XR, music and neurodiversity:

Design and application of new mixed reality technologies that facilitate musical intervention for children with autism spectrum conditions.

by

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ABSTRACT

This thesis, accompanied by the practice outputs, investigates sensory integration, social interaction and creativity through a newly developed VR-musical interface designed exclusively for children with a high-functioning autism spectrum condition (ASC). The results aim to contribute to the limited expanse of literature and research surrounding Virtual Reality (VR) musical interventions and Immersive Virtual Environments (IVEs) designed to support individuals with neurodevelopmental conditions.

The author has developed bespoke hardware, software and a new methodology to conduct field investigations. These outputs include a *Virtual Immersive Musical Reality Intervention* (ViMRI) protocol, a *Supplemental Personalised, immersive Musical Experience* (SPiME) programme, the *Assisted Real-time Three-dimensional Immersive Musical Intervention System'* (ARTIMIS) and a bespoke (and fully configurable) *'Creative immersive interactive Musical Software'* application (CiiMS).

The outputs are each implemented within a series of institutional investigations of 18 autistic child participants. Four groups are evaluated using newly developed virtual assessment and scoring mechanisms devised exclusively from long-established rating scales. Key quantitative indicators from the datasets demonstrate consistent findings and significant improvements for individual preferences (likes), fear reduction efficacy, and social interaction.

Six individual case studies present positive qualitative results demonstrating improved decision-making and sensorimotor processing. The preliminary research trials further indicate that using this virtual-reality music technology system and newly developed protocols produces notable improvements for participants with an ASC. More significantly, there is evidence that the supplemental technology facilitates a reduction in psychological anxiety and improvements in dexterity. The virtual music composition and improvisation system presented here require further extensive testing in different spheres for proof of concept.

Reading recommendations

To assist the reader's understanding of this research and navigation around this thesis, the author would recommend first reading the Abstract, followed by the Conclusion **(Chapter 5, pages 225-244)**, to ensure clarity before reading through at will.

Navigating the Thesis

Bookmarks are included for mobile and tablet devices. For desktop and laptop devices, all texts highlighted in **(bold)** are hyperlinked for the reader's accessibility — Control-click *(ctrl)* or Command-click *(CMD)*, any link in the document to navigate to the designated text. Alt and left arrow press (*alt* + ⇦) will navigate back to the (initially read) source text.

Supporting audio-visual material

The supporting video and audio material from the research trials are consensually approved by the participant's parents/carers and school **(see page 274).**

A picture icon near associated texts for **video** 🎬 or **audio** 🔊 provides a direct link to the source **(see Appendix N for complete media listings).** Examiners receive an individual USB drive.

ACKNOWLEDGEMENTS

Inspired by Stelios

The author's son, Stelios Ioannou (age 14), has inspired this research. Stelios has been an integral part of this thesis and is the inspiration behind the research and development of the virtual immersive musical instrument and interface.

At six years old, Stelios was diagnosed with a high-functioning autism spectrum condition (ASC). During early development, Stelios faced various challenges within a social context, reacting negatively to loud and unexpected noises — especially whenever there were large groups of people around him. As Stelios developed, he displayed common traits of ASC, and as a parent, these became increasingly clear.

Stelios often expressed his emotional and communication deficits, such as interpreting other people's feelings, hyperacusis, echolalic tendencies and avoiding eye contact with other children. Interestingly, Stelios preferred interacting with adults — compared to children of the same age.

The author's determination to support Stelios' needs and characteristics and help him overcome his personal, social, and emotional barriers led him to create a specialised system. During preliminary research, digital audio workstations (DAWs), creative software sequencers and *'off-the-shelf'* audio peripherals were readily available. However, they lacked automated (and pre-programmed) virtual interactive functionalities. Equally important, these alternative multi-track recorders could not support the rapid setup or personalised preferences of a neurodiverse individual.

These commercial solutions are not intended as clinical interventions; instead, they are for commercial use. The need became clear (through the above rationale) for developing an integrated and multi-faceted musical system with a flexible approach for individuals with ASC. Consequently, beta testing of bespoke software and hardware development processes for this research commenced during the global coronavirus pandemic, and Stelios could assist with this research during a nationwide UK lockdown (around a challenging period). Throughout the entire process, Stelios became the first point of call for the early results of this research.

I wish to acknowledge the following people who have played a vital role in my academic accomplishments. Without them, this research would not have been possible.

Firstly, to my beautiful wife Anthea, you have supported me along this long winding academic journey with your unconditional love, understanding and belief in me and my work. Thank you, Anthea, for alleviating me from many long periods away from you and our family, staring at the screen for hours upon end. I could not have achieved this doctorate without you; I owe you everything – I love you.

To my three beautiful children, Stelios, Sophia and Theo. I am deeply indebted to you all. Your encouragement, help, inspiration and most of all, your love have guided me and given me the strength and determination to continue providing you with a brighter future.

This endeavour would not have been possible without Dr Panos Ghikas, my dedicated and inspirational supervisor who nurtured and supported me through my undergraduate and postgraduate studies, leading to these doctoral studies herein.
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Thank you to Katie Reeves, Les Milton, and the School. Their steadfast support and for allowing me to conduct the Virtual immersive Musical Reality (ViMRI) trials over twelve consecutive weeks. Working with the children was the most memorable experience.

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I am also grateful to Canterbury Christ Church University and the well-being team who supported me and all those who gave their valuable time during the interview process: Susan Rivett, Emma Kaye, Ruth and Sarah.

Finally, this inspiring research in the field of Autism has been guided by Stelios.

Stelios, you were gifted to us by God, whom we thank each day.
This work is dedicated to your cause, In the hope that one day,
ARTIMIS *will* materialise.

Love from Dad X

…

In Loving Memory of my Mother

Panayiodoulla “Doulla” Ioannou

…

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LIST OF ABBREVIATIONS

AIT	Auditory Integration Training
AR	Augmented Reality
ARTIMIS	Assisted Real-time Three-dimensional Immersive Musical Intervention System
ASC	Autism Spectrum Condition
CARS -2	Childhood Autism Rating Scale, Second Edition
CiiMS	Creative immersive interactive Musical Software
DAW	Digital Audio Workstation
HCI	Human-Computer Interaction
HMD	Head Mounted Display
IDE	Integrated Development Environment
MATI	Musical sAccadic Transitional Interface
MIDI	Musical Instrument Digital Interface
MPE	MIDI Polyphonic Expression
MR	Mixed Reality
OSC	Open Sound Control
PBR	Physically Based Rendering
SEND	Special Educational Needs and Disabilities
SPD	Sensory Processing Disorder (SPD)
SPiME	Supplemental Personalised, immersive Musical Experience
uID	Unique Identification
ViMRI	Virtual immersive Musical Reality Intervention
VR	Virtual Reality
VRE	Virtual Reality Environment
VRMI	Virtual Reality Musical Intervention
VST	Virtual Studio Technologies
XR	Extended Reality
3S-TDP	3-Stage Technical Development Process

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FOREWARD

The fundamental principles of this research evolved from a series of investigations derived from the author's observations and scenarios in neurodiverse and special educational needs settings (SEND), culminating in developing a virtual reality supplemental musical prototype intervention. The author's initial investigations in clinical and therapeutic settings formed the rationale for developing a proof-of-concept to support future funding proposals and to provide a suitable companion device for music therapy and other creative musical interventions.

This concept is not a replacement for music therapy or music therapist. The proposed proprietary device is intended to provide immersive virtual and physical musical experiences as a creativity tool (in the form of virtual play) to encourage interactivity and collaborations and to strengthen social, emotional, and communication deficits. The following images represent the concept of a Virtual immersive Musical Reality setup (*Figure 1)*, followed by the proprietary system itself, to be explained shortly (*Figures 2 & 3*).

Figure 1. A Virtual immersive Musical Reality Intervention (ViMRI) scene.

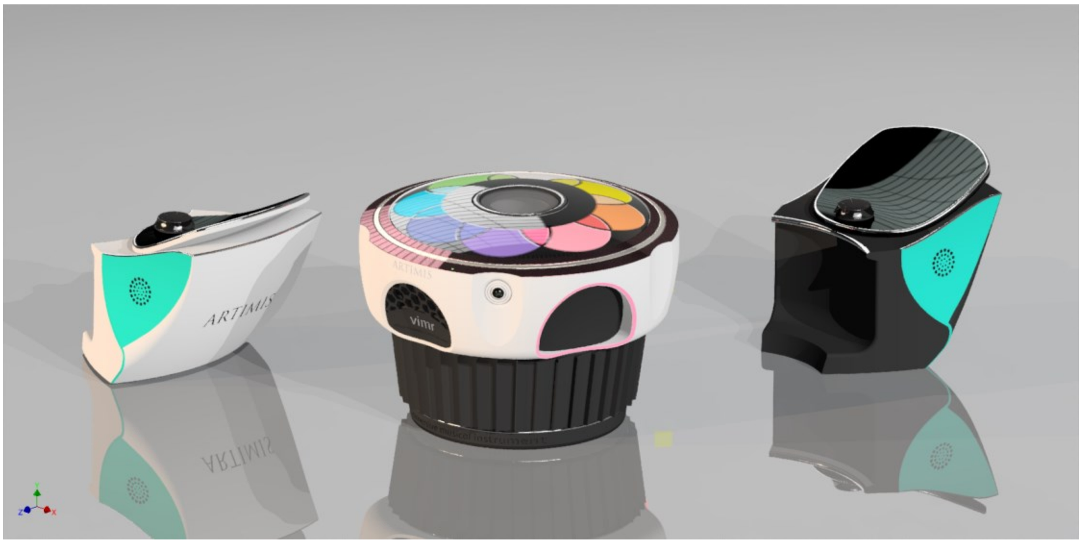

Figure 2. The proprietary musical system prototype and music pods.

Figure 3. The **ARTIMIS**© *Virtual Reality Musical Instrument.*

Chapter 1.
LITERATURE REVIEW

1.1 Overview

The first chapter presents the author's review of the academic literature and existing theories supporting the development of this research. Extended and mixed realities are investigated together with established therapeutic approaches. Thereafter, traditional creative music studio setups and technology-based therapeutic approaches are evaluated using a comparison grid **(page 52)**. A comprehensive review of virtual technologies, human-computer interfaces, applications for people with neuro-diverse conditions, and special educational needs are also offered.

1.2 Introduction to the Research

Virtual reality environments (VREs) are considerably more appealing for children with autism spectrum conditions (Mitchell, Parsons and Leonard, 2007). Virtual Reality based immersive musical experiences reduce cognitive stress, induce relaxation, and ease anxiety. In the author's experience, research into virtual musical realities is significantly understudied, especially in people with autism spectrum conditions. Many families with children with developmental conditions are disadvantaged by accessibility to traditional support methods (Chaplin, 2018); compared to their simulated VR counterparts, artificial musical environments provide reassurance and safety measures for individuals with autism (ASC). Virtual realities and technologies can appeal to autistic individuals as they inspire creativity and alleviate social anxiety (Adjorlu, Barriga and Serafin, 2019).

