's spatial conversations to be implemented in a completely different way. Conversations in Gather's spaces could fade in and out from much further distances if video were removed, leading to more natural movement between conversations with others as well as improving the accessibility of Gather for blind and visually impaired users. Being able to keep our focus on our screens and avatars could lead to further visual presentation. The ability to express emotions through our characters while talking could be implemented through emotes as many games do. While similar to emojis or GIFs, which are already popular, emotes amplify the significance of the avatars and help users feel more connected to them, and in turn with the virtual spaces they inhabit through them. These emotes only work if users are looking at avatars rather than video feeds.

If video is deemed important for certain use cases, it should be within the space itself as part of our avatars rather than overlaid on top of the primary experience to make it feel optional to participants. The ability to read a room is completely removed in video conferencing, and the same often applies to Gather. Once in a video call in Gather, people are forced stop moving in space to maintain the call, and this norm really answers the third question asked in the first part of this section (2a) around whether Gather addresses the disconnect people feel with video in video conferencing. I, Lindley and Green found ourselves loosing attachment to our characters, and therefore loosing connection to what is going on in the rest of the space, feeling a great significance to tapping in and out of what should be mingling joyful conversations due to how finite exiting and entering them is. Walking past a conversing group pops up a large video feed of your face on their screens, not allowing you to listen in to decide if it is a conversation you want to contribute to before being visually thrown into the centre of it, and in turn flattening the conversation back into a video conferencing state rather than embracing the spatial nature of natural conversation (Rosedale, 2020). Video conferencing, Gather, and general virtual space are all evolving and intertwined systems, with the designers constantly tweaking and adjusting them to find balance between over-specificity and ambiguity. Immersive mindsets need to be encouraged across virtual space, but perhaps video is the core system that needs to be removed to facilitate this. In order to systematically shift the ideas of virtual communication for mainstream audiences, allowing it to become both enjoyable and useful without the pitfalls of video conferencing, future systems need to critically consider past conventions relevance in digital space to enhance the interactions that make virtual experiences immersive.

Because of my takeaways through this chapter and the research it presents on reducing the prominence and significant of video on the experience of systems like Gather, the next section (and final main section of this thesis) will take this premise to its furthest potential. Focusing entirely on auditive experience, I want to challenge the hypothesis which I have started creating here that establishes spatial navigation in simple virtual environments is possible and enjoyable without visuals. If this is the case, not only will it improve how I and others design future spaces when balancing between over-specificity and ambiguity by allowing information to be spread across more senses as it is in the physical world, but it will also enable future virtual wayfinding spaces to have improved accessibility. This benefit is aimed not only at virtual web conferencing systems which may have limited use cases anyways, but also at games which are becoming an increasingly integral part of the modern world. Because of this need for spatial virtual games to be accessible to visually impaired people, this research feels incredibly important to me in finding balance between over-specificity and ambiguity in virtual accessible wayfinding.

3a. Access from Legibility

3a.1. A Personal Perspective on Accessibility

This mini-literature review begins the final of the three main sections, aiming to situate the subsequent chapter. Following on directly from the takeaways from the previous chapter, it will jump straight into my intent to find legibility in virtual accessible wayfinding. Focusing on legibility, it uses accessibility as a method to achieve this.

> "Legibility of spaces for the visually impaired is improved by the use of the right landmarks in the right places, and by appealing to multiple senses. When the layout is designed with consideration of appropriate sensory and structural landmarks, spaces will be legible for the visually impaired." (Belir & Onder, 2013, p. 11).

Within this section I will be focusing on applying this same principle idea within digital spaces, using sonification (a similar process to creating icons for visual first design) as the primary method to create wayfinding systems which are accessible to visually impaired people in virtual space. This process aims to design optimal legibility within generic hardware.

Before explaining the process of actually designing these systems, first I need to explain why generic hardware is important, and look at existing virtual wayfinding systems which have implemented this concept with varying success and aims towards different kinds of legibility. As reiterated throughout this thesis, games have been a vital source of literature in my ability to understand best practice in virtual wayfinding design due to having been developed and used by people much more extensively than other virtual wayfinding systems over the past three decades. This widespread uptake of game making and gameplay makes them a perfect vessel for the research I'm undertaking, both for testing systems with, and for looking at for inspiration.

To clarify the kind of virtual wayfinding legibility this final section is most focused on, I need to unpack how I am considering accessibility a little further here. When considering accessibility as a vague concept it is generally focused around the ease with which someone can engage with a thing. Due to this, each person will have varying accessibility needs in any given situation. Monetary accessibility and ease of access can often halt viable design innovations for accessibility (especially digital ones) due to products being too expensive to produce, and therefore hard to get in the hands of intended users. While sensory accessibility is the focus on this thesis, not considering monetary accessibility at all could lead to designs which are completely infeasible for the intended users.

Sensory accessibility is required when sensory bandwidth, which is discussed in Virtual Sensory Bandwidth (0b.4) is reduced due to sensory disabilities such as visual impairment. Sensory accessibility dictates legibility, and by considering the ways designs can be tailored to people’s unique sensory capacities can improve wider legibility in designed systems for everyone. A common place example of this is how “more than 60% of 18 to 24-year-olds now use subtitles when watching TV programmes and movies” (YouGov, 2023), even though only around 10% of people in that age bracket have hearing impairments (the original purpose of subtitling as an accessibility feature). Also, it “is worth noting that in 2019, Ubisoft experimented with having subtitles on by default, and with this feature enabled in Far Cry New Dawn, 97% of players kept them on” (Brown & Anderson, 2021, p. 708), suggesting that accessibility features are being used increasingly by mainstream audiences.

The chapter following this literature review focuses on similar ideas to these new approaches to subtitles, but instead isolates audio as a singular sense, using its bandwidth to explore potential limitations and capabilities that audio can provide in the design of virtual spatial wayfinding. To be able to convey and situate this idea, I need to explore existing audio focused accessibility systems in games, considering how they progressed accessibility within their designs, but also were limited by their wider design aims. However, before being able to do this, I need to rationalise why games are such an important vessel for this, rather than richer unique hardware-based audio information output systems.

3a.2. Value from Low Fidelity Interactions

A plethora of research has been undertaken around the use of rich audio in several applications through unique hardware devices. For example, Simpson's research explores the use of spatial audio displays, and how their "at best, relatively simple audio displays that do not fully exploit a pilot's auditory processing capabilities." (Simpson et al., 2005, p. 1602). This research explains how audio capabilities could easily be expanded on with more advanced hardware which is definitely a viable argument. Other research has delved into the use of "Wearable computers" (Wilson et al., 2007, p. 1) to "support audio-only presentation of information" which is highly likely to have impact for accessibility purposes, especially considering implementation of "pertinent data with non-speech sounds through a process of sonification."

There have also been examples of research which align even more closely with this final section of this thesis, such as "Training blind children to use audio-based navigation" through the use of "a 3D exploration game, which uses the headtracking capabilities of the Oculus Rift to create an immersive experience, and the new sound libraries AstoundSound and Phonon3D, to generate an accurate and realistic soundscape" (Allain et al., 2015, p. 1). However, while all these approaches are perfectly viable as research projects to improve accessible design, they all rely on the usage of bespoke hardware, or devices which are not yet commonplace in people's lives. While the Oculus Rift is arguably a monetarily accessible device, I believe that the likelihood of it, and the other devices described in the above rich audio accessibility research being standard place in the homes of the wider public is rather low. Furthermore, the benefits of any common place device are often far skewed in the favour of a visual users (with virtual reality headsets like the Oculus Rift being exemplary of this fact).

Considering the progression of tracking systems and visual progression of virtual reality headsets in recent years, audio capabilities have clearly lagged behind this progress. Because of this reality where design is so often enacted from a visual first approach, this chapter aims to focus primarily on mainstream and audio only games which provide noteworthy systems to improve their experiences for blind and visually impaired players using software, alongside generic hardware. This choice is made with the intent to focus my design research on devices which anyone may have easier access to, with the hope that it will help onboard blind and visually impaired people into virtual wayfinding systems.

This idea of generic hardware is something which I have continued to reiterate throughout this thesis, but pertains to the usage of either a keyboard and mouse or dual analogue stick controller, paired with headphones, earphones or speakers. For the purposes of simplifying how I talk about accessibility features going forward, I will assume the default is a dual analogue stick controller, with headphones. This is because for audio accessibility, headphones allow the most defined positional audio of all dual channel audio systems due to the left and right channels being much more clearly defined than in speakers. Following this same thought process around clarifying sensory bandwidth comprehension, dual analogue stick controllers are able to provide passive haptic feedback to the user in a way that a mouse cannot due to the absolute nature of its input compared to a mouse which translates its input in a relative way to the device it connects to based on momentum not position. Because a computer mouse has this lack of absolute input, blind people often use screen readers on their computers, operating them without a mouse solely through the use a of their keyboard.

Now that I've clarified that I'm focusing low fidelity auditive accessibility because of its general availability and higher likelihood of being available in the foreseeable future, I think it would be most fitting to discuss several recent mainstream games which have considered and implemented accessibility for blind and visually impaired people most holistically into their designs. I think this is important because as I previously discussed in Finding Solutions in Gaming Conventions (2b.6), mainstream game design is so heavily ingrained into our culture and enjoyed by so many that its systems are beginning to spread into wider virtual spatial wayfinding systems, and are likely to remain similar for some time. Therefore, looking at how accessibility can fit within these interactive play systems is critical to designing audio-focused experiences which may be convertible into accessibility features for mainstream games. Designing audio games which can fit within the tropes and genres of the mainstream can allow visually impaired people to engage with content designed for wider visually centric audiences, opening up the potential for further social interactions and integration.

3a.3. Accessibility in Mainstream Games

To begin to consider recent advances in accessibility features within mainstream games, and how they strive to improve accessibility, I need to acknowledge and present how accessibility features can be broken down into many different types depending on the sensory bandwidth limitations they aim to circumvent. While it is my view that the impact of these sensory bandwidth limitations (labelled as disabilities) have been exacerbated by systemic reliance on visual first design, first considering how visual first approaches are tackling their lack of accessibility can help to understand how to better tackle these issues from a non-visual approach. Aguado-Delgado et al.'s paper breaks down accessibility in video games in a very specific manner (2020, p. 171), however for my purposes, the general categories are only important to be generally aware of as surrounding information.

These categories can be broken into sensory, motor, and cognitive disabilities which require varied accessibility accommodations. While my main area of interest for the purposes of legibility through accessibility in this thesis is sensory, I would like to briefly highlight how the other areas are addressed in games. Cognitive disabilities can be accommodated by more carefully directed gameplay which fits better in certain kinds of games, and through varying difficulty options. These types of systems are already widely available to game players. Motor disabilities are currently effectively accommodated through the usage of altered peripherals for the user to allow them to play games in similar ways to how others would with a generic dual analogue stick controller. While this solution isn't always perfect, as most games control similarly (especially those within close genre fields), once remapping for specific motor disabilities have been defined for adaptive controllers, entire genres can be opened up to players.

This kind of rational is the same I'm aiming to apply to sensory bandwidth issues in games. By modelling audio only games with simplified versions of visual game's mechanics I aim to uncover if this approach is applicable to fast paced gameplay in Continuation of Game Development (3b.11). Sensory disabilities which significantly impact interactions with digital experiences general fall into two categories due to the limits of Virtual Sensory Bandwidth described in the identically named chapter (0b.4). These categories are defined by the user's sensory bandwidth limitations in either a visual or auditive capacity. Deafness limits a user's auditive sensory perception and can be accommodated through additional visual cues on screen (such as the visualisation of other players footsteps or subtitles). Often many more people will decide to use these kinds of accessibility features than just those they are originally designed for due the competitive advantage they can provide "such as Fortnite which shows players' sound effects like footsteps and gunfire." (Brown & Anderson, 2021, p. 715). "More than 100 empirical studies document that captioning a video improves comprehension of, attention to, and memory for the video." (Gernsbacher, 2015, p. 1), and it isn't farfetched to suggest that professional Fortnite player's usage of an audio to visual cue feature intended for deaf accessibility is for the same reason.

Accessibility accommodations designed for blind players are much less frequently available in games, and often when they do exist, they are only widely implemented when they are for low vision users, rather than those without any sight at all. Because of this oversight in accessible game development, only some of the most recent titles feature extensive non-sighted accessibility. As this is the area of accessibility orientated legibility, I'm most interested in (precisely due to how underdeveloped these systems are in modern virtual wayfinding systems), I want to highlight several recent titles which take great steps to improve non-sighted access through implementation of rich accessibility features for blind and visually impaired audiences. *Mortal Kombat 1* (NetherRealm Studios, 2023), *Forza Motorsport* (Turn 10 Studios, 2023), *The Last of Us Part 2* (Naughty Dog, 2020) and *God of War Ragnarök* (Santa Monica Studio, 2022) are some of the most recent, and non-visual accessibility rich titles which I will unpack below.

Figure 45. High Contrast/Standard Mode in God of War Ragnarök

To begin highlighting blind accessibility in recent mainstream games, *God of War Ragnarök* is noteworthy due to winning a range of awards with several specifically for its progress in the space of accessibility. Firstly, I would like to briefly mention one useful feature for low vision users which is becoming common place in many recent PlayStation titles allowing players to change character and item textures to single block colours rather than complex and non-informative skin and armour textures. For example, the player can make themselves appear bright blue while they visualise enemies an intense red, and interactable objects are a bold yellow. While this isn't useful for all players, especially those with no vision, as most blind people do have some sight, this is a noteworthy feature in the space between visual and non-visual play before delving into the purely non-visual features. All the subsequent observations I make in this section (which are around completely sightless play) draw from general reading around non-visual accessibility in games, alongside the well documented experiences of SightlessKombat (https://www.sightlesskombat.com/). SightlessKombat is a gamer with zero vision who plays games from an audio only perspective, documenting this experience through play on Twitch streams as well as in depth written reviews aimed towards informing other visually impaired gamers about their likely play experiences.

God of War Ragnarök's other non-visual accessibility features focus on Menu narration, clear audio cues for different attacks and varying incoming attacks (such as unlockable attacks, parrying, successful heavy attacks and more). It also includes a great navigation assistance feature, which enables the player to orientate the camera towards the current story objective whenever needed. This is an essential feature in an open world story game, greatly improving non-visual play experience. However, while many of the features in this title go much further than other similar titles in the genre, it still relies upon sighted assistance from a co-pilot during many sections (especially around puzzles) and lack of audio description for many story segments which can make them hard to understand as spatial events. This title, which to many appears as an accessibility marvel for non-sighted play shows how far design still must progress before we have truly equal experiences for non-visual gamers.

