Interactive Sonic Environments

Sonic artwork via gameplay experience

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Abstract

The purpose of this study is to investigate the use of video-game technology in the design and implementation of interactive sonic centric artworks, the purpose of which is to create and contribute to the discourse and understanding of its effectiveness in electro-acoustic composition highlighting the creative process. Key research questions include: How can the language of electro-acoustic music be placed in a new framework derived from videogame aesthetics and technology? What new creative processes need to be considered when using this medium? Moreover, what aspects of 'play' should be considered when designing the systems?

The findings of this study assert that composers and sonic art practitioners need little or no coding knowledge to create exciting applications and the myriad of options available to the composer when using video-game technology is limited only by imagination. Through a cyclic process of planning, building, testing and playing these applications the project revealed advantages and unique sonic opportunities in comparison to other sonic art installations.

A portfolio of selected original compositions, both fixed and open are presented by the author to complement this study. The commentary serves to place the work in context with other practitioners in the field and to provide compositional approaches that have been taken.

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Contents of the attached Flash Drive

A USB flash drive has been provided alongside the written discourse, comprising of all media files for the pieces presented in this portfolio. The drive includes the fixed pieces and all four sound toys formatted for Mac OS. A readme text file clearly states how to install and operate the builds. In case of issues opening these programs, the videos present are to demonstrate the sound toys in action. The files are organised into four separate folders: ’Sound Toys’, ’Fixed Media’, ’Source Code’ and ’Demonstration Video Recordings’. For performance reasons, it is highly recommended that the contents of the USB drive are copied to a faster HD or SSD drive before executing any of the files.

The ’Source Code’ folder includes the original Unity projects complete with C# scripts, and any other source material specific to the piece. This has been provided for examiners with some functional knowledge of the Unity development framework. Where it applies, the middleware files (Wwise, Fmod) are also available for consideration.

Acknowledgments

Many thanks to my supervisors Tim Howle and Colin Johnson for the continuing support, guidance and for stretching me academically as often as they could. To my wife Suzy and my children, for putting up with my moments of crippling self-doubt and for pushing me to believe in moments that I could not.

Declaration

All of the compositions both fixed and open are entirely my own work, the concepts, design and implementation of the systems provided have all been completed by myself. The visual assets such as textures, physical objects, environments and animations have been provided by the UNITY community. Obtained from its online asset store, all assets are royalty-free and are intended for commercial use.

1 Introduction

This folio contains approximately 43 minutes of fixed work and four interactive compositions which are open works and have no fixed ending. These works were completed between 2015 and 2018. The open and fixed compositions taken from interaction with the four systems are presented in stereo format. It is important to note that while this folio is centered around the sonic outcomes of 'playing' with the systems, they often present a visual component that serves to aid the multimodal perception of meaningful musical ideas, the systems (referred to as Interactive Sonic Environments or I.S.E's) therefore are offered as interactive compositions. The stated creative works are the outcome of preliminary practical investigations into the use of game engines in the disciplines of sound art and music composition. Each I.S.E aims to give a level of accessibility for the inexperienced user while also allowing the user (or player) to have some compositional control over the sound and music creation. They need to be experienced by playing them. These are presented for standalone Mac OS and require no other software.

The research has been practice-based; outcomes of this research are inherent in the videos, recordings and systems that exist within the folio. This document serves to provide additional information that outlines the creative process and to clearly define my role in building these interactive systems and their place in a broader context.

1.1 Research Aims

Video-game technology is gradually being employed in a variety of fields, including entertainment, medicine, marketing, and even the military. While some research on the application of this technology in sound art has been undertaken, a more in-depth investigation of the creative process is required. As a result, the research had two main objectives: to analyse the creative process while producing interactive sound artworks and to establish a discourse about the efficacy of these technologies. Furthermore, significant benefits and contrasts were revealed by comparing and contrasting the sonic output with current sound art platforms where interaction is also a fundamental component. Finally, the established language of electro-acoustic music composition techniques (derived from Wishart's "Audible Design") will be merged into a new framework that incorporates video game aesthetics and design technology.

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Strategies for the construction of a critique will also be investigated, developed, and situated within the larger context of current digital media culture via a methodical feedback loop of creative practice and theoretical reflection. The major emphasis of my work is the decision to employ commercially accessible video-game creation tools rather than more commonly known electro-acoustic music platforms such as MAX or Supercollider. My interest for the video game industry, as well as my experiences with producing physical sound installations in a gallery setting, inspired the concept. When presenting past fixed or site-specific work to audiences, I frequently encountered roadblocks. Financial cost, time, and display space are just a few of the constraints that can stymie a composer's creative process. Seeing and engaging in other fascinating sound art works was similarly difficult for me since I couldn't find the time to physically travel to the piece, which was generally only available for a limited period. One of the benefits of utilising game engines for creative practice is the convenience of designing for various platforms. I can export these programmes and display them using WebGL, allowing consumers to interact with my work without having to leave their homes. For many years, I have used Unity as part of my artistic practice. A vast number of free-to-learn tutorials and webinars on the use of gaming engines provided a reasonable manner of acquiring the skills required to make my work. Finally, and most crucially for me, the casual listener or non-practitioner was frequently perplexed by the experimental character of sound art, and some struggled to interact with it. Video-game technology and design approach enable those individuals to gain access to the often-exclusive nature of the sonic arts and the complexities of its language.

The Unity video game engine, a software-based design tool that includes, but is not limited to, a rendering engine for visuals and a physics engine for collision data and sound propagation, was used to generate four virtual platforms. Furthermore, two of the four applications will employ video-game middleware to expand the audio capabilities even further, but they all have a similar thread in that they will use commercially accessible and free-to-use software that was not originally meant for meaningful sonic arts expression. Each platform will investigate a distinct perspective (2D, 3D, first-person, third-person), all of which are identifiable within gaming culture. Comments on the work's usefulness, limits, and outcomes will contribute to the discussion.

1.2 Background

Sonic art, experimental music, electroacoustic composition, and a variety of other forms of sonic expression are all inextricably related to new and evolving technologies. From futurist Luigi Russolo's mechanical "noise machines" to Stockhausen's custom-built electronic synthesis and beyond, it is obvious that not only does technology play a vital part, but that the requisite technology is frequently altered and tailored from its original application. The intonorumori were custom-built to simulate industrial-era sounds. Musique Concréte arose from the development of advanced tape recorders by BASF in the 1930s and more recently the home computer. As the most prevalent consumption device for this new media, the home computer allows users to interact with the media, offering more options than just simple playback. Consumers are being given a part to play. This control is perceived as interactive, as it gives the user the option of seeing what they want to see and how they want to see it. Today, some of the most cutting-edge innovative technologies can be found in the video game industry, including virtual and augmented reality, procedural audio, binaural sound, and real-time parameter control, all of which have been integrated in order to provide greater realism and immersive experiences as a form of entertainment. These advances may also be very useful to sound artists and composers, and they are an important element of my own creative process.

1.3 New Media Tools

Video games are designed to be interactive, and they are frequently related with important concepts utilised throughout the inquiry into the creative process of my work, such as engagement and immersion. With the development of video game engines like Unity, it is now easy to construct and experiment with 3D simulated worlds complete with simulated physics, and I believe that video game engines provide alternative approaches to interactive sonic art. Art works which focuses on the listener becoming an active participant in the work's organisation and presentation. Electroacoustic music can be developed by providing the user or listener with multimodal impressions of meaningful audio structures through interaction and exploration. The casual listener is made more accessible by offering them with alternative listening modes. Using symbolic representation through game-like play. In many ways, the works presented in this thesis cannot be classified as games. This label may be perplexing to the user and may become "a barrier to an audience understanding of the theme" (Dolphin 2014). In many ways, they are more in line with "sound toys".

The I.S.E's musical purpose is not necessarily to produce fixed linear work; rather, the agency moves from composer to user. Each individual play-through gives a snapshot of musical possibility, a one-time-only performance. The developed musical works are constrained by the blueprint or performance area that was constructed. The inquiry reported in this thesis intends to further expand the sound toy design process and to establish different practical and theoretical ties with recognised electro-acoustic approaches, resulting in the development of a new framework with videogame technology as its central focus.

Practitioners can design 'sound toys' on a host of platforms; web applications such as flash which uses action script in its process, or practitioners can often create custom software for interactive art installations. However, because these systems usually demand a specific skill set in order to make such installations, this may generate time and money difficulties. This research offers an alternate solution to those issues. Professional videogame design tools can be used to create immersive settings for sound creation or as an interactive platform to explore and exchange musical creations without the need for a physical location or a limited display period. I've titled my work "Interactive Sonic Environments," or I.S.E, and will be referring to it by that abbreviation from now on.

It is critical to note that by utilising video-game technology, a plethora of ways for displaying content become available. The second wave of virtual reality (VR), for example, comes with it a host of new screens and input devices. New solutions to current problems on the hardware and software sides of VR technology are constantly being introduced. This software and hardware development is being pushed mostly by VR enthusiasts, as opposed to the established scientific community, which is also making use of the newly available technology to some extent. In addition to HMDs (Head Mounted Displays), other equipment including haptics devices, controllers, vests, omnidirectional treadmills, tracking technologies, and optical scanners for gesture-based engagement are finding traction in the field of commodity VR. The bulk of these technologies are already dependable enough for professional use and for research studies, but I contend that the research issues provided in this thesis can be answered without the employment of costly equipment. I recognise the significance of VR and the impact it can have on key criteria I offer, such as that of immersion. However, the thesis is motivated in part by the desire to use video-game technology to eliminate the costs involved with audio artworks and installations, rather than to add to them.

Few practitioners create sonic works in this manner, with a handful of significant exceptions; these exceptions will be examined more in chapter two. The comparatively low number of practitioners in this subject can be attributed to video games' strong graphical emphasis, both culturally and technically. Video games, like film, are largely regarded as a visual medium. Furthermore, without significant coding skill, game engine sound capabilities and real-time effects processing are frequently confined to simple playback triggers and little else. The work associated with this creates an understanding through the examination of the creative process, proving that significant coding experience is not required.

I discovered that not only are popular features inherent in traditional software, such as sound manipulation, processing, and storage, exist within video-game engines, but that these features and creative processes are frequently used by developers in the entertainment industry. Procedural audio, as well as the ability to network with more sophisticated audio systems such as middleware, expands the potential of these systems for sound artists. Visual output and complicated physics computations can now be connected solely to the game engine, while audio is provided separately to more robust and familiar sound synthesis software like Max/MSP and specific audio engines like Audiokenetic's Wwise. With this advancement, some artists have begun to primarily use this technology for experimental sound design, virtual

2 State of the Art

This chapter will look at the present state of research, focusing on video game technology and sound. Conversations between academics and game designers about the importance of video games as a recognised art form can be instructive when attempting to place the I.S.E platforms in a broader context. Sound art, electroacoustic composition, and other kinds of sonic art are all audio-based forms of artistic expression and, as such, are all taken into account when using virtual platforms like the ones used to support this thesis. In terms of concept, the mix of interactivity and audience participation in music is not unique to so-called "new" media. It existed in the arts long before the introduction of recording or computer technologies. Nonetheless, despite the growing number of authors involved in the creative process, interactive media ultimately encourages user interaction. The designers construct an experience, share the artistic tools, and give the user an unfinished work to apply and change as they see fit, resulting in sonic art output via gameplay experience.

2.1 Video Games as Art

There is a clear need to establish ‘principles of aesthetics, a framework for criticism, and a model for development’ (Adams, E.W., 2006.) when using computer game related creative tools. Video games as a medium have the potential to create exciting virtual environments for experiencing sonic arts. However, arguably the best place to begin constructing a framework for development and understanding is within the realm of commercial video games. Practitioners as early as 2006 began to theorise about what makes them viable platforms for expression and perhaps more importantly to this project, what role sound and music have in their creation. In an article published 2006 for Games and Culture journal James Paul Gee claimed that “Video games are a new art form, one largely immune to traditional tools developed for the analysis of film and literature” [Gee, J.P., 2006].

Both Gee and Adams comment that video games will challenge us to develop new analytical tools and methods of understanding. Gee attempts this by breaking apart one particular video game (Castlevania) into its core elements and suggests that these elements, when combined form a large part of the pleasure and ‘feel’ of the game. Ambience, mood, sound and visuals all contribute to the ‘tone’ of the game and can provide the player with a sense of being inside this ‘symphony’ as Gee states it. A blend of action and flow to create an artistic narrative that is unique to each player. “Castlevania is an instrument on which the player plays a visual, motoric, auditory, kinaesthetic, and decision-making symphony - a unique real-virtual story producing a new form of performance art co-produced by players and game designers” (Gee, J.P., 2006). Gee's analysis is reasonable in relation to the development of I.S.E.s. The system's design must include more than just a means of delivering sounds; rather, a successful mix of stimuli is required to produce an immersive experience, one that combines multi-sensory input with interaction that gives players agency.

According to the film critic Roger Ebert however, the very idea of interactivity in art precludes artistic meaning. In 2007 he argued that art-as-communication is between the author/artist to the viewer. The fundamental nature of interaction is to generate different experiences, one unique to each player, but he argues that doing so would take away some of the artists control over the piece and hence undermine its original purpose " Art seeks to lead you to an inevitable conclusion, not a smorgasbord of choices." (Ebert, 2010).

This was Ebert's first and only attempt. His examination of video game criticism was completely theoretical in nature. Importantly, his analysis failed to mention his own experiences while playing the game. According to Gee's earlier study, this omission fails to inform the reader about how he 'connected' with it, how it made him 'feel.' Art communicates ideas and meaning; it has an aesthetic that must be seen/heard/touched to fully appreciate the breadth of meanings. He later admitted that he was “a fool for mentioning video games in the first place” (Ebert, 2010) because he couldn't possibly comment on whether video games could be regarded art because he had never played one and will never play one. While I completely believe in Gee's analysis of "co-produced performance" (Gee, J.P., 2006), Egbert's blunder and subsequent retraction of his video-game review is pertinent to this project and the creative process. The paradigm of fixed-form media and artistic expression may be challenged by unlimited option. In short, while contact and engagement, experience, and feeling are all important components of this research and the works presented alongside it, creative control should be acknowledged.

These new 'laws' for composition in this media should be thoroughly investigated. My portfolio stems from my goal to demonstrate video game engines as a legitimate medium for artistic expression as well as a unique method to experience my electro-acoustic compositions. However, I discovered several distinguishing areas inside the standard commercial game development cycle that proved valuable when producing my work, such as the iterative design process and the utilisation of beta testing. It is crucial to highlight that the work shown here does not adhere to the same tropes and expectations that are associated with traditional 'games.' There are little risk/reward style rules, no character identities, and little to no narrative (in the literal sense) You cannot 'win' or 'finish' these platforms because they are not designed to create a 'Game Over' type scenario. That being said, it became clear from the research above that there must be important design rules, clear patterns, and relationships within each I.S.E that allow for a desirable or at least semi-predictable outcome, fulfilling both the aesthetic goals of the art work and maintaining a degree of artistic control. In the past, these types of auditory works were frequently referred to as "Sound-Toys."

2.2 Sound Toys

In 1998 Sound-toys.net launched a website dedicated to creating an online exhibition space for artists to curate exiting new audio-visual artworks, it is from this collection of works that we first associate the term sound-toy stating 'a forum for discourse around new technologies and the nature of sound-toys.' (sound-toys.net - home, 2019) Sound toys are sonic-centric interactive systems that enable the user to trigger, generate, manipulate, and modify sound. The whimsical approaches of composition used by sound toys enable an inexperienced user to compose by employing symbolic representations of often sophisticated underlying auditory systems. The visual domain is turned into a dynamic and aesthetic animated user interface for the player's study of sound and/or music. (Collins, Kapralos, and Tessler, n,d.) The title "Sound Toy" can be misleading because it implies that it is juvenile and has no purpose when, in fact, it simply alludes to the concept of playful interaction. Because of the connection between computer games and sound-toys, some have questioned their legitimacy as an art form, dismissing them as nothing more than a novelty item or toy. There is no 'physical' final product, no aim other than entertainment during the creating process and a deeper understanding of the experience for future playtime, as there is with a child's toy. I contend that this concept is central to the artwork.

Furthermore, each toy exists on its own terms, with its own set of rules, providing its own distinct experience. My goal is to examine those principles and apply them to gain a better knowledge of the approaches that composers might use to create their own I.S.Es.

In a society where less music is composed on traditional analogue instruments, sound toys can be extremely useful tools for musical creativity (Huntingdon, 2005) The sound toy medium provides improved access to music creating, with mobile devices allowing for more widespread composition and participation in composition. Within the domains of sound art, current computer music, electroacoustic and electronic music composition, and computer game-related technologies and techniques offer opportunities for improving existing ways of artistic presentation and dissemination. Sound toy systems may be created utilising tools that aren't often linked with the subject of composition, but they're regularly affected by many parts of compositional process, including related techniques, processes, topics, and aesthetic considerations. (Collins, Kapralos, and Tessler, n.d.)

Artist Andy Dolphin later gave a much deeper explanation in 2014, and both sources agree that the term 'Sound Toy' is defined as a medium for composition in which play and exploration are major themes. The platform is interactive in nature, with a focus on how the end-user can interact with, transform, and access the sounds presented by the composer. Dolphin claims that they can provide "novice user access to interactive composition through the symbolic representation of often complex underlying systems." This representation may influence the user's level of engagement and, eventually, the outcome. The usage of these sound toys contributes to the composition's openness. A sound practitioner is developing a virtual interface to explore their musical composition or collection of sounds. To some extent, preconceived notions and assumptions regarding the composition are abandoned. Instead, the piece is frequently determined by the level of involvement and how the artist delivers the music within the system. The more options the user has for exploring the audio, the higher the possibilities for the sonic outcome. Dolphin (2014)

Despite the apparent randomness of the outcome a Dolphin suggests that a structure does still exist, a specific framework that centers around interaction and engagement rather than a narrative, rigid rules and risk/reward goals. The term ’toy’ suggests they are intended for play or recreational experiences; it can make these platforms sound disposable with no investment warranted by the time spent making them.

However, Dolphin successfully argues that they offer a ’playful framework for composition [. . .] provide scope for developing existing modes of artistic presentation’ (Dolphin, 2014). It is clear that computer game-related technologies offer improved access to music-making and the work presented here demonstrates a unique creative process, the framework for composition and a model for development when using Unity in particular. The nature of the sound toy, the level of control available to the player, and the type or styles of player interactions with the computing system all influence whether sound toys can be regarded instruments, compositions, or tools for composition.

Dolphin usefully suggests that there are three areas or definitions that help to clarify where sound toys sit in regard to the compositional process, [Figure1] as a composition tool; a platform that offers unique ways of presenting the composition, as an Instrument itself which can be used as part of a larger ensemble, or as an open work and co-produced composition. My works exists at the crossroads of various concepts, a confluence of these possibilities. For example, I may enter pre-produced sounds and musical gestures from composers into the system, allowing for some participation in the composition and transforming it into a creation tool. Furthermore, when I utilise the system, I will gain mastery as I grow more comfortable with the manner of interactivity. I can create more focused musical motions, much like I would when practising the piano or another musical instrument. Finally, the work itself can generate new auditory results that are co-created with the user, resulting in a composition or non-fixed open work.