One of the most challenging aspects of implementing an adapted virtual musical system is creating a safe, familiar environment akin to the most vulnerable in our society (Garzotto *et al.*, 2017). Universal multi-track recording setups and creative music technology configurations are widely available for professional and consumer applications. [1] Most existing configurations are restricted to real-time performance and thus are not ready for interactive input or providing interactivity for the needs of neuro-diverse individuals. Currently, no creative music technology devices (or standalone musical systems) exist that function within clinical or special educational needs and disabilities (SEND) settings, capable of receiving virtual musical interactivity, as borne out by Hahna *et al.* (2012).

This research proposes a combined integrated software and hardware system comprising a remote online *Musical Instrument Digital Interface* (MIDI) functionality; to act as a complementary and transferrable therapeutic tool (The MIDI Association, 2020).

The global coronavirus (Covid-19) pandemic has propelled positive shifts in remote group learning and individualised methods of communication. The gap between musical preferences and technological innovations is narrowing exponentially between

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[1] These are widely utilised by amateur and professional musicians. Disc-Jockeys (DJs), producers, creative audio applications, free-improvisation within live and studio session recording.

Millennials and *Gen. Z* (Generation Z). Technological advancements see new and exciting approaches to exploratory technologically mediated musical interventions. These are all becoming within reach.

NOTE: A comprehensive analysis of the systems used in this research is presented in subsequent chapters. Within this introductory chapter, however, they are referred to as ARTIMIS and CiiMS (see page 56). [2] [3]

1.3 Extended (XR) and Virtual (VR) Realities

Compared to their real-world counterparts, autistic individuals often prefer virtual computer-generated realities because of their synthetic simulation.
Perini *et al.* (2019) explore the impacts of simulated social interactions by employing virtual avatars to support fearful situations and reinforce individuals' negative social bias. [4] Virtual reality avatars assist autistic individuals within a virtual environment and provide methodical control over their perception.

More recent conceptual studies by Lorenzo, Newbutt and Lorenzo-Lledó (2021) posit the remarkable effectiveness of community integration to help strengthen and support social interactions. Notably, social deficits in high-functioning autistic individuals are (significantly) better regulated using virtual supports than by undertaking the same unaided real-world interaction (Camilleri, Dingli and Haddod, 2019). Furthermore, academics have conducted systematic reviews of VR technologies for autistic audiences using simulated environments and virtual routines that combine simulated tasks to encourage autistic people with more controlled and safer self-assurances in the real world (Bradley and Newbutt, 2018). *Table 1* is the author's acknowledgement of the historical founders and inventors of original VR developments; listed chronologically:

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[2] ARTIMIS is the: *Assisted Real-time Three-dimensional Immersive Musical Intervention System* hardware and VR interface.

[3] CiiMS is the: *Creative immersive interactive Musical Software* application and user interface.

[4] Fearful situations such as fear of heights, spiders or large crowds.

Table 1.

Key chronological founders of virtual reality: innovations and patents

Founder	Invention	Works	Patent filed	Patent No.
Jaron Lanier	Conceived the term Virtual Reality	*The Sound of One Hand*	1987	10192363
Edwin Link	First flight simulator	*Link Flight Trainer*	1931/1930	1,825,462
Myron Krueger	First augmented reality	*Psychic Space*	1971	
Ivan Sutherland	Interactive computer-aided design	*Sketchpad*	1965/1969	3,639,736
Morton L. Heilig	Actual reality simulation. First stereoscopic TV apparatus (for personal use).	Sensorama simulator *Telesphere* mask	1957/1962 1957/1960	3,050,870 2,955,156
Thomas Zimmerman	First optical glove	The Digital Data Entry Glove	1981 1989	06302700 4,542,291
Young L. Harvill **Samuel Cooper Davis**	Virtual power glove (peripheral interface)	Abrams Gentile Entertainment (AGE)	1989	4,988,981

1.3.1 Extended Reality (XR)

Extended realities (XR) comprise augmented reality (AR), virtual reality (VR), and mixed reality (MR). The expression XR (*pronounced ex-arr*) has collectively emerged under the VR umbrella term, amalgamating all immersive technologies (i.e., AR, VR and MR). According to Marr (2019), XR is open to future expansion and will presumably encompass new variations of synthetic realities that will be introduced with new variations of extended realities.

> ***'In contrast to augmented reality, in a virtual reality experience, users are fully immersed in a simulated digital environment. Individuals must put on a VR headset or head-mounted display to get a 360 -degree view of an artificial world that fools their brain into believing they are, e.g., walking on the moon, swimming under the ocean or stepped into whatever new world the VR developers created. ' Marr. B, 2019***

1.3.2 Virtual Reality (VR)

VR, a term coined by visual artist Jaron Lanier in the 1980s, grew from earlier manifestations of computer-based communication interfaces (Lanier and Pflüger, 2015). Lanier's work encompassed diverse areas of music technology that involved classical and novel experiments, and he was fascinated by discovering unusual sonic structures within distinct musical realms; this persuaded his advancement to support unconventional instruments (Lanier, 2014).

Drawing upon free-improvisation techniques, Lanier experimented by composing musical pieces using the diverse and uncommon characteristics of subcontinent instruments and various organic organisms such as plants. However, it was through experimentation with instruments from the Asiatic cultures (Esraj, Suling Flute, Khaen, Guzheng [*pronounced Gu Zheng*] and Bowed Psaltery) that Lanier discovered resonant tunes through expressive interactions — resulting in his passion for unconventional musical improvisation.[5] [6]

Lanier continued investigating hybrid instruments that eventually led to his application of virtual reality as the primary means of musical expression.[7] The first 'freely improvised' real-time virtual composition and live performance (pioneered by Lanier) was entitled *'The Sound of One Hand.'* Lanier's achievements matured into a bespoke "*Swivel 3D*" VR computer software application (Evergreen, 2015) that was mediated entirely by his identifiable data-glove interface (Zimmerman *et al.*, 1986). Lanier's original VR musical performance was composed of arbitrary sequences and sporadic hand gestures in a fully developed virtual immersive environment.

1.3.2.1 Early manifestations of virtual reality

Before virtual reality (VR), *Edwin A. Link* (1930), *Morton L. Heilig* (1962), *Myron W. Kruegar* (1971) and *Ivan E. Sutherland* (1963) independently pioneered diverse

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[5] Jaron Lanier developed soft resonating melodies by plucking needles of a Saguaro cactus and strumming.

[6] Cactile is available at: http://www.jaronlanier.com/cactile.html

[7] Lanier's specialised VR hardware system, incorporated three unique virtual instruments, the *CyberXylo*, *Cybersax*, and the *Rhythm Gimbal*.

computer-based communication interfaces. [8] Historically, the earliest landmark of the three-dimensional immersive environment traces back to Link's hybrid *Flight Trainer* (1943), aptly named the "Blue Box". Heilig's training device became essential to British military training during World War II (De Angelo, 2000).

Figure 4. Edwin Link's Blue Box Flight trainer (credit: British Fleet Air Arm Station, 1943). [9]

The Link Trainer interactively prepared over a quarter of a million student fighter pilots introducing natural flight experience through interactive, immersive flight simulation. Link's successful innovation inspired the development of other multimodal interactive devices, including Heilig's *Sensorama* simulator (Heilig, 1960).

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[8] During the 1930s, 1960s, 1970s, and 1980s,

[9] Image courtesy of *Fleet Air Arm, Royal Navy* 1939-1945. Available to the public domain: Copyright protection exempt. File download: Link to source:

> ***'It is the Sensorama Simulator…it is a trip through the streets of New York City on a motorcycle, dodging traffic, with the wind blowing in your face and a slight aroma of car exhaust fumes.'* (Wood, C. 1969, The Hollywood Reporter).**

The novel arcade-style gaming booth provided peripheral vision, aromatic air, vibrations, and binaural sound (Hoffman, 1965; Virtual Reality Society, 2017). Heilig's cinematography and highly accredited award-winning filmmaking vitae set the groundwork for an innovative stereoscopic television apparatus entitled the *Telesphere* (Everett, 2022), specifically intended for personal enjoyment. The device featured individual controls for micro-adjustment of audio, olfactory and video inputs. For its time, the *Telesphere* closely resembled that of a widely available, modern stereoscopic head-mounted display (HMD) unit such as the Quest 2 (Meta, 2020). The earliest manifestations of stereoscopic devices appeared in 1832 by *Charles Wheatstone* (Bowers and Wheatstone, 2001). Heilig's optical *Telesphere,* on the other hand, gave rise to interactive computer-aided designers such as Sutherland (1965), inspiring early computer scientists to rapidly develop variations of his interactive experience.

Sutherland's vision for a portable form factor culminated in a version based on an interactive graphical user interface (GUI) and computer-based on-screen sketch solution entitled *Sketchpad* (Voyatzaki, 2014). Sutherland's application comprises a digital linear toolset that allows users to sketch on-screen using a dedicated light pen with X and Y coordinate transformations as input. This interface method provides precise, effortless mathematical positioning, perfectly adapted for civil, design and electrical engineering applications (McGrane, 2009). [10] Sutherland's development of an *ex-vivo* interface replaced the era's conventional, time-consuming, hand-drawn "technical" processes and closely resembled modern computer-aided design software (CAD) applications.

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[10] Sutherland's technology, incorporated a light-pen tracking input device for precisely positioning and composing objects within a virtual world coordinate system. *Sketchpad* was the first important step toward computer efficiency, establishing techniques that are now referred to as 'copying and pasting.'

1.3.3 Virtual Spaces

The repositioning and orientation of artefacts within a virtual space are defined by using a technique referred to as spatial mapping (Eslami, 2018).

> ***'…you cannot comprehend and inhabit any space without having the perception […] that helps you measure and actively define it.'***
>
> **Eslami, A. (2018)**

1.3.3.1 Using cartesian spatial mapping in 3D environments

The placement of 3-dimensional vector coordinates and direction are represented according to their 'normal' vectors to map their exact position within a 3D environment. A computer processes precise coordinates (in real-time) following *Descartes's* original Cartesian coordinate system (Lafleur, 1960) to reference the X, Y, and Z axis (horizontal, vertical and 3-dimensional depth) locations that are required to calculate the position of visual trajectories, collision avoidance and robotic motion-based tracking. The mathematical vector points along a numerical axis determine the measurement of accuracy within a simulated 3-dimensional environment (Corke and Sukkarieh, 2006). [11] [12]

Spatial mapping techniques are especially suited to augmented and mixed reality applications. HoloLens (Microsoft Corporation, 2022a) is an example of augmented reality technology that can accomplish virtual objects' positioning directly onto existing surfaces *(Zeller et al.,* 2022).