The Last of Us Part 2 is another story driven semi-open world game which came out very recently, taking many similar great strides towards bettering general user accessibility. Both it and part 1 are fully playable without co-pilot sighted assistance, something which is extremely rare for games to be able to do completely without their visual elements (with even God of War being unable to achieve this feat). Rigorous auto-aim mechanics are available to the user to enable attacking enemies without being able to see them which obviously benefits blind gamers. The game also includes the ability to skip puzzles (which can often be impossible without sight), use navigation and traversal assistant (when obstacles are too confusing to navigate without visual cues), use enhanced listening mode and be entirely invisible to enemies when prone to take time to listen to your surroundings through the enhanced listening. All of these features, paired with the slower paced stealth orientated nature of the game make this experience quite unique in its playability without sight amongst other exploration story driven games.

Forza Motorsports varies quite significantly in its gameplay from the previous two titles as a driving game. However, as another wayfinding dominated genre in mainstream gaming, the accessibility accommodations it has designed to provide access to non-visual players are just as noteworthy. It includes Blind Driving Assist (BDA) which is specifically aimed at users with low or no vision, mixing spoken word and audio through stereo headphones. By either playing the player's car engine noises through the left or right ear more prominently, it conveys which direction the upcoming corner is in. A beeping sound also alerts the player if they are nearing the edge of the track similarly to modern parking assist features in the physical world and somewhat mimicking electric car sonification (Lenzi et al., 2022). Vocal queues also exist which tell the player what kinds of corners are approaching in similar fashion to rally pace notes in real-life off-road racing. These rich and innovative features which mimic the physical world but are quite willing to leave behind the need for realistic audio in favour of usability for their users are great improvements for non-sighted accessibility without the need for railroading movement controls. The game also includes many much more standard auditive accessibility features such as narrated menus, alt text for visual customisations and accessibility feature previews without having to leave the menu.

Mortal Kombat 1, the final mainstream title I want to cover in this chapter, has a very different control scheme approach in the form of an arcade style fighting game. This enables it to implement incredible accessibility without the need for visuals as much of its standard in-game input is absolute in nature (meaning joystick push direction directly correlates to onscreen movement, rather than it being related to character and camera position controlled by the player). The game already includes highly distinguishable audio queues to represent in-game actions and events such as attack types, special moves, jumps and fatalities (one player defeating another). Taking this auditive richness even further, layered on top of this is a system for spatial perception with the ability to perceive distance and positioning on the 2D fighting stage through stereo audio headphone output allowing a player to have greater spatial awareness within the game, rather than having to perceive it from the same flat position that the visual camera must. This is relevant as while the side on camera may bring clarity and legibility to the visual experience, shifting the position from which sound is understood for non-sighted players has the potential to drastically increase their ability to perceive the game experience and therefore its legibility.

While I believe that being aware of all the above features from mainstream titles is incredibly important in beginning to understand how non-visual accessible games can be designed, looking at titles which completely side-line visual design from the outset in favour of audio or haptics has the potential to have even greater benefits. Looking at these games in the following section, I aim to further clarify how legibility can be increased through uniquely accessible designed experiences.

3a.4. Leaving Visual First Game Design

In this final part of this literature review, before I begin to talk about the game I developed (focused around legibility through non-visual accessibility) I want to consider examples of audio and haptic focused games which are especially relevant to my own game's design. When looking at these games, I will primarily be considering their control schemes, and how these control mechanisms facilitate accessible virtual wayfinding in virtual space. While there are many games which are designed with a non-visually accessible gameplay focus, I will focus on just a few which are uniquely relevant to my research aim. These games are *Sightlence* (Nordvall, 2013), *Papa Sangre 2* (Somethin' Else, 2010), *The Vale* (Falling Squirrel, 2021) and *A Blind Legend* (Dowino, 2015). I want to discuss each of these somewhat briefly, considering how they accommodate non-visual audiences, and how they balance gameplay richness and legibility without visual elements using generic and widely available controllers. Several of these games take unique approaches towards control schemes and interface design, making them highly relevant to much of the later research within the next chapter.

The first title I mentioned, *Sightlence* is a re-creation of the classic arcade game *Pong* (Atari, 1972) which relies solely on upon haptic feedback, through the Xbox controller it is played with, to convey what is happening within the game. The controller simply vibrates when the player's in-game paddle is in-line with where the ball currently is (not where the ball will hit). This unique output modality actually is so distanced from the original experience of playing pong, that as a player you are almost unaware that you are playing at all until you are shown the usually hidden visual debugging screen, and are merely inclined to follow the vibration through using the controller until a harsher vibration indicates you've missed the ball. Thinking about the implementation of a standard Xbox controller as the input method heavily influenced how I designed my audio game in the following chapter. I considered the potential benefits of instead using a slider embedded within a housing, with a motor inside for the control of this game. This would allow the player finite start and end points for the paddle which an Xbox controller does not allow for, potentially better conveying the game the user is playing. However, talking to the developer of this game, I realised their distinct reason for not doing this was their focus on generic and widely available hardware to boost the accessibility of their game beyond purely sensory access, and into affordable and availability-based accessibility as well. This compromise to legibility comes at the benefit of access for users.

This complex balancing act is what forms the three main sections of this thesis, between over-specificity and over-simplicity, and it also became highly relevant to my own research even more specifically in this final data chapter (3b). This choice to favour access over legibility made me choose to centre my audio game's development around the use of a standard controller. This decision makes the game I designed potentially harder to play, but then focused the research more heavily around designing control schemes to fit with this standard controller. Learning from play of Sightlence also made me realise how I could use the absolute movement of a dual joystick controller to facilitate gameplay similar to that of *Enter the Gungeon* (Devolver Digital, 2016) or *The Binding of Isaac* (McMillen, 2011), and split some of the perceivable sensory bandwidth into haptic format through this.

Figure 46. Touchscreen Interface for *Papa Sangre 2* (Somethin' Else, 2010)

Papa Sangre 2 is equally noteworthy in its control scheme, using iPhone as both the platform and controller. It is controlled through gyroscope-based turning for the orientation of the player, and uses four buttons (one in each corner of the screen) to control each of the player characters hands (for grabbing) and feet (for movement). This control scheme makes it completely accessible without sight, although some description is required, and is designed to allow the player to close their eyes and be immersed in the world. While this control scheme provides incredible accessibility, it does limit it to a mobile device-only experience without expensive hardware such as a virtual reality headset. This is something which participants in our workshop, detailed in the following chapter, expressed a desire to escape from, rationalising our decision to use standard controller and keyboard and mouse as controllers instead. Regardless, this control scheme used in *Papa Sangre 2* is still highly noteworthy for future porting of our game to mobile devices and highlights the variety of ways accessibility can be implemented. This gyroscope-led control scheme is also relevant when considering wider accessibility for mainstream games, where if their visual requirements were removed, there is strong possibility that they could run on modern mobile devices and employ similar control schemes to enable blind users to play them with absolute movement for turning which is a major obstacle in the subsequent games mentioned in this chapter.

Papa Sangre 2, A Blind Legend and *The Vale* all use stereo audio and breadcrumbing (gradually leading the player through frequent points in-between destinations), systems for audio way-pointing something which I was initially hesitant to take forward into the development of our game. However, with the intent to improve the control scheme systems and combat fluidity afforded, having this way-pointing feel more like a subversive echoing (where reverb around corners is more informative than realistic and continues indefinitely). *A Blind Legend* and *The Vale* both exist on computer and are controlled in an extremely similar manner to visual games when played with a controller, with the left joystick controlling the player movement and the right joystick controlling the player's orientation (which also alters how you hear as both the player's body and head are controlled as one). Both games also implement flat fighting segments where the player enters a different play style phase when they reach combat segments. While these flattened fighting systems are enjoyable, and certainly accessible, going forward into the development of our game, I was wary to avoid this as to not limit how transferable our game's systems could be to wider accessibility features in games which were originally visually focused.

As you can see throughout this chapter, which considers literature and games equally, there are many ways in which accessibility for non-sighted users can be implemented. However, within this, control schemes are likely to significantly shift how these games are able to be played, alongside the genres these games reside within dictating control schemes themselves. Because of this, the next chapter will focus on a maze explorer game due to the wayfinding centric nature of this type of game, pushing how this type of game can be controlled, and analysing how visually impaired people play and reflect on this experience in an attempt to improve legibility within accessible virtual wayfinding. Within this research I primarily aim to address these questions:

- *What Kinds of Games do Visually Impaired People want to Play?*
- *How do Controllers and Control Schemes Effect Play of Audio Centric Games?*
- *Are Non-Narrative Virtual Games Enjoyable Without Visual Elements?*

3b. Audio Game Design

3b.5. Increasing Need for Non-Sighted Accessibility

As this thesis has been re-iterating throughout, peoples' need to access spaces of virtual togetherness is constantly increasing. These virtual systems are inherently 'space', but their spatial nature is only increasing, as well as their widespread adoption. Web conferencing systems like Gather, which I explored extensively in A Gather-ing Problem (2b), as well as other similar systems (HyHyve, 2022) have adopted spatial presence as a mechanism for initiating smaller conversations and attempting to make them 'feel' more natural. Such spatial approaches are still in their exploratory stages and, while facilitating fluid spatial conversations, this space-based approach can prove problematic for legibility when specific users have accessibility needs (Mason et al. 2022), such as visual impairments - as the previous section began to explore. I would like to again note here that this chapter will often use the idea of legibility and accessible interchangeably as it seeks to promote the idea that legibility is not a universal principle, and therefore accessible design is completely relevant to making more universally legible systems. Party due to the lack of tactile or haptic feedback available through standard digital interfaces, virtual accessibility for blind and visually impaired people (especially those with no sight at all) must predominantly rely on sound in order to be legible. The combination of the spatial design metaphor that these platforms use, and the types of interfaces which are generally available to visually impaired people in the physical world - but not available in these platforms - makes such virtual spaces almost unusable for blind and visually impaired people. Globally, over 2.2 billion people are blind or visually impaired (World Health Organisation, 2022). Roughly half of these visual impairments cannot be prevented or addressed. This is such a large group of people which cannot be ignored when designing virtual spaces, especially as these spaces are now often essential for everyday life.

The games industry has a rich history of innovation in accessible virtual spaces, with games such as *Sightlence* (Nordvall, 2013), *Papa Sangre* (Somethin' Else, 2010) and *Blind Legend* (Dowino, 2015) being exemplary of non-visual-first approaches (as discussed in Leaving Visual First Design). Games are excellent sandboxes for exploring virtual accessibility for people without a visual-first understanding in order to make virtual systems legible for everyone. Video games as an evolving medium have always explored novel ways of evoking and utilising the notion of space inside game worlds. However, perhaps most vividly demonstrated by the name video game, they have tended to have a visual-first approach. Most games are entirely playable without sound which is great for deaf people, or people with hearing loss. However, this means sound is often added purely to embellish and draw attention to certain events occurring visually onscreen. Haptics, mechanical systems that allow users to touch and feel virtual game elements are utilised even less than sound for core game mechanics because game developers want to produce equitable experiences across all platforms. Because most PC players use keyboard and mouse input, any game designed for PC must make haptics an optional sensory output, which proves problematic when designing games for platforms which blind and visually impaired people desire ready access to.

In this section of my thesis research, I aim to utilise the premise that designing games as sandboxes can provide insights relating to emerging accessibility issues in digital spaces more generally. Specifically, this chapter explores how sound can be best used to create a sense of space in an audio-only game. This research seeks to understand how designing within the framework of audio-first, (an alternative to visual-first game design) might provide insights that could be beneficial for the future of accessible virtual spatial design. This data chapter uses Co-Design to fuel the development of an audio-only game using stereo spatial-audio (Frauenberger & Noistering, 2003), utilising generic low-end computer and game hardware as a constraint. The first Co-Design workshop which is documented here kicking off this iterative development approach was facilitated in collaboration with sight loss charities, with the objective of exploring how to create more inclusive virtual spaces which "address and incorporate design issues for the sensory impaired at the beginning of the design process" (McElligott & Leeuwen, 2004, p. 1). Through synthesis of these conversations, I hope to bring to light a desire from blind and visually impaired people to include non-visual accessibility as a core consideration in the design of virtual space software and hardware to support the future of non-visual cyberspace access.

Virtual games that use sound or haptics as their primary output are starting to appear more frequently with titles such as *Sightlence*, *Papa Sangre*, *The Vale* (Falling Squirrel, 2021) and *A Blind Legend* coming out in recent years (as discussed more extensively in this section's literature review, 3a). Mainstream AAA games such as *The Last of Us Part 2* (Naughty Dog, 2020), *Mortal Kombat 1* (NetherRealm Studios, 2023) And *Forza Motorsport* (Turn 10 Studios, 2023) are now beginning to implement rich accessibility options, such as remapping controls, tying audio queues to game events and spoken menus as discussed in Accessibility in Mainstream Games (3a.3). These efforts are also contributing to the platforming of sensory accessibility in game design. Through the Co-Design workshop documented in this chapter, I aimed to amplify the voices of blind and visually impaired people who have an everyday need for accessibility in visually dominated media, continuing with the progress made in the aforementioned sound and haptics first titles. People like *SightlessKombat* (a blind gamer and design consultant) who helped with accessibility on *God of War Ragnarök* (Santa Monica Studio, 2022) are more commonly being included in the development of large-studio games. In contrast I saw it as important to develop auditive games for people who are not experienced in non-visual digital navigation, in order to understand how I could maximise the accessibility of the tools designed going forward, rather than tailoring to these super users.

Many of the audio games released in recent years have followed a trend of focusing on narrative elements within the game's design due to the lack of spatial time sensitive movement required in genres like choose your own adventure, for example *Real Sound: Kaze no Regret* (Warp, 1997). While this makes the games accessible and legible to the players at all ability levels, there is a danger that they can turn into 'audio book' versions of games. These games, which could be described as 'gamebooks', can have rather limited interactivity, often failing to represent a gaming challenge for players who are interested in skill-based gameplay. Accordingly, there is a lowered replay potential or skill development. This means that for visually impaired players the passion for gaming that would emerge from re-playable and skill-based games rarely occurs. For this reason, I decided to focus the game's design workshop on how the players were able to interact with the game space in ways that did not rely on sight to maximise impact for "partially sighted and blind communities" (Targett & Fernstrom, 2003, p. 1). Isolating the interaction mechanics of the game would allow narrative elements to be considered later in the game's production and push the focus more specifically on movement, controls, balanced difficulty and sounds ability to "create perceptions of a variety of spaces" (Grimshaw & Schott, 2007, p. 1). By tapping into increasingly advanced audio engines like the one used in *Demon Souls* (Bluepoint Games, 2020) I aimed to make a game which is challenging for beginners, with an enjoyable learning curve that could translate to wider digital applications.