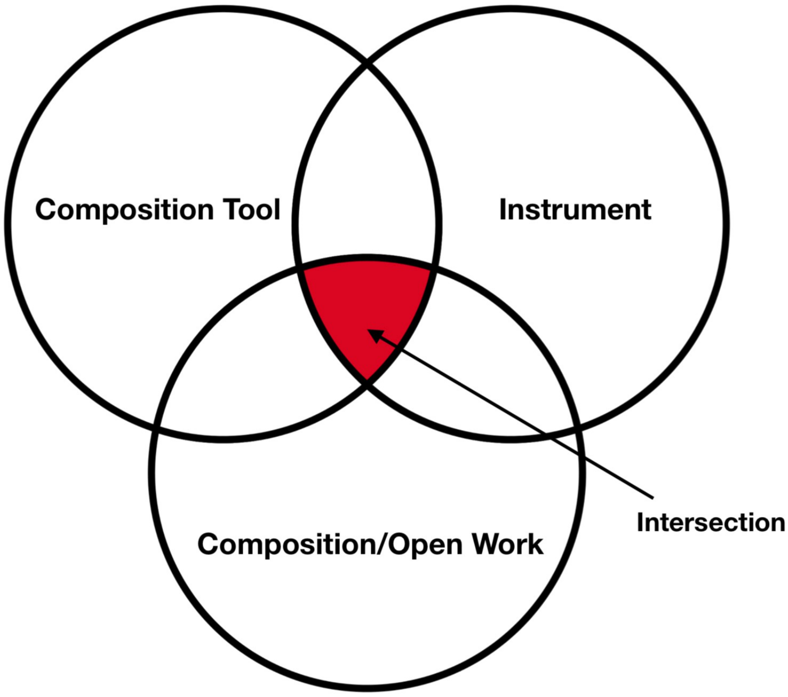

Figure 1: Dolphin's intersection of terms and classification

3 Case Studies

The I.S.E platforms do not exist in a vacuum, while the process of using video-game tools for musical expression is still in its infancy within the sonic arts, some practitioners are now beginning to utilise this software in other walks of life. Medicine, sciences, education are all now using video-game engines for an array of uses. (Marks, Windsor, J. and Wünsche, 2007) Workplace are now using video-games to train their staff, the results of a study published in 2011 by Traci Stizmann found that when gamification and gaming simulation is used for training, the trainees learned more. The survey concluded that ‘Self-efficacy, declarative knowledge, procedural knowledge, and retention results all suggests that training outcomes are superior for trainees taught with simulation games relative to the comparison group’ (Stizmann, 2011) Canon U.S.A., for example, uses a video game to train new copier technicians. (Canon U.S.A., Inc. | Press Release Details, 2022) To play, technicians must drag and drop parts into the right spot on a virtual copier. IBM developed "Innov8," a role-playing game that is said to teach graduate students a combination of business and IT skills. The Hilton Garden Inn, meanwhile, introduced the first training game for the hospitality industry, which places employees in a virtual hotel, interfacing with customers and fielding typical guest requests. (The Entertainment Software Association, 2019). Moreover, doctors in America are beginning to prescribe video game therapy for patients with ADHD. In early 2018 the FDA’s cleared a prescription program called reSET, the first prescription "digital therapeutics"—an emerging class of evidence-based interventions that are predominantly driven by software rather than drugs. (Molteni et al., 2019)

The capabilities of software like Unity extend far beyond entertainment and art. This chapter, however, cannot cover all of the new and unique ways in which game engines, game design, and interactivity are now used; instead, there are a few significant sonic-centric examples that have served to create the groundwork for my approach. As a result, a debate is required to identify, compare, and contrast some of them among their counterparts. The analysis is not a critique in the traditional sense, but rather an attempt to broaden awareness in order to improve the language and offer an opinion on its expanding theoretical framework.

I made a concerted effort to give a diverse range of artist concepts, each aiming at a distinct audience but with commonalities that fall into one or more of the three classes shown in figure 1. This is not an entire list, but they all share similarities with my work, highlighting both there limitations and how they have influenced my own creative process. Stanley's Rubiks installation for example, reflects my aim to use play in composition as well as my ambition to make these art works accessible outside of an installation-gallery experience. Elektroplankton is classified as a compositional tool and is the closest thing to a typical video game, having been sold alongside more traditional video games. Swirls is a musical instrument that focuses on the system's performance features. Finally, Andy Dolphin's Magular, which may be understood to dwell within all of these words, at the intersection, and Björk's interactive album Biophilia, which is a collaborative musical composition between the artist and her audience.

3.1 Cubed

Doug Edric Stanley teaches Algorithmic Design and Playable Media in the Media Design Master at the Geneva University of Art and Design. He is dedicated to researching algorithms and code as creative materials, with a particular emphasis on the use of play in the discovery of new art forms. He has organised innumerable workshops related to creative programming for various non-profits, museums, universities, and art schools. While he mostly works with installations, he is also interested in the process of interaction as an art form. Stanley outlines a “move away from specific interactive objects as an end-all and the emergence of a culture of software, instruments, and platforms for artistic creation" (Stanley, 2021). His work on Rubik's cube DJ is an excellent example of combining play and musical output. The use of a well-known childhood toy as an interface, such as the Rubik's cube, allows the user to interact with the toy, which works as a symbolic layer behind which complicated audio is functioning. The complicated audio in this scenario is generated by a 6-track loop-based sequencer. What is significant to me in this piece is Stanley's motivation for creating it. He claims that digital music, such as DJ sets and complicated sequencers, frequently gives the listener little information about how it is generated; "that's an issue for the audience that wants to experience the development of the music." (Stanley 2006). The physical terminal enables users to make music using a real Rubik's Cube. Because the terminal employs visual tracking technology, many physical cubes can be used to save musical groups, much as the states of software algorithms can be stored on diverse media.

In this way, many Rubik's Cubes function as a form of floppy disc, allowing manipulators to move from one cube to the next, essentially loading and saving musical variants with each exchange. The difference here is that the "saved" permutation may be read just before it is executed by the computer; in other words, the entire data on the drive is visible. The work presented here has comparable goals to mine, especially since Stanley constructed an online version that anybody can play. He acknowledges that the physical installation requires time, location, and money. In terms of funding the physical edition, he admits that he is "trying to find someone to bite" (Stanley 2006).

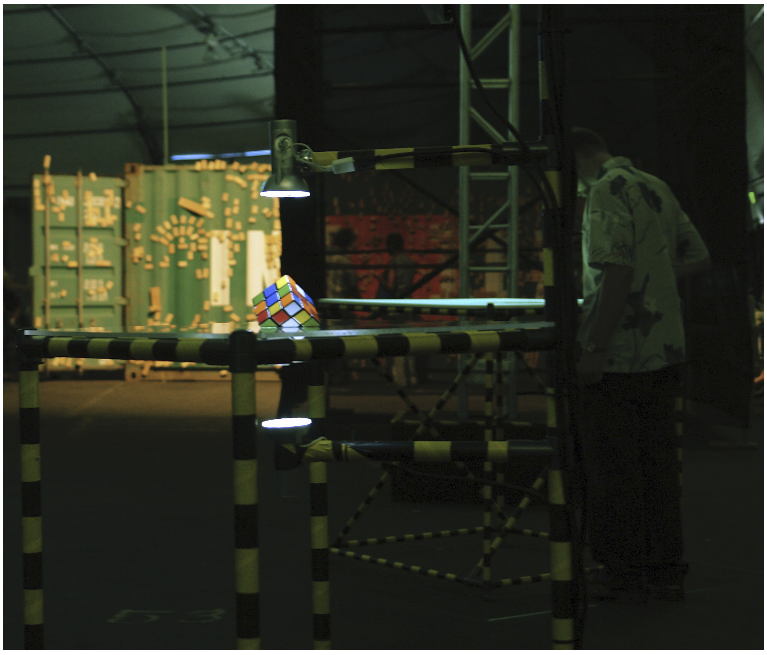

Figure 2:Stanley’s Cubed installation

3.2 Elektroplankton

Toshio Iwai's Elektroplankton is a music game that was launched in 2005 for the Nintendo DS and then internationally the following year. The DS system and its manner of interaction piqued his curiosity; therefore, the game was built using interactivity as the major creative impetus. It's a notable example of interaction design that bridges the gap between user production and creative experience. To begin, it is critical to recognise that Elektroplankton is not a game. It is an environment where the player can just interact with the organisms and generate sounds and music, rather than the 'player' working toward a goal or end.

The game's concept is simple: the player can generate music by interacting with ten different types of plankton. The majority of the game's content is in Performance Mode, where the user can interact directly with the plankton. The game also has an Audience Mode in case the player wants to turn off the system to listen to music. The game notably lacked a save feature. The absence of this function frequently reduced the game's experience by eliminating menus and making it more of an improvised experience. Despite this, of all the reviewed sound toys presented here Elektroplankton is the closest thing to a commercial video game in that it was released on a platform aimed for the casual gaming market and was made available in game stores around the world. However, due to the peculiarities of the concept and target audience, the game was not well received at launch, with several reviewers describing Iwai as just an "eccentric." (2019, Life) Perhaps most intriguing in terms of my own I.S.Es is the lack of any save function, a feature common in commercial video game releases. The user is unable to save or resume their work from the most recent notable composition. Iwai expresses openly his goal to keep users engaged within the creative space rather than behind a wall of menus and screens.

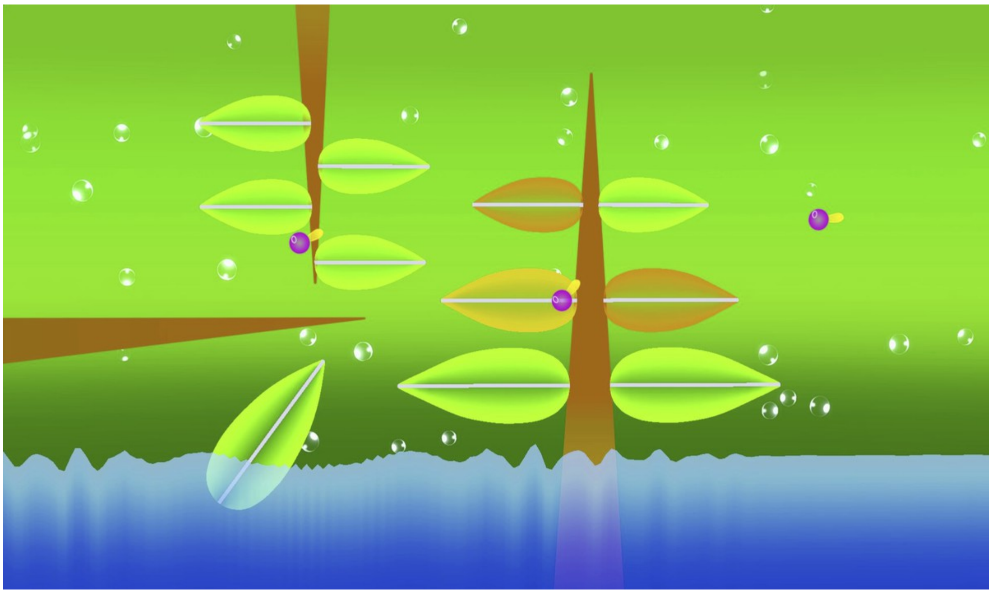

Figure 3:Iwai’s Elektroplankton Interface

3.3 Swirls (Ignacio Pecino 2011/12)

A piece written for the concert hall encourages the audience to participate as active listeners in the composition's development. The musical experience is referred to as Concert Hall Interactivity. This work investigates the creative possibilities of an interactive music composition based on a 3D virtual environment that audience members in a performance venue can navigate utilising smartphones as wireless input interfaces. Pecino's platform is a performative one. Again, as with Elektroplankton, there is no save option. It is an interactive sound installation in which the composer relinquishes control over which element of the composition is to played and for how long. At the same time, while the level of interaction itself may be simple, the mode of interaction is far more intriguing—offering the audience a way to interact from their normal seated position in a concert hall, using only their smartphones to explore the space, albeit with only two active participants. The piece's structure is provided through a series of pathways or branches painted on the topography of a virtual setting in Unity. These paths, or branches, are organised in a fractal style, with several swirl patterns crowded together (see figure 4). Each of these clusters is linked to a synthesiser instance in MAX/MSP via Ableton Live (for easier data mapping). Pecino does desire some control over the musical structure. However, he notes the need for tactics to precisely predict user behaviour in order to "keep a sense of development" [Pecino, I. (2011)]. 3–4 [towards his final artistic idea], Swirls (2011/12).

Surprisingly, the solutions to those techniques fall well within the purview of game design rather than musical creation. He suggests employing fog to establish zones of activity, as developers use to keep their users in a specific region. In addition, he intends to employ the camera's position and a force mechanic to keep users on track. There is a substantial visual component here, which could be argued to exist independent of the music. Its main goal is to keep the user on track, or at least close to the audio sources. The issue of utilising third-party software to compensate for Unity's audio engine remains. The use of MAX/MSP needs the use of a separate network bridge to connect the two programmes. In my work, I make an effort to maintain the traditional and well-established game creation linkages, such as Unity + Wwise or Unity + Fmod. These links are already existent in Unity's asset store system and are simple to implement while adhering to the established chain of current video-game design workflow.

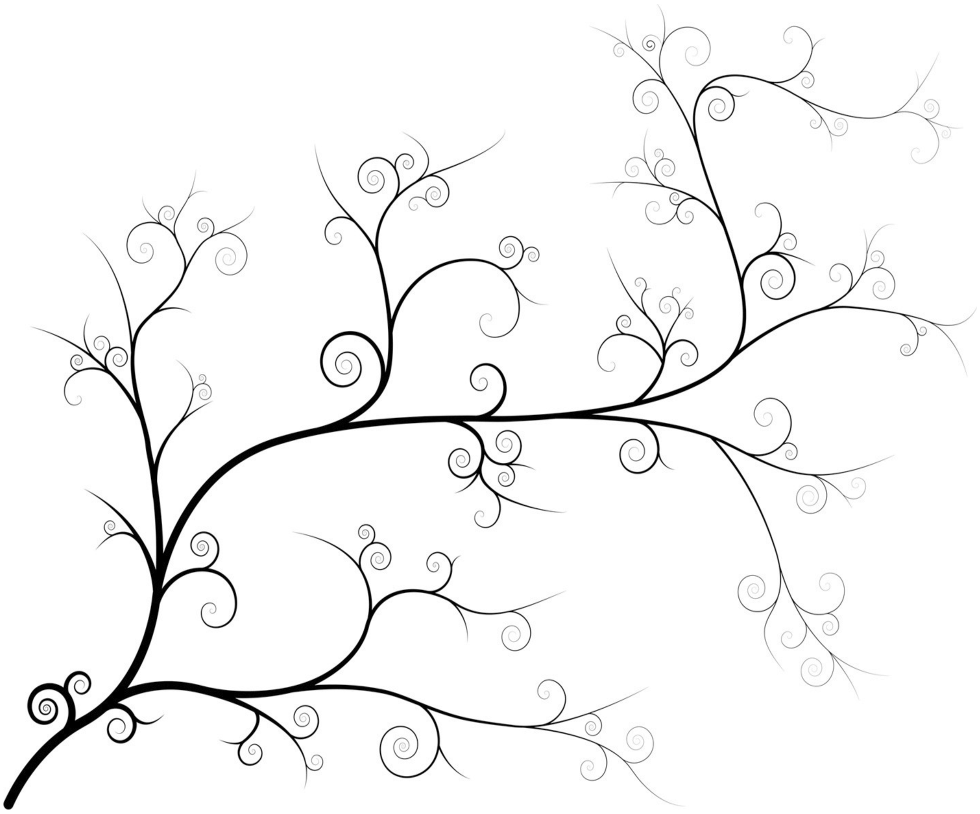

Figure 4:Ignacio Pecino's Fractal Swirls

3.4 Biophila (Björk)

Biophilia by Björk is the world's first app album, a multifaceted exploration of music, nature, and technology. Biophilia is accessible as ten in-app experiences while flying through a three-dimensional galaxy that complements the album's theme song, Cosmogony. It includes a one-of-a-kind music score, interactive, instructional artwork, and aural artefacts. Each in-app experience is inspired by and investigates the connections between musical structures and natural occurrences ranging from the atomic to the cosmic. Björk's songs can be used to produce and learn about music, to learn about natural events, or simply to enjoy (Björk: Biophilia App — Scott Snibbe-Interactive Art, 2021). Biophilia is not a toy in the traditional sense. While it does feature little toy-like mechanisms, it is actually a multimedia project designed and developed by According to the musician Björk, the whole package includes an album, a slew of mobile apps, live events, and a range of additional activities and artefacts. Although developing a mobile application isn't a novel concept, other bands, such as French-based singer Nouvelle Vague, have embraced the medium to broadcast information and social material such as band announcements and future show dates. Björk engages the listener by incorporating interaction into her own music. The suite of apps built in tandem with the physical record is what distinguishes Biophilia. The suite is made up of a master application called the box, which has its own music called Cosmogony. [See Fig. 5]

This app acts as a portal to the remaining applications, each of which corresponds to one of the album's nine remaining tracks. There are several options within each of these apps, such as "Play," which presents the song with an interactive multimodal semi-educational game; "Animation," which is a graphical scrolling score with playback; and "Score," which is a notated score with midi functionality as well as lyrics, credits, and articles. Each of these apps allows the user to delve deeper into the song's themes and concepts.

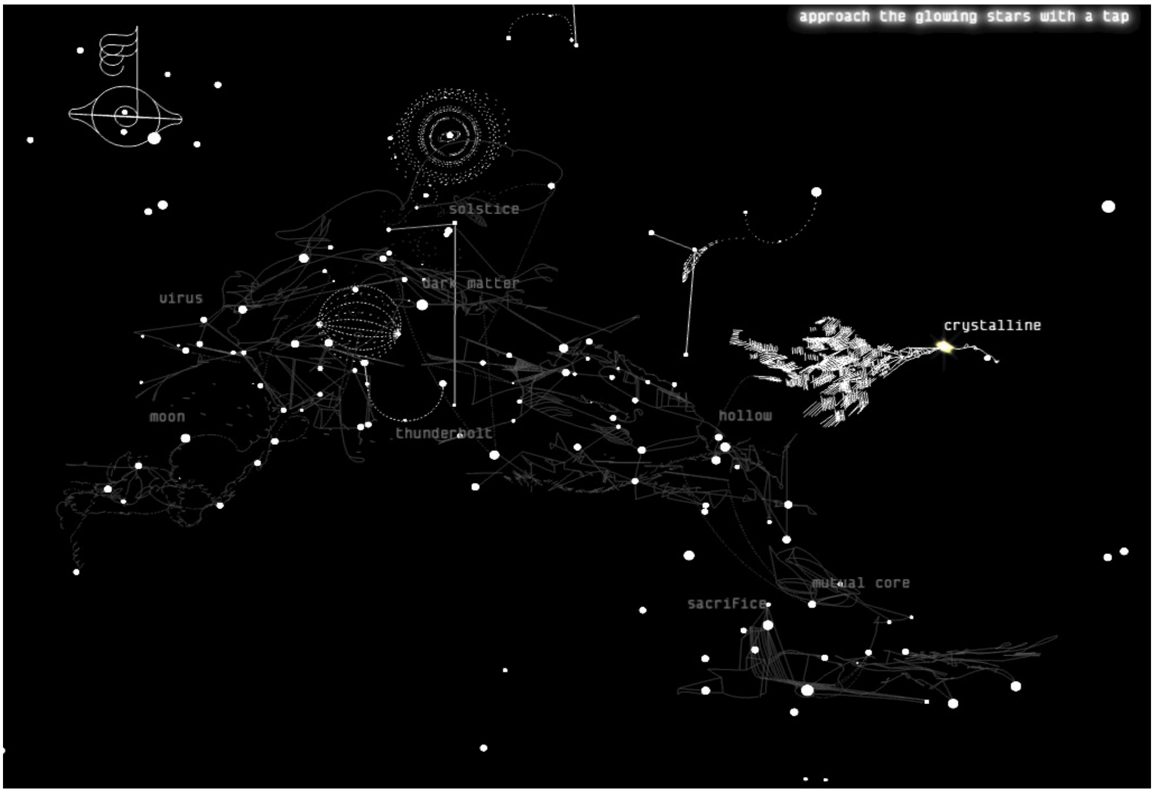

Figure 5:The 'Box' Main user interface

Interactivity ranges from linear audio-visual content to musical instruments resembling sound toys. The goal of the project's design appears to be to transform the fan experience by utilising the interaction between graphics and sound, which is supposed to tie directly to musical structures and processes in each scenario. Björk's concept was to employ touchscreens as an easy tool for music-making as well as a platform for interactive, educational experiences that would allow the user to learn about some part of musical structure through play. The audio-visual link functions as a teaching tool, alerting users about the musical qualities of individual songs that can be used as metaphors for musical processes.