1.3.3.2 Teleportation and virtual reality locomotion: an overview

Diminished Reality (DR) and Virtual Reality locomotion reduce the number of observable stimuli to create a more effective and uncluttered virtual environment. [13]

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[11] In the context of 3-dimensional geometry, a normal vector object refers to the direction of travel that is perpendicular to a given 3D object or plane (depending on the user coordinate system UCS).

[12] The Cartesian coordinate system refers to flat geometric X, Y or Z planes that are precisely plotted via numerical coordinates to determine the exact position of a 3-dimensional object. The placement of objects is referenced around the *X, Y and Z* origin of (0,0,0). For example: (0, 20, 350)

[13] Diminished reality technology facilitates the removal (visibility) of objects inside a VR view by deleting unwanted artefacts within the virtual environment.

Locomotion points to an artificial travel method that assists virtual transportation between a "virtual location" and another “virtual enclave”, and the process results in navigating a virtual scene (in real-time) by employing teleportation. This experience occurs while the user is static — even though they are physically moving within the virtual location and provides the user with a sense of full-body relocation (Slater, Usoh and Steed, 1995; Usoh *et al.*, 1999). Locomotion navigation techniques are most commonly used in architectural demonstration applications to allow clients to explore conceptual spaces within virtual area navigation techniques. Serafin argues, *‘… a virtual reality has the potential to augment real-world scenarios’* by *‘providing a sense of presence to trigger positive influences’* that otherwise would not be possible in the physical world (Serafin *et al.*, 2016).

1.3.3.3 Wearable technologies for virtual reality

Many wearable technology devices are available to assist the traversal of virtual environments. For example, head-mounted displays (HMDs) and wearable immersive virtual reality (WIVR) devices remain popular. Future inputs and higher precision wearable haptic technologies for virtual reality are constantly developing **(see 1.3.7.2 High-precision wearable haptic feedback technology, page 17)**.

The technology is presently available in the following two forms:

i. Embedded solutions
ii. Modular solutions

Embedded solutions comprise a commercial HMD utilising integrated optical tracking sensors and outward-facing cameras to track physical room boundaries. The electronics regenerate virtual environments using integrated hardware processing software and sensors. First-generation HMDs, previously required external base stations placed around a physical room to define the extent of the virtual boundary (HTC Corporation, 2022). [14]

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[14] First-generation head-mounted displays (HMDs) required separately positioned external proximity sensors to compensate for room and environmental scaling during immersion.

Walking in Virtual Reality (WIVR) solutions have increased in popularity over the past few years, offering considerable scalability and cost savings, and academic researchers from medical healthcare sectors are advancing WIVR technology in neurodevelopmental studies for intervention (Bernardes *et al.*, 2015).

1.3.3.4 Long-term exposure to virtual and augmented reality

Individuals with sensory processing disorders (SPDs) have the innate ability to respond rapidly to social situations (Channon *et al.*, 2001; Vanmarcke *et al.*, 2016). Children with neurodevelopmental conditions (i.e., Asperger's Syndrome) find social situations particularly challenging, and such social incitements inspire the author to research fundamental issues of long-term exposure to virtual and augmented reality. McCleery *et al.* (2020) provide a thorough investigation of prolonged stimulation using VR interventions within the policing domain for autistic groups with high intelligence quotients (IQs). The study comprises a virtual police officer avatar for unplanned training supported by two-phased research studies involving participant immersion. Over extended periods (several hours), participants reported various minor physiological symptoms, ranging from mild headaches to muscle strain. Abnormally prolonged operation of head-mounted displays within the study alluded to the effects of long-term exposure.

Empirical comparisons of prevalent techniques studied by Boletsis and Cedergren (2019) examine safety measures and verify low-risk motion sickness evidenced through frequent participation when walking in place (stationary). [15] The studies mentioned above exemplify and clarify very mild symptoms through long-term VR exposure, alluding to the fact that VR experiences do not cause severe physical injury. **[16]**

NOTE: The perspectives of virtual spaces informed the author's approach to the concept and design of a virtual multi-sensory room (see Chapter 2. Methodology 1, Page 72).

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[15] The walking in place (WIP) studies of Boletsis and Cedergren were conducted using controller-based inputs ranging from ray-casting and head-mounted direct inputs. Upon completion of usability testing, no harmful or threatening side effects occurred during Phase 1, and Phase 2 of their studies and only mild side effects were duly reported.

[16] Botelis and Cedergren studies (2019) posied around 30-50% from session to session — between 7%-30% of the sample group

1.3.4 The Evolution of Immersive Theatre

The origins of immersive theatre can be traced to the industrial revolution in the era of exquisite Shakespearean productions by *Samuel Phelps* (1804-1878), who derived his variations at the *Sadler's Wells Theatre* (Allen and Sorell, 1971; Cameron McCourt, 2019). *The Theatres Act reform legislation* (1843) was later introduced to restrict larger gatherings of middle-class participants, allowing for more diverse and inclusive audiences (Barker, Bay and Izenour, 2020). Biggin (2017) substantiates immersive theatre as "theatre works"; characterised by aesthetic signifiers (drawing upon philosophical, cognitive science and computer games paradigms) and audience-specific configurations. These distinctive attributes amalgamate into layout recommendations for rooms and sceneries within immersive experiences, breathing them into life.

Comparatively, the characteristics of the theatre performance share similarities with musical performances. Take, for example, a staged pantomime where the storyline prompts human participation and interaction to provoke a call-and-response between the audience and the actors (Carrozzino and Bergamasco, 2010).

1.3.4.1 The aesthetics of therapy and counselling spaces

Client exposure to a physical environment is one of the most important aesthetic considerations clinicians or therapists face before administering a personalised programme. Research findings from Pearson and Wilson (2012) determine the optimal design and layout for therapy and counselling spaces. The author approached a professional play therapist *Emma Kaye*, who concluded that client seating arrangements are equally important. Kaye noted that children should be positioned a short distance away from a caregiver (preferably face-to-face) and as close to an exit as possible. Additional advisories, including ample lumbar support and adjustment, should be provided — with minimal movement to elevate caregivers above clients — in the event of an unforeseen situation. Considering these aesthetic arrangements; encourages dialogue and builds trust between client and caregiver.

> ***'One of the most […] beneficial treatments that could utilise virtual reality in a clinical setting would be to support autistic individuals who are experiencing specific phobias.'*** **(Maskey *et al.*, 2014)**

1.3.5 Virtual Reality Exposure Therapy (VRET) Feasibility Studies

Collaborations between Newcastle University (2017), Oxford VR and Thirdeye technologies (Hutchinson, 2019) conducted randomised controlled feasibility trials of virtual reality treatments. Cognitive Behaviour Therapy (CBT) and exposure therapies (VRET) were evaluated for specific phobias in people with an ASC (Maskey *et al*., 2019).[17] Child participants supported by caregivers were administered CBT in the virtual reality *Blue Room* booth that utilises exposure therapy methods (Hutchinson, 2019; Maskey *et al*., 2019a). [18] The *Blue Room* from the company *Third Eye Neurotech* (Fern, 2018) is a self-contained (stand-alone) unit that comprises a compact and immersive 360-degree virtual reality projection system with embedded spatial audio technology (Maskey *et al.*, 2014). [19] [20] *Blue Room* has been successful in supporting commercial and mission-critical applications, including:

- Military-grade combat simulation.
- Supermarket and retail space environment simulation.
- Medical mapping for neurological and biological surgery.
- Architectural design, planning and logistics.

NOTE: The author explored literature in different areas of research; worth noting:

- VRET for remote psychotherapy (Matsangidou *et al.*, 2020)

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[17] The word phobia refers to a recognised trigger, whereas fear is an emotion of something one would perceive.

[18] VR exposure therapy is conducted in the presence of a clinical practitioner.

[19] Third Eye Technologies works in partnership with academic institutions offering immersive, neurological and military simulations for health and industry applications http://thirdeyeneurotech.co.uk/partners.html.

[20] The Blue Room booth consists of a 4 metre cubed module, furnished with integrated screens on walls and ceilings.

- VRET advanced simulation interventions to encourage positive emotional responses (Vincelli, 1999; Vincelli and Riva, 2000; Vincelli, Molinari and Riva, 2002).
- Successful digital interventions and management of well-being for autistic individuals (Maples-Keller *et al.*, 2017; Carl et al., 2018; Chan *et al.*, 2018; Lindner *et al.*, 2019).

Each case proposes virtual reality as an effective treatment for disorders associated with stress and anxiety and demonstrates the veracity of VR in its application.

NOTE: The above investigations formed the basis for developing a ViMRI because of their association with an autism spectrum condition.

1.3.5.1 Autism-friendly emergency rooms: provision of safe spaces

Multi-sensory rooms are physical environments that provide controlled and soothing sensations to reduce irritation and promote engagement. Sensory overload occurs when proprioceptive input heightens exponentially. As a result, this forms a significant issue for autistic people — impacting harmful disruptions during their everyday lives. Studies in autism-friendly emergency rooms in health facilities reported by Cotter (2020) successfully relieved heightened pathologies associated with ASC, alluding to increased awareness. [21]

Diverse formal studies suggest that multi-sensory room aesthetics improve concentration while reducing challenging behaviours. Hypo-sensitive (under-stimulated) or hyper-sensitive (over-stimulated) stimuli, including light and sound, have a variety of negative consequences affecting autistic children. Multi-sensory environments for these sensory problems provide calming spaces (Fowler and Pagliano, 2008).

NOTE: Overstimulation informed the author's approach to designing a virtual sensory lighting concept (see Chapter 3. Methodology 2, Page 119).

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[21] Further information regarding the autism sensory rooms at Robert Wood Johnson University Hospital, New Brunswick available at: Press Story: Autism-friendly emergency room – DCC Design Group

1.3.6 Traditional Music and Technology-Based Interventions

Classic characteristics of an autism spectrum condition (ASC) point to deficits associated with various disabilities. Distinguishing factors include areas of difficulty that surround:

- Social-emotional interaction
- Social-behaviour
- Non-verbal communication
- A fervent dislike to change
- Preference for repetition

Research in clinical applications of advanced technology and virtual reality-based supports hold promise in addressing undesirable social impairments (such as those listed above) (Lahiri *et al.*, 2014; Wang, Wang and Xu, 2022). More notable, families with children diagnosed with ASC receiving traditional music therapies administered by trained clinicians are more likely to incur significantly higher whole-life expenses (costs) than their atypical counterparts (Horlin *et al.*, 2014). A comprehensive report published by the '*National Foundation for Youth Music children and young people's relationship with music people*' (National Foundation for Youth Music, 2020) documents that 74% of atypical children from 20% of the wealthiest backgrounds are 50% more likely to receive musical training (Mori, 2020).

NOTE: investigations into traditional issues associated with music therapy interventions, developmental disorders and social limitations of children with ASC led the author to implement an educational pathway in the form of a *Supplemental Personalised, immersive Musical Experience* (SPiME). See Chapter 2. Methodology 1: Intervention Design, page 100.