Limiting the output aspect of the game's interactions to audio-only enabled me to explore how sound alone could generate a sense of space without any need for haptics. While I acknowledge haptics and movement-based interaction devices can enable the "full potential inherent in audio based gaming" (Röber & Masuch, 2005, p. 4), I wanted this game's experience to be provided through generic controllers and output devices (such as headphones and arcade-joysticks, or keyboard and mouse). With a high possibility of audio games releasing on desktop computers where haptics feedback is unavailable through standard keyboard and mouse (due to the low amount of visually impaired people buying games consoles focused around visual fidelity) I saw it important to explore audio games without haptics in this first instance. To further focus the feedback, the game experience avoided menus for the workshop, putting the players straight into the gameplay.

There is an abundance of information around non-visual menu navigation available to draw upon for a potential future release of the game, such as avoiding infinite scrolling systems (i.e. when you reach the bottom of a menu, the cursor returns to the first option on one further downward input) and including dictated menus (Barlet & Spohn, 2012).

3b.6. Designing Gameplay

The game's instructions were segmented into three short statements that are dictated using a text-to-speech engine (which would become recorded voice-over in later versions). The game's concepts are introduced through the first few levels with all other information being conveyed through software-generated stereo audio that is played through a standard set of headphones. The game used a joystick for workshop purposes but is also playable with keyboard alone (as mouse-based character movement can be hard to keep track of non-visually) and due to general feedback, a generic game controller is being used in further development. Using the joystick was intended to make the necessary peripheral easily accessible and affordable, as well as give the game a more familiar entry point that using a mouse and keyboard would not have achieved. It is noteworthy that while any given game may be designed for sensory accessibility, it is also important to have monetary affordability. This is something that audio-only games can achieve quite easily when compared to the resource-intensive visual fidelity of many modern games; with audio games there is no need for expensive graphics cards or games console hardware, with lower end computers being more than sufficient to play them.

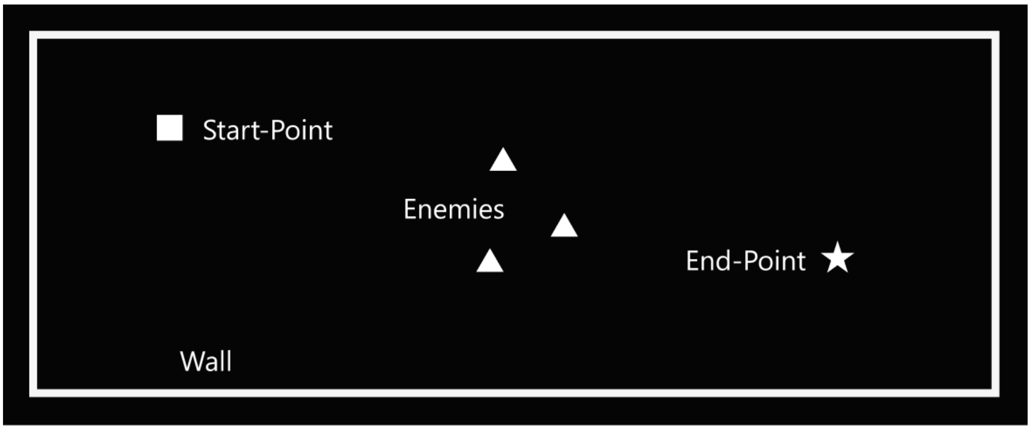

Figure 47. Diagram of Game Level Elements.

The game was designed and produced using *Unreal Engine 5* (UE5) which was in late-stage alpha at the time of the workshop. I made the choice to use this engine due to its popularity in mainstream game production alongside rich features for generating sounds within the engine itself and off-the-shelf spatial sound functionality (although this has some limitations when compared to real world binaural audio recordings). Using UE5 not only sped up production of the game but enabled me to explore the engine's suitability for sound focused game design.

The initial version of the game used in the workshop, designed and created by myself, was developed as a maze explorer game with linear level design and inspired by games like *Pac-Man* (Namco, 1980). This genre choice was supported by several comments made in virtual meetings prior to the in-person workshop, with many other potential audio games being envisioned during the workshop's conversations. This genre of game proved great for pushing the player to move in varied ways, forcing them to explore the environment with the aim of encouraging them to build a sense of game space throughout (in the case of this game via sound feedback). Moreover, this game genre afforded a learnable playstyle, an important factor for entry level audio-only and accessible games to avoid "constructing new disabling barriers" (Andrade et al., 2019, p.2) while still incorporating some "time-critical and competitive" aspects (Atkinson et al., 2006, p. 27).

The game was produced with 15 levels for the Co-Design workshop with each level adding additional obstacles and elements to increase the difficulty. Through the testing process it was noted that the game played similarly to some titles in *bit Generations* (Skip Ltd, 2006) created for Game Boy Advanced and later released on WiiWare and DSiWare. However, this game does rely on some sighted segments and was heavily limited by hardware in terms of audio fidelity. For the first two levels of the game I developed, the player is introduced to the goal sound in isolation. The aim of this was to enable players to get accustomed to positioning a singular sound while playing. Level 3 introduces the concept of walls as non-aggressive obstacles with a single corner to navigate around adding to a gradual increasing level of complexity and requiring the player to differentiate several sound elements. The fifth level introduced enemies. If a player bumps into these adversaries, the player is reset to the start point of the current level. Enemies are characterised by a 'negative' sound when they are nearby and/or bumped into.

The game features both proximity-based sounds within the space that play when close by, as well as active sounds that play when the object is touched. The proximity sounds are spatialised using stereo audio and get louder as you approach them, playing louder in one channel (left or right) dependant on their position in virtual space. There is a limit to how quiet the endpoint can be as it acts as an audio beacon for wayfinding, so the player does not lose track of their position entirely within the level even if they move infinitely far away from it. This showcases how the effects of sound can be tweaked from those experienced in the physical world. Each active sound has a corresponding game-state change, with the endpoint sound starting the next level, the enemy sound restarting current level and the wall contact sound bouncing the player away from them. At the end of the final level, the player also receives a spoken notice telling them they beat the game, something which several players came very close to and lead them to express a strong desire to play the game more once published (even if it were to be a paid experience, even though this game is intended to be a free release). The Co-Design process for this game has been continued with several further iterations of the game using Wwise and Project Acoustics (audio plugins) to increase the auditive fidelity further and increase the information perceivable through sound alone beyond what UE5's built in sound engine can achieve. These further versions will be discussed at the end of this chapter and was worked on by two separate developers as well as input from Joseph Lindley.

3b.7. Workshop Recruiting and Structure

Workshop recruitment was a significant part of this research due to the importance of finding participants who had lived experience with significant visual impairments. It was highly valuable to get insight from people who not only had experience living with visual impairments, but also had an interest in games or broader virtual interactive experiences. Participants were recruited by collaborating with *SASL* (Sight Advice South Lakes, 1956) who are a sight loss charity local to my research centre. *SASL* connected this game's research with a group of people from across the UK, leading to the inclusion of *Galloways* (Galloways, 1867), another nearby sight loss charity. All the research stages were put through Lancaster University's ethics approval system, and participant consent and information were provided before the in-person workshop (with participant information and consent forms documented at the end of the thesis). These documents were made to *SASL's* accessible specification and adapted where needed for the blind and visually impaired participants through their internal processes.

Figure 48. Workshop Participants Playing Audio Game.

The research was organised as a full day Co-Design workshop in Manchester with 12 participants (a range of beginner to advanced visually impaired gamers, from young adults across all adult age demographics) plus the workshop facilitators. "Co-design with people with disabilities is important for designing systems that they perceive to be useful and usable" (Brewer, 2018, p. 258). The justification for why this workshop was Co-Design and not just participatory is detailed in Continuation of Game Development (3b.11), but in general it proved to be an incredibly powerful tool in developing understanding of this design challenge by involving participants more deeply within the design process, focusing on "how to provide means for participation to wider target groups, rather than how to create 'special' methods for 'special' users with 'special' needs (Magnusson et al. 2018, p. 411). It also completely directed the continued development of the game going forward (as detailed in 3b.11), leading the game to be redeveloped from the ground up with entirely new features, and even leading to a experimental game with VR head and hand tracking inspired by comments by one participant about a '*tin pan'* alley game further detailed in Improving Audio Game Design (3b.9). The day's focus revolved around getting the participants to take part in three different interactive experiences. Dividing up each of these interactive sections were three thirty-minute segments of open conversation around the participants' opinions on the experiences they had just interacted with. The first of these segments had each of the participants trying a binaural haircut audio experience. This was intended to immerse them within the space of sound, and subtly nudge them towards thinking about distinguishing position of objects through stereo audio played through headphones.

The second section of the workshop was the participants first experience of playing the game, seen in the above figure. The workshop's design aimed to give as little as possible away about the game itself beforehand to capture their initial reactions to the gameplay (even though their discussion in several preliminary online calls had directed the game's development from a very early stage). Participants were guided through the use of the controller (which was a traditional arcade joystick with 4 buttons). Through 4 different setups, each with 2 sets of headphones and a single joystick, 4 participants were able to play, and another 4 were able to listen in and help guide with the experience of playing. A third person was able to audibly perceive their reactions, giving each workshop attendee three perspectives on the gameplay experience and sufficient time to absorb the game's elements and details. During their time playing through the game, 12 of the 15 levels were beaten by workshop participants with most players reaching around level 8. This meant all players were able to experience all the games mechanics, and the designed game was understood, played and then able to be reflected on. This was ideal for this research's purposes suggesting the game was appropriately difficult and importantly learnable without sight. It is very reasonable to assume that the participants would have continued to beat further levels with more time due to the scaling of the levels in the game.

Figure 49. Workshop Participant Building Lego Level Map.

During the final section of the day workshop, participants were asked to make a LEGO map of a future level they would want to play, either designed for the game they played, or another audio-centric game (seen in the above figure) which they elaborated on in the following discussion. These were useful for seeing how the participants would like the game to change in further development and demonstrated how the participants understood the game as space by asking them to translate its mechanics and sensory modality from audio into a tactile and visual experience.

3b.8. Workshop Observations and Outputs

After each session (the haircut audio, playing the game and making levels with LEGO) participants were asked about their experience. Through recording of these vocal discussions, I identified comments ranging from their thoughts on the experiences to how best to develop the game going forward, and from new audio game ideas to their preferred controllers and consoles for accessibility purposes. This focused conversation around audio games, stimulated by the staggered interactive play sessions, proved to be extremely fruitful in generating feedback. Repeated ideas were taken note of and while many comments reaffirmed some of the assumptions I made during the design process, some revelations I hadn't considered about designing audio games also emerged. I intend to implement these in future iterations of the audio game's design, as discussed in Improving Audio Game Design (3b.9).

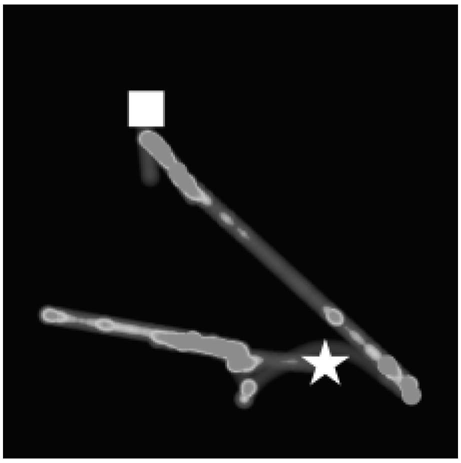

Figure 50. Level 2 Heatmap Using Tank Controls.

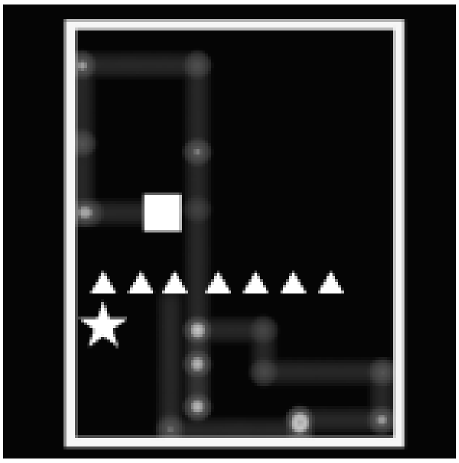

Figure 51. Level 8 Heatmap Using Crab Controls.

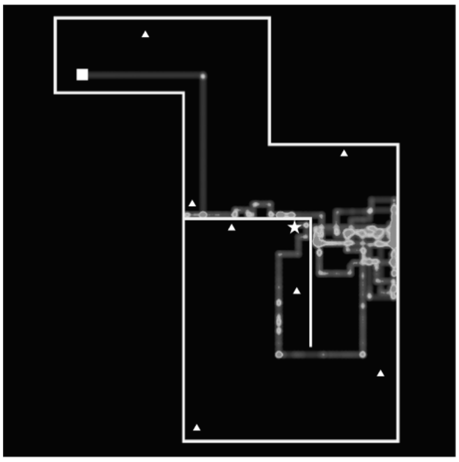

Figure 52. Level 11 Heatmap Using Crab Controls.

The gameplay of players was recorded through a heat-map generation script within the game, represented inthe above figures 50-52 (and at the end of the chapter). I made this specifically for the game to capture the diverse ways in which players moved through the game space and was useful data for the researchers who otherwise could not see the movement of players. While a 3D map with time being the vertical dimension could have provided a "greater sense of the actor's movement" in time (Coulton et al. 2008, p. 2), these 2D maps show more clearly the way players control the character through the controller, which is useful for the control scheme success analysis intended. Each heat-map represents one attempt at a level, ending when the endpoint is reached, or an enemy is collided with (meaning the level is lost and reset). The maps highlight the difference in movement between the two controls schemes and successful movement strategies. These maps were visualised from a top-down viewpoint mimicking Pac-Man's camera positioning, enabling rapid adaptation into physical depth maps through 3D printing for accessibility purposes to "increased real time understanding" (McDonald et al. 2014, p. 276). The 2D perspective of the heatmaps was important to be able to convert them into 3D objects using displacement maps using colour as depth.