The song "Solstice," for example, lets users watch melodic sequences visualised as planets circling a sun on the screen to get a sense of how sophisticated looping methods function in music. The player can learn about arpeggios by changing the length and height of lightning arcs on the app screen. Arpeggios are a type of musical structure that preserves the same necessary interval arrangement even when range and tempo change.

3.5 MagNular

MagNular is a sound-toy that can be used by one or more people. The user selects and drops an array of particle objects into virtual space. Each of the 15 accessible particles has simulated physics behaviour and represents a separate sound group. Interaction comes in the form of magnetic paddles that attract or repel the particles, allowing them to be freely moved around the environment, resulting in collision events that trigger and modify the sounds. The collision area, velocity, and directionality are all controllable characteristics. Importantly, MagNular employs traditional gamepads as its input mechanism, aiming the platform squarely at gamers and casual users. Dolphin used Unity to compute the graphics and physics, but all sounds were routed to Max. Users' interaction with the virtual sound environment is, interestingly, totally symbolic, with no audio parameter names presented. This ambiguity allows the user to explore the virtual space and sound world "without the distraction of specialist terminology that may be intimidating, confusing, or "off-putting" for a user with limited knowledge of sound synthesis terms." [A. Dolphin, 2009] The project is intended to be an experience. Controlling the sound engine via the animated interface relies on the user's understanding of gravity and the physical behaviour of magnets. Dolphin's work is fundamental to my own in that he champions technology as a viable platform for expression. MagNular, in particular, employs a very familiar gaming interaction, the game pad. The visuals rely heavily on colour and lighting, as well as the use of physics.

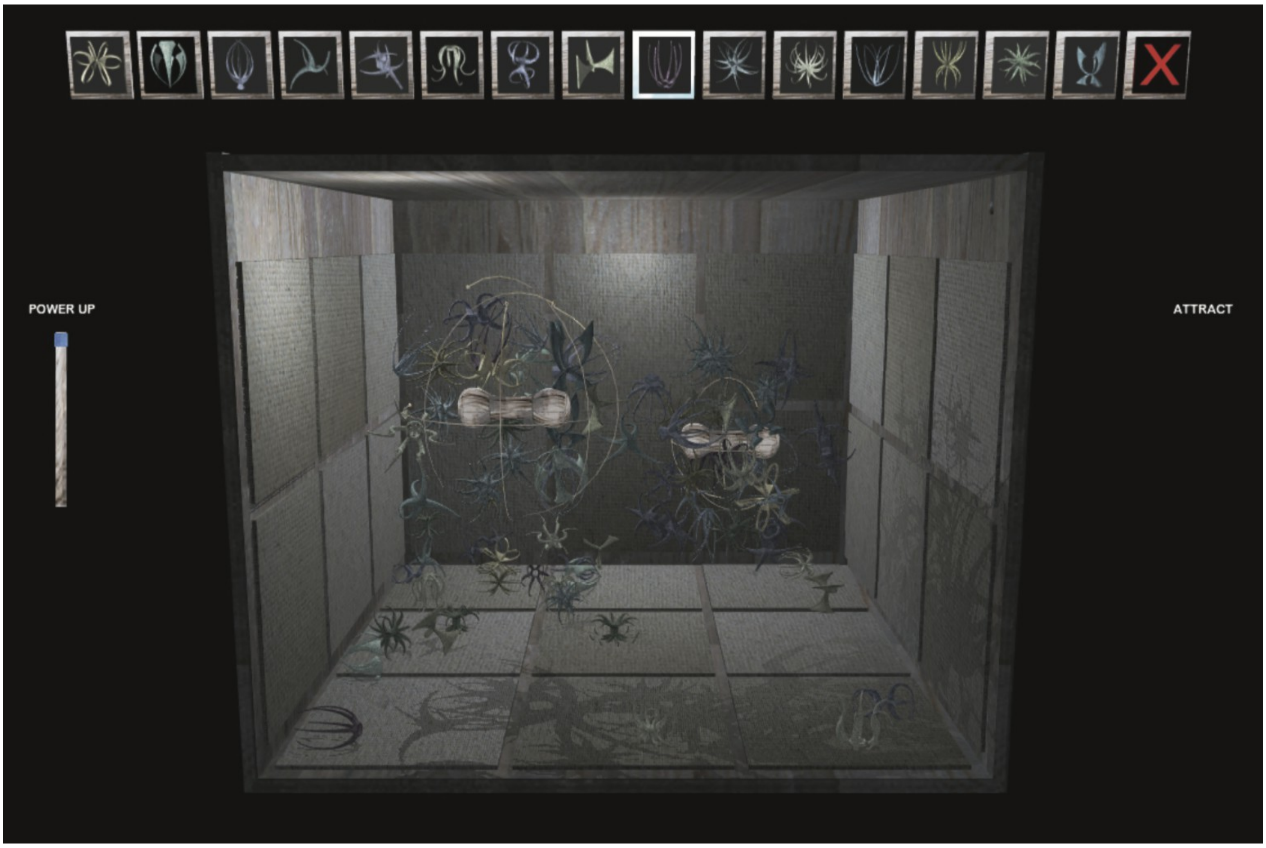

Figure 6:Dolphin's MagNular Interface

4 Play

Play and playfulness became an important part of my creative process, and my emphasis has always been on experiencing art through agency. The relationship between art and play is complex, and it deserves closer examination in order to help frame the practical discourse. While most definitions of the word suit the project goal, it is with the meaning of 'engaging in an activity for enjoyment and recreational purpose' that the portfolio is driven. Play as a topic is far too broad to be adequately addressed in this thesis. Instead, this is an attempt to identify factors in the development of the interactive compositions that accompany this thesis. 'Play is neither the orientation nor even the state of mind of the creator or those enjoying the work of art, nor the freedom of a subjectivity engaged in play, but the mode of being of the work of art itself,' summarises Gadamer (Gadamer, H pg. .102). Most forms of musical composition can often have a conscious beginning, including an idea of what the art project will turn out to be (Stebbins R.A 2015) It could be argued that artistic compositions with a predetermined end or goal frequently only allow for play to be experienced in the middle of artistic creativity, during the act of creation, rather than at the end and beyond. The I.S.Es discussed and presented in this thesis attempt to make the experience of interacting with and exploring the performance space the composition itself, and in some cases to serve as source material for the fixed versions of the composition. If we consider 'play' as described by Stebbins, then the goal is to achieve 'augmented' play. I attempted to deconstruct this process into three key components: difficult circumstances, inventive solutions, and ongoing activity. The goal was always to develop a set of rules, blueprints, and guidelines that could be applied to my creative design process.

4.0.1 Challenging Circumstances

My I.S.E platforms were first conceived with these ingredients in mind, and upon reflection, I found them to be the most difficult to implement. This is due to the fact that, as previously stated, the platforms are not games, so the traditional risk/reward troupe required to create 'challenging circumstances' is virtually non-existent. Instead, the circumstances are much broader and were motivated by more personal objectives such as;

- Can I explore the world?
- Can I understand the origin of the sounds, and how can I alter them?
- Can I create a soundscape or composition?

It can also be interpreted as an attempt to compose music within a virtual play space or environment. The goal is to create engaging multimodal environments and present sounds that can be manipulated in simple ways, as well as to provide a layer of mastery that comes with continued use, similar to a musical instrument.

4.0.2 Inventive Solutions

The solutions to the preceding suggestion revolve around the creator's primary modes of interaction. The control inputs in the portfolio presented vary depending on perspective within the virtual environment; for the most part, a mouse/keyboard combination or an Xbox control pad was used. Other schemes, such as an infrared leap motion controller, have been tested. This, however, resulted in unintended difficulties with interaction, breaking the immersion. How sound propagates within the virtual environment provides a wide range of interactive options for the user and is frequently based on ideas and processes already familiar to game designers, such as systems that recreate physics, including magnetism and velocity, which appear as critical components in the creation of music and the ability to pick up and drop objects. With the right multimodal feedback, these can become symbolic representations of a desired audio effect and, combined with the appropriate multimodal feedback, examples of sonic art practice can be created without the use of complex language. Throwing a game object in the simulated play-space may set off a number of triggers that either generate sound, play a pre-recorded sound sample, or transform it in a meaningful way. Placing a sound object, such as a cube, on top of another can serve as an easy metaphor for presenting superimposition as both a complex electroacoustic gesture and an engaging interaction within the virtual play-space.

4.0.3 Continued Activity

The I.S.E platform's success is heavily reliant on its ability to engage the user to the point of achieving a flow-like state. Because some of the works are open (basically a recorded 'play through' of a session), the user/composer/active-listener has some control over the content such as its length and complexity.

To encourage the user's continued participation, a balance must be struck between the two previously mentioned ingredients: challenge and inventive solutions. When it comes to my I.S.E.s, I create engaging sonic interactions as well as exciting ways to recreate and manipulate them.

5 Open field of possibilities

Focusing on the concept of play and its impact on my process, it became clear that the idea of presenting a fixed medium was only a small part of the system's potential. The output of I.S.Es is frequently unfixed and open. Similarly, Umberto Eco's concept of "the open work" was an attempt to comprehend contemporary artworks that could be rendered open by their designer and then offered for completion by the user. In the creation of openwork, he proposed two distinctions: multiplicity of meaning and audience participation in the making of the art. In reality, the artist designs the work so that the meaning is ambiguous. The interaction with the audience, or in my case, the player or user, frequently contributes to those meanings. Participation must be able to change the work, and the author does lose some control over the outcome (if any). This idea can help to validate the variety of interpretations that a single work can provide.

Having unlimited variations of artwork, however, can create a complete disconnect with the artists' original intentions, so some degree of control is advised. For example, Karlheinz Stockhausen's Klavierstück XI (1956) contains nineteen events that are composed and notated traditionally, but their arrangement is determined by the performer's spontaneity during the performance. In essence, this may appear to have an infinite number of interactions depending on each performer's interpretation, but this is not the case. Stockhausen maintains control by limiting the number of variations, the areas for improvisation, and even the shapes designed in the score that elicit similar responses when performed. Eco explains in "The Open Work" that "openness" does not imply "infinite possibilities" or complete freedom. (Eco, 1989). There are a variety of rigidly pre-established and well-thought-out interpretative solutions available; these rules never allow the listener to leave the author's strict control. With the example of Stockhausen’s musical piece, it is evident that the performer does not rewrite the composition but instead works with the composer to create something new.

This distinction is critical because open works, despite being 'performed' by a third party, still belong to the composer in part. The composer is the one who proposes possibilities that have already been rationally organised in some way. These are then given specifications such as which sound should be generated, where it should be located in virtual space, and how it can be manipulated. This, too, was important to Eco, as it ensured that the work would be a work. The result would be a "mere conglomeration of random components ready to emerge from chaos" if there was no authorial intent (Eco, 1989, p.20). Artists can now easily incorporate interactivity, changing the artwork based on audience (user) stimuli, thanks to the advancement of digital technology. An exciting aspect of openwork is that the artist's intention is to create new ways of communicating with audiences. The composer-listener relationship evolves from a one-way to a collaborative two-way channel. Eco's theories were clearly intended for a different musical environment, as they were developed and published prior to the widespread use of computer-based gaming and interactive technology, but their significance to the field of sound toys cannot be overstated.

6 Interactivity, Engagement and Flow

To render the works in the folio open, a system with rules applied by the artist/creator and a degree of freedom and interactivity for the user is required. With that in mind, conventional video-game aesthetics tells us that the ability to create immersive experiences is essential for continued activity in the game world and keeping the user engaged. Using conventional approaches found in commercial video game design aesthetics, an understanding of how the user experiences immersion played a significant role in the process of designing the sound-toys. Immersion exists in many forms and across media, from television and film to literature, but videogames provide an alternative form of immersion, one born from overcoming challenges and the concept of spatial presence. Psychologists use the term "spatial presence" to describe the concept of absorption in any type of media. This is defined as "a sense of being there," with the main characteristic being "the conviction of being located in a mediated environment." (Wirth et al., 2007) Successful video games, particularly immersive open world games, have a number of characteristics that give players the impression that they have left real life behind and are physically present in the virtual world.

To begin, video games employ a variety of sensory channels, including sight, hearing, and touch, to provide a more realistic gaming experience. This is a significant distinction from more traditional forms of media such as film.

Zac Whalen attempted to clarify specific broad labels used to describe the interaction with video games in 2004 in the international journal of computer game research, claiming that a large part of the effect playing video games can have on a user is psychological. Because the academic nature of video games is still relatively new, comparisons to film and other seemingly related media are frequently made. Whalen suggests that terms like immersion and engagement, which have been used to describe the user experience in video games, may not be adequate in describing the entire user experience. Whalen instead uses the term 'Flow' to argue that immersion is the act of being 'in the moment' without being aware of what it takes to be in that moment, whereas engagement is the inverse, a process of being aware of the object supplying the new schema.

Although Whalen does not claim to have coined the term flow, Mihaly Csikszentmihalyi first used it in this context in his 1991 article Flow: The Psychology of Optimal Experience, which will be expanded upon later. Whalen's methods include using his own experiences playing Grand Theft Auto as an example, highlighting two distinct control-methods within the game.A driving mechanic and a third person shooting mechanic over the shoulder. He points out that learning a new control method within the same game can lead to player frustration, potentially breaking immersion. Whalen continues to emphasise the significance of flow by pointing out that in this case, it is a balance between the game rewards for completing unintended challenges and the game's intended challenges. According to Whalen, "achieving a flow state successfully can be likened to being actively immersed in the moment of engagement" (Whalen, 2010) It appears that the physical process of attempting to engage with the game, beating or overcoming those unintended challenges, is critical to achieving this flow.

Whalen believes that using sound to maintain this is an important part of doing so. By emphasising the distinctions between immersion, engagement, and flow in the context of video games, I conducted a detailed analysis of how sound can be used to help achieve the desired balance of flow and engagement, as well as what role sound and play in achieving the desired balance. It was prudent for me to become aware of how music and sound can be used to keep player distractions balanced between immersion and engagement as a composer and sound designer. Whalen accomplishes this by making two critical distinctions in sound within a game. First, as a metaphor, Whalen refers to the player experience, of being inside (diegetic/immersed) and outside (non-diegetic/engaged), and how one type of music can be used to draw the player in, and the other to serve as a metonym for progress within the game, rewarding excellent or lousy performance by using musical cues. The second distinction he makes is with an actual game-playing device, such as learning to play an instrument in a game; the player is actively controlling his avatar in some way to interact with sound. "In order to achieve the desired flow state of gameplay, a user must embrace the paradigmatic gestures of a metaphoric function of game music as well as respond to and interact with metonymic functions" (Whalen, 2004) As a result, a video game composer must target the game's more engaging and immersion-breaking moments to prevent the player from feeling detached from the action. Composers must be aware of the importance of assisting the player in remaining immersed and that attempting to engage with the control method is an unavoidable part of flow.

6.1 Interactivity

There are many types of interactive art that allow audience participation, but it can be difficult to determine how interactive it is. Art installations, for example, frequently include human interaction, but the participants are not essential to the completion of the artwork. The interactive compositions provided with this thesis are insufficient without the physical presence of human interaction; they are not self-contained. Interactions between audience and artwork tend to focus on the journey rather than the destination, on how the interaction works and affects the art. Audiences are often accustomed to a fixed form of artwork, such as a painting, a song, or a novel; artwork that is constantly changing can appear foreign to them; interaction is one way to change this perception and bring the audience closer to the art process. Artwork influx, such as those available as interactive compositions in the portfolio, should be interpreted as a significant departure from traditional artwork.

This can be challenging for composers because audiences are not always aware that they are dealing with a different type of art. However, the meaning of this work is generated by the audience's experience, not by physical contact or even by artwork in constant change; physical interaction and constant change are simply part of the collaborative process in making meaning. Interactivity between the artist and whatever construct or system is being used contributes significantly to the sonic arts, to the point where it can become the 'default' mode for many sound practitioners. (Gibbs, 2010) When using the term "interactive," it is critical to define its meaning in the context of this study. As previously stated, many researchers, including Lev Manovich, believe it is first and foremost a psychological interaction. He even cautioned that "there is a risk that we will take 'interaction' literally." (Manovich, 2001) This means that a simple mouse click cannot be considered truly interactive because it has no psychological meaning. This definition is based on knowledge of other narrative media, such as film and literature. It disregards the physicality, also known as the interface, which is the point of contact with the schema. According to Gibbs, it is "the most important part of any interactive [sound] system." (Gibbs, 2010). A paper presented at an interactive entertainment conference in 2005 by Andrew Polaine attempted to argue that "true interactivity is a feedback loop of action-reaction-interaction and involves collaboration or exchange with real or computer agents." (Polaine, 2005)

Polaine convincingly argues that it is difficult to accurately define interaction without first considering the physical process. He criticised a variety of interactive experiences that all had one thing in common: the user was always aware of the physical world and unable to immerse fully into the environment due to the apparatus required to interact with that environment. He achieves this, like Gee, by "stripping back interactive works to their essentials and attempting to understand what principles cause the state of play and flow" (Polaine, 2005)

6.2 Flow principle

When designing interactive sound toys, then, the user must be able to grasp quickly or at least be engaged in learning how to control the interface and begin to create a flow state as explored by Csikszentmihalyi. His eight conditions for this experience came from years of research devoted to understanding experience-based immersion:

> "First, the experience usually occurs when we confront tasks we have a chance of completing. Second, we must be able to concentrate on what we are doing. Third and fourth, the concentration is usually possible because the task undertaken has clear goals and provides immediate feedback. Fifth, one acts with a deep but effortless involvement that removes from awareness the worries and frustrations of everyday life. Sixth, enjoyable experiences allow people to exercise a sense of control over their actions. Seventh, concern for the self disappears, yet paradoxically the sense of self emerges stronger after the flow experience is over. Finally, the sense of the duration of time is altered; hours pass by in minutes, and minutes can stretch out to seem like hours. The combination of all these elements causes a sense of deep enjoyment that is so rewarding people feel that expending a great deal of energy is worthwhile to be able to feel it"

Flow can be found in a variety of professional and recreational pursuits, including sports, creative creation, shopping, performance activities, and, of course, video games. Some attempts have been made to quantify flow and provide empirical data for study. While this is applicable to various fields, this thesis concentrates on identifying flow predictors and providing an interpretation for use in the creation of sound toys.