1.3.6.1 Review of music therapy in the UK

Methods of musical expression rely on multimodal and nonverbal characteristics to effectively facilitate joint attention (Kim, Wigram and Gold, 2008; Giannopulu, 2013); this is a fundamental premise of music therapy defined by the BAMT (British

Association for Music Therapy, 2022). Accredited music therapists have high levels of performance and music skills at the postgraduate level and knowledge of psychodynamic relationships between therapist and client. They facilitate conversations through vocal and instrumental exchanges and encourage facial expressions, saccadic eye contact, synchronous movement and gestures. Group music-making sessions (on the other hand) are meaningful social learning experiences, including turn-taking, joint attention, and empathetic interaction (Molnar-Szakacs *et al.*, 2009).

Nordoff Robbins (2020) has been recognised internationally by prominent music therapists working in various clinical and charitable settings; their unique therapeutic approach focuses principally on collaborative engagement. [22] [23] The client's musical responses and gestures are integrated into the co-creative music process — allowing for musical expression — even if verbal communication is disrupted. The Nordoff Robbins model exercises a proactive client and therapist's musical engagement, regardless of the client's cognitive abilities.

1.3.7 Interaction Design: An Aesthetic Approach

Interaction design (ID) precedes users' convenience, focusing primarily on meaningful communication that adheres to collaborative cycles, considering humans and technology (Norman, 2013). Two of the most fundamental characteristics of good user interaction (UI) require a virtuous level of *"understanding"* and *"discoverability"*.
In addition, interaction design relates closely to human-computer interaction (HCI) and immersive technologies. Contrastingly, Interaction Design (IDX) bridges the gap between ID and HCI by improving the individuals' aesthetic understanding to what degree communications work logically. As its name implies, interaction design is defined broadly by facilitating user-artefact interaction. Moggridge (1999) and Siang (2020) evaluate IDX as a connected digital experience that has become common among smartphone and online web applications. The user is guided aesthetically to the result

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[22] Founders Paul Nordoff (1909–1977), and Clive Robbins (1927–2011) were the first to pioneer the music-centred therapy approach, originating through a longstanding relationship since 1959.

[23] During a Nordoff Robbins Session, recordings are made wherever possible using audio-visual formats for revisiting thereafter to analyse significant moments to plan therapeutic aims for future progression.

through various media entities and concepts. [24] In Interaction Design (IDX) paradigms, the concept of *understanding* points primarily to "how things should be used" to navigate the human interface — given the control parameters.

On the other hand, *discoverability* identifies the unique (achievable) and observed actions needed to perform previous interpretation tasks. Interactive design is an iterative (repetitive) process that provides seamless experiences via specific criteria and considerations for interaction designers to implement. Observations, interviews and examination of existing solutions guide designers to help them build expressive relationships between the user and the interface (Steane, 2018). When contemplating how autistic individuals might learn to navigate a product, the use of reduced (minimalist) forms and 'real-world' feedback experiences (i.e., mass, density, and texture) become more evident. Before creating their designs, user experience designers first examine transferrable abilities from virtual to real-world contexts.

NOTE: Interaction design theories influenced the author to develop an external short-throw projector system (undergoing further development).

Table 2.

Somatosensory senses and 'sub-sensory' categories by neural input

Somatosensation (sub-category)	Sub modalities by neural input
Mechanoreception	Vibration, pressure, discretionary touch
Thermoreception	Temperatures
Nociception	Pain
Equilibrioception	Balance
Proprioception	Sense of movement and position

Hall and Hall (2020) explore proprioceptive modalities; they argue that people's social, emotional and behavioural characteristics are highly likely to influence their

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[24] Aesthetic guidance refers to media entities such as graphics, sound design, and animations in a structured and guided manner.

perceived interactions emotionally. These aspects depend partly on the input response the Central Nervous System (CNS) receives to determine which multimodal interactions to prioritise. In the context of VR, the most appropriately prepared sense is ready to achieve the most suitable motor control (response) for each interaction (Autism Speaks, 2019).

1.3.7.1 Proprioceptive and kinaesthetic multimodal interfaces

Multimodal interaction is a communication process between a human and a computer (or a technology system) which uses a combination of multisensory modalities to achieve a real-time feedback response. The purpose of a multimodal interface is to enhance user interaction between humans and computers, and introduce robustness to exploit any redundancies that may be present between the modalities. Mills and Alty (1998) emphasise that multimodal systems should create an interaction that feels as natural as possible. In addition, multimodal interaction is beneficial for controlling large quantities of distributed intelligent devices (e.g., localising commands within a single area to make it possible to interact with smart appliances). Various complementary gestures, such as the Lip-mouth application, can invariably achieve multimodal user experiences (Multimodal Systems Department, 2010). Such interfaces are designed primarily with consideration to physiological modalities to provide technology-related feedback channels — through a monitor or haptic hand controllers.

1.3.7.2 High-precision wearable haptic feedback technology

Wearable haptic feedback devices incorporate high-precision kinaesthetic and cutaneous (skin) technologies, allowing users to experience objects passing through virtual space. Vechev *et al.* (2019) have evaluated the ability of such systems to manipulate virtual objects to communicate effectively using tactile feedback within the virtual environment. Commercially available haptic glove technologies enable virtual objects to move while receiving effective haptic feedback by electrostatic brake mechanisms to allow handling. This technology is valuable for emulating controlled environments — prior to performing critical tasks in the real world.

Dexterous articulation feedback and wearable technology testing equivalent to two kilograms of force have shown higher accuracy when mimicking frictional forces within VR environments. [25] Besides providing greater accuracy, *Dextarobotics Haptic Feedback Exoskeleton Gloves* thin form factor haptic glove technology is ideal for mission-critical applications, especially where exact simulations are required to grasp a virtual object (Solvelight Robotics, 2020).

NOTE: This compelling research area influenced the author to develop a novel haptic interface relating to cognitive and affective interventions.

1.3.7.3 Kinaesthesia: a multimodal response to biological functions

Biological activities and processes provide physiological input on numerous proprioceptive sensations to the Central Nervous System (CNS) (Martín-Alguacil *et al*., 2013). The human body is unique and can memorise biological functions interactively within an organic environment. Through physical sensations (i.e., see, hear, taste, smell, and balance), the visual, auditory, gustatory (olfactory) and vestibular impulses are simultaneously initialised. The intensity of associative receptors and mixed sensory perceptions (for each biological response) is in line with proprioceptive stimuli. Furthermore, somatosensation (often referred to as our sixth sense *(Whiston, 1712)*) — occurs as a response to the somatosensory and posterior parietal cortexes (Romo *et al*., 2002).

1.3.7.4 Wearable galvanic vestibular stimulation devices for VR

Sra, Jain and Maes (2019) provide extensive reviews of lightweight wearable galvanic vestibular stimulation devices, alluding to VR experiences, effectively reducing cyber-sickness. [26] Galvanic Vestibular Stimulation (GVS) interfaces mediate the VR experience with proprioceptive feedback to aid the physical presence of intensity within a VR. As a result, GVS interfaces replicate proprioceptive feedback by generating G-forces during rapid manoeuvres, gravitational impacts, and navigation throughout virtual simulations.

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[25] Frictional forces are achieved using an electrostatic brake that consists of a pair of freely sliding (conductive) thin metal strips. Once a control voltage passes through the strips, an electrostatic attraction causes a high level of friction and the strips to disconnect.

[26] Galvanic Vestibular Stimulation link to video

Other alternative proprioceptive devices developed through military training include *ProVolver* (*ProTubeVR*, 2022). This technology enhances recoil-haptic feedback sensations and virtual responses that mimic the spring-loaded action of reloading a firearm (Virtual Reality Oasis, 2020).

NOTE: The research areas discussed throughout the previous section influenced the authors' decision to develop a novel reactive interface that is undergoing future development.

1.3.7.5 Tactical proprioceptive feedback and gesture control

The author believes that the future of multimodal interfaces is shifting towards re-creating realistic kinaesthetic sensations that will leverage friction-force technology. Provancher (2019) supports this with evaluations of skin-stretch feedback interfaces and Tactical Haptics Motion Controller Devices (TMCDs) that use VR software to simulate natural elasticity, inertia and impact resistance forces (via tactical and proprioceptive feedback). Mechanically, sliding plates are tightly coupled to the surface of the physical interface to achieve a friction force. [27]

The novel feature of this tactical technology is its unique ability to reconfigure itself automatically for various virtual applications. [28] Given the physical weight of earlier haptic technologies and their financial implications, previous devices required additional external equipment to operate and configure. In comparison, single multi-functional devices offer greater flexibility for various virtual reality applications: teleportation, sword fighting, fishing or virtual tennis.

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[27] Reactive Grip™ incorporates shear haptic-feedback to convey motion and force data utilising tactile feedback.

[28] TMCD's, can be connected to traditional controllers to give friction and communicate feedback. Examples include: climbing down a rope or re-coil as a crossbow or handlebars of a motorbike. Magneto-optical sensor points are incorporated into these controllers to reduce the requirement for multiple devices.

1.3.7.6 Hygiene concerns: touchless haptics during a global-pandemic

> ***'The coronavirus [pandemic] has made me rethink my willingness to touch things in public places. This is an unnecessary risk, so I'd rather not…'* Vasickova *et al.* (2010)**

Ultraleap (2021) has conducted quantitative analytical research around consumer health concerns and physical hygiene contact — during a global pandemic. Vasickova *et al.* (2010) evaluate the sanitisation levels of touch displays — positing that physical activity is significantly more unhygienic — favouring microorganisms, particulate matter, and pollutant growth on complicated surfaces. Vasickova's survey findings concluded that from a sample of 271 people, 81.1% actively disagreed with using public touchscreens due to hygiene, while 19% actively agreed.

The emergence of touchless kiosk technologies has influenced retailers to update their touchscreen technology (Ultraleap, 2020*)*. Modules attached to existing digital kiosks and terminals can be adapted using a Leap Motion Controller (Ultraleap, 2021a) consisting of stereo IR170 cameras to provide mid-air touch capability. This tiny device includes a universal serial bus (USB) connectivity and UI integration with appropriate tracking software to assist the user in configuring and controlling various solutions using hand gestures. [29] Hand movements detected over the device during mid-air interaction contribute to the conversion of an on-screen user interface. This device offers an alternative guidance method for the user via touch screen interaction. [30]

Hygiene and cross-contamination in public areas became an essential concern for numerous people throughout the coronavirus pandemic. Ultraleap (2021) responded to such challenges and developed mid-air feedback solutions for hygiene applications. Immersive mid-air haptic hardware and software solutions were developed and made available for existing user interfaces and computer vision applications. [31]

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[29] Examples include digital screens, interactive kiosks, and holographic displays.