Places where the players spent little time are represented as darker greys, with parts crossed many times drawn in increasingly lighter shades displaying points where they lingered longer in one place. On these maps the walls, player start-points, endpoints and enemies are also shown. These are displayed as white straight lines, squares, stars, and triangles respectively. The maps visualise the confusion in understanding corners sonically. Giving walls varied audio dependant on their spatial orientation would potentially alleviate this, or the use of an absolute movement system which is described in more depth at the end of this chapter.

As well as the recordings of discussions being translated into transcripts from each of the 30-minute sections after each interactive experience, the discussions and comments throughout the day were also converted into visual sketch notes to give access to the outputs of the workshop in a variety of different sensorial media to increase accessibility options and improve understanding. Looking forward, it could be potentially possible to use an audio system similar to this game to create audio sketch notes with a spatial element.

3b.9. Improving Audio Game Design

From the workshop, several takeaways emerged from repeat comments from the participants. All the participants expressed a strong positivity either towards the game itself or about further experiences within digital audio interactive spaces. They expressed enjoyment towards the difficulty and learnability a level-based maze game afforded them. When asked what they thought of it, the initial response was 'It was really good' from one participant, and when questioned further:

> *'Because the further you go the more complex it gets with the introduction of the walls and the monsters. But I thought the monsters were quite easy to bypass. It was the walls that were a more difficult challenge.'*

Some other participants seemed to share this feeling:

> *'as you get through the levels it's getting more and more difficult, so you've got something like a challenge to work through, rather than making like a narrative roleplaying kind of game which once you've done it you've done it, you can only really change the story, you can't kind of get to the next level kind of thing. So that's why I prefer this kind of game.'*

The enjoyment and enthusiasm of the participants during the Co-Design workshop towards the experiences which was presented to them was clear, and so furthering the development of research within this space is paramount. This also answers the question of whether non-narrative virtual games can be enjoyable without visuals, proving that at least to some users, engaging mechanics are enough fulfilment. The issue of enemy difficulty can be resolved by giving them movement in subsequent levels, or adding this as an option through varying difficulty modes.

The data from the heat-maps, along with players reaching the later levels within the game heavily suggests that the sound alone was enough for them to perceive and understand the game environment. However, the methods of navigation visible in the heat-maps appeared bound to trial and error, meaning collision with walls (especially at corners) was extremely common and enemies were also hit frequently. This issue could potentially be rectified in this game and avoided in future audio games using a form of haptic mini-map such as "a glove that transforms visual information into haptic feedback using small pager motors" (Yuan & Folmer, 2008, p. 169). Rich audio not bound to stereo (dual channel) alone could also be employed which would need further user testing and runs the risk of falling into the problematic issue of making hardware required for these games' play non-accessible.

It was also clear from the workshop that participants were excited about the potential of varied audio and accessible games (answering the question around what kinds of games visually impaired people want to play), with them suggesting many different audio games including racing, alley shoot 'em ups and mystery solving games:

> *'I'd love to play a racing game. That's one of the genres of game that I miss the most.'*

> *'if you have like a tin pan alley kind of thing, and you had different sounds. It may be a fun game if you did get it to work with a directional thing.'*

> *'For me it was like I thought it would fit maybe well with something like where you're a jewel thief trying to break into something, or you're trying to do something delicate and tricky'*

The majority of participants appeared pleased by the move away from narrative focus within this audio game, but most still had some desire for narrative elements or framing in some capacity. The idea of creating an iconic audio game, and how this game compared stylistically to classic visual games like *Tetris* (Pajitnov, 1984) (which have no narrative elements at all and uses electronic 8-bit audio (Zappi, 2020)) was discussed: *'I think what would be good as an abstract game, if you just went all out, like Tetris is an abstract game'*. This point was very noteworthy, highlighting ideas around replay-ability of non-narrative games due to "fun core gameplay that take some skill to master" (Adellin et al. 2019, p. 1) and how the different kinds of players they attract would translate when designing audio only games.

3b.10. Increasing Accessibility Beyond Games

Beyond the differentiation between different genres of games, the game's movement and output mechanics were also seen as useful by the participants with some suggesting audio maps as a calmer experience for them to enjoy or use before going to a new place:

> *'I was thinking I would love to take that element (audio navigation), make it quite easy, and put some really nice sounds in it, like create environments. I'm more into that.'*
>
> *'Say if there was like an audio map that you can access beforehand and figure out how to get from this place to that place. You could use it in so many different settings, even like in shopping centres and know which shops are where.'*

These could be used before attending public spaces such as museums, airports, or train stations allowing a "blind user to navigate through a virtual representation of a real space for the purposes of training orientation and mobility skills" (Sánchez et al. 2010, p. 3991). This idea pushes the question posed at the end of the previous chapter around the types of games visually impaired people want to play beyond just the idea of games, and into wider virtual wayfinding design. With anyone who has played the game, there has been a period of time needed to get accustomed to the audio navigation. This is something I noticed during the game's design process as each time I personally tested the game during development I found it easier to play and comprehend. This was also the case for informal testing with colleges as well as the workshop participants suggesting *'Distinguishing between three sounds in a field took me a bit of getting used to.'* Due to this it seems important to standardise systems for audio navigation in digital spaces, such as Metaverse environments and games. This would reduce the learning required for each new virtual space entered, similar to the standardising of controls and controllers across visual games which has occurred naturally over recent decades.

The workshop proved that sound navigation systems are sufficient on their own, but also that as additional accessibility options alongside visual output in existing spatial web conferencing systems like Gather or Mozilla Hubs, they would only increase usability if properly implemented. This functionality could also be used in similar ways to subtitles being turned on by wider audiences who do not have a reliance on them as an accessibility feature but have improved ease of access when watching programs or films with them (Davies, 2019). But it is also important to be aware that sound can be used in ways that does not mimic normal perception of physical spaces allowing users to "transcend what it is like to experience and understand the world as a human being" (Gualeni, 2011, p. 1), potentially increasing the amount of information conveyed.

While there was clear interest in haptics as a secondary sense within this game or other future titles, it didn't appear as important to the workshop participants as I expected: '*I do play games at home occasionally and I do like the kind of haptic feedback that you can get from game controllers'*. While this lack of haptic interest could be in part due to the framing of the workshop, it was commented that if haptics were implemented it should be as a sensory output which isn't required for gameplay: *'It should be optional. For that reason, I suppose you can't have it as a main feature'*. This is similar to how sound is often not required in visual games: *'you can enhance it but it shouldn't deprive the game if it's not switched on.'* Haptics may be overlooked due to a lack of hardware that supports it so exploring them further in a very similar fashion to how this research does (with sound in isolation) could help to clarify usability, something that has been explored in one aspect by Sightlence: a haptic-only adaptation for *Pong* (Atari, 1972) for Blind and Deaf users. This further exploration of senses beyond the visual is something I will continue in the conclusions of this chapter, but before that, its relevant that I address how the game's development has continued and evolved based upon the feedback from the workshop detailed above.

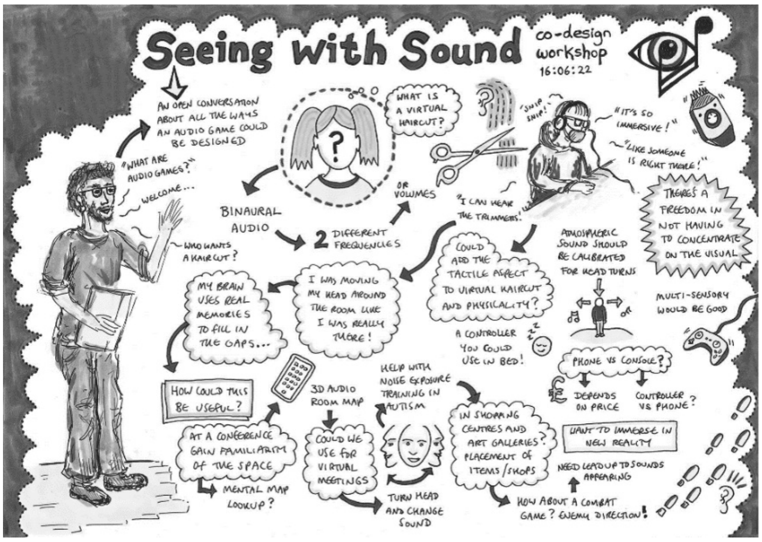

Figure 53. Stage 1: Sketch Notes from Workshop

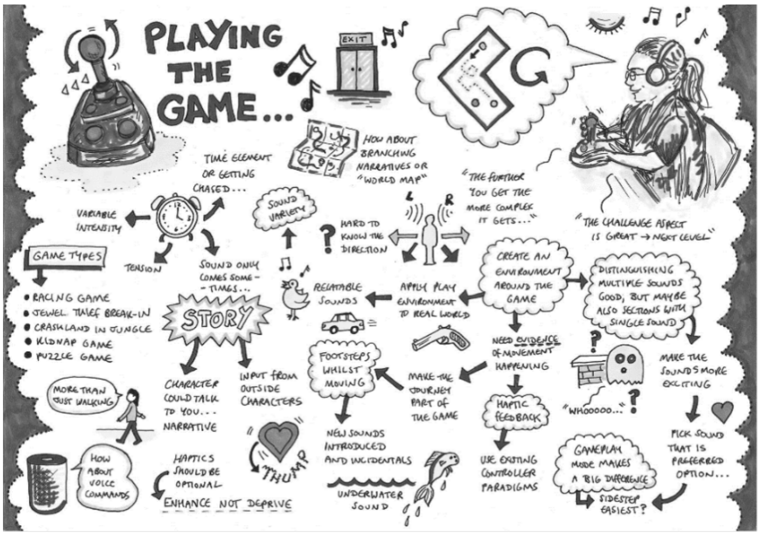

Figure 54. Stage 2: Sketch Notes from Workshop

Figure 55. Stage 3: Sketch Notes from Workshop.

3b.11. Continuation of Game Development

While I undertook a significant amount of development in the stages leading up to the workshop detailed in this chapter, many overhauls have been made since, specially targeted at the feedback from the workshop myself, David Green and Joseph Lindley ran. Control schemes, limits to the spatial nature of the audio, controller input methods and sound design have all been iterated upon many times in attempts to improve the legibility of the systems I designed, as well as the addition of a new sonar scanner system which reduces the requirement of players to constantly need to bump into walls to orientate themselves.

Control Schemes and controller inputs methods have very likely been the most designed, and then redesigned systems within this accessible game development and Co-Design process. This redesigning happened many times, even in the initial version of the game I created. This was largely due to informal testing with people in my research department leading me to believe a turning based movement system would best. This was probably because everyone I tested in this environment had played visual games before where gradual turning is expected. When David Green and Joseph Lindley took the game to the workshop, with two control scheme options, almost all successful attempts were from the crab system movement when looking through the heatmaps of completed levels.

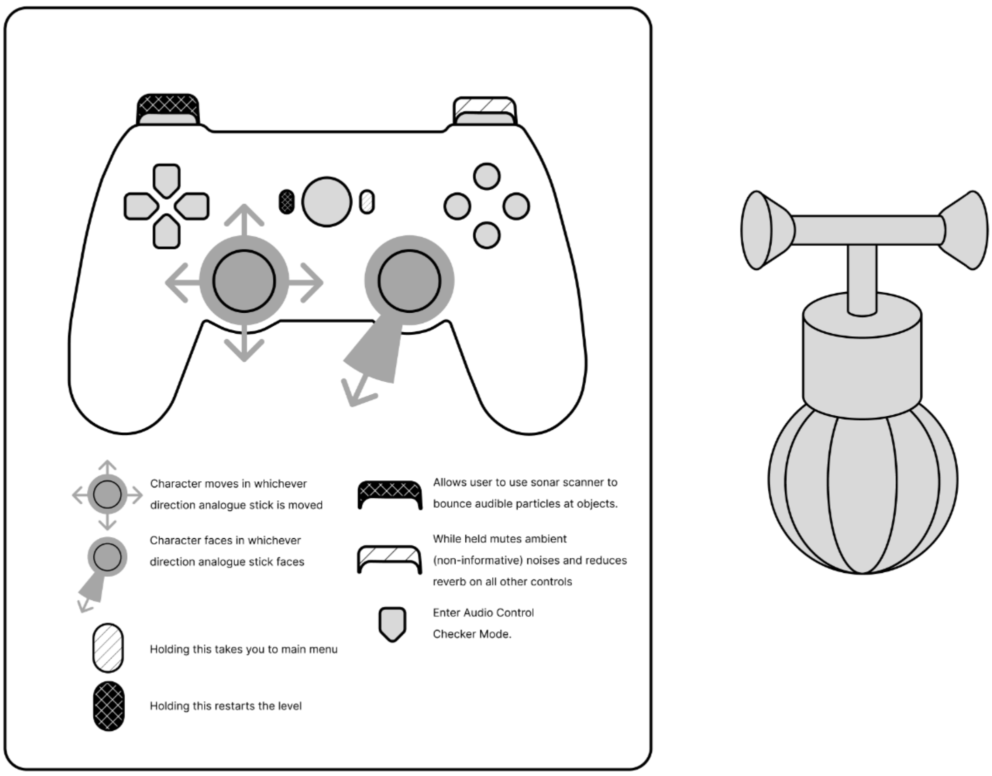

Figure 56. Control Scheme Graphic and Character Design.

The crab-style movement allowed players to know their movements were absolute; rather than moving forwards, backwards, left, or right, they would instead move north, south, east, or west. The other tank style movement allowed turning left or right, and then moving forwards or backwards. In the workshop, no player managed to make it past level 4 with the tank style relative control scheme, but players made it as far as level 13 with the crab control scheme. Iterating on these controls schemes, me and Joseph Lindley attempted to enable an even more common place control system with dual joysticks when working with two developers (Luigi Avanzato and Dmitry Vasilyev) on furthering the game based on the findings from the Co-Design workshop, one allowing movement, the other turning. However, while this is commonplace in visual games, I believe that it is largely less applicable to audio games where users usually do not have as much awareness of landmarks to anchor our comprehension of orientation and position even after becoming disorientated. Due to the limited number of auditive objects most humans can keep track of, employing a control scheme more like top-down arcade style games (such as *Enter the Gungeon* (Devolver Digital, 2016)) seemed better fitting for improved legibility. As the person who has played this game for the most hours, I also have concluded that over time, the absolute movement style has a higher skill ceiling, enabling more rapid and complex gameplay manoeuvres to be used, even if the tank controls seem simpler to grasp as a new user.