This presents itself in four areas that correspond to Csikszentmihalyi's explanation of activities and should be taken into account by the composer/creator: (1) provide opportunities or challenges that can be adjusted manually or automatically to the users' abilities; (2) provide feedback via an audio or visual system; (3) provide clear information on how the user is doing; and (4) have multi-modal information that screens out distractions and aids concentration (Csikzentmihalyi, 1993). Csikszentmihalyi's well-documented insights emphasised the importance of creativity and its connection to play. He talked on the nature of less competitive pursuits and how rewarding they may be. "People who regard their work as primarily creative rather than competitive are also motivated by intrinsic rewards" (Csikszentmihalyi, 1993). It is clear that a combination of simple interactivity and control, as well as player invention and agency, may achieve the desired effect of the auditory "experience" in my I.S.E's.

6.3 Embedded vs Emergent Structure

The user interacts with the I.S.Es through a non-linear set of pathways that provide a variety of options. Preliminary research drew upon Eric Zimmerman's two models for the structure of interactive media that presented interesting insights when creating a creative framework for this research: "content-based or embedded structure" and "system-based or emergent structure," in order to maintain the idea that the creation of my sound toys is situated within video game design aesthetics. The user navigates a pre-generated number of paths in the content-based (embedded) structure. The content is pre-installed in the system. As they go through the system, the user may choose different paths. Each of these options, on the other hand, has only one possible conclusion because it has already been determined. If you choose an alternative path, you have to start the system from scratch. The other choices will also only offer one possible outcome, and the number of possible paths could be significant but finite. A choose-your-own-adventure book, such as those published by Steve Jackson and Ian Livingstone, the founders of the Fighting Fantasy series, which has sold millions of copies worldwide, is an excellent example of an embedded structure, and there may be multiple choices available in the narrative. Each outcome, on the other hand, is a single experience that must be re-entered to obtain a different result. A system-based (emergent) structure, on the other hand, is guided by "sets of rules and procedures," resulting in "many diverse experiences from the same set of options" (Tekinbas & Zimmerman, 2003).

Cage's chance operations, such as 'Imaginary Landscape No. 4', provide an excellent example. The Chinese Book of Changes was used to compose the music for the piece. There were 12 radios, 24 performers, and a director in this performance. Each radio has two players: one controls the radio's frequency, while the other controls the volume level. Cage included detailed directions in the score about how the performers should set and modify their radios. Of course, the music that came out of them was completely random; whatever radio broadcasts were playing at the time and place of performance took centre stage. Every performance was unlike any other. The system creates unexpected possibilities by establishing rules and procedures in advance. The artwork is unpredictable and arises from the process itself, however it does follow set principles to aid the artist's expectation of probable outcomes. The I.S.E platforms have a considerably more emergent structure, defining a set of rules and instructions that provide some indeterminacy but all within a set of predetermined rules, such as those stated by Eco.

7 Design Tools

The decision to use video game engines to create sonic artwork stems from a number of factors: personal preference (I enjoy video games), professional experience (I've been using Unity professionally to explore non-linear music composition and adaptive music creation), and finally, practical considerations. Unity comes equipped with all of the tools needed to develop both emergent and embedded structures. Most games attempt to create immersive, engaging experiences, and Unity helps you do just that with a wealth of easy-to-follow tutorials and a wide range of free game assets. Unity is a game engine developed by Unity Technologies. It was released in June 2005 and was intended for OS X exclusive games. Since then, it has been extended to support 27 platforms, including iOS and Android. A rendering engine for 2D or 3D visual graphics, a physics engine for collision detection, sound propagation, animations, artificial intelligence, and a slew of "back-end" computations are all part of the engine's core capabilities. Of course, certain limitations were anticipated, while others emerged during the research design process. Known limitations (I had little to no knowledge of C# code) and technological problems included potential challenges such as having to maintain a computer system capable of running the software. Other challenges arose throughout the development phase, such as engine audio processing issues and the industry's preference for graphics above sound.

Without substantial coding skills, the sonic capabilities were less complicated than those given in Max or Pure Data, for example. These limitations, on the other hand, were merely a means of framing my research question: I wanted to investigate if these platforms might be used for creative reasons. Game engines provide a developer with a variety of essential design tools in a unified development environment. This offers a much more intuitive and simplified process for the design than being purely code and data-driven. There are also commercial complexities that enable developers to be highly competitive, such as time to market, platform abstraction (the ability to launch on multiple platforms with a simple click of a button), and cost efficiency by having a system that enables game design "right out of the box". Having had previous experience developing small games in Unity and having an awareness of free online tutorials and with some experience using their beneficial community forums, Unity was a logical choice.

7.2 Middleware

Audio middleware is a software programme that serves as a conduit between the game engine and the system's audio hardware. It's a solution that allows a non-programmer to adjust music and sound in real time while playing the game. The capabilities of a separate audio engine can often outperform those of the game engine's audio options. It includes typical features like pitch randomization, fades, and attenuation that are required for every project. The ability to choose a sound at random from a group or family of sounds is a simple technique to improve immersion. Furthermore, it may mimic a commonly used DAW, such as Ableton, which many composers are familiar with. This technique can allow a project's audio team direct access to the game, with little or no code required. With additional expertise, it became evident that many of the features of a dedicated audio application could be duplicated within Unity. During the three-year study period, the programme received dozens of modifications, resulting in the addition of new features, mainly in the audio. Middleware, on the other hand, is significantly superior and has a far shorter learning curve in the domain of adaptive and dynamic musical scores.

8 Methodology

This research is the product of a thorough evaluation of the present state of the art, culminating in a body of work that includes both literature and a review of contemporary sound-toy examples. The conclusions are based from this database, which contains useful components and considerations for sound-toy practitioners. The reader is informed on creative processes and design concepts through a reflection on the practical work that is included with the thesis. The research will also seek to investigate two key elements, the first of which will be used as a compositional tool, with the output forming the basis for 43 minutes of electro-acoustic music. Using more traditional editing and compositional procedures, this initial "play" will be captured and focused (see below). Layers, gestures, transitions, and transformations are then identified, isolated, and fed back into the system, allowing for even more 'Play.' The second step was developing a compositional framework through an iterative design process. The goal was always to construct interactive platforms that might strive to better enlighten the user in semantic and causal sound exploration, and to produce short compositions themselves derived from simply studying the collection of motions, movements, and transitions. A comparison and contrast of the two ways was also attempted, with one being a more structured and organised approach and the other being a "play" product.

8.1 Electroacoustic Compositional Techniques

The term "electroacoustic compositional techniques" refers to a variety of sound manipulation and production techniques, as well as Unity's creative decisions to replicate and recreate them. Techniques that have been used throughout electroacoustic history are included in the thesis's practical section. While this is by no means a full list, the strategies presented were primarily derived from Trevor Wishart's categorization in "Audible Design" (Wishart, 1994). This project focuses on only a few ways due to the enormous number of methods that have been reported over the years. The study focuses on the process of employing video-game technology as a feasible platform and finding existing video-game aesthetics that can be leveraged to facilitate these strategies. These strategies were first utilised to create a fixed work based on system exploration, which was then fed back into the system for further discovery through play:

- Sound Synthesis: artificial creation of sounds that originate through electronic processes.
- Recorded Sounds: found sounds, unplanned and unperformed, sounds in their natural state, often referred to as field recordings.
- Signal Processing: the manipulation of those sounds through electronic components such as plug-ins and virtual instruments.
- Mixing: the deliberate superimposition of more than one sound and the placement of sounds in a soundscape.
- Constructed Continuation: the extension of a sound by some compositional process. (Wishart, 1994)
- Dynamic Interpolation: The process whereby a sound gradually changes into a different sound during a single sonic event (Wishart, 1994)

8.2 Sound-toy Compositional Techniques

One of the main goals was to figure out how video game audio techniques can be translated into electro-acoustic sound processes. (For example, those provided by Wishart) The time I spent building the applications allowed me to find characteristics of unity that, upon deeper examination, have electro-acoustic composition techniques in common. These systems provide a variety of audio delivery choices that can help composers expand their toolkit and are, in most cases, exclusive to this type of composition:

- **Attenuation Sphere:** (See figure 7) Each sound object that produces a sound requires an attenuation sphere, a process of identifying how far must the listener be before the sound is inaudible. Once the min/max curves have been identified, further manipulations are available in the form of the type of roll-off curve you require within the distance previously identified. The curve can be linear, logarithmic or customised for your needs.

- **Random Container/Multi-sound:** Sounds chosen to occupy the system can be a single sound either set to repeat when triggered. Alternatively subtle (or not so subtle) randomisation can be achieved through multi-sound containers. Video-games can demand hours of gameplay and sounds can quickly become repetitive and immersion breaking. Unwanted phase issues can also occur if two sounds are played at the same time such as footsteps, for example, sounds one would often hear in a first-person shooter, and the sounds can quickly become repetitive. Randomisation containers are folders that could potentially house multiple arrays of that particular sound each one subtly different, within that container additional variation can be added in the form of volume and pitch creating an unlimited number of variations. Composers can use this device to introduce groups of sounds inside each container then associate that container to the symbolic, graphical object. Examples of this randomisation can be experienced in all four sound-toys presented with this thesis.

- **Adaptive/Dynamic music:** An adaptive score that can be altered by player interactions within the virtual environment, often this would be based on game world locations or perhaps narrative decisions, in the I.S.E's interacting with the game objects creates divergent music. There are many ways of integrating adaptive music into a game engine. A standard method is to arrange the musical piece into stems (separate tracks for different instruments or groups of instruments) and then play each stem at different times in order to give the music the feeling that it is evolving, or changing. Another method that is commonly used with the stem approach is to play different intensities of music based on the player's and

• **A.I.'s actions.** In a commercial game, for example, an investigation music cue is played when enemies are unaware of the player but then switches to a combat cue when the enemy A.I. become aware of the player. This gives the game a lifelike feel in that it is responding to player interaction and gameplay style, as well as creating a type of transdiegetic dialogue, communicating between the player and the player's character along with the narrative. Now the non-diegetic music warns the diegetic character vicariously through the player. Composers must now create evolving pieces that adapt to the change in gameplay and the style of the player. It does this seamlessly and can offer one continuous dynamic score that reacts to your every move. Moving from an exploration type score into a fight scene and back again into exploration is one example of this technique. This again adds a narrative to the game that is non-repetitive, reactive and helps maintain immersion. A simple form of this can be experienced in the sound-toy 'Flock.'

• **Snapshots:** Snapshots are incredibly powerful in Unity. The idea behind a snapshot is to be able to save the current state of your audio mix and call on them via scripting. It is possible to create multiple snapshots within the mixer. If for example, locations within the virtual space have different audio values, amplitude, dynamics or modulation, it is possible to create multiple snapshots. The advantage of this rather than merely triggering multiple sounds is simply memory allocation and optimization. Calling multiple sounds can tax the system and ultimately break immersion, with snapshots all the audio tracks are playing simultaneously and the snapshots adjust the mix once triggered.

• **RTPC:** Real-time Parameter Controls (RTPCs) enable you to control specific properties of various objects (including sounds, containers, control busses, and effects) in real-time based on real-time parameter changes that occur within the game. Examples would be in a racing game, and you can control the volume and pitch of a car's engine sounds based on the speed of the car and RPM of the engine. In a ski or snowboard game, the sounds generated by the skis can change with speed and angle. [Audiokenetic 2019] This can be experienced in CubeCrash, a sine wave was assigned to one of the cubes, and the pitch and velocity were linked to its axis, distance and height in relation to the listener

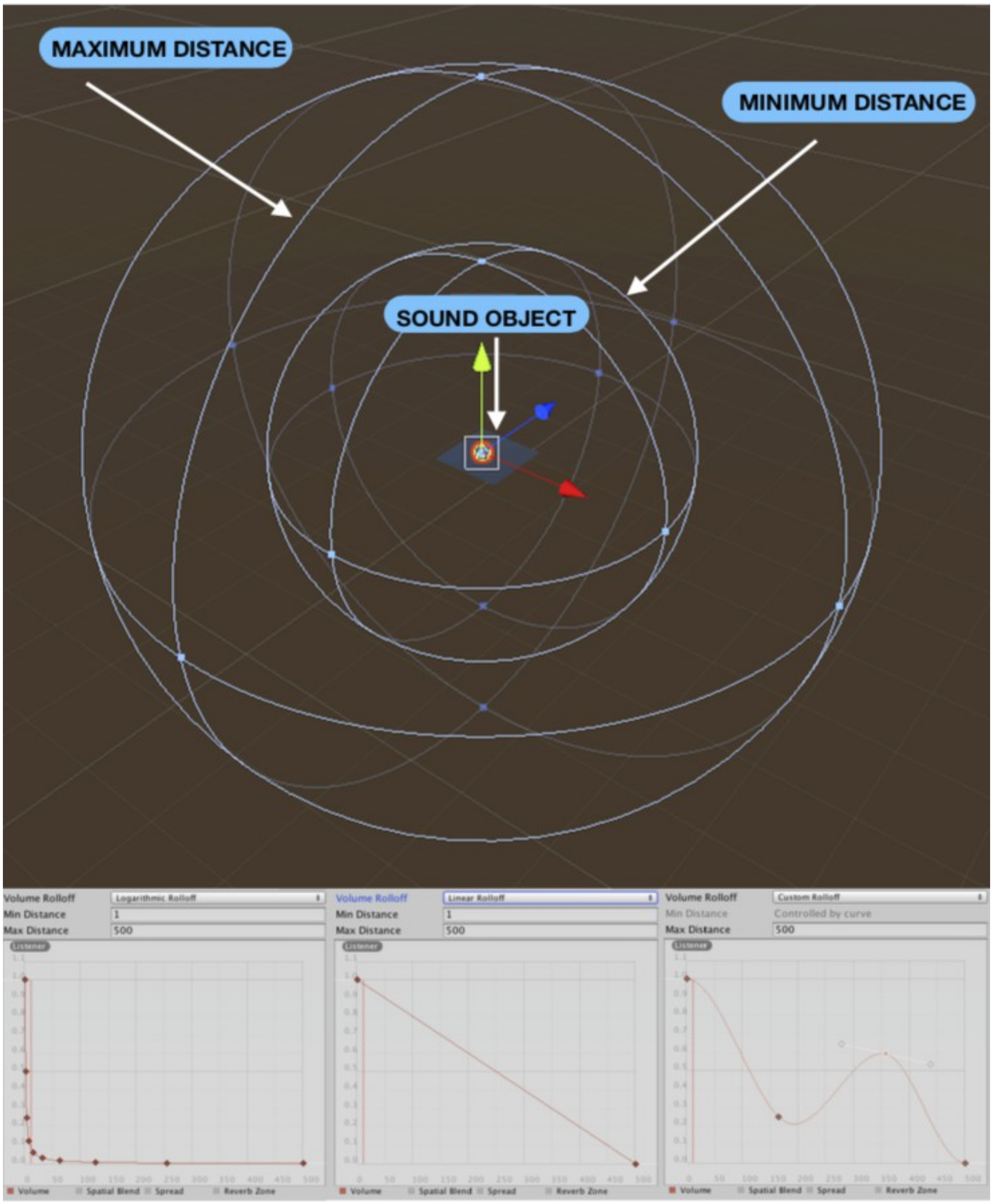

Figure 7:Attenuation Sphere and Volume Roll off Curves

9 Interactive Sonic Environments

The musical output resulting through cyclic exploration and revelations formed by attempting to 'play' the game with the mentality of a sound practitioner, as well as a study of the sound toys in relation to my creative process, will be explored in this chapter.

9.0.1 Instructions for Listening and Watching

Please copy all files to a Laptop/Desktop to avoid glitching and crashes. A mouse and a keyboard are required to control the systems, a sound system (preferably not laptop speakers) is required to hear the sonic output of both the interactive compositions and the fixed.

- Cube Crash

  Mouse Keyboard combination; WASD for movement within the environment, head movement is simulated via the mouse and the left mouse button is used to launch the light orbs.

- Platonic Solids

  Stereo audio only file, can be played on standard speakers. No specialist equipment necessary.

- Octahedral Symmetry

  Stereo audio only file, can be played on standard speakers. No specialist equipment necessary.

- RollerDrone

  Mouse Keyboard combination; WASD for movement within the environment, camera movement is simulated via the mouse.

- Tempering Valves

  Stereo audio only file, can be played on standard speakers. No specialist equipment necessary.

• Flux

Stereo audio-only file, can be played on standard speakers. No specialist equipment necessary.

• Immersive Heating

Stereo audio-only file, can be played on standard speakers. No specialist equipment necessary.

• MagnaWave

Mouse Keyboard combination; WASD for movement within the environment, camera movement is simulated via the mouse. The mouse wheel brings the objects closer to the camera. To instantiate a sound object Z X C V are used there is no limit to the number of objects you can instantiate however, be advised. This is a 3d graphical application and as such the more objects on screen the slower the frame rate. To activate the magnets within the environment simply walk over the switches on the floor.

• Residual Induction

Stereo audio-only file, can be played on standard speakers. No specialist equipment necessary.

• Dimensional Tolerance

Stereo audio only-file, can be played on standard speakers. No specialist equipment necessary.

• Flock

Mouse only, right mouse button to apply force to the cells, left mouse button to pick up the larger cell structures camera movement automatically follows the mouse.

• Codominance

Stereo audio-only file, can be played on standard speakers. No specialist equipment necessary.

• Polymorphism

Stereo audio-only file, can be played on standard speakers. No specialist equipment necessary.

9.1 Cube Crash

Initially, the plan was to start constructing an environment where I could govern the overall aesthetic (graphics, AI, and interaction schema). Due to skills limitations and a desire to start the development process, I turned to Unity's asset store. The piece's goal was to start looking at the idea of altering traditional game design templates to focus on meaningful auditory interaction. The inspiration for this build came from a Unity tutorial project. The three-video course introduces new users to the Unity systems gradually through the creation of a basic "knock down the cubes" game. It demonstrated how to navigate the editor, how to manipulate the camera in 3D space and how the physics engine works. This essentially allowed me to familiarise myself with both the basics of unity and begin analysing how to apply my sounds and to make notes on the creative process with this type of work. Interestingly the audio tutorial was minimal, no option to add variation to the blocks, this became very frustrating and perhaps endemic of the industry. Visuals and physics first, audio last. At this stage of the research, I was frustrated somewhat with the apparent lack of real time sound control, at least at my level of coding expertise.

By adding sophisticated audio systems provided by Wwise (of which I already had experience using commercially) I found it provided the platform with far more sonic possibilities. This was done from a desire to focus on learning unity as an application, again with little additional coding knowledge it was difficult to easily implement my aesthetic goals. Wwise allowed me time to experiment with the visual aesthetic of unity and leave the heavy lifting of sonic manipulation to Wwise. Reflecting on my aims of the output of the work highlights some commonalities that consequently became the main-stay of my creative process. Firstly, a combination of interactions was required; a mixture of short attack/quick decay sounds and an activated or triggered legato gesture. Allowing for the user to combine these and engage with sounds. Interestingly and perhaps unexpectedly, a major part of the creative process of I.S.Es revealed itself.