[30] Areas of dispersed air pressure can select icons or scroll through content using menus in mid-air www.ultraleap.com

[31] See How to Turn Touchscreens into Touchless Interfaces | Ultraleap

Hardware modules of the STRATOS Inspire and Explore (Ultraleap, 2019) emit high-frequency sound waves over sonar signals — inaudible to the human ear (Carter, 2019).[32] Complementary haptic technology modules, comprising 256 miniature (8.6mm diameter) ultrasonic transducers with a refresh rate of 40kHz, are individually arranged in an array formation. The combination of gestures or patterns detected within the boundary frame during mid-air interaction (i.e., above the array) or above the maximum sonar range threshold of 700mm establishes a localised area of high pressure. Resultingly, these actions displace the skin's outer surface to virtual control objects (in mid-air), providing the user with a sense of frictional feedback. The supported software transfers mid-air pressure coordinate points between detected motions corresponding to 3-dimensional virtual areas of localised space (Carter, 2018; Evans, 2021). Mid-air haptic technology is ideally suited for hygienic 'on-screen' menus or virtual musical applications (for example) to compose music in mid-air. This innovation allows for cleaner and more precise creative environments.

NOTE: Hygiene became a relevant factor for the author during the study, particularly for children using a VR headset during a coronavirus pandemic and throughout the trials.

1.3.7.7 Psychological sense of balance

Proprioception is a vital neuromuscular sense that defines the precise physical spatial coordinates of the body in any given physical space. For example, one would expect to trust *Whitson's* (2018) initially coined "sixth sense" (1712) to navigate effectively whilst walking through a dark basement without observing their surroundings (Cooper, Taylor and Feller, 2005; Ager *et al.*, 2020). This "blind motion" requires sensing geographic positioning via the sense of smell, touch, or temperature to avoid hitting a wall or causing physical injury. Amid synthetic virtual interaction, proprioception helps to achieve real-time feedback and a physiological sense to determine the exact position of our body (without looking at ourselves).

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[32] Tom Carter (2019): link to source

The author considered the following factors whilst developing the VR intervention:

- Sense of real-world balance (e.g., positioning of the feet whilst walking)
- A physical position of the body concerning its surroundings within the virtual 3-dimensional space

1.4 ASC: Established Interventions & Approaches

> ***' […] autism and music are closely linked […] acting as an adhesion that brings back all the pieces together into one cohesive unit.'***
> **Bergmann, T. (2015)**

People with autism spectrum conditions respond favourably to music therapy. However, many other therapeutic approaches are available to people with ASC (Lofthouse *et al.*, 2012; Bergmann, 2015). Furthermore, music therapy encompasses various psychotherapeutic and psychodynamic approaches that form a crucial part of therapy discussion between client and caregiver. Co-creative processes resulting from integrating client musical responses and gestures are essential for the success of many of these interventions (Robinson, 2015).[33]

Neurological music therapy (NMT) is a technique based on an individual's understanding of musical perception and neurological pathways that influence non-musical behaviour (i.e., sensory and motor skills in social interaction). Active musical participation is an effective evidence-based mediation that induces spontaneous improvisation to facilitate all-encompassing creative and expressive forms of interaction. *Research Autism Information* (a division of the *National Autistic Society)* continuously updates many fundamental approaches to established treatments and intervention

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[33] See **Appendix I** for several discussions with music therapists who indicate it is essential for practitioners and caregivers to be present during a music therapy session to influence their improvement of any physiological well-being with a client.

methods. [34] [35] The considerable increase in undiagnosed ASC patients recognises an increased necessity for embodied therapies (Srinivasan and Bhat, 2013), emphasising the importance of investigating the feasibility of a virtual reality musical intervention.

1.4.1 Play Therapy & Autism: The Inner Dynamics of Childhood

Georgescu *et al.* (2014) provide a detailed analysis of the mechanisms and communication challenges underlying people with ASC. Play therapy originated as a means to analyse young children's underlying behavioural characteristics through a range of media by promoting individual development and encouraging self-expression (Klein, 1923; Rogers, 1995). *Hermine Hug-Hellmuth* (1912) conceptualised psychoanalytical approaches toward young children and adolescents as an advocate of the discipline. Hug-Hellmuth's analytical and therapeutic approaches to play therapy have turned into many other forms of creative intervention (Gardner and Yasenik, 2012).

Virginia Axline's (1964) *Play Therapy: The Inner Dynamics of Childhood* is the first contribution to theoretical practice in child psychology that pioneered non-directed play. The early literature of Maclean (1986) and Winnicott *et al.* (1989) emphasise Axline's psychoanalytical explorations of vulnerable children presenting challenging behaviour. Their accounts allude to a remarkable transition of an autistic individual (through a process of psychotherapy and the art of play), Axline (1990) introduces *Dibs* (rather appallingly) as *'a mentally retarded'* child alluding to his suffering as "a deep-seated mental illness".

> ***'There was something about Dibs' behaviour that defied the teachers to categorize him, glibly and routinely, and send him on his way. His behaviour was so uneven. At one time, he seemed to be extremely retarded mentally.'*** **(Axline, 1990, p. 5)**

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[34] Areas include healthcare services, alternative and complementary medicine, developmental and behavioural impairments, psychological, and other assistive, augmented and adaptive (AAA) therapies.

[35] Updates to established therapeutic approaches within the UK's healthcare and special-education communities through a network of clinical, psychological, and teaching professionals (Raglio and Oasi, 2015).

Axline's antiquated and disturbing account poses similarities to first-hand accounts of those documented by *Kanner* (1968) and later *Bettelheim* (1973)**,** who compared autism with "poor parenting" and "a genuine lack of warmth" **(see page 38).** [36] Similarly, Kenner's, Bettleheim and Axline's accounts were each documented in an era (and by a generation of psychoanalysts) who made their diagnosis on the grounds of a psychiatric (genetic) illness. [37] Furthermore, little was known about autism and mental health disorders in children around this era (Bratton *et al.*, 2005).

1.5 ASC Interventions: Technology-Based Approaches

Table 3 provides an overview of four sensory applications and use cases of current human-computer interaction applications (HCIs).

Table 3.

Human-Computer Interaction (HCI) sensory applications

Interaction	Interface	Method	Applications	Pros	Cons
Voice	Conversational Interface	Spoken Input	HCI Siri, Alexa, Google Assistant	Direct Access to information, No manual	Ephemeral (short-lived) response. Background noise interference.
Visual	Screens (smartphones) Camera Facial recognition	Optical tracking	Websites, Mobile Apps, Navigation systems, Ticket booths	Permanent	Overwhelming information
Touch	Haptic, gestural, and tactile	Multi-touch (varying pressures) Mid-air Kinesthetics	Smartwatches, automotive interfaces	Hands-free interaction, finger occlusion (e.g., wet conditions)	Localised point of feedback determines temporal and spatial perception
Auditory	Audio User Interface (AUI)	Sonic frequency	Early warning systems, collision avoidance, speech signal extraction	Complex information reduced to auditory signals	Improper design and use cause inconvenience

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[36] Autistic Disturbances of Affective Contact. Kanner L (1943).

[37] See: Dibs in Search of Self (Axline, V. 1964), for a first-hand account of an autistic non-verbal individual named Dibs; deficient in social and emotional interaction with an extremely high IQ (168).

Using haptic technologies in immersive musical reality demonstrates the scope for other paradigms (e.g., stroke rehabilitation). Somatosensory and proprioceptive technologies can also be incorporated into technology devices to facilitate individuals in grasping musical instruments in virtual scenes. Interactive physical technologies are crucial to inspiring people with ASC and other neurodevelopmental disorders to help them engage physically — by using virtual interfaces to learn repetitively. Immersive VR experiences promote multi-sensory perception and integration through embodied learning (Juntunen, 2020).

The *Cyprus Interaction Lab* (2022) assessed the efficacy of multi-sensory interactive floors and other technologically mediated learning activities surrounding formal educational settings. [38] Their experimental activities have provided young children with an enriching and engaging experience (Georgiou and Ioannou, 2020). These examples indicate how far haptics have evolved and further reinforce the concept of haptic (virtual-musical) participation through creative play (CaptoGlove Inc, 2020).

1.5.1 HCI: The future of 3D-Based Gesture Recognition

Human-Computer Interaction (HCI) relates to the study and design of operations for interactions between humans and computers. Li *et al.* (2019) and Zhang *et al.* (2020) investigate the complex challenges of three-dimensional gesture-based recognition in virtual reality contexts. The future of HCI is moving toward more naturalistic "intelligent" human-centric approaches that empower people with physical, visual, and neurological conditions (Blashki and Isaias, 2020). [39] Many HCI applications offer direct and indirect methods that use low-level computer software and mobile applications (e.g., health and fitness apps). Recent investigations of mobile HCI devices and biometric data for musical interaction (Roy *et al.*, 2021; Rhodes, Allmendinger and

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[38] The Cypriot led 'Embodied learning on interactive floor project', consists of a projector, floor sensors and various interactive graphics to allow children to 'step onto' as a response to acknowledge a correct solution to a given question. By specifying a correct or incorrect response to the multi-modal interface, this generates animations projecting back to the floor. Anna Magidou (2017).

[39] User-centred design techniques are a process of human-centred design (HCD) that encourage user inclusion, a topic typically addressed when designing products for individuals with special needs (Blashki et al., 2020).

Climent, 2022) guided the author to implement portable HCI technologies within the proposed immersive and virtual reality musical interface.

NOTE: Eye-tracking, HCI, and retinal technology issues led to the author's investigations, influencing the development of a virtual and retinal musical interface within the Unreal Engine.

Advances within the HCI paradigm accelerate the adoption of fundamental physiological senses (as listed below) and integrate them seamlessly into computer input modality interfaces.

- Sight (visionary)
- Sound (auditory)
- Touch (somatosensory)
- Smell (olfactory)
- Taste (gustatory) (Iwata, 2008)

Present technology makes it possible to map modalities to the three senses: sight, hearing and touch (Strawderman and Olmos, 2017).

1.6 Virtual Reality Treatments

This section addresses existing virtual reality treatments — including virtual exposure therapies (VRETs) — and multi-user virtual reality (MUVR) methods and processes that the author has used to develop a virtual musical technology system.

1.6.1 Exposure Therapy

Exposure therapy works by immersing a person into previously encountered traumatic experiences, fears, or phobias by repeatedly stimulating their physiological and emotional anxieties (Abramowitz, Deacon and Whiteside, 2019). Periods of repeated exposure to disturbances also result in the desensitisation of an individual's stimuli (Gupta, 2021). Furthermore, images or sounds can also support the process of gradual and repeated exposure to distressing events. Exposure therapy is a form of cognitive behavioural therapy (CBT) requiring the supervision of a trained clinical professional (Stallard, 2020).

There are numerous variations in exposure therapy. These include interoceptive exposure (IE), virtual reality exposure (VRE), imaginative exposure (IE) and in-vivo exposure (IVE) (Rizzo et al., 2010; Gonçalves *et al.,* 2012). In-vivo exposure occurs during a genuine exposure to a fear or phobia in a physical and controlled manner (for example, exposure to a real tarantula or a hand dryer) (Matsangidou *et al.*, 2020).