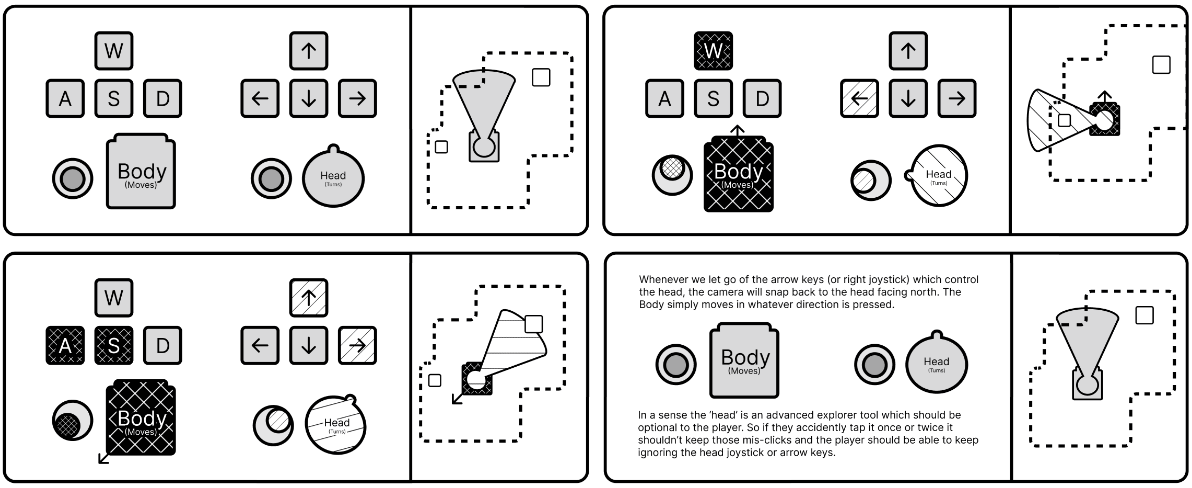

Figure 57. Examples of Game States with Crab Style Dual-Joystick Movement.

Because of this realisation, the current version of the game developed through two key stages after the Co-Design workshop (Firstly with Luigi Avanzato, and then continued with Dmitry Vasilyev) uses a generic game controller and uses the left joystick for absolute movement (north, south, east, or west) and the right for absolute listening. These are not tied together, but listening does snap back to the north direction when let go of, meaning players can ignore the second joystick to opt for the original crab style movement if it is easier for them.

This ability to detach listening from movement allows listening to become a form of scanning. This realisation fed into the development of a further sonar scanning system which allows audible particles to be blasted at objects, and the time it takes for them to return to indicate distance away from the player. This feature was implemented after the realisation through the Co-Design workshop that while nearer spaces could be comprehended, those further away could not. The sound played on return also indicates the kind of objects hit, and when the object hit is an enemy, the player automatically stuns them for several seconds, adding more complex gameplay systems into what was previously quite a basic gameplay loop. This example shows how designing fundamentally different controls and in-game mechanics for audio games can shift the way an audio only game can be played to allow features closer to complex visual games, even if the controls are distinct. Alongside this implementation, the spatial audio of the game has been improved several times based on workshop feedback. Initially working with a master's student, the game's audio was routed through a plugin called Wwise which did enable some more advanced audio reflection and reverberation. This proved to still not be detailed enough, and working with a second more experienced developer, Microsoft Project Acoustics was implemented to refine the diverse acoustic experience many of the workshop participants had expressed desire for. This was done alongside improvements to the sounds used to indicate objects, bringing them into a narrowing auditive bandwidth to enable them to be better spatially understood by the player and maximising legibility of the virtual space.

An audio control scheme menu was also implemented after the Co-Design workshop when Joseph and I were working with Luigi Avanzato (a game audio masters student who helped with further development), allowing players to enter it and then press any button on their controller (besides the audio control scheme button itself) to see what it controls in game. This was successful in alleviating a long tutorial section and allowing the player a similar system to those common in visual games, as well as reducing time spent in menus fiddling with accessibility settings. During the development with the master's student, myself and Lindley also experimented with the ability to reduce reverb to allow better spatial legibility by pinpointing objects, as well as removing walls from the acoustic output to enable an X-ray like sense. This was in response to some mixed opinions in the workshop about whether more realism would reduce the playability of the game, enabling the user to choose themselves. While these systems were rather fun from a player perspective, the sonar scanner, improved control scheme and implementation of project acoustics proved more enjoyable and better for player understanding of the virtual space and including all these mechanics was too overwhelming for playability.

While all the overhauls to gameplay described in this section are worthwhile and showcase the impact the Co-Design workshop had on the game and research trajectory, the control scheme adjustments specifically are most relevant as they begin to highlight the barrier this research has reached. Using absolute movement enables the controller to provide a form of haptic feedback. A player knows moving the joystick up in this mode is moving them north (or listening north), whereas in the relative mode, the player only knows they are moving forward, but does not have a constant bearing. While audio beacons can be implemented to alleviate this, doing so takes up much of the precious audio bandwidth which we are almost entirely reliant on for in-game feedback. As my key aim is legibility for virtual spatial wayfinding, it seems essential at this point in this research that it explores beyond software approaches. This research stuck to accessible hardware (meaning affordable computing devices, standard headphones, and a generic game controller), but the continuation of it does not necessarily have to as the conclusion of this chapter, and the concluding section of this thesis will begin to explore.

3b.12. Issues in Accessing 'Accessible' Media

While this research into non-visual and audio games has given me many starting points to explore further avenues, the most pressing issue it has highlighted are the struggles visually impaired users often face even before gaining access to these game's main menus. Once blind and visually impaired users have managed to launch their chosen games, all accessibility features which have been researched, designed and implemented are available to them. However, on the desktops, home-screens or dashboards of their computers, mobile devices and games consoles, the accessibility focused game developer hasn't yet managed to take control. During the workshop there was justified advocation from the participants for chances to break free from their mobile devices:

> *'I think it would be nice to actually put the iPhone away and go to something else for a specific thing. Because I think as a blind person, you're constantly using that device because of its accessibility, and therefore do you want to really implement something that's meant to be a sort of escapism to a day-to-day device?'*

While mobile devices usually are the most accessible devices for visually impaired people, this rationalised desire to have separation or escape from a singular device for all purposes, an issue most digital device users who rely on visuals may be completely oblivious to, is really significant to the design of accessible games.

Because games consoles are becoming more expensive, and these extra costs are generally going directly to improving the visual fidelity of the games people play, games consoles themselves are not considered worthwhile for visually impaired users if they are not benefiting from the visual components. If non-visual games were to release on the newest consoles, not only would the hardware be very underutilised, but the variety of other non-visual games available to play would be very low. While some games have released with a sound output focus on Windows/MacOS (*The Vale* for example), making an account to purchase and download these games can often be almost impossible as a blind or visually impaired person. One of the participants noted that they had significant issues using Steam's login system (the most common place to download games on computers) when using screen reader software (a tool used by visually impaired people to convert on screen content into sound) after the workshop inspired them to try out other non-visual games available at the time.

With this research project winning the Visionary award (Visionary, 2022) alongside the feedback from the workshop and many larger studios rapidly adopting accessibility options, there is clearly great desire and promise for the future of digital accessibility for non-visual audiences. However, regardless of the games and software solutions I and others develop, if the hardware itself isn't tailored for rich sensory experiences other than through visual output (Hoogen et al. 2009, p. 5) (however immersive this may be for visual users), the sensory bandwidth will always be limited and so will legibility. This is important to consider when striving to enable accessibility in mainstream games rather than as niches purely for accessibility purposes, with "games that cater for both visually impaired and sighted players" being quite "scarce" (Metatla et al. 2020, p. 1).

With sensory bandwidth in mind, designing a console or device specifically for non-visual audiences could be the way to promote accessibility with the greatest impact. The limitations of current hardware and software in non-visual respects has been made abundantly clear during the design of this game even while using a mainstream game engine, as well as during the workshop itself. Controllers for early game consoles were less defined, leading to differentiation on a per game basis and enabling massive potential for accessibility as discussed in this thesis' initial literature review (0b.9). Nowadays, peripherals for accessibility are often hard to come by, both in terms of monetary cost and scale of production (Parisi, 2015) and are generalised to fit a wide range of accessibility needs. If a non-visual console was envisaged, it could save the users money by cutting out the need for graphics cards which are becoming increasingly expensive. Non-visual consoles could provide lower resolution visuals while running the same games as mainstream hardware, trading visuals for higher fidelity audio and haptic outputs which would be a more legible experience for certain people. Through focusing on haptics and sound output, the future of accessible games could skyrocket, and while games would benefit from this first, all digital spatial environments would be advantaged over time. This idea of either a non-visual games console (or specific peripherals to support blind gaming) is hyper relevant to the continuation of this research around digital wayfinding in virtual space. Because of this, the next section around where this research could continue will focus primarily on this idea. While I will continue to develop the game through Co-Design, its development is limited by software and hardware designed for visual purposes. By creating devices tailored for accessibility rather than hacking together accessibility features with inappropriate hardware, virtual wayfinding both games and otherwise can extend their accessible reach much further. Through a hardware and software combined approach, accessibility and more diverse legibility can become a core consideration at all stages of games and wider digital design, carefully treading the line between over-simplicity and over-specificity in systems and onboarding design. This approach is paramount to people who are only limited by our societal devotion to visual-first design.

3b.13. Heatmaps

The following pages include (somewhat) randomly selected heatmaps for levels 1-9. 4 heatmaps per level were selected by generic file name only to demonstrate how players move in very different styles from one another. Symbols for enemies, end-point and start-point are not included to focus the viewer on movement itself:

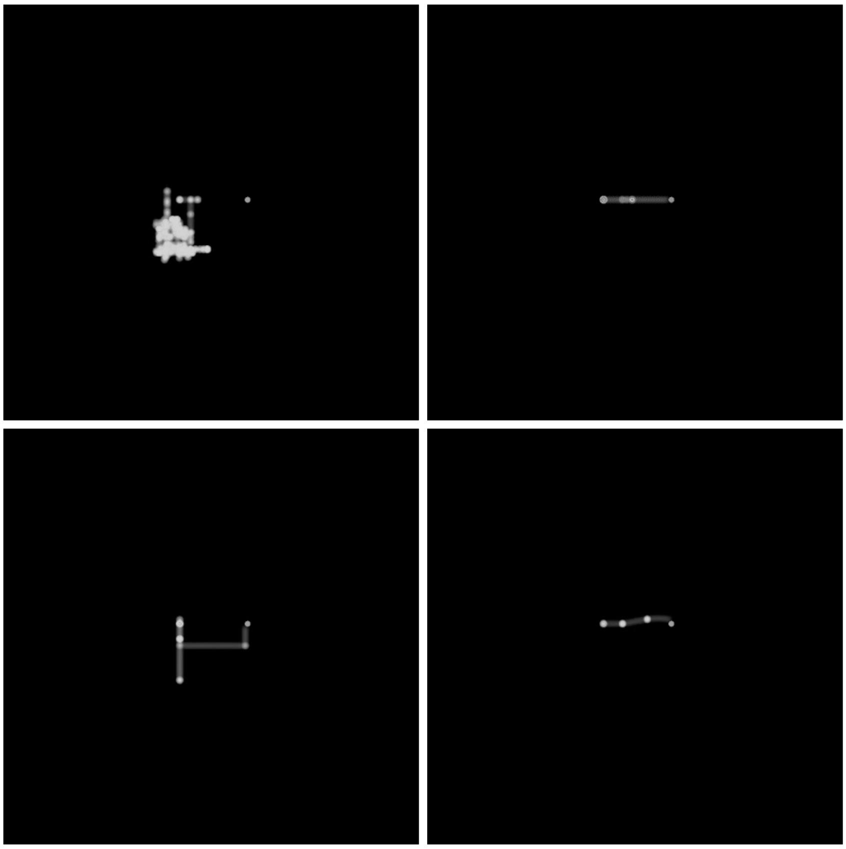

Figure 58. Level 1 Heatmaps.

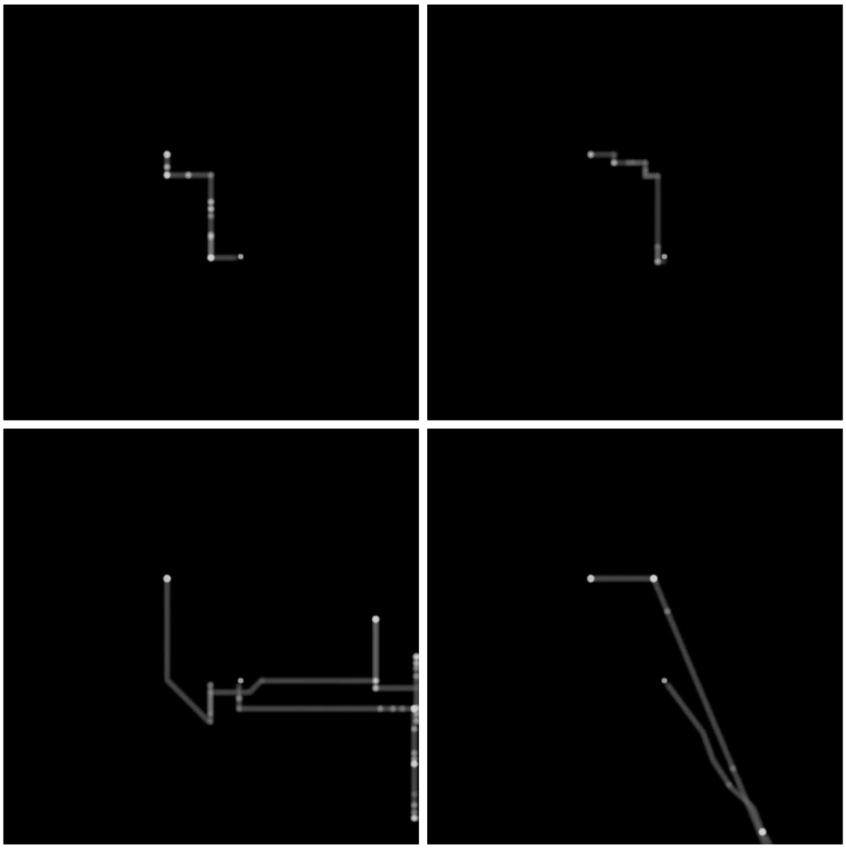

Figure 59. Level 2 Heatmaps.