I assumed that a significant portion of the time given for this build would be spent learning how to implement the code and stabilising the build, but instead, the audio-visual relationship took up a significant amount of time. After gathering the sounds, I discovered that I was attempting to impose a visual aesthetic onto the audio. While the form of interaction, triggers, lights, and other game design principles were all met, I came to the conclusion that the next development should focus on this relationship prior to building the application. The end result is a proof-of-concept sound toy that shows how to use a simple on/off audio trigger, a throw script, and multi-sound containers to illustrate the power of game engines in avoiding repetition. Within the confines of this modest 3D environment.

The user can throw small spherical objects that clash and make a sound when they collide. Unity calculates the reaction time, velocity, and direction of energy transfer, responding with the environment using the cube's pre-calculated mass. Wwise, a middleware software, detects the collision trigger, and the associated audio is extracted from an audio container containing five grouped sounds. The sounds are classified according to the cube's texture. Three drone panels are located across the landscape and can be triggered by the players' thrown orbs. These extra layers provide extended 20-second loops with slight pitch alterations each time they are played. The goal is to establish an environment where people may interact with each other. By generating spectacular sound collisions, The user can begin to investigate how these sounds connect to one another by blending brief attack sounds with lengthy drone-like pads. The 3D texturing of the cubes provides clues as to the potential auditory output, which helps the user. Several technical and aesthetic challenges developed during the development of the sound-toy, providing useful information for the development of subsequent sound-toys:

- The environment, while visually appealing, lacks a feeling of spatial depth in terms of sound. The sounds are presented in a vacuum, allowing the user to get a feeling of position and size, which can help with semantic listening and give them a more immersive experience.
- Rather than stopping and starting, the drone panels build each sequence on top of the previous sound. By overloading the audio engine, it is eventually feasible to crash the system. In the future, I'll have to avoid this. The immersion may be shattered if the user becomes aware of the applications' limits.
- In order to provide more types of interaction, the ability to pick up, spin, and throw the cubes was required.
- The thrown spheres of light do not have any collision sounds themselves and as such only make noise when struck on the cubes.

9.1.1 Platonic Solids

The first attempt to turn a game experience into a more lasting media yielded mixed results. This piece is tonal in character, with long pitched sequences that have been clipped and reversed; it was unquestionably a work based on timbre, with many aspects of electro-acoustic composition methods that I have come to appreciate; The cube impacts from the raw material have been cut into grains and reconstructed. Various pitches have been overlaid with high-pitch drone panels. The cube impacts contrast with the pitched pad-like drones and are often absent of reverberation, which is an intentional choice to keep the textured material front and centre. Plenty of free space is provided by the reverberant, pad-like tuned material. The space is large, similar to the virtual environment in CubeCrash; however, a reverb zone was not included in the build because CubeCrash was supposed to be a proof-of-concept sound toy, and my abilities at the time were not quite up to the task. While the piece was satisfying on one level (as an electroacoustic composition), I began to question if the fixed media in any way matched the I.S.E; could I claim that the original material was from a virtual environment that was only being played with? The outcome was still unclear at this point.

9.1.2 Octahedral Symmetry

After analysing Dolphin's sound toy principles, I began to utilise CubeCrash as an instrument to try to master it, and it revealed certain flaws that eventually impacted my future designs. Issues like the on/off trigger not halting the preceding sound (which was later fixed with an if/else C# script), leading it to increase in loudness, as well as some minor phasing issues. As I moved around the space, these drone-like pads were engaged and could be triggered concurrently, causing phase and comb-filtering. Later, I corrected this by adding a starting offset to the audio engine, ensuring that the sound would be played at a random position within a pre-determined range with each trigger. This starting offset quickly became an aesthetic as well as a functional choice in my emerging creative process, as it was a completely unexpected component of my evolving creative process. It's apparent that the individual cubes' auditory textures have enough variance to avoid repetition, a technique borrowed from commercial game design and used extensively in the I.S.E's composition. The lack of reverberation also allowed the listener to concentrate on the sound object rather than the space, which I later decided to avoid. The 'feel' of the piece, in my opinion, was heavily influenced by the location, visual aesthetic, and sense of place. The RTPC-controlled cube, on the other hand, was a huge hit, and it gave me the option of using procedurally generated synthesis in my future works. (I subsequently abandoned this idea since the procedural components of game audio always clashed and stood out against my found sounds, and they were too similar to generative audio design, which I wanted to avoid.)

9.2 RollerDrone

The goal of RollerDrone was to create a more engaging controller method based on what skills that were mastered during CubeCrash. I wanted the user to feel like they were getting better at utilising the I.S.E, so I referred to Dolphin's sound toy classifications for inspiration. The musical output gets more focused, and the user can begin to map a course to actively produce more meaningful compositions by exploring the environment. This sparked the notion of creating a graphical score that might be used to motivate a performance. This I.S.E is certainly closer to Dolphin's instrument classification, but only in terms of mastery via repetition and exploration. The player controls a sphere within a virtual space populated by other 3D objects that all create sound or manipulate it using real-time effects like modulation and distortion. Wwise, a middleware engine designed to handle all audio before it reaches Unity, is in charge of 3D position data. The output is derived from a combination of 'Play' and intentional compositional selections made by the user using Real-Time Parameter Control (RTPC). RollerDrone is a 3D virtual world for sound editing and exploration. It utilises the robust physics engine within Unity to create a realistic touch and ‘feel’ to the objects within the environment

The underlying system breakdown is seen in Figure 8. While it does involve some competence, it is mostly aimed for casual gamers and interested sound practitioners. It has no player 'goals' as such, instead encouraging the user to explore the sounds and experiment with ways to modify them. The player-controlled 'ball' can freely travel around in its 3D surroundings, with directions allocated to the WASD keys and the camera or 'Eyes' linked to mouse movements

The ‘Ears’ or listening device is also mounted to this camera, allowing full 3D sound manipulation tied to the direction that the player is looking. Occupying this environment are several spherical objects that emit both light and sound in the form of continuous drones. All of these sounds were derived from a water immersion heater's various sonic structures. The player can move the objects by colliding with them; UNITY simulates the physics and velocity calculations, which are then communicated to Wwise. Each object's mass and drag are linked to its sound; the more massive the object, the lower the sound frequency, and vice versa. The environment has panels that affect the sound when the objects roll over them, ranging from pitch changes to reverberation and phase/flanger. These effects happen in real time and are influenced by the camera's 'Ears' and 'Eyes' positions. Because there is no obvious indication or label on the panels as to what effect can be achieved, the player must rely on trial and error or improvisation to figure it out. This sort of Real-Time Perimeter Control (RTPC hereafter) relies heavily on the connection between UNITY and Wwise.

The audio engine in Unity is perfectly capable, however generating the amount of randomness required would necessitate substantial coding knowledge. Wwise does away with the requirement for code, allowing the designer to experiment with new sounds and effects while simultaneously testing the results. The following interactive variables were established for the user:

- Panning and directionality via the camera controls
- Transformation of the sounds via the effects panels can alter any sound within its space, visual confirmation through particle effects contributes to multi-modal feedback
- Velocity of the drones, more speed equals a sharper attack or quicker decay to the sound being emitted.
- Superimposition of overlapping drones as they are collided with and gathered.
- Duration

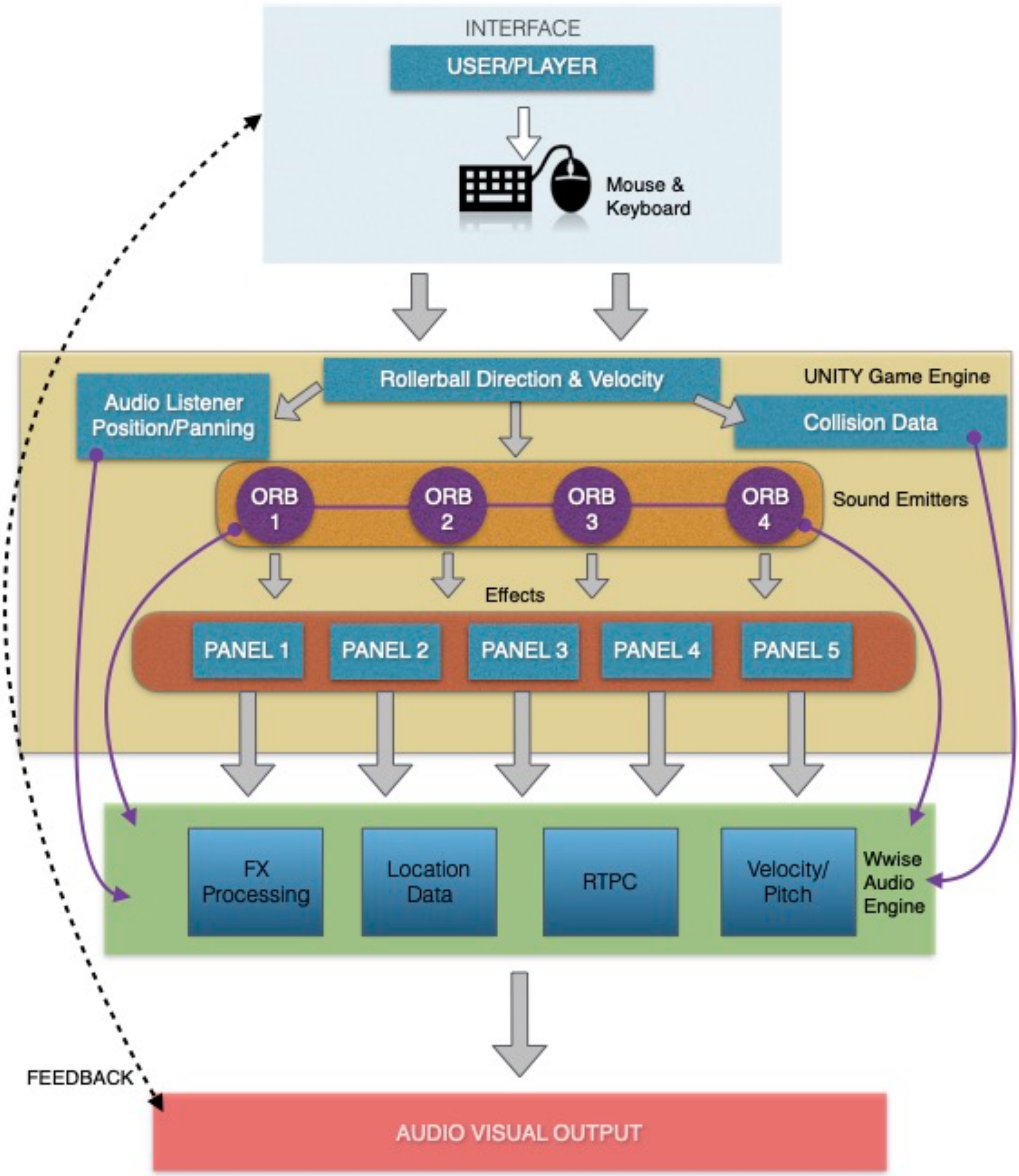

Figure 8:RollerDrone System Structure

The audio from these play sessions is directly routed into Logic for further editing and composing work. It's worth noting that an attempt was made to keep the original mobility or exploration of the 3D environment during this process. All of the panning and dynamics from the game's first playthrough have been preserved. Only minor editing has been done when making these compositions; the most prevalent techniques are sound grouping and texture modification to produce motions, which are then fed back into the game, and the cycle repeats again. The composition is refined each time to provide the user a better understanding of my compositional process. All of this is done within the context of an analysis framework based on questions like "How engaged am I?" "How immersive is this?" and "Is it easy to interact with?" RollerDrone is built for collaboration, with a graphical score (figure 10) that allows a user to follow a pre-defined course and a legend or key to explain the symbols. It's only a guide; the specific sound orb to find and interact with, as well as which effects panel to utilise, aren't specified; this is just an example of how one may use it in a concert setting.

I proceeded to consider how to instruct a practitioner on how to use this as an instrument or as a creative tool, and the sound design specifications list was born (figure 9) This document contains instructions for sonic artists who want to create sounds for this platform. It's merely a guide, but it covers the audio source location (where the sounds come from) and type (impact, drone), as well as the types of real-time effects that are applied within the environment and how the composer can define those effects. The macro interpretation of his or her work encourages the composer to concentrate on individual sounds by group (drone, impact), as well as the possibilities for manipulation and change, resulting in a sort of reverse engineering of their work.

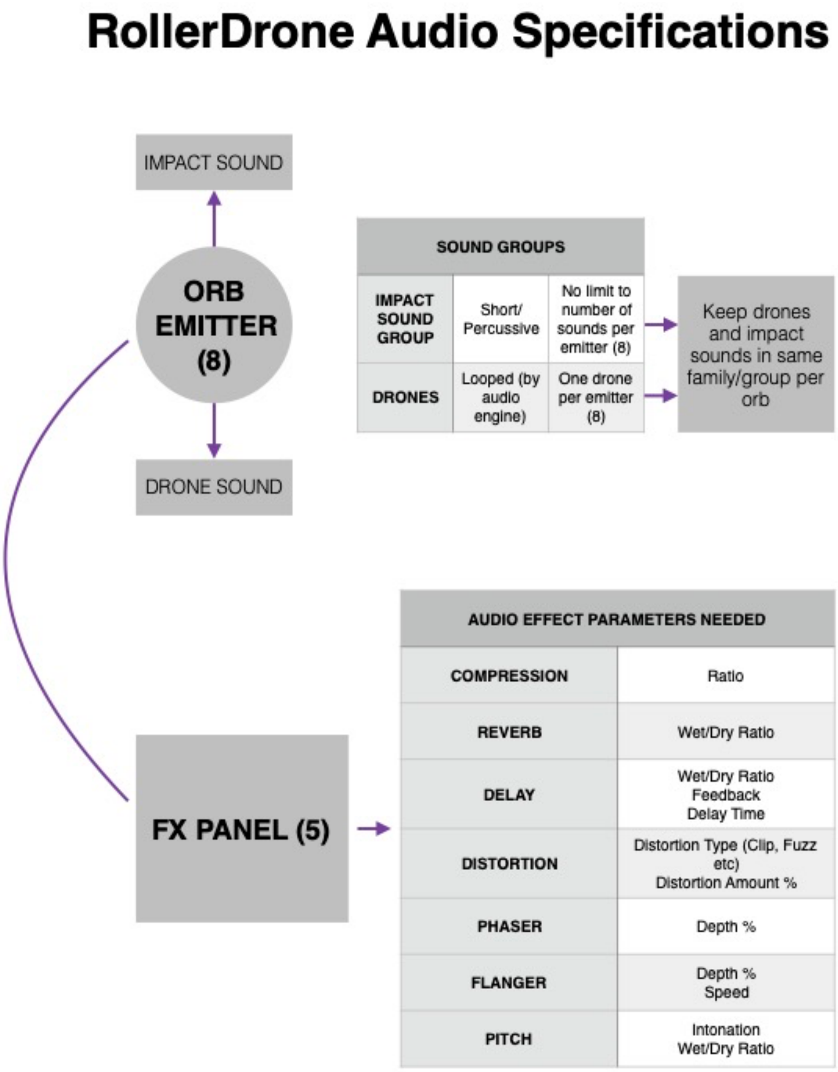

Figure 9:RollerDrone Audio Specifications

All sounds originate from an immersion heater and noise generated from the plumbing in a bathroom, the theme was to use metallic sources that resonate and produce sound when under heat and pressure or activated.

Sounds Used:

1. Musical/Pitch/Drone:
   (a) Musical Bell & Water Drip
   (b) Musical Metal Scrape
   (c) Water Dripping
2. Repetitive/Short/Impact:
   (a) Immersion Heater Knocking
   (b) Pitched up Boiler Ignition
   (c) Splashing Water
   (d) Pipe Knocking & Water Dripping
   (e) Light switch on & off pitched both up and down

9.2.1 Output_1: ’Tempering Valves’ Open Interactive Composition with Graphical Score

Tempering Valves is the name given to a complete 10-minute play-through of RollerDrone that is completely unedited and has undergone no extra processing (save for mastering compliance) The sound groupings in the interactive composition are the same as in the fixed piece. This is an example of the several kinds of musical gestures that the 'play' session can provide. This is not a definitive version; rather, it is an illustration of the varied character of this event, which must be experienced to fully appreciate its potential. A hybrid composing technique was used for many of the fixed pieces in the folio. The source material was taken from 'play,' and then electroacoustic techniques that are well-known were used. With this piece I wanted to experiment with a completely untouched composition, one that can be 'conducted' or steered using either the graphical score or several play-through attempts, and then rehearsed and mastered. Tempering Valves is the end outcome.

9.2.2 Discussion

The work, which arose from improvisation while attempting to learn the controls method, exemplifies the platform's possibilities. The 0:00 to 0:13 second introduction sequence displays how easily one drone sound may be contacted, pushed into an effects panel (distortion), and then passed by another drone while the listener or controller drone goes into a new space. This effectively generates a musical gesture by seamlessly transitioning from one drone to another with realistic real-time amplitude adjustments and crossfades. At the 1:00-minute mark, an example of focusing on one specific drone texture, a pitched musical bell a gamelan style texture, can be heard. The listener drone slowly approaches and begins almost pianissimo as it surrounds the musical bell, gently probing and pushing the drone into an effects panel (1:09), and once there, the listener drone goes about the space changing its amplitude once more. The gamelan gesture melts away, revealing the bowed stretched metallic drone, and contact is made with an effect panel once more after a brief respite induced by the listener drone detecting another off in the distance. When listening to the stereo fixed file, these types of interactions appear contrived, although these motions are produced in real time.

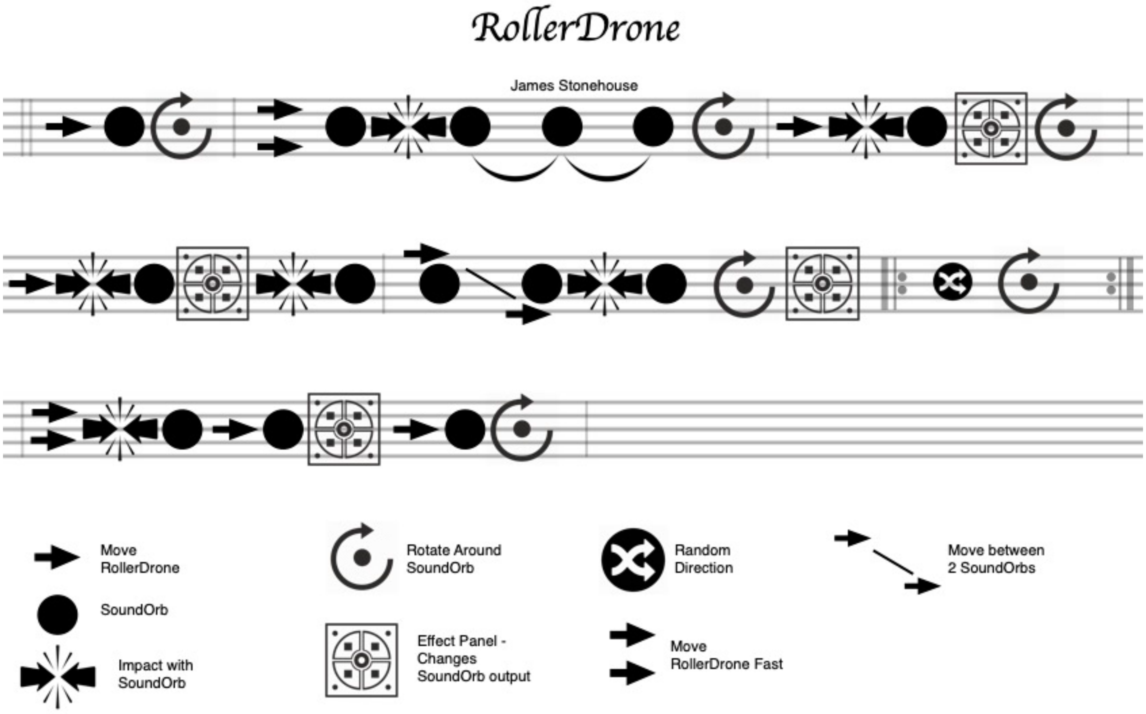

Figure 10:RollerDrone Notation

9.2.3 Output_2: ’Immersive Heating’ 10mins

The goal of this piece was to keep the freedom of the original open composition while imposing a defined sound metamorphosis from one 'drone' or 'sound object' to another. The focus was on pitch, directionality, and intensity, with a desire to render the sounds with a mechanical timbre to maintain the theme's structure. The pre-composed output is the result of pure experimentation and play, with no preconceived notions of how the sound would develop. The act of playing RollerDrone reveals two basic forms: the act of learning the system in terms of how to move the listener and the input required to make things happen. This leads to a very abrupt jump from one sound source to another, rapid rotations of the camera and moments of silence as the user are adapting to the feedback presented. As the user adapts to the schema, sounds are presented in a more focused manner, with the user locating a sound and experimenting with ways to change it. As a result, panning, intensity, and real-time effects control become increasingly measured. The sound in the system has already been manipulated in subtle ways, with the bulk of it comprising of adding reverberation to change timbre (rather than being utilised to create space) and modifying frequency content. Before applying conventional compositional techniques, the system should have enough fascinating sound information to stand alone.