- Interoceptive exposure is a trigger response to feared physiological sensations.
- Virtual reality exposure is simulated exposure to stimuli within an immersive digital environment.
- Imaginative exposure requires cognitive participation to re-imagine vivid fears, phobias, or past traumas.

1.6.2 Virtual Reality Exposure Therapy

The author investigated other significant contributions to clinical and mental healthcare interventions utilising virtual reality exposure therapy technology (VRET) applications. Maskey *et al.* (2014), Souza (2018), and Matsangidou *et al.* (2020) each verify that virtual "imaginative" exposure therapy applications (when facilitated by technology) are successful in their approach. [40]

1.6.3 Multi-User Virtual Reality

A Multi-User Virtual Reality (MUVR) offers simultaneous immersive experiences between client and therapist, offering a virtual perspective by replicating a first or third-person. This interaction (i.e., client and caregiver) occurs during a music therapy session (Thomas *et al.*, 2014; Gong *et al.*, 2020).

MUVR offers many physiological and psychological benefits, including:

- Reduced anxiety
- Reduced negative emotion

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[40] Matsangidou *et al.* (2020) have published findings for a study to treat high-risk eating disorders including Body Dysmorphic Disorder (BDD), Anorexia Nervosa and Bulimia Nervosa.

- Increased sense of presence
- Increased confidence

1.6.4 Virtual Reality Systematic Reviews: CBT and ET

Peer-reviewed research articles by Botella *et al.* (2015) and Wu *et al.* (2021) postulate the efficacy of VR therapies as meaningful interventions. Their evaluations of virtual reality exposure-based therapies (VR-EBT) and virtual reality cognitive behavioural therapies (VR-CBT) reported that these evidence-based interventions were effective for patients experiencing post-traumatic stress disorder (PTSD), anxiety, and depression.

Consequent to 2013, there has been a surge of virtual reality exposure therapy (VRET) clinical trials conducted for gait rehabilitation and Parkinson's disease (Brandín-De la Cruz *et al.*, 2020). Trials posit that virtual reality exposure-based therapies within traditional mono-directional simulated environments (i.e., clients in the presence of a therapist) — are widely practised. The advancements surrounding immersive simulated environments and digital health technology concepts are particularly encouraging for larger digital therapeutics companies. Limbix (*Limbix Health Inc.*, 2020), for example, introduce a complete digital therapeutics solution for clinical settings to treat depression and other psychiatric conditions surrounding mental health paradigms. Their digital prescription service encourages practitioners to conduct VRET to alleviate long waiting times.

1.7 Additive Manufacturing & Computer-Aided Design

This section reviews the existing technologies and processes for rapid prototyping and virtual reality asset and scene creation required to develop a proof-of-concept.
Table 4 (see the following page) compares examples of thermoplastic material filaments and their use for respective applications — often utilised as a part of the additive manufacturing process that the author explains in the following texts (Clark, 2016).

Table 4.

3D Printer filament types use and comparisons

Material filament	Examples of application	Properties	Temperature range (printing)
Acrylonitrile Butadiene Styrene **(ABS)**	Moving parts, toys, electronic assemblies, Instruments, Smartphone mounts, rings.	Durable component creation. Higher strength applications. Impact-resistant.	210°C – 250°C
Polylactic Acid **(PLA)**	Biodegradable packaging or prototype components, wrappers.	Eco-friendly, recycling. Thermoplastic renewably sourced material	190°C – 230°C
Polyvinyl Alcohol **(PVA)**	Paper adhesive, thickening agent, packaging film	Biodegradable, non-toxic, Water-soluble, low flexibility	180°C – 230°C
Polyethylene Terephthalate **(PET)**	Packaging, plastic bottles, phone cases, mechanical parts	Flexible, high heat resistance, shockproof	220°C – 250°C
Carbon Fibre Reinforced Polymer **(CFRP)**	Protective casings, shells, high durability applications	High rigidity, layered adhesion, lightweight.	195°C – 220°C

1.7.1 Additive Manufacturing

Additive Manufacturing (AM) is a rapid prototyping method for producing three-dimensional components using a computer-aided design (CAD) or computer-aided-manufacturing (CAM) system to generate stereolithography (.STL) file formats. The STL file format can be exported directly to a 3D stereolithography printer to create a 3D-printed artefact using a printing head whilst offering high precision (Gibson *et al.*, 2021). A layered incremental printing approach employing heat-resistant thermoplastic materials fuses filaments at high temperatures. Ordinarily, this process is utilised during the rapid prototyping stages when manufacturing critical components (Killi, 2017).

Three-dimensional printing technology has advanced to alternative "cutting edge" techniques. DeSimone's (2015) Continuous Liquid Interface Production (CLIP) technology is an early development of efficient 3D printing capable of reproducing micro-fine detailed artefacts in substantially less time (50%) compared to conventional stereolithography 3D printers (Tumbleston *et al.*, 2015).

1.7.2 Photorealistic, Physically Based Virtual Scene Methods

3D animation and modelling software has become more readily available for home enthusiasts to create computer animations easily. Animation studios such as *Pixar* (Disney), *Walt Disney Animation Studios* (Disney Enterprises, Inc.) and *DreamWorks Animation* (2022) previously relied upon in-house programmers and engineers to develop early animations using bespoke software and hardware render farms (Watt and Watt, 1992; Miles, 2015; Negrón, López and Aguirre, 2020).

Software rendering technologies such as *RenderMan* (Pixar, 2021) were prerequisites to recreate photorealistic scene elements; these incorporated natural materials and photometric lighting (Watt and Watt, 1992; Pharr, Jakob and Humphreys, 2017). [41]

> ***'Pixar movies can take anywhere from 4 years to 7 years!***
> ***The bulk of the production, though, such as animation and lighting, only takes about 6 to 8 months…but mostly it takes about 4 to 6 years or so to develop. It's not quick and easy to make [compared to live-action films.'*** **Bruce Kuei, 2018 – Animator Pixar**

Table 5.

Physically Based Rendering (PBR) example material component-maps

Texture map	Defined by:	Function	Information
Diffuse	Texture or scanned image	Represents model colour with lighting	Light and Shadow
Albedo	Texture	Represents model colour only	Light and shadow data removed
Normal	Texture	Project high-resolution detail on low-resolution models	Pixel data for resolution

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[41] Rendering refers to the process of regenerating 3D graphics (scenery) by capturing individual images (still frames) within a software or hardware graphics rendering engine. The frames can be played back in sequence to form a showreel.

Table 5. ***(Cont.)***

Roughness	Bump	Creates a relief (displacement) to give the illusion of depth	Black (embossed) and white (protrudes) values
Metallic/Specular	Texture	Defines glossiness	Positional data
Ambient Occlusion	Shadow	Defines dark areas and shadows based on local co-ordinate distance	Black (dark) and white (lighter) value masks
Alpha Transparency	Opacity	Adjustment of opacity or transparency	Black (opaque) and white (visible) value masks

The rapid advancement of (previously required) hardware rendering technology has reduced the cost of customisable equivalent plugin software renderers such as *VRAY* (*Chaos Software EOOD*, 2022).[42] [43] In parallel with software advancements, computer graphics processing technologies (NVIDIA, 2022) have enabled seamless integration into the VR and mobile rendering pipeline.[44] Some examples of high-end visual processing software used to reconstruct physical lighting and create complex procedural textures include:

- Quixel Megascans (formerly DDO Painter) (*Epic Games*, 2019)
- MARI 5.0 (*FOUNDRY*, 2021)
- Substance 3D (*Adobe Substance 3D*, 2022)
- Mudbox 2023 (*Autodesk*, 2022d)
- Zbrush 2022 (*Maxon Computer GmbH*, 2022)

> ***'Another important aspect of player immersion is the character the player is controlling in the game. Most all games are about role-***

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[42] Previous technology to digitally render a single frame of an animated movie required long durations between 4-24 hours, and rendering farms would be outsourced with large data-server rooms storing vast processing power. A typical feature-length animated movie requires a processing capacity of more than 5000 processors and over 100 terabytes of storage. See Pixar Rendering

[43] Rendering innovations are now accessible via accelerated cloud based rendering subscriptions.

[44] Ray tracing and physical-based lighting capabilities for mobile platforms and head-mounted displays.

> ***playing to some extent. And if the character the player is controlling, his surrogate […], the player's immersion will be disrupted...'***
>
> ***(Rouse, 2004, p. 13)***

NOTE: Physically based rendering methods informed the author's process of developing realistic procedural texture maps for the virtual immersive musical scene.

1.7.3 Photometric Lighting, Animation and Special Effects

The *Illuminating Engineering Society* (IES) is a central hub for technical specifications and recommendations for illumination within electrical engineering and lighting disciplines (DiLaura, 2020). The first technical presentation, *Transactions of the Illuminating Engineering Society,* was published in February 1916 as a response to standardise lighting specifications (Illuminating Engineering Society, 1916). In its present form, IES contributes toward a digital standard dedicated to functional lighting, energy consumption, and environmental sustainability issues (Illuminating Engineering Society, 2021). Three recognised lighting standards published by the IES address fluorescent and light-emitting diode (LED) technology; these include:

- RP.33.14 – exterior environment lighting
- RP.20.14 – lighting for parking facilities
- LM.41.14 – approved methods for testing of photometric indoor luminaires

Since November 2020, the IES has superseded most of its lighting specifications, adhering to the *American National Standards Institute (*ANSI).

NOTE: The author relied upon physical-based lighting specifications from the IES catalogue to create photorealistic elements and animations for the virtual scenery and musical interface.

Table 6.

Physics-based animation systems for a virtual reality scene

Animation elements	Scene assets for this project
Illumination	IES Lighting profiles for sensory lighting
Sequence level animations	Animations including musical notes and floral instrument
Trigger volumes	Walking into / approaching posters on walls and TV screen
Particle systems	Bubbles
Live stream	A live video feed of the therapist on the virtual TV screen
Dynamic audio effects	Ambisonic spatial sound and positioning of audio within the scene
Collision detection	To prevent the client from walking outside of walls. Collision of instruments
Triggers	Box collisions to trigger lighting and audio

NOTE: This area of investigation led to the author's development of real-time animation, dynamic particles, physics, lighting and audio depth via texturing and modelling techniques.

1.7.4 Summary

The game's design process was thoroughly investigated and found to be a valuable comparison for the author to draw upon VR practices for deploying the interactive musical interface and VR system. Resultantly, decisions were made for the most appropriate integrated development environment (IDE) to create a 3D sensory room during the *3-Stage Technical Development Process* (3S-TDP). [45] The approaches used

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[45] Throughout this thesis, the author refers to Unreal Engine 4 (version 4.26.2) (EPIC, 2019) as the integrated development environment chosen for developing the VR system.

throughout the methodology (including areas outlined throughout the literature review chapter) informed the development of a functional physical interface and transferrable tool.