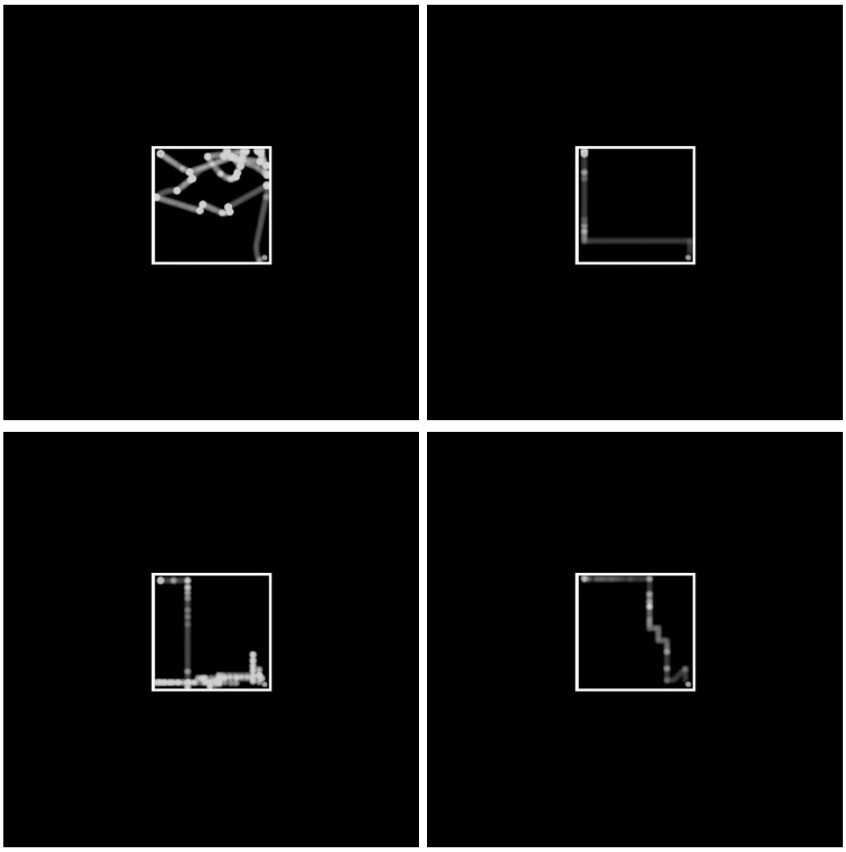

Figure 60. Level 3 Heatmaps.

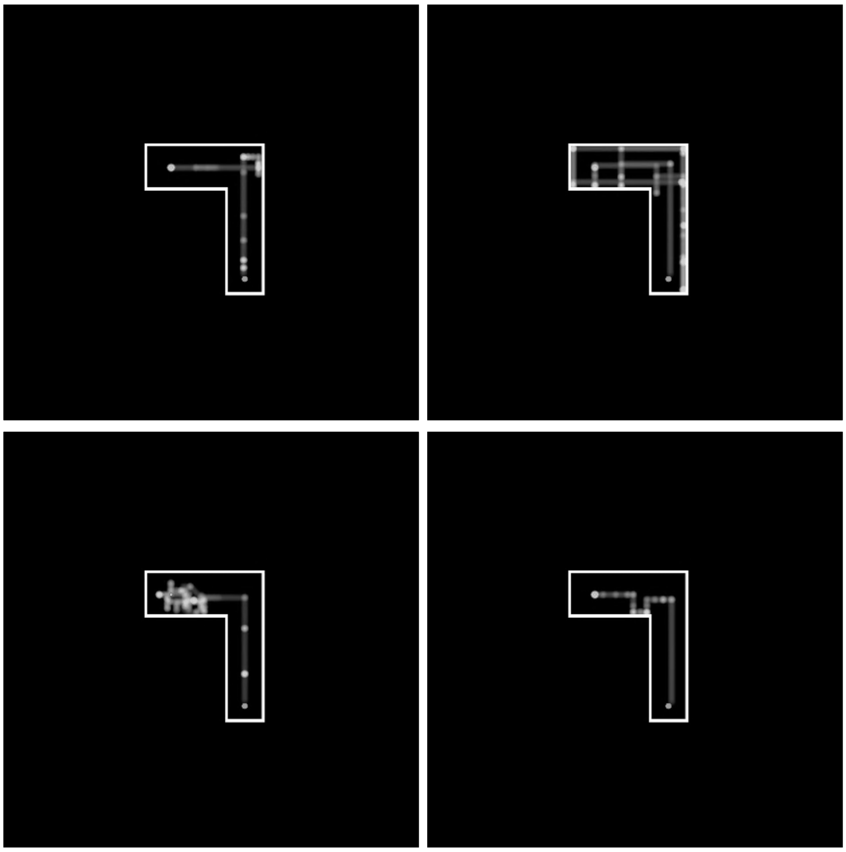

Figure 61. Level 4 Heatmaps.

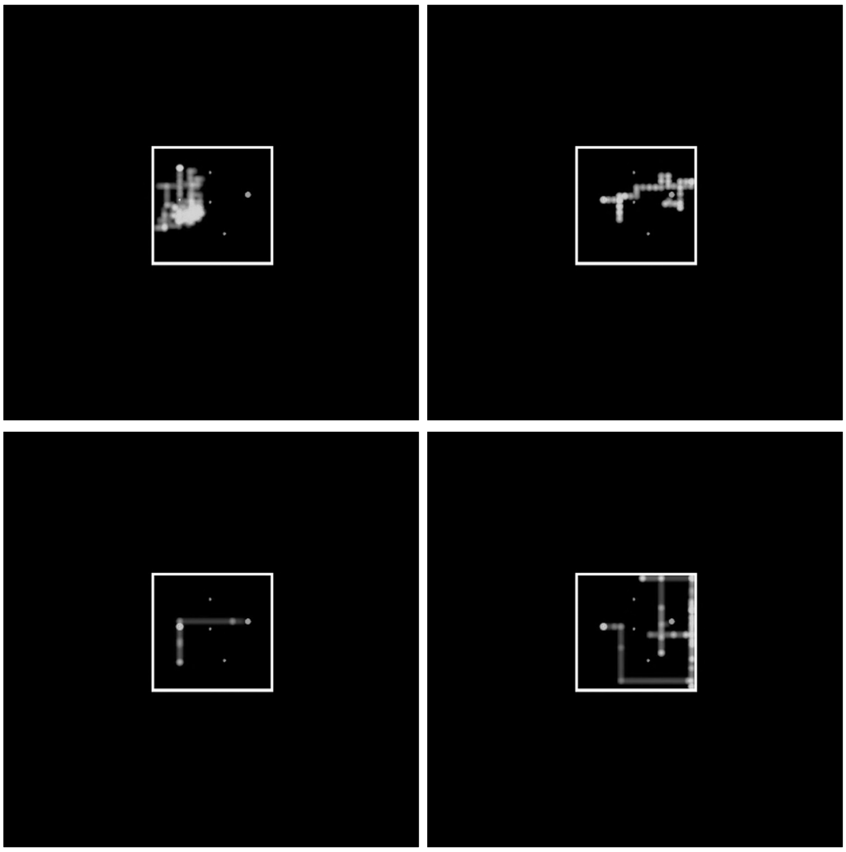

Figure 62. Level 5 Heatmaps.

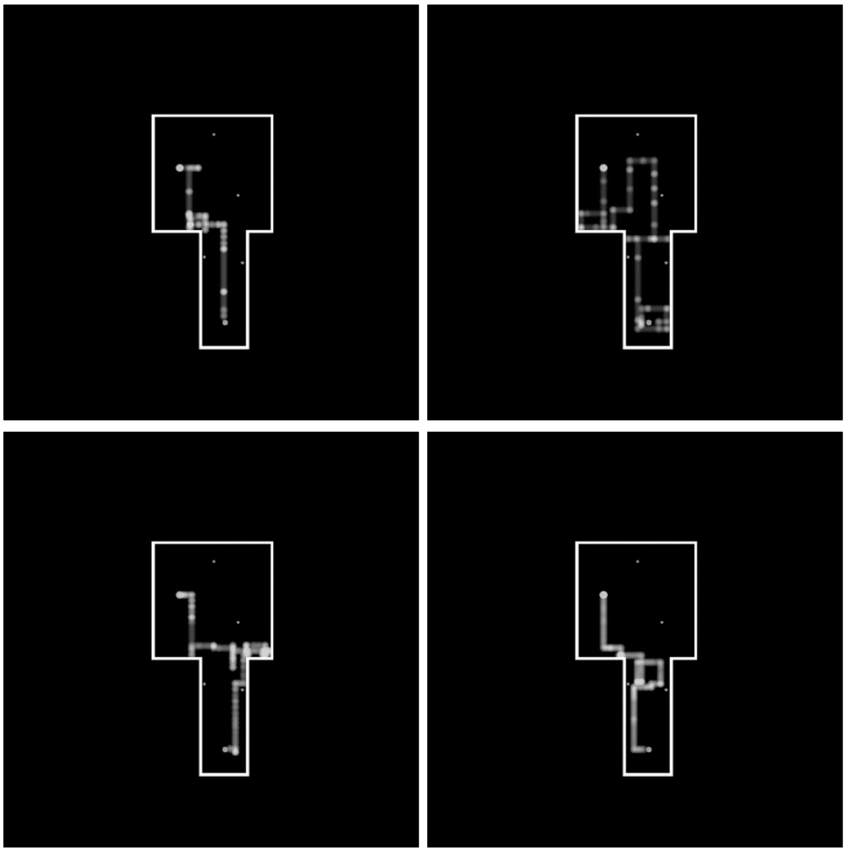

Figure 63. Level 6 Heatmaps.

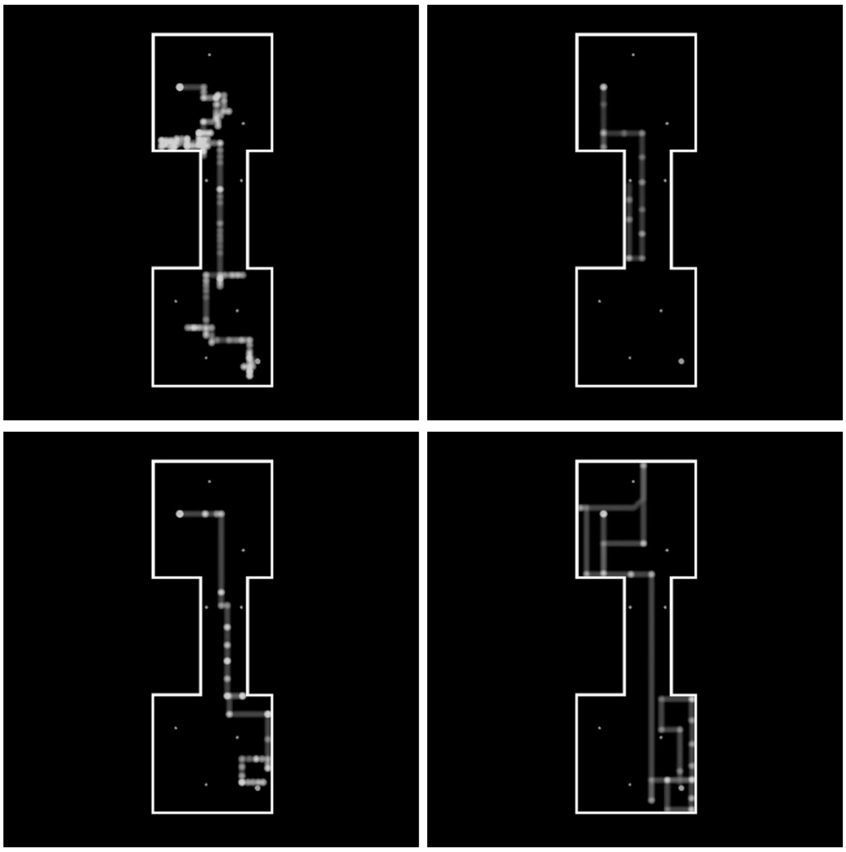

Figure 64. Level 7 Heatmaps.

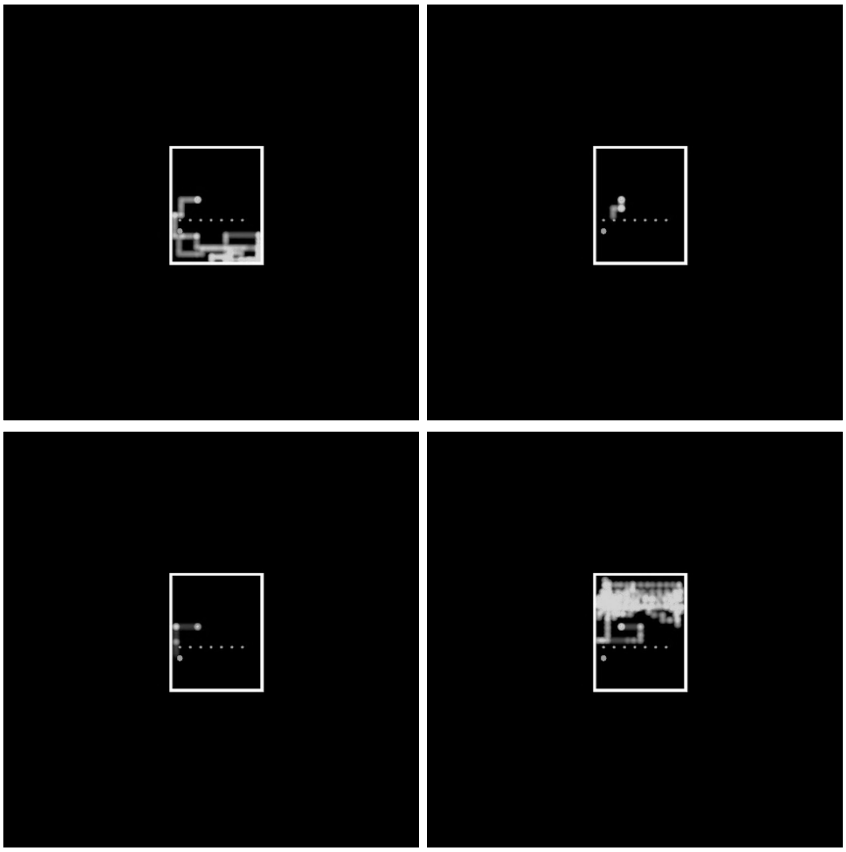

Figure 65. Level 8 Heatmaps.