9.3 MagnaWave

At this point in the study, it became clear that one of the most important considerations to make while designing I.S.Es is the control mechanism. This insight was crucial for developing a framework; without a clear idea of how the user will interact with the sound, it's difficult to make meaningful connections between the audio and the images. MagnaWave’s interaction mode was inspired by popular video game aesthetics from the first-person shooter genre. A first-person perspective 3D environment in which the user can interact with sound elements. I also wanted to be able to design a means for the user to create or utilise items on their own. This gives the user more control over the work by allowing them to choose how many sound elements to utilise.

Additionally, once the objects were instantiated an option to allow manipulation of three magnetic fields was presented, one large and two smaller in order to create audiovisual formations affected by magnetic forces. The size of the magnets is directly related to the strength and size of the magnetic energy field. All three are set to attract or repel the sound objects that have been created. A small positive sphere, a considerable negative sphere, a small positive cube, and a large negative cube are generated with the Z, X, C, and V keys, each with a different polarity and musical quality: There is no limit to the number of these that can be added to the scene. In addition to a more prolonged sonic gesture that is tied to the object being dragged or rolled, each generates a short impact sound on collision with small pitch fluctuations to avoid repetition. It is possible to turn on and off the magnets in the environment. The area has also been portrayed musically, with the goal of instilling a feeling of place that would enable the user become immersed in the environment. As a fundamental source of inspiration, all compositions produced from MagnaWave are magnetic. The numerous forms of magnetic behaviours and how magnetic forces interact. The song has a metallic quality to it, and there's a desire to keep the motif going. Texture, movement, and perspective all play a role in the creative process.

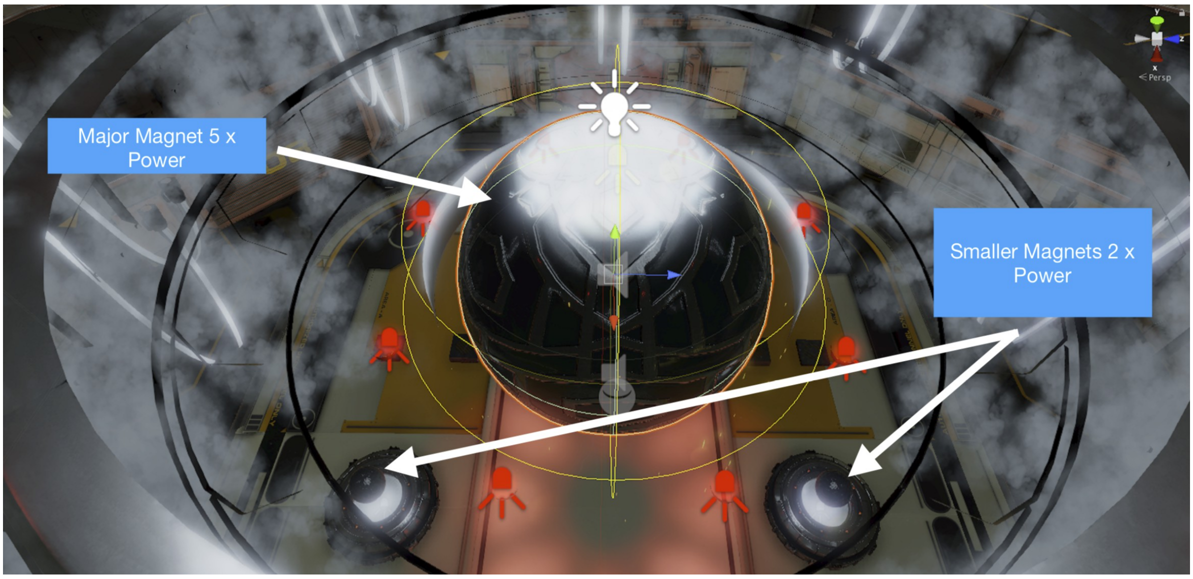

Figure 11:Top-down View of Magnet Locations in MagnaWave

Sounds Used:

1. Piano Box:

   (a) Piano strike in C with +/- 10 % pitch variation on each collision

   (b) A 0:30-second drone derived from the piano with velocity and doppler interaction

2. Rubber Ball

   (a) Rubber ball impact on concrete. 4 Variations with +/- 5% pitch variation on collision

3. Brick Box

   (a) Brick Impact on stone 4 variations used with +/- 5% pitch variation on collision

   (b) Brick scrape on stone 2 variations 15 seconds long

4. Plastic Box

   (a) Large plastic box on concrete impact 3 variations with +/- 10 % pitch variation on each collision

   (b) Plastic box scrape on concrete 15 seconds long with velocity and doppler interaction

5. Large Metallic Sphere

   (a) Glockenspiel in key of C with +/- 10 % pitch variation on each collision

   (b) Cello legato note in A with velocity and doppler interaction

9.3.1 Output_1: Flux (Open Interactive Composition)

This work, like Tempering Valves, is based on a play-through after a certain level of mastery has been achieved. The overall goal of the piece was to magnetise sound objects and build clusters of them. As the magnetic forces are applied, these clusters provide highly vivid visuals. Only a few piano boxes are instantiated into the scene from the beginning until roughly 0:45 seconds; the listener hears how they interact with the surroundings and each other, and they are occasionally moved, allowing the lengthier drone-like sound to be heard. The rubber balls are introduced at 0:53 seconds and begin colliding with the piano blocks at 0:55 seconds. The pitched piano dominates the upper frequencies, while the bounce sound of the rubber balls dominates the lower mid frequencies. The piano blocks tumble about the area, creating a *Sonagliato*, a ringing of miniature bells. The sound is a piano striking in the key of C, but the pitch variations performed when building the sound toy result in a cascade of high pitch notes. At 1:20 seconds, the first magnet is turned on.

As the magnetic forces are applied, the bell-like piano boxes begin to race around the environment, and the second magnet is introduced shortly after. As a result, the piano box structure [Figure 12] begins to take shape. The interaction with the piano box magnetic structure continues for the following 2:00 minutes, with boxes being taken from the structure and then released back into the magnetic field, making little movements of pitched piano strokes followed by dragging drone-like noises. The glockenspiel-like metallic sound orbs are picked up and collided with at 4:00 minutes, making them louder and more defined than the piano strikes, and then the brick and plastic items follow. At 4:30, all of the possible sound groups occupy the scene, and in order to make one more dominant than the other, either more objects are created, or the listener moves to the sound group he or she desires louder. More interactions between the sound groupings are heard in the final 60 seconds.

Figure 12:MagnaWave Sound Group Formations

9.3.2 Output_2: Residual induction

The objective here was to play with the diegesis after placing ambient location noises (server fans whirring) within this sound-toy. To achieve perspective shifts in the music, the goal was to stay close to the original material, apply small sound alterations gradually, and keep the sense of place from the beginning, gradually moving away from the source material and into a metallic succession of pitched hits. The perspective swings away from the original space (the diegetic) and towards a non-diegetic space filled by drones, scrapes, and tonal sweeps at 40 seconds. This viewpoint shifts back and forth repeatedly, with minor pitch undertones. At roughly 60 seconds, there's a rising, low-frequency drone that stays in the centre as various gestures are placed on top of it, as well as glitched beats that dance around the stereo field (1:23) The glitching is introduced to keep the piece's nonorganic origins, and it progresses to a series of glitched piano strikes before ending.

9.3.3 Output_3: Dimensional tolerance

In manufacturing and engineering, dimensional tolerance refers to the capacity to compute the tolerance for a dimension. Using the same source material (the initial play-through of the interactive composition) and incorporating this subject into my piece meant that I had to first identify the dimensions that I would be stressing and bending. As a result of my decision to interpret the dimensions using frequency bands, three dimensions were grouped. Material with low, mid, and high frequencies. It was possible to construct a low-pitched tone drone that steadily varies from G to A in a 40-second loop obtained from ambient sounds of the environment using a combination of filters and alterations utilising flex-time. The composition begins with a mechanical growl in the low mid-range with a boost at 40hz, followed by a low-frequency layer about 80-100hz combining and attaching itself to the drone. This layer is full of stop-starts and has a distinct metallic mechanical sound; it is cut and looped from the sound of the brick object within the sound-toy, so some effort has been made to retain the large hanger-like reverberant space; underneath this layer is a low C hum provided by a morphoder adding a pure sine wave.

All low and mid-frequency content has been eliminated, and a resonant filter has been applied to provide a diffused noise-like structure that builds to a crescendo at 1'25". The third band is introduced at 30 seconds; this mid-range dimension is slightly tonal and has a long drone-like gesture that is occasionally disturbed by filtered brick drops; the midrange has been boosted, and the track gains an underwater-like quality that when superimposed by the other dimensions creates a complete sound-field. A sequence of pitch bends and distortion with quick stop and start sound objects, mainly in the high-frequency range, were used at various points throughout the piece to stress these dimensions, to bend, stretch, and break them. Finally, from 2'30" onwards, just the low and high dimensions remain, both of which have been fractured and their pitches changed. The high-frequency dimension is scratchy, while the low-frequency dimension has a pulsating amplitude, indicating that the structure is unstable.

9.4 FlockAudio

Flock is the conclusion of the abilities developed in the design of earlier sound-toys, an environment that was created from the beginning with a clear aesthetic and functional aim, using the Sound Toy Compositional Process diagram (figure 14) With a better grasp of the process, I was able to better plan my time; although being a completely new control system, this I.S.E took a third of the time to construct as compared to the others. Original backdrop artwork, dynamic lighting, particle effects, and artificial intelligence are all examples of my impact in this 2D composition. I wanted to ensure this was as far from a UNITY template as I could get, I also made the decision that I would incorporate multiple aspects of sound interaction, from triggers to sounds that continuously play. The decision was made to use a 2D interface to make it easier for users, feedback from previous I.S.Es highlighted a steep learning curve to some, navigating in a virtual 3D space can be perplexing to the uninitiated. The theme is one of being inside a living organism and interacting with banks of microscopic cells. The visual representation of these cells houses several sound objects that each emit a single sound upon collision. The collision event is taken from an array of sounds that are randomly chosen when called for, in addition small pitch and volume variations have been added in order to continue with non-repetition. Three ‘banks’ of cells each exhibit adjustable behavior within a group.

This behavior mimics herd mechanics, more commonly referred to in the gaming industry as flocking mechanics, a rudimental form of Artificial Intelligence whereby game objects have a simulated animal herd behavior attached to them. In the context of this sound-toy, the user observes sonically, and visually complex group dynamics and behaviors, specific parameters of the AI script can be affected by the user, altering the speed, accuracy, directionality and proximity from each other using sliders on the user interface.

The flock mechanic works on three basic principles: the item or particle, which we'll refer to as cells in this case, examines its average location in relation to its group's neighbours and adjusts its position based on the information provided. The second rule is to determine the average heading of the group and alter its own heading accordingly. Finally, it must be able to avoid clashing with its immediate surroundings. Flock's level of involvement is displayed in numerous ways, the most notable of which is the customisation of herd behaviour within each group, as well as the position of the listener, which influences panning and volume. In this example, the listener is tied to the mouse pointer, and further impact noises will be triggered by colliding and pushing the sound objects/cells across space. To minimise repetition, subtle pitch changes are used, and organic features that simulate obstacles inhibit herd development and activate a sound when struck. Flock’s objective is to play around with AI, and the sliders alter the behaviour of each sound group/herd, allowing the user to create fascinating interactions between them.

9.4.1 Creative Functions

The main aspect of this sound-toy is the large number of variables that allow artificial intelligence to adapt the behaviour of a group, which considerably expands the auditory possibilities. The unit manager (shown in Figure 13) is positioned within the scene and provides a user-friendly interface.

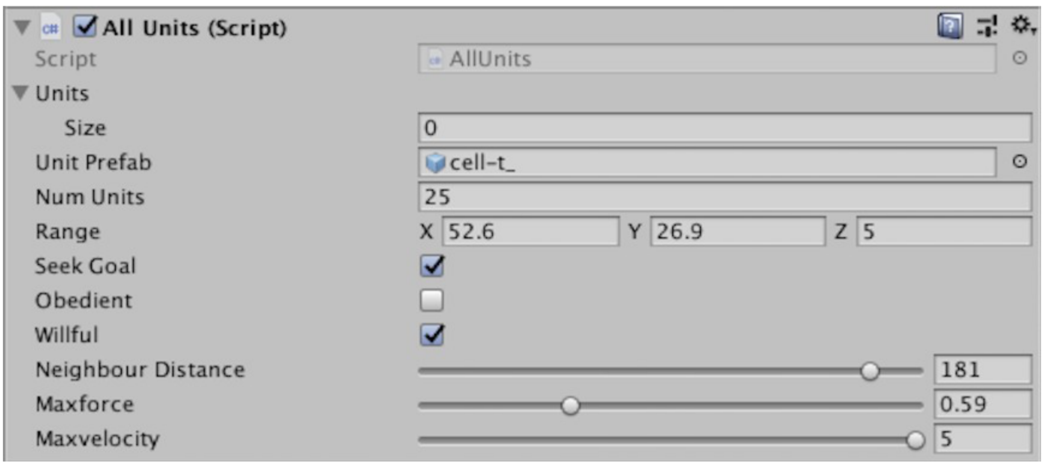

Figure 13: Flock Component Variables

• Size: This variable enables the designer to introduce more than one type of cell prefab that may or may not have its own set of components, that are governed by the groups' behavior settings.

• Num Units: The number of visible cells on screen at one time.

• Range: This is the range in which the cells can roam regardless of its behaviour settings, essentially the amount of the screen they can potentially occupy

• Binary Variables: Three on/off variables that directly control how the cells react to one another. The seek goal variable enables the individual cells to head towards a location defined by the unit manager, the obedient variable defines the relationship of the cell to its neighbour if the cell has no goal to seek it will instead decide to flock and maintain its given position to its neighbor creating a herd or flock. The willful variable defines how much attention to pay to its neighbors, essentially giving the cell individuality.

• Neighbor Distance: The distance relative to other cells within its flock or group.

• Maxforce: The maximum amount of force applied when colliding with objects.

• Maxvelocity: How fast the cell can potentially travel as it abides by the above rules.

9.4.2 Output_1: Polymorphism (Open Composition)

The final 'live' play-through of Flock came after applying the ability to push out the smaller microcells and the ability to move the focus cells which the micro-cells gravitate towards based on the AI parameters mentioned earlier. The piece opens up on a quick tour of the four drones structures that reside in the four corners. At 25 seconds, the first sounds of interaction with a group of microcells are encountered. These mid to high-frequency clicks move in the stereo field from left to right, and due to the lack of reverberation on these microcells, the perspective is very close making the drone quadrants distant and ambient. This echoes the visual style, as the cell wall is far behind the foreground, causing it to move at a different speed, a method known as 'parallax' in game production, which I intended to imitate in the audio realm. The foreground had to be fast, acute, and aggressive, while the backdrop needed to be ambient, distant, and tonal. Around 1:06, the first interaction between two cell groups occurs, with high-pitched clicks flowing from the left to the right, where more mid-range sounds arrive, gradually giving way to one of the drone quadrants.

The piece's fundamental characteristic became the contrast between foreground and background. One of the sound groups breaks off around 1:24, as the microcells urgently struggle to find their focus or host cell. This results in stuttering or glitching; this is not a programmed effect because it occurs in real time. This is another example of the kinds of interactions that may be found within a sound toy and can be used to represent more well-known electroacoustic composing techniques. As the microcells' paths narrow, a series of tiny clicks and scratches occur as they bottleneck at this point.

9.4.3 Output_2: Codominance

The premise of Flock was cells within a live body, and the capacity to manipulate their behaviour can lead to superimpositions with a degree of limited indeterminacy. This composition combines two strong forces in the audio, brief attack clicks and a pitched fast attack sound, as the title suggests. Rather than having one sound dominate the other, the goal was to make both of them inhabit the sound field. The short clicks add a noisy texture that mimics the other sound's pitch, transforming the pitched cell into a non-pitched noise. It works as a juxtaposition to highlight the two dominating cells and their relationship by superimposing these sounds upon a third cell that occupies the sub frequencies. As previously stated, the mouse pointer serves as the listener. The user has complete control over the location of the pointer and the sound's focus. The cell manager can also be picked up and moved with the cursor, which is the purpose that the users assigned to that manager are attempting to achieve. This frequently results in rapid cell displacement when attempts are made to split the cells apart in order to better understand how the AI behaviour functions to bring them together. In sonic terms, this leads to short, loud clusters of sound and movement from left to right. Codominance attempts to maintain that movement. Another defining factor in this piece is the use of additional pitched material, a decision based on the theme of organics. While the sounds are mechanical in nature (recorded nuts and bolts being dropped onto a sheet of metal) superimposing that onto a resonant chord reverb emitting a minor triad in C brings a harp-like ringing that diffuses into the background.

10 Creative Strategies

The following insights were taken from notes pertaining to the design and testing phases of the I.S.Es. The reflective approach to the framework was necessary due to the way that the all the I.S.Es informed my process for the next application. Each time the process became more intuitive and structured. Each I.S.E presented new unique challenges but by the time ‘Flock” was designed the majority of the sound gathering and artistic intention (Internal Composition, see figure 14) was standardised. In order to look more closely at my compositional process and aesthetic intentions with the I.S.Es, it’s impossible to overlook the effect of playing video-games has had on me. In addition to being a composer, I have been an avid gamer for nearly twenty years. It is clear to me now that this has had a major impact not just on my hopes of using video-game technology to create sonic artworks, but also on how I design and test the systems I am creating.