NOTE: Throughout the design process, the author investigated theoretical methods and concepts in addition to those described in this chapter; they included:

- **Catmull-Clark algorithms**
- **UV mapping**
- **Software toolsets and IDE comparisons**
- **3D benchmarking and optimisation**

1.8 Autism & Special Educational Needs

This section presents a review of the prevalence of autism among the population and introduces established diagnostic criteria and ratings for an ASC. A short review of early publications on autism and connections to music and ASC is also highlighted.

> ***'Autism is a lifelong developmental disability which affects how people communicate and interact with the world. One in 100 people are on the autism spectrum and there are around 700,000 autistic adults and children in the UK.'*** **(Alan Gardner, 2019)**

1.8.1 Autism Prevalence

Census data provided by the Office for National Statistics (ONS, 2020) provides information regarding autism prevalence amongst those with long-term health conditions between the ages of 16-64 within the UK, estimated by the ONS as 2.9% of the annual population as shown on the following page *(Table 7)*.

Table 7.

Prevalence of autism among people with a long-term health condition (16 to 64 years)

Ages	Estimate%	Lower 95% confidence limit	Upper 95% confidence limit	Unweighted sample
16-19yrs	17.6	15.7	19.6	294
20-24yrs	10.1	8.7	11.5	204
25-29yrs	6.6	5.5	7.7	149
30-34yrs	3.2	2.5	4.0	96
35-64yrs	0.8	0.7	1.0	246
16-64yrs	2.9	2.7	3.1	989

Source: Office for National Statistics (ONS) - Annual Population Survey

The ONS analysis affirms that there are still many undiagnosed cases of autism within a global and UK population, illustrating a more widespread prevalence than people consider. Rapid variability factors make monitoring the real-time ASC prevalence as a single diagnosis challenging. The sociodemographic status, biological gender and other comorbid long-term health conditions indicate that the most recent estimates are obtainable only by systematic reviews (Zeidan *et al.*, 2022) or statistics based on sample populations — on a two years (or more) basis (Office for National Statistics, 2021).

During the author's early stage of this research (2017), the National Autistic Society (NAS) estimated that approximately 700,000 people in the UK were diagnosed with ASC. [46] [47] Prevalence among children in the UK with an ASC diagnosis was reported as 157 per 10,000 children (Sun *et al.*, 2013; *NICE*, 2017). By comparison, the figure of 7,000 from 6,580 reveals an increase of 6.185%. [48] At present (2022), estimates of ASC in Asian countries such as Japan and South Korea suggest a greater prevalence.

Lower developed countries with larger populations and lower incomes are also

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[46] Data obtained via autism.org.uk

[47] Estimates derived from the worldwide prevalence among children in the UK 2017 census figures based on epidemiological surveys (WorldAtlas)

[48] 94 per 10,000 equates to 70 x 10,000 of the 700k population = 6,580 (diagnosed). The NAS quotes one in 100 people (equating to 7,000).

unequivocal. Africa, for example, has a population of over 1.4 billion, which equates to approximately twelve million undiagnosed cases of autism spectrum condition (ASC) — resulting in a lack of funding or trained clinical services to support any intervention (Baron-Cohen, 2017; *ICD-10 Version:2010*, 2022). [49] The rate of prevalence for early diagnosis of ASC continues to increase rapidly.

1.8.2 Diagnosis criteria and ratings for an ASC

The *Childhood Autism Rating Scale – Second Edition* (CARS-2) (Schopler *et al.*, 1980) is one credible clinical rating considered by psychologists to interpret an ASC diagnosis. There are three formats available for the CARS-2 direct observation method, shown in the following table: [50]

Table 8.

Childhood Autism Rating Scale (CARS-2) available formats

Model	Summary	Requirements	Criteria
CARS-2-ST (Standard Form)	Clinician ratings via information gathered from clinical observations and completion of a supporting CARS-2-QPC questionnaire.	Children below or above six with an estimated intelligence quotient (IQ) score; lower than 79.	Significant communication impairments.
CARS-2-HF (High Functioning)	Clinical ratings from two known sources. Direct observations and information gathered in different settings—by individuals aware of the child's behaviour.	Children aged six or older with an estimated IQ score of 80 or above.	Fluency of communication.
CARS-2-QPC (Questionnaire for parents and carers)	Parental or carer ratings observed in a known setting.	Children below or above the age of six. To be completed by the parent or carer of the child through observation of the child.	Substantial communication impairments or fluency of communication.

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[49] Data from 2016. Details for 2017 remain close to 1.2 billion: Link to source

[50] The CARS and CARS-2 were developed for children and adults. Division TEACCH was created in 1966 as a pioneering program serving individuals on the autism spectrum for all ages throughout the state of North Carolina. Link to CARS-2 source

The *Childhood Autism Rating Scale - Second Edition* (CARS-2) rating scale informs a revised psychometric assessment to support the diagnosis of conditions of higher functioning autistic individuals (CARS-2-HF). Professionals and psychologists working closely with autistic people (who may have comorbid intellectual functioning deficits) rely on the CARS-2 diagnostic toolkit. A termination (cut-off) score corresponding to the CARS-2-HF severity group rating ranges *(Table 9)* is referred to via a *T-score range* to calculate a final assessment shown below:

Table 9.

Childhood Autism Rating Scale – Second Edition (CARS-2): severity groups

Severity group rating	***T-Score range***	***T-Score range (age 13+)***
Minimal-to-no symptoms of ASC	15 - 29.5	15–27.5
Mild-to-moderate symptoms of ASC	30 - 36.5	28 -34.5
Severe symptoms of ASC	37 or higher	35 or higher

A psychological evaluation and diagnosis for an autistic spectrum condition are recommended under the trained supervision of a clinical psychologist. Evaluations for diagnosis in the U.K. are conducted based on the recognised ICD-11 specified under the hierarchy of *Disorders of psychological development* (section F84) within the *International Classification of Diseases* (ICD-11) for mortality and statistics (Version: 05/2021). [51] In the U.S., the equivalent *Diagnostic and Statistical Manual - fifth edition* (DSM-5) is cited (*American Psychiatric Association*, 2013; *ICD-10 Version:2010*, 2022). Both standardised scales are tools used by clinical professionals to measure the progress of a child's neurological and social development for the diagnosis of a childhood autism spectrum condition.

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[51] The ICD-11 clinical guidelines are closely based upon those set out by the American Diagnostic and Statistical Manual—currently in its fifth edition (DSM-5) for all audiences (autism.org.uk)

NOTE: The CARS-2 scoring system informed the author to devise a unique virtual immersive musical scoring equivalent. [52]

1.8.3 Leo Kanner: Early Undertones of Autism

Leo Kanner (1943) ambiguously defined autism as a "*syndrome*", comparing it lucidly to "a secret egotistical aspect of schizophrenia". Kanner established the fundamental problem through observations comprising his study of eleven cases of children — each exhibiting different clinical conditions and social interactions since birth (Kanner, 1943). Kanner's results were interpreted (confusing cause with effect), accusing a lack of maternal warmth and coining the term 'Refrigerator Mothers.'

> ***'One other fact stands out more prominently. In the whole group, there are very few really warmhearted fathers and mothers.'*** **(Kanner, 1943, p.250)**

Psychiatrist Paul Eugen Bleuler (Fusar-Poli and Politi, 2008) first used the term autism (1911) (Greek; meaning *self*) to illustrate a withdrawn schizophrenic patient; the term autism was later coined by Bruno Bettelheim, who described 'infantile autism as *'the most severe psychotic disturbance of childhood known to man'* (Bettelheim, 1972; Kartemquin Films, 2008). Bettelheim presumed himself an expert in the care and treatment of autistic children (based on his own experiences) and was subjected to exile in Vienna in 1938 (Fleck and Müller, 1997). Although his work was widely cited, Bettelheim became subject to extreme criticism within the social sciences (Osteen *et al.*, 2008).

Austrian paediatrician *Hans Asperger* (1906-1980) identified a pattern of behaviours based on four patients termed "autistic psychopathy" (or self-personality disease) (Rogers *et al.*, 2006). Asperger's subjects often presented severe social

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[52] The term autism 'spectrum' (as it was referred to prior to the 2003 Genome Project) within the context of the range of impaired characteristics; offered a more widespread description of the scale for diagnosing an ASD. Previously, individual neurodevelopmental deficits such as Asperger's Disorder, Pervasive Developmental Disorders PDD-NOS, and Rett syndrome were specified as Disorders of psychological development (F80-F89). ICD-10 Version: 2015

impairments, and each demonstrated exceptional memory skills and talents despite deficient levels of functioning, referred to today as Savant Syndrome (Treffert, 2009).

1.8.4 Autism Spectrum Condition (ASC) Characteristics

ASC is a lifelong neurological condition developing in an increasing undiagnosed population of young people. [53] Physiological and psychological comorbidities are recognised across various spectrums (Office for National Statistics, 2020). Music therapy is an evidence-based strategy — favoured by practitioners and clinical professionals for its active and receptive form of intervention. Several qualities of music therapy are associated with neurological disorders, such as social interaction, emotional engagement, and behavioural communication (Sharda *et al.*, 2018).

The heterogeneous complexity associated with ASC (i.e., social, emotional, and behavioural impairments) is contingent on biological factors and heritability that apply only to the individual (Abrahams and Geschwind, 2008). [54] Furthermore, the distinctive characteristics of an autism spectrum condition (ASC) identify deficiencies that result from a triad of impairments. The key distinguishing factors include intricacies surrounding social-emotional interaction, social behaviour, non-verbal communication, and a fervent dislike to change. Autistic people like repetition and routines because this reassures them.

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[53] The Annual Population Survey (APS) is based on data collected by the Office of National Statistics (ONS). The final datasets published by the ONS are restricted to data collection between 16 to 64 years of age. APS does not report or collect data for individuals under 16.

[54] Heritability within the context of ASC refers to the proportion of differences in expression justified by genetic variation.

OTHER AREAS OF RELEVANCE TO THIS RESEARCH

The following section outlines other areas of relevance to this research (some of which are tangentially related to the thesis) that the author has explored to help form virtual musical reality intervention methodologies. Areas of interest include sensory processing disorders, sensory dysregulation, executive function and pioneering virtual reality healthcare services.