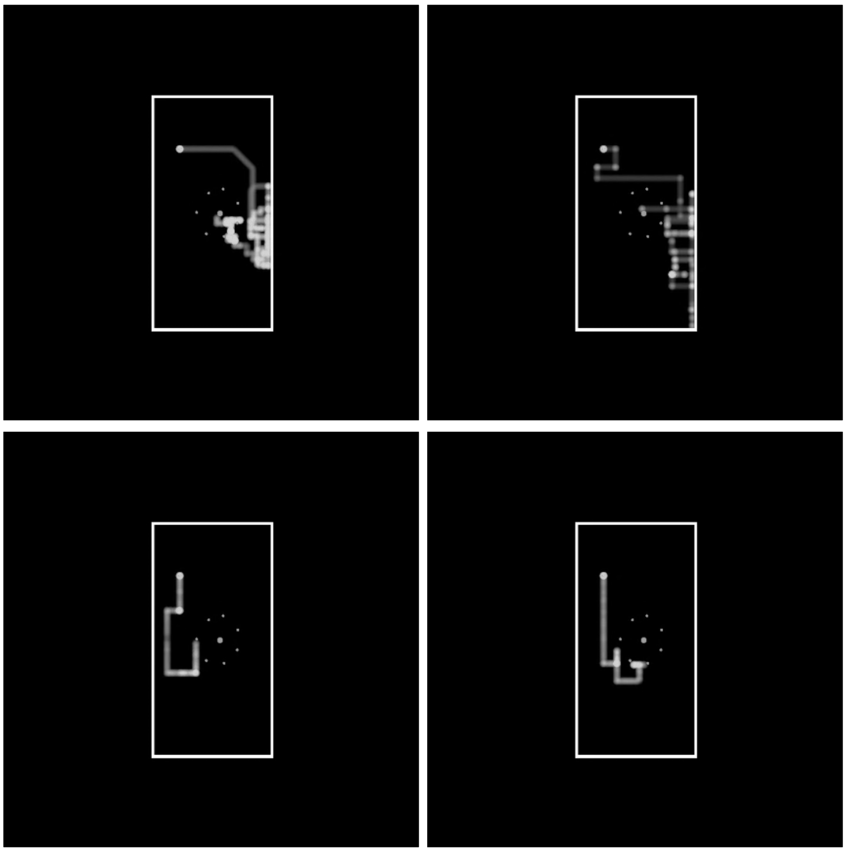

Figure 66. Level 9 Heatmaps.

4a. Conclusions

4a.1. Reflecting on the Why, What and How of this Research

The research I document though this thesis was originally motivated by a desire to find spaces which could bring an enjoyable sense of togetherness to non-gamers during the virtual only social times of the COVID-19 pandemic. Through design of virtual spaces through varied software, from Gather to Unreal Engine, I found a new motivation to design more inclusive virtual systems, which may also facilitate more natural spaces for virtual togetherness. This newfound motivation came from a realisation that it may be better to target those who are excluded by design rather than the choice not to engage with game spaces.

Originally, I sought to answer the questions: What is Legibility in Virtual Spatial Wayfinding? How Can We Improve it? When is a Virtual Space Over-Specified? These broad questions became more specific through this research journey as I realised that using accessibility as a conceptual lens could help address these questions, which turned into a series of more specific questions which are addressed by each of the sections within this thesis. I began to position legibility as a type of accessibility and explore how improved legibility could be achieved by widening the usage of mixed sensory information. Reducing over-specificity could be achieved by exploring the limits of design beyond visual-first approaches. Because of the emergent reframing of the research (a common feature of RtD) the questions, design practice, and answers, presented within each chapter became a flowing conversation with one another as presented below. Those flowing conversations are represented in this thesis as text and images; however, the reality is that the journey involved animation, modelling, conversations with other researchers and designers, working with community groups and learning to design from a non-visual approach.

4a.2. Answers within Messiness

At this point I would like to address some overarching answers beyond those within the general flow of this thesis defined in each individual chapter. Each of the three main sections within this thesis positioned themselves with several questions which were generally answered by more questions, which led on towards more research and questions in each following section. The literature review which started this research exploration (0b) had three overarching questions mentioned above which split into more specific questions as the research's focus on accessibility grew. However, as I outlined in my initial abstract, each of 3 main sections of this thesis also asks a high-level question as a primary research contribution. I would like to address those questions here as they generally encompass the focus of each section, and the learnings that came from them, as well as highlighting the questions which lingered. These allowed each section to feed into subsequent research and what I hope makes a worthwhile conclusion for the reader:

0. How can we unpack the history of virtual wayfinding design?

The initial literature review of this thesis sought to look back at the history of virtual wayfinding and its conception, identifying a gap or a sensible place to start exploring how this could be done better. Subsequently the methodology chapter explains how RtD is an appropriate way to use the creative design process to explore how to improve upon wayfinding approaches of the past.

Are there teachings to unpack from historical virtual wayfinding? Based on the projects documented in (1b, 2b and 3b) I think definitively the answer to the question is yes, as there will always be lessons which can be learnt from observing historic design evolution. Controllers and Sensory Output in Games (0b.9) begins to stumble upon one of the main lessons present in games history in my opinion. This lesson brings this thesis full circle at the end (3b), presenting the idea that stagnation in interface design for virtual wayfinding systems has reduced the variety of ways we can interact with games and created 'generic' hardware which all games must design within. Controller and keyboard and mouse controls haven't changed significantly since 1997 (0b.9) and while designing for accessibility has become much more valued (especially in the space of games), there appears to be strong reluctancy to deeply consider its integration into games beyond software approaches. The PS5 Access and Xbox One Adaptive controllers begin this process specifically for motor based accessibility, but this is only a narrow subset of the accessibility needs we should begin to address (completely omitting visually impaired based accessibility).

Virtual Sensory Bandwidth (0b.4) and Wanderlust and Disillusionment in Open-Worlds (0b.8) also led me towards several realisations centred around onboarding and diverse sensory bandwidth information for the improved design of games. These realisations around the need for information to be spread across senses to maximise the usable sensory bandwidth, as well as the importance of onboarding in unique virtual experiences led me to explore unique ways in which we can use existing hardware to create virtual worlds which convey space and wayfinding experience non-visually in later chapters. This consideration for gradual onboarding and splitting sensory bandwidth where possible led me to realise alternative control schemes would be applicable when designing my audio only game, and that even mechanics as simple as turning the character left and right could benefit from detailed tutorials in an audio game while they might be unnecessary in visual contexts. Understanding sensory bandwidth also enabled me to appreciate the complexity of balancing legibility in the less walked space of audio games. Perhaps this means we should look towards designing a world where people can be enticed by bespoke controllers to provide more equitable, and sensorially rich virtual experiences, regardless of their accessibility needs.

The summary section of this chapter (0b.10) highlights the fact that through looking at the history of virtual wayfinding experiences, we can conclude that legibility is a balancing act. For example, standardised controllers might make experiences simple for the majority of people, but might heavily reduce legibility for those without sight. Because of this truth, accessibility cannot be a one size fits all solution, and by inheritance, neither can virtual wayfinding design.

1. What is the design of virtual wayfinding spaces with current tools like?

Whilst I personally found the process of designing virtual wayfinding to be enjoyable, the complexity of the tools available could be daunting. I discovered this when designing the virtual spaces in Immersing Together (1b.10). While I found it simple to digital translate artefacts and objects into the shared space, my collaborator (working in data visualisation in their day to day job) often lacked the skills to compress 3D models or texture them correctly, highlighting a barrier to entry that the complex skillset currently required to build virtual spaces creates. Furthering this, when I compare the experience of designing this Mozilla Hubs space to the experiments in Playing with Immersive Data (1b.9) and Staying Digital to Avoid Over-Specificity (1b.8) the virtual creation of this Mozilla Hub space was by far the simplest, further highlighting how severe these barriers can. These statements may seem to be caused by my collaborator's inability to learn new software, but when we consider the visual centric nature of these pieces of software (and current software as a whole), we might begin to see a wider issue around access and accessibility which needs to be addressed.

Because the answer to this question is that the design of virtual spaces with current tools is 'rather complex', this chapter's conclusion really is that exploring simple mediums for virtual wayfinding could be more interesting to a wider audience, but that this is not a sustainable long term solution. This is why the following section moves onto exploring Gather, focusing on usage of virtual spaces rather than ability to design them. This is not only because of its simpler tools for designing spaces, but also its more successful implementation at a fine balancing act between game and video conferencing space. This is important because games and video conferencing space are arguably the two pillars of virtual wayfinding space. However, it is important to say that virtual wayfinding is everybody's business (not just gamers and those able to use the complex tools to design them). While ensuring everyone can design virtual spaces easily is an incredibly challenging problem, providing better access to the spaces which are designed is much more reasonable, especially from the position of accessibility and legibility, and is something this thesis continued to do through sections 2, 3 and 4.

2. How do we design virtual wayfinding spaces for maximum accessibility?

This question, and the section focused around answering it, really began to further cement the idea that maximum access cannot just be applied as a universal principle. Accessibility, and through inheritance access for the maximum number of people relies on granular and finely tuneable controls hidden behind simple systems for beginners to dip their toes in and begin to onboard themselves. Conventions from Physical Space (2b.11) concludes that translating spaces we know from the physical world before subverting them can massively improve access and understanding.

However, when this isn't possible due to the space required virtually, linear handheld experiences can help in guiding initial understanding before opening out into more natural wayfinding experiences. In Balance and Chaos (2b.12) this concept is explored through both the ImaginationLancaster Research Gather space and 'The Egg', highlighting how complete linearity proves boring, but nearing complete chaos only works when the space is designed for a specific audience. Learning Through Play (2b.13) furthers this idea of segmented virtual wayfinding design concluding that when many complex virtual systems are assumed to be understandable, users beyond the target audience will find themselves completely out of their depth.

The final key takeaway from the section which explores maximum access through visual design is that often, designed systems copy over elements from their predecessors without proper reason. Video is the Elephant in Video Conferencing Space (2b.14) begins to unravel this issue in Gather, where video feeds break apart the intermingling ability that spatial web conferencing aims to create. Not only that, but due to a societal necessity for video at the time, the designers chose to overlay it on top of the spatial environment, both flattening it and walling it off from view, rather than focusing on improving audio capabilities to allow the position of people to be heard through sound. Beyond the reduction of spatiality this brought, it also made access for blind users almost impossible due to their lack of ability to understand where others were in relation to them.

This realisation that having more ambiguous and natural feeling virtual wayfinding spaces could easily remove so much accessibility is the key idea to be concluded from this chapter. Because of this, I saw it as paramount to shift the research direction towards making spatial virtual wayfinding systems, both games and otherwise more accessible. This conclusion felt so necessary as I could see the global adoption of games and other virtual systems which centred around space without the concern for access for blind users.

3. How could virtual wayfinding spaces be made more accessible?

Through testing and design of an audio only game I hoped to answer this question. I think for the time being, the answer is conclusively yes, as most systems like Gather, Microsoft Teams, Discord and game communication systems as a whole generally lack spatial voice chat. When this is implemented, it vastly improves communication abilities, and if this is the only possible alteration to a virtual wayfinding system, it is a worthy one.

However, the ability to make mainstream virtual wayfinding spaces more accessible goes far beyond just the use of voice chat. Sonification as a wider field needs much further research in virtual space systems. Even within the brief development cycle of the game documented within this thesis, Joseph Lindley and I collaborated with two separate developers where we designed several novel and unique gameplay systems for audio first access. The systems described in Designing Gameplay (3b.6) were iterated upon improving them and innovating further in Continuation of Game Development (3b.11). Increasing Accessibility Beyond Games (3b.10) concludes that these same approaches which work well within game contexts were also deemed highly suitable aiding physical space navigation planning by blind and visually impaired people, such as when planning to travel through an airport or visit a museum.

The primary conclusions of this thesis also realise that while careful audio design using informative reverberation and object identification sounds can help significantly in virtual spatial accessibility, there are many further gains to be made for improved accessibility beyond the virtual wayfinding spaces themselves. Issues in Accessing 'Accessible' Media (3b.12) begins to describe how beyond the bounds of the games, the programs which manage downloading and opening of them are often unusable for screen readers. The final part of the same section (3b.12) also alludes towards the ideas I will present in the further research suggestions which suggest general purpose hardware will be the final limiting factor when designing non-visual games and other virtual wayfinding spaces. Virtual Sensory Bandwidth (0b.4) limits information available to non-sighted users, and therefore reduces the affordances they can perceive. This affordance limitation is described in Accessibility and Affordances (0b.5) and is incredibly problematic for translating mainstream games to non-sighted audiences. The conclusion of this section and thesis is that while mainstream virtual wayfinding spaces can be made more accessible, we must design affordable (monetarily accessible) varied sensory devices to facilitate that access fully.

4. Is equitable access to virtual space fixable by hardware redesign?

The answer to this final question is something which I would like to address much further. Despite this, my beginning thoughts around where to start answering it are caused by the other conclusions in this thesis and form the very final section of this thesis (4a.5). Before talking about that potential further research, I would like to address the general research contributions this thesis makes beyond answering these questions.

4a.3. Research Contributions

The main objective of this research was originally intended to be a personal reflection of designing and using virtual wayfinding spaces. I set out to explore how as a maker, we might navigate these systems and found that within this exploration there were pressing issues of access which I felt worthier of my time to consider. Because of this, there is a large amount of emphasis around my own personal wayfinding experiences through this research adventure. This is especially true within the first section, but also within any reflective moment throughout.

This personal journey of reflection seems a fitting enough contribution on its own, especially for people intending to design virtual spaces of the future, or people who might be completing or considering starting a PhD using RtD. Moving beyond this I have shown a personal realisation of truly accessible design principles where the self is almost never focal when designing, instead regard for sensory bandwidth and varying person specific affordances are always paramount. The thesis also highlights that this is best achieved, and completely possible through participatory and Co-Design methods, something which is extremely relevant to my intended audience who are often forced to omit these imbedded processes in time constrained industry settings as I highlighted at the start of the thesis.

Moving into the contributions for academic research in design, my work contributes towards literature around game design, virtual wayfinding and accessibility design as well as the RtD process. It also highlights the interdisciplinary nature of RtD, positioned in the liminal space between visual (or auditive) thinking, Co-Design and HCI studies and finding its own way between these practices through its own wayfinding.

Even further from academic research, this thesis contributes to continued efforts in the realm of accessibility in games and virtual social spaces for work, play and otherwise. It does this through varied methods, adding further proof to the notion that design can be useful when designers are non-dogmatic with the methodology and tools they use, and merely focus on the end aims. It explores these themes using generic and affordable hardware, by testing the limits of generic stereo headphones and dual-analogue joysticks. Because of this this thesis' contributions are able to be relevant to almost all games now and, in the future, as the potential accessible gameplay richness outlined here will only be increased when using more expensive and bespoke hardware. While this thesis is usefulness to the future of audio-only games, mainstream games can also benefit greatly through new accessibility features (such as the sonar gun allowing for far field understanding), as well as wider virtual spatial wayfinding design applications such as Gather.