Although these platforms do not use gamification in the classic sense, I still wanted to give the user a meaningful interactive experience by leveraging traditional video-game input methods like mouse and keyboard or gaming pad. With that in mind, it's reasonable to say that interactive media all have a complicated relationship of images, interactivity, feedback, and sound, therefore designing one required me to consider all of them while staying true to the work's aesthetic objective. Textures, environment size, control technique, and camera perspective all became key parts of my creative framework as I quickly realised the vast number of non-musical artistic choices required to develop these I.S.E platforms. In order to highlight important contrasts between an I.S.E composer and a composer of a more traditional or fixed linear media, it is critical to illustrate the particular problems of this medium during the design phase.

It became clear early on in the design phase that 'software development' would consume a significant amount of time. While a working knowledge of Unity was already in place, some systems necessitated a deeper grasp of 3D environmental level design, particularly when attempting to produce 'engaging' and 'immersive' experiences, similar to Dolphin's 'metaphorical functions.' When considering attenuation, for example, this notion comes into play.

When the audio-trajectory and location are merged into a single on-screen gesture, the virtual space can be better understood. The decision to utilise visual feedback of auditory occurrences in my interactive works served as assurance to the casual listener that they had altered the sound in some way. I discovered that some sounds and gestures in the virtual environment can be changed in ways that are too subtle for some users, so the logical solution was to employ massive, easy-to-understand alterations like modulation, reverberation processing, or distortion. That, however, would leave out more subtle changes such as moderate dynamics processing or listening for examples of superimpositions, which was not an option. As a result, the compositional process now includes artistic visual aesthetics and multimodal feedback that are more in line with commercial game design than with the sonic arts; particle effects, lighting, and textures are now arguably as important as musical gestures and motifs. This procedure resulted in three issues:

To begin, while building playful experiences, the manner of engagement is crucial, and ease of use is essential. A traditional video-game control mechanism was adopted for the most part, and to provide some type of continuity. A mouse/keyboard combination or a controller familiar to gamers made these builds more approachable to the non-practitioner target audience, letting them to become active listeners and participants in electro-acoustic creation. Surprisingly, while these control mechanisms provided access to the average listener, they had the reverse effect on experienced sonic artists. They were unfamiliar with the game-like control approach.

Second, the systems can sometimes transcend into the domain of instruments by conforming to well-known commercial video-game aesthetics to stimulate play and immersion. Time spent on the system can result in a much more concentrated composition, and with repetitive play, a level of skill can be acquired, allowing you to fully explore the system's capabilities.

Finally, to keep the build as Sonic-centric platforms, a balance between audio and visual has to be struck. A concerted attempt to make the graphics simple enough not to dominate yet sophisticated enough for the listener to grasp its link with the play space and provide visual feedback was used to overcome this process.

Although classification is to some part a matter of opinion, with numerous definitions often overlapping, categorising the I.S.Es is dependent on the interactive approach used. They do, however, have certain similarities in terms of design. All of them make an effort to encourage the user to shape and reconstruct the sound over time. This implies that the I.S.Es are fundamentally compositional, with rules established by my compositional framework. I intended to define the steps of design as the research progressed, both to better my own process and to give a formal analysis to the field of study. I had enough information after designing three of the four platforms to formulate a framework, one developed from the cyclic process of designing, testing, and rewriting the I.S.Es. Three critical stages of the I.S.E compositional process were discovered (see figure 14) Each comprises a variety of activities that are both familiar (to a composer) and unknown..

The nested Venn diagram was used to emphasise the impact of the phases on the bigger entity, in this case the sound output. Before thinking about the audio component, the early stages of creating the I.S.E started with the environment and style of interaction. These environments were frequently adapted from Unity's asset store's royalty-free game templates or tutorials. While this provided me with some much-needed game production abilities, it also consumed a significant amount of my time. After a six-month development phase during which I produced a variety of modest applications, it became evident that I was attempting to 'shoehorn' my musical ideas into these surroundings rather than examining the visual aesthetic and its relationship to the aural input. After I felt I had the knowledge and skill set to comfortably develop the applications, I stepped away from the gaming engine and instead began the process of sound gathering and composition.

10.1 Internal Composition

I began gathering sounds and other musical gestures that I would require for each piece, as well as organising and processing them according to the topic or aesthetic aim, which I dubbed the internal composition stage. Composers will be familiar with this stage, which is similar to traditional ways in that an overall topic is discovered and presented. The sounds are processed in Logic X using recognised editing and sound manipulation techniques.

I discovered that I could either divide a completed fixed musical composition into smaller gestures or stems by carefully considering the sonic opportunities when interacted with (real-time pitch control, panning, and reorganisation in a 3D space), or I could choose sound objects less holistically, instead choosing sounds on their own merit and potential for meaningful musical interaction. The latter concept was more appealing to me since it provided greater room for indeterminacy and unpredictability.

10.2 Medial Composition

The second phase took the longest because I discovered that a rational approach was required when designing the rules that will govern the system, such as the placement of sounds within a virtual environment, the visual aesthetic, which could be literal or metaphoric, and coming up with interesting ways to interact with these sounds to provide meaningful feedback for the user, all with the goal of making the experience engaging through my chosen mode of interaction. This I dubbed the middle composition process because it typically took months to complete and followed a more traditional iterative design process. In terms of a cyclical stage of design, implementation, and testing, it's similar to commercial video game production. This stage was often frustrating for me, especially with CubeCrash and RollerDrone, as numerous versions crashed or created game systems that did not perform as I wanted, but it was during this phase that I learned the most. As a result, I've learned that having a lot of patience is necessary, and that taking a systematic approach to a problem typically solves it, as well as accepting that designing game systems and modes of interaction will always be challenging owing to my lack of coding knowledge and game design experience.

10.3 External Composition

I dubbed the final stage "external composition." I intended to merely capture the output of playing with the application at first, but I soon realised that the output demanded a more intuitive way. After playing the I.S.E platforms, I now realise that this phase can be so much more, especially when considering Dolphin's sound-toy classification. This understanding prompted intriguing creative questions, such as how will these systems' final musical output be presented? Either through fostering immersive experiences to create interactive open works, or by leveraging the 'play' session as raw material for a fixed medium, and eventually as a playable instrument. This understanding would prove useful to me because, as the final output of my I.S.E platforms can have elements of all three.

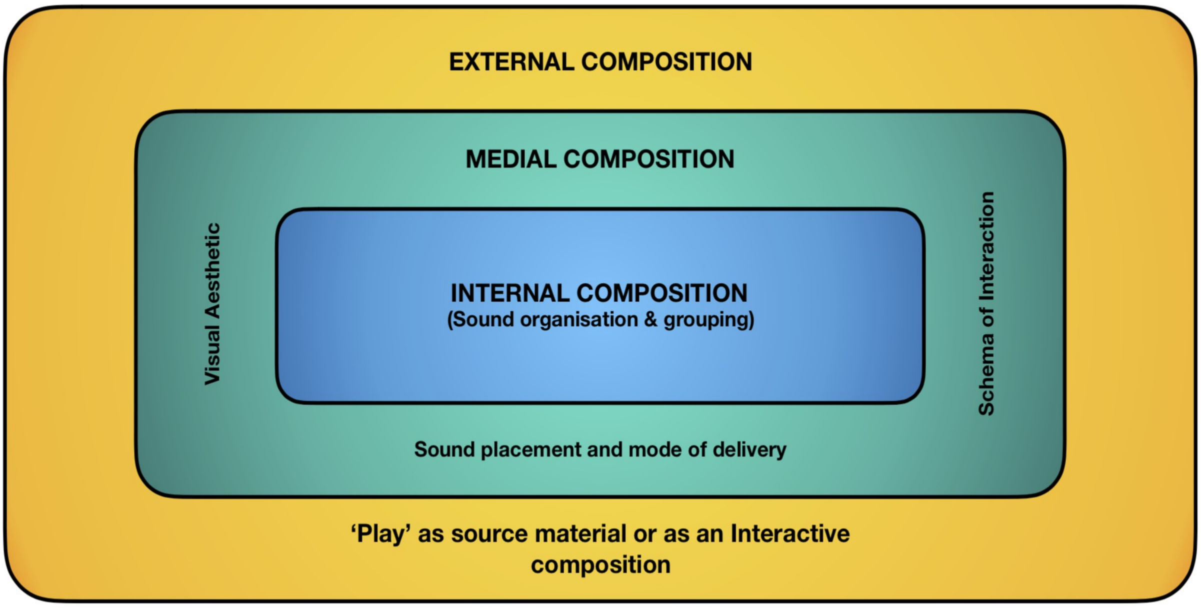

Figure 14: Sound-toy compositional process

11 Conclusion and Further Research

As a result of the sound-toys' creation and testing, my abilities as a composer improved during this research. By releasing my sounds, phrases, and musical gestures in a nonlinear manner, I am able to experiment with imposing symbolic and metaphoric visual and kinesthetic functions into a 3D interactive environment. It grew more difficult to compose fixed pieces by the conclusion of the four years. Using the I.S.E's output in this way felt limited and exclusive, as if it was just for the initiated or learned practitioner, which was something I intended to avoid. The purpose was to provide inexperienced listeners the chance to interact with electroacoustic works through interactive play. As a result of reverse engineering my work, I started to rethink the piece's overall aesthetic. Making a fixed piece first, then identifying gestures and occurrences that could be made interactive in a virtual environment. My research started out as more of an instructional tool, a way to encourage participation in what can be a challenging art form to grasp. The I.S.Es immediately turned their focus from education to advocacy for this programme as a viable platform for sound arts practice. I believe I've successfully demonstrated this, as well as developed a framework for critiquing it.

The project's findings showed me that capturing and holding the user's attention is crucial, and that the feedback offered by interacting with the systems allows the user to attempt mastery through play, much like a typical toy or musical instrument. Despite the fact that this continuous attempt at mastery may not have supplied consumers with the formal language to articulate what was going on with the music in the same way that a composer would, the metaphoric functions still served their purpose. By merging Zimmerman's emergent gameplay approaches with Stebbins' improved play possibilities, a framework for composition was built.

Users can re-create electro-acoustic techniques like panning, superimposition, diffusion, cutting, splicing, and amplitude control, as well as a variety of processing effects and dynamics control, by physically manipulating the mouse and keyboard in a simple control scheme that gamers will recognise. The versatility of video-game-related technology was never in doubt; the multitude of industries that have adopted the software indicates that your imagination is the only limit to what you can do in a virtual world. There is a notable lack of video-game-produced material in the sonic arts, which I now find astonishing. All of the skills I acquired while putting together my portfolio were self-taught or acquired through a variety of free workshops and tutorials. The software's shallow learning curve when used for these purposes is demonstrated by the fact that I just learned a few lines of code and was able to make four unique sound-toys with it.

Throughout this project, I wondered why there are so few people who make interactive sonic material using video-game software. Research suggests it derives from a general aversion to accepting video games as art, as well as the belief that video game engines lack advanced auditory capabilities. While I first believed the latter, as my talents in video game creation improved, that problem was remedied. Finally, there's the fear factor. Fear of the steep learning curve of game development, as well as the notion that in order for video game technology to be effective in the arts, you must fully comprehend and speak C# or Java. These preconceptions were tested as I built my artistic practice over the last four years. Because there were so many community-made tutorial videos for the commercial arena, I knew it could be done, and I knew I could utilise them to fill in any knowledge gaps. The thesis and portfolio demonstrate that Unity and other game engines can provide not only all of the tools necessary to be a viable platform for artistic expression, but also that the community has a wealth of educational resources to enable an easy transition into the use of this software. Despite the fact that Pure Data, a popular visual programming language used by many sound artists, and Supercollider, a similar programming platform, are nearly 30 years old, many practitioners still utilise them.

The skills required to utilise this software, in my opinion, are significantly more difficult to learn than those required to use video-game technologies. While Max's and others' capabilities are still more than adequate for our needs, there appears to be a hesitancy to use video game engines. While applying scientific methods and observations to collect data on comprehending immersion was outside the scope of my thesis, important insights were observed through my compositional work and by seeing other users interact with the four sound-toys. Participants often go through an investigation phase in which they try to figure out how to 'operate' or ‘manage' the system. When the control technique becomes second nature to all participants, the first exploration stage ends and they transition into the control state. This shift can be compared to play theorists' description of the transition between investigative exploration (what can the item do?) and diversified exploration (what can I do with the object?). Following then, everyone seemed to be tinkering with the system's various features.

11.1 Future Research

Unity's seemingly unlimited use can open up opportunities for future work, depending on what creative area you are in. With sonic environments, the intersections diagram [figure 1] can assist you in determining the direction you want to take the project. By adopting a more controlled and strict risk and reward structure, sound-toys could potentially be employed as instructive and teaching aids. For example, the game may ask you to make a typical gesture like "cut this sound and compress it," and then use symbolic actions like literally cutting and squeezing the sound. The game would reward you if you were successful. The most important field for future research is expected to be contact modalities. More immersive visual stimuli will be provided by virtual and augmented reality than by Leap Motion control or a smart phone. Gyroscopic functions and GPS location data can provide you new ways to engage with the sonic environment. The lack of multiplayer experiences has been my main disappointment, this will be the focus of any future sound-toys I create. The ability to share a virtual space and interact with more than one user or collaborator in the composition adds a more performative element to the piece. Multichannel versions may also offer potentially interesting techniques to spatialize music.

12 Glossary of Terms

AAA: A triple A game is a game that has been developed for play on any number of consoles and possible for play on personal computers. A triple A game usually has very high production standards, usually incorporates cinematic events, and features a full roster of characters, sound treatment, art treatment, and level design. Expectations are usually high for triple A games.

Audio Listener: A component usually attached to the main camera and acts as the virtual characters ears.

Asset: Any content that is made for a game is called an "asset". Assets are put into the game and are what the player sees (art and animation), and hears(sound). They are the basic building blocks of every game.

Audio Source: A component attached to a game object within the virtual environment. The component acts as the origin of the sound and can be adjusted in numerous ways.

Build: A build is a version of the game that can be played in a standalone format. It has all the required computer code and is effectively a "snapshot" of the game as it currently stands. A build may be said to be "broken" if it does not run. Through a game's development there will be many, many builds of the game made, and content creators often need a build in order to run the game and view or hear their contributions to the game. The game does not run without a build.

Engine: The software architecture that a video game is built upon. This software generally contains an associated editor where the user can build levels, add enemies, animations, sounds, etc., into the game. Examples of popular engines include the Unreal Engine (Epic Games) and CryEngine (Crytek Games).

FPS: First Person Shooter. This type of game does not separate the player from the action on screen. It is as if the player is the one controlling the gameplay as there is no on-screen representation of the player (avatar). Some popular FPS games include Doom, Call of Duty, and Bioshock.

GUI: Graphical User Interface. This is the interface that users interact with on screen. This could be the game's menu system, or some other part of the game that the user interacts with.

Middleware: Audio middleware is a third-party tool set that sits between the game engine and the audio hardware. It provides common functionality that is needed on each project such as randomizing pitch or volume, fading sounds in or out, and picking randomly a sound from a set of sounds. More advanced tools allow the creation of adaptive music scores.

Prefab: A game object made up of many separate game objects. A third person character for would be made up of; A camera rig with an audio listener, a character control method, animations and meshes.

RTPC: Real-time Parameter Controls (RTPCs) is specific to Audiokenetic's Wwise, it enables you to control specific properties of various Wwise objects (including sounds, containers, control busses, effects, and so on) in real time based on real-time parameter changes that occur within the game. examples of this can be seen in Cube Crash, a specific cube has pitch controlled by the elevation of the cube in relation to the audio listener.

Wwise: (Wave Works Interactive Sound Engine) is Audiokinetic's software solution for interactive media and video games, available for free to non-commercial users and under license for commercial video game developers. It features an audio authoring tool and a cross-platform sound engine. This was used in the build RollerDrone.

FMOD: A proprietary sound effects engine and authoring tool for video games and applications developed by Firelight Technologies, that play and mix sounds of diverse formats on many operating systems. This system was used for Flock

UNITY: is a cross-platform real-time engine developed by Unity Technologies. The engine can be used to create both three-dimensional and two-dimensional games as well as simulations for its many platforms. Several major versions of Unity have been released since its launch.

Unreal 4: A game engine developed by Epic Games, first showcased in the 1998 first-person shooter game Unreal. Although initially developed for first-person shooters, it has been successfully used in a variety of other genres, including stealth, fighting games, MMORPGs, and other **RPGs.** With its code written in C++, the Unreal Engine features a high degree of portability and is a tool used by many game developers today.

Leap Motion: Designed by Leap Motion Inc. An American company that manufactures and markets this computer hardware sensor device that supports hand and finger motions as input, analogous to a mouse, but requires no hand contact or touching.

Script: In computer programming, a script is a program or sequence of instructions that is interpreted or carried out by another program rather than by the computer processor.

Bibliography

We Make Money Not Art. 2021. Interview with Douglas Edric Stanley. [online] Available at: <https://we-make-money-not-art.com/can_you_tell_us/> [Accessed 11 January 2020].

'From Tape to Typedef: Compositional Methods in Electroacoustic Music' (2013). Adams, E. W. (2006) 'Will computer games ever be a legitimate art form?', Journal of Media Practice, 7(1), pp. 67-77. doi: 10.1386/jmpr.7.1.67/1.

Bamberg, M. (2003) 'Digital Art', Production, p.224. doi: 10.1111/j.1365-2559.2011.03814.x.

Basanta, A. (2015) 'Extending Musical Form Outwards in Space and Time: Compositional strategies in sound art and audiovisual installations', Organised Sound, 20(02), pp. 171-181. doi: 10.1017/S1355771815000059.

Bencina, R., Wilde, D. and Langley, S. (2008) 'Gesture ≈ sound experiments: process and mappings', Proceedings of the 8th International Conference on New Interfaces for Musical Expression (NIME08), pp. 197-202. doi: 10.1.1.140.3830.

Berry, J. (2009) 'Live Music and Performances in a Virtual World', Data Engineering, pp.2006-2008.

Böttcher, N., Martínez, H. P. and Serafin, S. (2013) 'Procedural Audio in Computer Games Using Motion Controllers: An Evaluation on the Effect and Perception', International Journal of Computer Games Technology, 2013, pp. 1-16. doi: 10.1155/2013/371374.

Cairns, P., Cox, A. and Imran Nordin, A. (2014) 'Immersion in Digital Games: Review of Gaming Experience Research', Handbook of Digital Games, pp. 339-361. doi:10.1002/9781118796443.ch12.

Calvillo-G, E., Gow, J. and Cairns, P.(2011)'Introduction to special issue: Video games as research instruments', Entertainment Computing,2(1), pp. 1-2. doi:10.1016/j.entcom.2011.03.011.

Cames, D. et al. (no date) 'PLAY ALONG Digital Games, YouTube, and Virtual Performance'.Candy, L. (2006) 'Practice Based Research: A Guide', CCS report, 1, p. 19. Available at: http://www.creativityandcognition.com/resources/PBR Guide-1.1-2006.pdf.

Cheng, M. T., She, H. C. and Annetta, L. A. (2015) 'Game immersion experience: Its hierarchical structure and impact on game-based science learning', Journal of Computer Assisted Learning, 31(3), pp. 232-253. doi: 10.1111/jcal.12066.

Cheng, W. (2012) 'Technologies of Transgression and Musical Play in Video Game Cultures'.Collins, K. (2008) Game Sound: An Introduction to the History, Theory, and Practice of Video Game Music and Sound Design, Pelitutkimuksen vuosikirja 2010. doi:10.1093/jdh/epp021.

Collins, K., Kapralos, B. and Tessler, H., n.d. *The Oxford handbook of interactive audio*. pp.45-62.