While the game designed in section 3's data chapter (3b) is likely the element within this thesis most likely to cause change within the wider design world, it is not a product. In its current state it is an artefact which exemplifies how altered perspectives can improve the design of virtual spatial experiences. It also is by no means a finalised artefact, as it keeps evolving based on user feedback and Co-Design input (as shown in 3b.11). It also presents a fundamentally important idea, which is that design for alternative sensory experience shouldn't merely be adapted from visual design but should draw upon lived experiences from those it aims to serve.

Other contributions of this research include the awards this research has received (such as those from Epic Games' MegaGrant program and Visionary's Inspire award), alongside the published free version of the latest version of the game on Steam. All these contributions have given game design for accessibility exposure to different audiences. Furthermore, the research within this thesis enabled my supervisor Joseph Lindley to work with another master's student to create a prototype audio game using VR head and hand tracking. This not only expands the contributions of this thesis by demonstrating the power that the Co-Design workshop had, but also demonstrates that the game designed within this thesis is able to spark inspiration for further audio and accessibility focused games.

Adding to the contributions of the audio game research even further, I aim to take this game, and the Co-Design workshop feedback even further into another entirely unique game which is openly accessible and available to people in order to champion the future of non-visual virtual wayfinding design and the alternative control schemes which can flourish within it. I am able to do this due to the Epic Games MegaGrant funding received through the research detailed within this thesis showing its direct contribution to continued game accessibility development in three completely separate branching directions.

Finally, I think its important to note that the research within this thesis has directly contributed to my awareness of accessibility, especially for blind and visually impaired people (who are often extremely marginalised in virtual spaces). This awareness is something I am continually expressing to everyone around me in my current role as a UX Designer in industry, furthering the awareness, and implementation of accessibility focused design.

4a.4. Research Limitations

While I firmly believe the research in this thesis has strong use cases and learnings to be further unpacked, the scope of this research is limited. When compared to the vast amount of research and designing which has been done in the space around virtual wayfinding design it is merely a drop in the ocean. For example, while section 1's data chapter (1b) is incredibly introspective, it could have gone further with user testing to uncover more about rich wayfinding spaces through the use of virtual reality and user testing. The second section's data chapter (2b) would be less limited in its contributions if it included detailed user tested studies on each of the Gather spaces from a plethora of perspectives and different user groups. Equally, the third section would benefit from developing games with more varying genres for audio only games testing, and testing with wider audiences with more iterations of the Co-Design process. However, this limited scope within each section enabled the research to explore much further than it could have otherwise, flowing towards the audio game's design.

All of these limitations come heavily down to time constraints, and a desire to explore wider contexts within an RtD research method. The time I had available, both within my personal life, and through the funding of the PhD limited the scope and therefore caused the agenda I addressed to be much more targeted than what might have been optimal for wider research benefits. However, within the limited scope of a PhD I have covered a wide range of areas which have potential benefit towards the future of accessible virtual space design, and provided further points from which other research can continue to contribute to this space.

In many ways the research I enacted throughout this thesis flowed continuously, with each section merging naturally into the next until it reached a natural wall close to the end of my funded time. This wall came in the form of the generic hardware limitations stopping audio sensory bandwidth conveying more information. I believe this may be improved upon through the design of affordable hardware device, but without going through the process of designing fully functional hardware, along with software to support that hardware, some of my findings cannot be verified. However, approaches such as speculative design and design fiction may be able to better understand some of the engineering challenges without necessarily having to invest in full product-development cycles. Exploring this idea would benefit from an entire PhD thesis of its own, however I have included some starting ideas at the end of this thesis (4b) after my final conclusions.

4a.5. Concluding Statements

For the final concluding statements, I think the most important takeaways are that there is great room for improvement of Accessible Design for Varied Sensory Wayfinding in Virtual Spaces within existing hardware. This thesis largely moves towards potential in audio, but accessibility of all kinds (be it motor, sensory or otherwise) has great potential to be improved, and many of these potential improvements have already been touched upon in existing software (especially in games). Beyond this, redesigning hardware could promote this increased accessibility potential even further, providing a more diverse sensory starting point for designers and developers to create from (with one potential starting point for this detailed in the next chapter (4b)). Beyond the accessibility of the spaces themselves, this thesis highlights an even greater lack of accessibility in the tools which are available for designing these spaces. This area needs even greater exploration going forward, providing even more potential research directions.

As for my own current pursuits following on from this research, I intend to continue this research through my own personal project for a separate audio only game (for which I received funding from the Epic Games MegaGrant program). This game will grapple with integrating more complex game mechanics without visual components, likely requiring the incorporation of rich haptics through the ideation in the next chapter. Finally, I will be moving to a full-time position at ElastaCloud (a software development company in London), focusing on their UI/UX design as an accessibility specialist ensuring strict adherence to WCAG guidelines. This role will enable me to continue to design and implement experimental accessibility features for their users, continuing to push the passion I found for accessibility through this research journey, especially for the benefit of visual impairment.

4b. Further Research Beginnings

4b.6. Accessibility Beyond Audio-Only Design

These final thoughts first became translated from vague haptic interface ideas to some kind of useable artifact when I was in the Lake District at a Design Research Jamboree organised by my supervisor. I realised that while most of the research people were beginning at the time related to the Jamboree was about connecting with the world and thinking about often 'more than human design', we were still focused on a fascination with visual experience.

I began to think about audio quite extensively. We had a room filled with objects and amongst these were some blank audio clip cards (intended to leave a custom birthday message) which I had suggested may bring some more varied sensory approaches to the Jamboree outputs. The presence of these cards amongst many tactile artefacts allowed me to consider how tactility may apply within my research further. While the other researchers there were thinking about more than visual approaches, their presentation of their ideas remained largely in sight and sound.

Because of this realisation, I created a Lego model of a haptic watch which could allow someone to feel the mountains and topology of the world around them. This idea came to me due to everyone at the Jamboree continuously talking about the beauty of the mountains and nature around us, and my realisation that this would be unavailable to visually impaired people (even if sound was still audible).

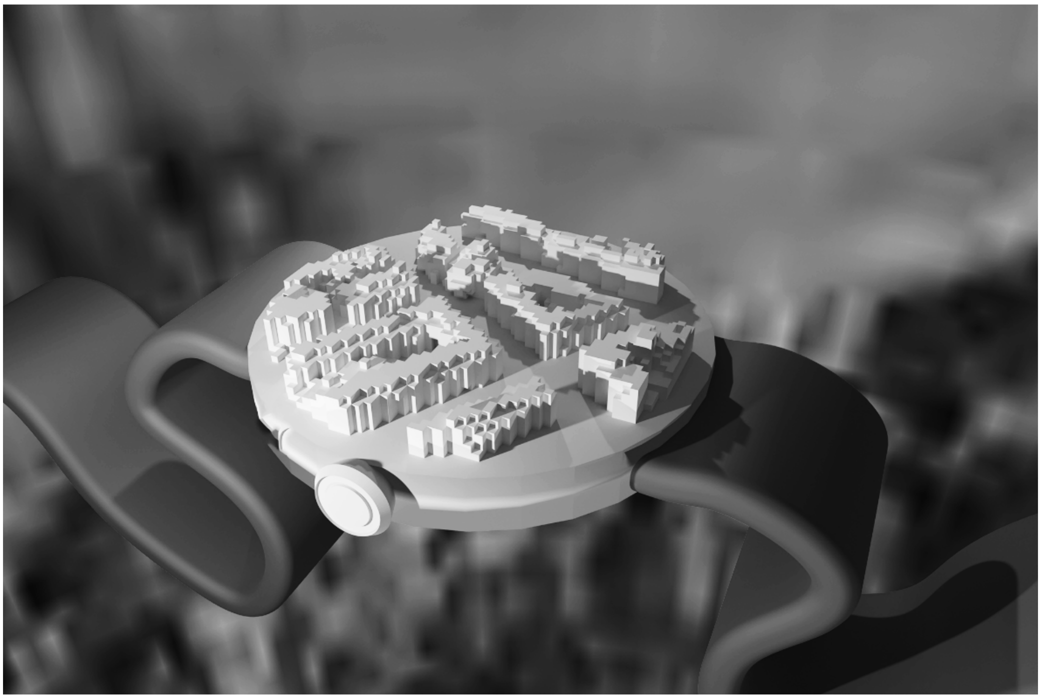

Figure 67. Computer Rendered Image of Haptic Wrist-Mounted Mini-Map.

From this initial Lego prototype, I designed a CAD 3D model version and rendered this to visualise what this could look like in reality, theorising that it could be using data from a source like google maps, and miniaturised motorised touch-display similar to some we are beginning to see in research (Siu et al., 2019). The dial could function as a volume knob of sorts, used to reduce, or increase topological height multiplication. This could be helpful if used in very flat, or very mountainous regions, or areas with extremely tall buildings.

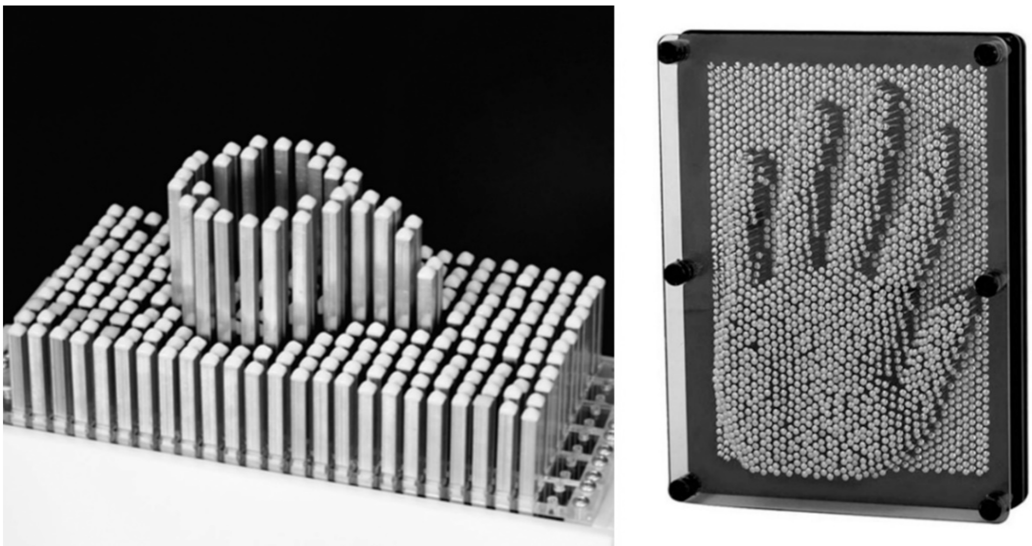

Figure 68. Note: Touch-Display. Reprinted from "shapeCAD: An Accessible 3D Modelling Workflow for the Blind and Visually-Impaired Via 2.5D Shape Displays", A. F. Siu et al., 2019, ***21st International ACM SIGACCESS Conference on Computers and Accessibility*****, p. 1. and Pin Toy Comparison.**

The idea for this haptic wrist-mounted watch came to me when remembering a toy at my cousin's house which I would find myself fascinated by whenever we would visit on holidays. This toy allowed you to press your hand into a series of suspended pins, and they would form the same topology without texture for you to see and feel, extruded on the other side. This technology has already been proven to increase navigation ability through "the construction and memorization of cognitive maps when vision problems occur" (Brayda et al., 2019, p. 14), and so for my proposed design intended purely to increase sensory bandwidth access and immersion (where we want the user to simply be able to feel their environment more) it would certainly be beneficial.

From considering sensory bandwidth repeatedly throughout this thesis, and from designing and testing an audio only game, several things have become apparent. I now know that while audio can provide help when trying to comprehend a near field space such as a single room, it struggles to project the grandness of the further landscape (beyond vague booming echoes) in physical world scenarios and convey information such as UI and mini maps to the player in virtual settings. Haptics on the other hand are not only underutilised, meaning their entire bandwidth is largely open to new design usages, but also can perfectly fulfil these requirements.

Figure 69. Face View of Haptic Mini-Map Game Controller.

Figure 70. Back View of Haptic Mini-Map Game Controller.

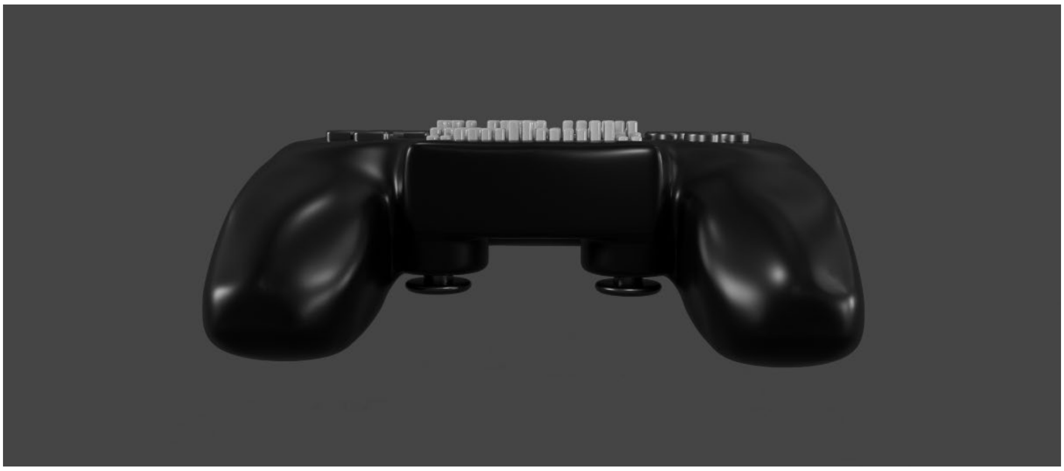

Figure 71. Side View of Haptic Mini-Map Game Controller.

Figure 72. Front View of Haptic Mini-Map Game Controller.

As these prototype CAD renders show, perhaps implanting this technology into a controller is the next logical step within accessible design for varied sensory wayfinding. Creating a true next iteration within the space of controller design could be the future of far field understanding in non-visual games. Touch-displays, however they may be implemented have the potential to vastly improve accessible design for varied sensory wayfinding across the board. While further research must be done, there is no doubt that this technology could be beneficial for everyone, but would be game changing for blind and visually impaired people everywhere…

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