Csikszentmihalyi, M. (1975) 'Beyond Boredom and Anxiety: Experiencing Flow in Work and Play', The Jossey-Bass Behavioral Science Series, p. 231. doi: 10.2307/2065805.

Demers, J. (2006) 'Dancing machines: "Dance Dance Revolution", cybernetic dance, and musical taste', Popular Music, 25(03), p. 401. doi: 10.1017/S0261143006001012.

Dobrowolski, P. et al. (2015) 'Cognitive enhancement in video game players: The role of video game genre', Computers in Human Behavior, 44. doi: 10.1016/j.chb.2014.11.051.

Dolphin, A. (2009) 'Compositional Applications of a Game Engine Creative Practical Applications in Sound Art and Music Composition', 2009 International IEEE Consumer Electronics Society's Games Innovations Conference. IEEE, pp. 213-222. doi:10.1109/ICEGIC.2009.5293598.

Donnarumma, M. (2014) 'Ominous : Playfulness and emergence in a performance for biophysical music', Body, Space \& Technology, 14

Douglas, Y. and Hargadon, A. (2000) 'The Pleasure Principle: Immersion, Engagement, Flow', Proceedings of the ACM on Hypertext and Hypermedia 2000, pp. 153-160. doi:10.1145/336296.336354.

Farnell, A. (2010) 'Behaviour, Structure and Causality in Procedural Audio', Game Sound Technology and Player Interaction: Concepts and Developments, p. 29. doi: 10.4018/978-1-61692-828-5.ch015.

Farra, R. D. (1985) 'Re-thinking the gap : electroacoustic music in the age of virtual networking'.

Fish, J. B. (2003) 'Interactive and Adaptive Audio for Home Video Game Consoles', Audio, (July).Fritsch, M. and Strötgen, S. (2005) 'How to Identify Live Music Performances', 5(1), pp. 1-16.

Gee, J. (2005) 'Why are videogames good for learning?', Spectrum, 32, pp. 25-32. Available at: http://cmslive.curriculum.edu.au/leader/default.asp?id=16866&issueID=10696.

Gee, J. P. (2006) 'Why Game Studies Now? Video Games: A New Art Form', Games and Culture, 1(1), pp. 58-61. doi: 10.1177/1555412005281788.

Gibbs, T. (2010) Fundamentals of sonic arts and sound design., AVA Publishing. Available at: http://eprints.mdx.ac.uk/3940/.

Gilroy, S. W., Cavazza, M. and Benayoun, M. (2009) 'Using affective trajectories to describe states of flow in interactive art', Proceedings of the International Conference on Advances in Computer Enterntainment Technology, pp. 165-172. doi: 10.1145/1690388.1690416.

Gadamer H-G., 'The ontology of the work of art and its hermeneutic significance', chapter in: Truth and Method, 1960, pg 102

Hamari, J. et al. (2016) 'Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning', Computers in Human Behavior, 54, pp. 170-179. doi: 10.1016/j.chb.2015.07.045.

Hamilton, R. (2008) 'Q3Osc or: How I Learned To Stop Worrying and Love the Bomb Game', Proceedings of the International Computer Music Available at: https://ccrma.stanford.edu/groups/mcd/publish/files/2008-icmc-q3osc.pdf.

Huntingdon, A., 2005. soundtoys.net - artist journals & interviews. [online] Soundtoys.net. Available at: <http://soundtoys.net/journals/> [Accessed 22 January 2019].

Hart, I. (2014) 'Meaningful play: Performativity, interactivity and semiotics in video game music', Musicology Australia, 36(2). doi: 10.1080/08145857.2014.958272.

Hollerweger, F. (2011) 'The Revolution is Hear ! Sound Art , the Everyday and AuralAwareness', Social Sciences, (March).Huff, D. (no date) 'musique concrète', pp. 1-39.Hug,D. and Zurich University of Arts, Switzerland (2011) 'Game Sound Technology and Player Interaction: Concepts and Developments, chapter 18 Daniel Hug', 5.

Iazzetta, F. (2000) 'Meaning in Musical Gesture', Trends in Gestural Control of Music, pp. 259-268. Available at: http://www.music.mcgill.ca/~mwanderley/MUMT-615/Papers/Class03/P.Iaz.pdf.

Irvine, U. C. and Kwastek, K. (2009) 'Embodiment and Instrumentality', Embodiment and Instrumentality. Jennett, C. et al. (2008) 'Measuring and defining the experience of immersion in games', International Journal of Human Computer Studies, pp. 1-44. doi:10.1016/j.ijhcs.2008.04.004.

Jørgensen,K.(2007)'On Transdiegetic Sounds in Computer Games', Northern Lights, 5(I), pp. 105-117. Available at:http://www.atypon-link.com/INT/doi/pdf/10.1386/nl.5.1.105_1.Jørgensen, K. (2010)'Time for New Terminology? Diegetic and Non-Diegetic Sounds in Computer Games Revisited', Game Sound Technology and Player Interaction Concepts and Developments, pp. 78-97. doi: 10.4018/978-1-61692-828-5.ch005.

Kim, J. H. and Seifert, U. (2007) 'Embodiment and Agency : Towards an Aesthetics of Interactive Performativity', International Conference of Sound and Music Computing (SMC'07), (July), pp. 230-237. Available at: http://www.smcconference.org/smc07/SMC07 Proceedings/SMC07 Paper

Kim, J. Y. et al. (2016) 'A Study on Expression of the Digital Game Art Form A Study on Expression of the Digital Game Art Form',(April).Labelle, B. (no date) 'Background Noise Second Edition'. Landy, L. (2006) 'Electroacoustic Music Studies and Accepted Terminology: You can't have one without the other.', Electro-acoustic music studies conference, Beijing, pp. 1-8. Available at: http://www.ems-network.org/spip.php?article242%5Cnhttp://www.ems-network.org/IMG/EMS06-Landy.pdf%5Cnhttps://www.dora.dmu.ac.uk/handle/2086/5226.

LENNART, E. Nacke; GRIMSHAW, M. (2011) 'Player-Game Interaction Through Affective Sound', Game Sound Technology and Player Interaction: Concepts and Developments, pp. 264-285. doi: 10.4018/978-1-61692-828-5.ch013.

Levitin, D. J., McAdams, S. and Adams, R. L. (2002) 'Control parameters for musical instruments: a foundation for new mappings of gesture to sound', Organised Sound, 7(January 2003), pp. 171-189. doi: 10.1017/S135577180200208X.

Lindborg, P. (2006) 'Reflections on Aspects of Music Interactivity in Performance Situations',(Internet review of the Canadian Electroacoustic Community) 10(4), 10(4), pp. 1-10.List, L. et al. (2001) 'No Title', (Cd 10130).

Manovich, L. (2001) 'I Lev Manovich The Language of New Media Copyright MIT Press, 2001', Screen, 27(1), p. 354. doi: 10.1386/nl.5.1.25/1.McCann, G. (2003) Real-time Physically Based Audio Generation. Available at: https://docs.google.com/file/d/0B3N-C9xfG_CPR29pRFJHSnI4d1E/edit.

Mccormack, J. (2005) 'Open Problems in Evolutionary Music and Art', LNCS 3449 Applications of Evolutionary Computation, Proceedings Of EvoMUSART 2005, pp. 428-436. doi: 10.1007/b106856.
Movies, E. et al. (2012) 'No Title'.Nacke, L. E., Grimshaw, M. N. and Lindley, C. a. (2010) 'More than a feeling: Measurement of sonic user experience and psychophysiology in a first-person shooter game', Interacting with Computers, 22(5), pp. 336-343. Doi:10.1016/j.intcom.2010.04.005.

Nacke, L. E. and Lindley, C. a. (2010) 'Affective Ludology, Flow and Immersion in a First-Person Shooter: Measurement of Player Experience', Loading..., 3(5), p. 21. Available athttp://arxiv.org/abs/1004.0248.

Nakamura, J. and Csikszentmihalyi, M. (2014) 'The concept of flow', in Flow and the Foundations of Positive Psychology: The Collected Works of Mihaly Csikszentmihalyi, pp. 239-263. doi: 10.1007/978-94-017-9088-8_16.

Oldenburg, A. (2013) 'Sonic mechanics: Audio as gameplay', Game Studies, 13(1).Paine, G. (2007) 'Sonic immersion: Interactive engagement in real-time immersive environments', SCAN Journal of Media Arts and Culture, pp. 1-13. Available at: http://www.scan.net.au/scan/journal/display.php?journal_id=90.

Park, H. J. and Lim, K. H. (2014) 'A study of Interactive Game Art Expression with Gamification Application', 4(3), pp. 2-5.Park, H. and Lim, K. (2013) 'A Study on a Gamification-Based Interactive Game Art Form', 39, pp. 99-103.

Paton, C. G. (2011) 'Modelling Footsteps: Procedural Audio in Games'.Patteson, T. W. (2015) Instruments for New Music: Sound, Technology, and Modernism. Available at: https://books.google.ru/books?id=shLCsgEACAAJ.

Paul, L. (2011) ‘Granulation of sound in video games’, . . . : 41st International Conference: Audio for Games, pp. 1-5. Available at: http://www.aes.org/e-lib/browse.cfm?elib=15760.
Plans, D. and Morelli, D. (2012) ‘Experience-driven procedural music generation for games’, IEEE Transactions on Computational Intelligence and AI in Games, 4(3), pp. 192-198. doi:10.1109/TCIAIG.2012.2212899.

The Entertainment Software Association. (2019). Use of Video Game Technology in the Workplace Increasing - The Entertainment Software Association. [online] Available at: http://www.theesa.com/article/use-video-game-technology-workplace-increasing/ [Accessed 24 May 2019].

Pocknee, D. A. (2017) ‘How to Compose a PhD Thesis in Music Composition’, (September).

Polaine, A. (2005) ‘Lowbrow, high art: Why Big Fine Art doesn’t understand interactivity’, Crisis, pp. 1-9. Available at: http://193.171.60.44/dspace/handle/10002/344.

Price, C. B., Price, C. B. and Grove, H. (2008) ‘ “ UNREALART ”. A NEW MEDIUM FOR ARTISTIC EXPRESSION USING A COMMERCIAL GAME ENGINE : GALLERIES AND INSTALLATIONS .’, pp. 215-224.

Rees-Jones, J., Brereton, J. and Murphy, D. (2015) ‘Spatial audio quality and user preference of listening systems in video games’, Proc. of the 18th Int. Conference on Digital Audio Effects (DAFx-15), pp. 1-8.Roden, T. E., Parberry, I. and Ducrest, D. (2007) ‘Toward mobile entertainment: A paradigm for narrative-based audio only games’, Science of Computer Programming, 67(1), pp. 76-90. doi: 10.1016/j.scico.2006.07.004.

Rutherford, S. (2008) ‘Procedural Methods for Audio Generation in Interactive Games’, Vasa. Available at: http://medcontent.metapress.com/index/A65RM03P4874243N.pdf.

Salen, K. and Zimmerman, E. (2004) ‘Rules of Play: Game Design Fundamentals’, Nihon Ronen Igakkai zasshi. Japanese journal of geriatrics, p. 672. doi: 10.1093/intimm/dxs150.

Sanderhuiberts (2009) ‘GAMEAUDIOLAB-ANARCHITECTURALFRAMEWORKFOR NONLINEARAUDIOINGAMES’.

Simoni, M. H. et al. (1999) ‘A Theoretical Framework for Electro-Acoustic Music’, Proc. International Computer Music Conference, pp. 333-336.

Skains, R. L. (2018) ‘Creative Practice as Research: Discourse on Methodology’, Media Practice and Education, 19(1), pp. 82-97. doi: 10.1080/14682753.2017.1362175.

Smalley, D. (2007) ‘Space-form and the acousmatic image’, Organised Sound, 12(1), pp.35-58. doi: 10.1017/S1355771807001665.

Smuts, A. (2005) ‘Are Video Games Art ?’, Contemporary Aesthetics, 3, pp. 1-16. Available at: http://www.contempaesthetics.org/newvolume/pages/article.php?articleID=299.

R.A Stebbins. The interrelationship of leisure and play. (2015). Basingstoke, Hampshire: Palgrave Macmillan.

Soutter, A. R. B. and Hitchens, M. (2016) ‘The relationship between character identification and flow state within video games’, Computers in Human Behavior, 55, pp. 1030-1038. doi:10.1016/j.chb.2015.11.012.

Tamborini, R. and Skalski, P. (2006) ‘The Role of Presence in the Experience of Electronic Games’, Playing Video Games Motives Responses and Consequences, pp. 225-240. doi:10.4324/9780203873700.

Tong, T., Zingaro, D. and Engels, S. (2014) ‘Design guidelines for audio-based game features’, Proceedings of the first ACM SIGCHI annual symposium on Computer-human interaction in play - CHI PLAY ’14, pp. 443-444. doi: 10.1145/2658537.2661307.

Toro, B. (2013) ‘Using Procedural Audio to Control an Algorithmic Composition that is Controlled by a Computer Game’.

Veneri, O., Gros, S. and Natkin, S. (2008) ‘Procedural Audio for Game using GAF’, Citeseer,(figure 1). Availableat: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.161.3316.

Verron, C. et al. (2013) ‘Event-driven interactive solid sound synthesis’, in Proceedings of the 10th International Symposium on Computer Music Interdisciplinary Research, Marseille, France, October 15-18, pp. 960-966.

Vorderer, P. and Bryant, J. (2006) ‘Playing Video Games: Motives, Responses, and Consequences’, Playing video games Motives responses and consequences, p. 464. doi:10.1139/h2012-043.

Whalley, I. (2009) ‘Software Agents in Music and Sound Art Research/Creative Work: current state and a possible direction’, Organised Sound, 14(02), p. 156. doi:10.1017/S1355771809000260.

Pecino, I. (2011) ‘Swirls (2011/12)’, pp. 3-4.Pecino, I. (2014) ‘SPATIAL AND KINEMATIC MODELS FOR PROCEDURAL AUDIO IN 3D VIRTUAL ENVIRONMENTS’, (September), pp. 14-20.

Spracklen, K. and Studies, L. (no date) Series Editors : Titles include :Green, O. (2011) ‘Agility and playfulness: Technology and skill in the performance ecosystem’, Organised Sound, 16(2), pp. 134-144. doi: 10.1017/S1355771811000082.Hennigan, K. (2018) Music in Liquid Forms: A Framework for the Creation of Reactive Music Recordings.

Dolphin, A. (2009) ‘Compositional Applications of a Game Engine Creative Practical Applications in Sound Art and Music Composition’, System, pp. 213-222.

Jin, S. A. A. (2012) ‘ “Toward Integrative Models of Flow”: Effects of Performance, Skill, Challenge, Playfulness, and Presence on Flow in Video Games’, Journal of Broadcasting and Electronic Media, 56(2), pp. 169-186. doi: 10.1080/08838151.2012.678516. Kuoppala, V. (2013) ‘Commentary for composition portfolio’, (September). Available at: http://etheses.bham.ac.uk/4718/.

Seidel, S. M. (2014) ‘A portfolio of compositions and an investigation into electroacoustic compositional techniques and aesthetics in cinematic film’. Moore, A. and Moore, D. (2011)

‘Sonic Art: Recipes and Reasonings’, Text Book, (December), pp. 1-130. Available at: papers3://publication/uuid/E9269705-A49A-4C2B-B117-1885D4D13652.

Solnit, A. J. (1998)‘Beyond Play and Playfulness’, Psychoanalytic Study of the Child, 53(1998), pp. 102-110. doi:10.1080/00797308.1998.11822478.Polaine, A. (2010)‘The Flow Principle in Interactivity’, Proceedings of the second Australasian conference on Interactive entertainment - IE ’05, pp.151-158. Available at: http://dl.acm.org/citation.cfm?id=1109180.1109204.

Weibel, D. and Wissmath, B. (2011) ‘Immersion in computer games: The role of spatial presence and flow’, International Journal of Computer Games Technology, 2011. doi:10.1155/2011/282345.

McCormack, J. and D’Inverno, M. (2014)‘On the Future of Computers and Creativity’, AISB14 Symposium on Computational Creativity, pp. 1-4. Available athttp://doc.gold.ac.uk/aisb50/AISB50-S04/AISB50-S4-McCormack-paper.pdf.

Costello, B. et al. (2005) ‘Understanding the experience of interactive art’, Proceedings of the Second Australasian Conference on Interactive Entertainment, (November), pp. 49-56. Available at: http://dl.acm.org/citation.cfm?id=1109180.1109188.Stockhausen, K. and Martenot, O. (1971) ‘CHAPTER 6 Electro-Acoustic Compositional Techniques’, pp. 97-133.

Farnell, A.(2007) ‘An introduction to procedural audio and its application in computer games’, Audio Mostly Conference, (September), pp.1-31. Available at:http://www.cs.au.dk/~dsound/DigitalAudio.dir/Papers/proceduralAudio.pdf.

Menzies, D. (2009) ‘Phya and VFoley , Physically Motivated Audio for Virtual Environments’, in AES 35th International Conference, pp. 1-8.Chapman, O. (2005) ‘The Affect of Selection in Digital Sound Art’, M/C Journal: a journal of media and culture, 8.

Dolphin, A. (2009) ‘MagNular :Symbolic Control of an External Sound Engine Using an Animated Interface’, Proceedings of the International Conference on New Interfaces for Musical Expression, pp. 159-160. Available at:http://www.nime.org/proceedings/2009/nime2009_159.pdf.

Whalen, Z. (2004) ‘Play along - An approach to video-game music’, Game Studies, 4(1), p. http://www.gamestudies.org/0401/whalen/. Available at:http://www.gamestudies.org/0401/whalen/.

Life, N. (2019). Review: Electroplankton Beatnes (DSiWare). [online] Nintendo Life. Available at: http://www.nintendolife.com/reviews/2009/11/electroplankton_beatnes_dsiware [Accessed 18 May 2019].

Jørgensen, K. (2014) ‘Sound in a Participatory Culture’, the international journal of computer game research, 14(1). Available at: http://gamestudies.org/1401/articles/kjorgensen.

Scott Snibbe - Interactive Art. 2021. Björk: Biophilia App — Scott Snibbe - Interactive Art. [online] Available at: <https://www.snibbe.com/biophilia> [Accessed 17 Jan 2021].

Usa.canon.com. 2022. Canon U.S.A., Inc. | Press Release Details. [online] Available at: <https://www.usa.canon.com/internet/portal/us/home/about/newsroom/press-releases/press-release-details/2019/20190107-partner/20190107-partner> [Accessed 9 February 2022].

Marks, S., Windsor, J. and Wünsche, B., 2007. Evaluation of game engines for simulated surgical training. *Proceedings of the 5th international conference on Computer graphics and interactive techniques in Australia and Southeast Asia - GRAPHITE '07*,.

SITZMANN, T., 2011. A META-ANALYTIC EXAMINATION OF THE INSTRUCTIONAL EFFECTIVENESS OF COMPUTER-BASED SIMULATION GAMES. *Personnel Psychology*

Wirth, W., Hartmann, T., Böcking, S., Vorderer, P., Klimmt, C., Schramm, H., Saari, T., Laarni, J., Ravaja, N., Gouveia, F., Biocca, F., Sacau, A., Jäncke, L., Baumgartner, T. and Jäncke, P., 2007. A Process Model of the Formation of Spatial Presence Experiences. *Media Psychology*, 9(3), pp.493-525.

Wishart, T., 1994. *Audible design*. York: Orpheus the Pantomime.