1.9 Existing Alternative Interventions

Based on established therapeutic approaches and existing interventions, more than 1,000 individual categories of services are available to people diagnosed with ASC (Hyman *et al.*, 2020). [55] Alternative therapies exist, including socio-cultural, behavioural, educational, developmental, psychological, and pharmacological approaches. [56]

1.9.1 Virtual Immersive Therapy for ASC

Telehealth and other breakthrough therapies using VRs open up a clear gap in music technology in clinical applications. These unresolved areas of music technology as an intervention (i.e., not included in a current list of clinical areas) require addressing. The author believes that further research to investigate preventative VR treatments and support characteristics of children with lifelong conditions (such as ASC) will rapidly validate the requirement for a virtual immersive musical reality intervention. [57] In addition, verbal signals and visual and auditory supports are three key communication areas described by the *National Institute for Health and Care Excellence* (NICE, 2012) that require further attention in autistic paradigms. [58] [59]

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[55] Interventions identified in the US by the CDC. See: Treatment and Intervention Services for ASC

[56] Sensory dysregulations; over or under stimulation (hyper, or hypo-sensitivity) to sight, sound, touch, smell or taste.

[57] Particularly within the healthcare and special educational needs spheres.

[58] Clinical guidelines provided by the National Institute for Health and Care Excellence. Please see Autism spectrum disorder in adults: diagnosis and management. Clinical guideline [CG142] Published on 27th June 2012 and updated on 14th June 2021.

[59] Linguistics is one characteristic of ASC that impacts the development of social communication.

1.9.2 Sensory Processing Disorders

Sensory Processing Disorder (SPD) is a hypersensitivity to somatosensory stimuli most often associated with autistic spectrum conditions (Mielnick, 2017; Hyman *et al.*, 2019). People with profound aetiological comorbidities and neurodevelopmental disorders often experience one or more combined emotional, intellectual, or physiological sensory impairments. [60] [61] Somatosensory dysregulation leads to deficiencies that significantly affect an individual's ability to interact with their environment — thus causing problematic distractions for children with ASC that affect their ability to focus on a specific task (Nelson, 2019).

Examples include exposure to intense sunlight, fluorescent lighting, clothing texture and minor common occurrences (i.e., perfume scent). Although barely perceptible to a neurotypical person, SPDs can tremendously impact the neural stimuli of an individual diagnosed with an SPD (Marco *et al.*, 2011). Autistic people with SPDs sometimes encounter dilemmas in manipulating and processing sensory information; multiple sensory modalities often affect the following input senses (as previously mentioned):

- Vision (sight)
- Auditory input (hearing)
- Tactile stimulation (touch)
- Smell sensation
- Variations in taste

1.9.2.1 Sensory dysregulation and physiological responses

It is usual for people with ASC to feel overwhelmed when hearing the sounds of everyday objects. For example, a neurotypical person is ordinarily unaffected by the drone of an ambulance siren or the hum of fluorescent light. Nevertheless, an autistic

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[60] Mutual occurrences amongst those with ASC and people with dementia include hypersensitive (over) or hypo-sensitive (under) stimuli within their given environments.

[61] Sensory processing disorders (SPDs) comprise multimodal origins that disrupt somatosensory stimuli.

individual would respond via a physiological response (e.g., covering their ears) because of hypersensitivity — caused by high-frequency oscillations. [62] Sensory dysregulation results from excessive sensory input (sometimes called sensory overload), causing an imbalance in the sensory receptors of the central nervous system (CNS). Prolonged hypersensitivity stimulation can lead to extreme pain (Sherman, 2019).

Saccadic eye movements often occur in social settings caused by inappropriate stimuli. The optic nerve system is one of our fastest-moving human body parts (Frey *et al.*, 2013). Children with autism spectrum conditions can constantly fixate on inorganic objects and people (Klin *et al.*, 2002). [63] To counteract the effects of sensory dysregulation, graphical avatars, verbal signals, and visual supports are employed to assist autistic people and help them better comprehend. These visual resources improve learning and communication (Freeman *et al.*, 2018).

1.9.2.2 Auditory integration training (AIT): sensory intervention

Anxiety is an early cognitive marker of ASC, more prevalent in neurodevelopmental conditions (Wu, J. *et al.,* 2021). Other archetypes of regulated sensory integration (i.e., hypo- and hyperacusis) have proved to be long-standing issues within the autistic population (Stehli, 1992). Auditory integration training (AIT) (Bérard and Brockett, 2011; Rimland, 2015) is one example of sensory intervention. The non-invasive intervention employs randomised frequency and amplitude modulation algorithms applied to music and presented to the listener over a broad frequency range. Using varying intensities of random switching strengthens auditory stimulation and rebalances the auditory cortex **(see Appendix L. for additional texts)**. AIT has been prescribed for over three decades to treat symptoms of hyperacusis and tinnitus. However, the *Food and Drug Administration* (FDA) has questioned the veracity of AIT and discredited its effectiveness; as a controversial intervention. To this day, long-

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[62] The noise levels of an emergency siren typically fall within the range of 95 to 115 decibels. A spoken conversation is usually within the range of 65 decibels. Link to source

[63] The hearing frequency range falls between 1000-4000Hz. Beyond this range, it can be challenging for individuals with an ASC and hyperacusis.

established auditory intervention remains a controversial and long-standing issue for some (Sokhadze *et al.*, 2016).

1.9.2.3 Executive function in autism

The pre-frontal cortex is often associated with behaviour and social interaction and facilitates executive function (Pellicano, 2010). This regional hemisphere of the brain manages higher-order conceptual understanding, intuition, fear, empathy, and emotional regulation. (Macmillan, 2002). While there have been many differing accounts (*Phineas Gage*, circa 1848) regarding the classifications of executive functions, a singular characteristic is evident; executive function gives cause to provide a regulated and organised pattern of behaviour. This particular neurological role is essential for people with an autistic spectrum condition.

Executive function key constructs and various components include:

- Working memory — verbal and spatial
- Effective planning — ability to articulate tasks
- Inhibitory control — conscious control of thought
- Attention shifting — focussing on any current activity
- Rhythmic Auditory Stimulation (RAS) [64]

1.9.2.4 Stereology

Stereology is a method of 3D geometric interpretation that uses cross-sectional scanning to quantify small, concentrated areas of interest (Knudsen, Brandenberger and Ochs, 2021) and is ideally suited for clinical and biological applications because of its microscopic spatial precision and mathematic interpolation qualities.

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[64] Rhythmic Auditory Stimulation (RAS) is a training technique utilised to facilitate the rehabilitation of intrinsic biological movement such as gait. Based on auditory rhythm and sensorimotor skills, RAS assists to improve and stabilise many functions caused by neurological impairments (such as a stroke). RAS is a common clinical technique used in Neurological Music Therapy (Reed, A. 2019)

The investigation of neural correlates led to the author's examination of various methods of communication in greater detail. These forms guided the development of virtual expressions for the supplemental musical intervention, summarised in *Table 10* (Deepka, 2015).

Table 10.

Various forms of communication via virtual expression

Type	Occurrence	Features	Application	Outcomes
Aesthetic communication	Creative expression	Music, dance, art, and theatre	Performing and execution	Transmit overall message using expressions
Physical communication	Bodily movements	Smiling, frowning, saluting, touching, winking	Social interactions and conversation	Transmit feelings of attitude via postures
Sign	Mechanical signalling	Formation gestures and sounds	Messages conveyed via aircraft formations, 21-gun salute communication	Non-verbal communication via displays (i.e., horns or sirens)
Symbols	Use of material oncology (belongings)	Jewellery, clothing, accessories, and cars	Promote social status	Communication of social or financial status

Virtual neurological evaluations appear to be more popular as technology advances (Phutela, 2016), and for high-functioning autistic people, it can be challenging to interpret social cues when being assessed. Facial expressions and movements, such as those previously mentioned in *Table 10,* demonstrate standard forms of non-verbal processing. The author agrees, as Georgescu *et al.* (2014) rightly point out, to assist with various forms of social communication, children with high-functioning ASCs would benefit from using digital avatars (characters) as customisable profiles to transfer their virtual expressions into real-world scenarios. [65]

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[65] Avatar describes a digital character within a virtual environment. Avatars can be customised to a users preferences.

1.9.3 Telehealth: Pioneering VR Technologies

Mobile technology and digital infrastructure advancements have allowed more practical online applications in clinical areas by offering and supporting patients remotely. Telehealth is well-defined by Noel and Fabus (2022) as; the use of telecommunications technologies that enhance public and educational healthcare delivery. According to Martich (2016), the primary strategy for Telehealth services (sometimes referred to as *Telemedicine*) is to provide optimal patient-centred and quality remote medical care to clients with chronic or severe illnesses more effortlessly.

Telehealth is accessible to those who require routine care and face financial hardship or physical accessibility because of poor health and medical conditions; it can also benefit the elderly and people living in more rural areas. Since the unpredictable coronavirus pandemic, the demand for telemedicine has increased exponentially, and remote monitoring technology has addressed many medical challenges during social distancing restrictions through the lockdown.

Koonin *et al.* (2020) reported that virtual visits during the last quarter of March 2020 (the pandemic lockdown) had increased by 154% compared to the same period in 2019. According to media statistics (Acumen, 2019; *BBC Wires*, 2020), the global telehealth market will reach approximately 14.9% (£41.05- billion) by 2026. [66] To clarify, the World Health Organization (WHO, 2020) differentiates between telehealth and telemedicine to form two parallel terms of healthcare:

- **Telemedicine** utilises telecommunications to diagnose and treat clients, restricted only by the delivery of a trained physician.
- **Telehealth** (utilising telecommunications and ICT technologies) is reserved for healthcare professionals such as general practitioners, pharmacists, and nurses.

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[66] Data obtained from the report: Telehealth Market (By Type: Product and Services; By Application: Radiology, Cardiology, Urgent Care, Remote ICU, Psychiatry, and Dermatology; By End use: Healthcare Facilities, Homecare, and Others) – Global Industry Analysis, Market Size, Opportunities and Forecast, 2019 – 2026 (Acumen, 2019)

Peters *et al.* (2008) illustrate the financial implications of transport and travel time required (i.e., working hours) to deliver first-class healthcare, particularly in rural areas of poorer countries. Accessible healthcare, technology, and infrastructure (i.e., transport networks) outline some disadvantages for developing countries — especially in more remote, difficult-to-reach areas — such as the Himalayan Mountains.

NOTE: The proposed ARTIMIS and CiiMS system has been comprehensively tested by the author and holds the potential to offer a fully remote musical interactive experience.

1.9.4 Virtual Reality Therapies (VRT)

Virtual reality therapy (VRT) and virtual reality exposure therapy (VRET) are [relatively] recent platforms (Gonçalves *et al.*, 2012). They provide therapeutic interventions across various clinical settings. Telehealth treatments are conducted (remotely) through technology-based and portable electronic devices. These eliminate the need for patients to appear in person for preventative therapies (Canning *et al.*, 2020; Kennedy, 2020). Virtual Reality Therapies are still in their infancy and have enormous potential in medical paradigms. The concept of a fully immersive environment capable of isolating individuals from the outside world is part of an ever-emerging list of therapeutic areas that the author highlights in the list below:

- Medical education (e.g., student dissection)
- Virtual surgery (e.g., critical or open-heart surgery)
- Urgent care (ambulance and intensive care)
- Rehabilitation (stroke recovery)
- Psychiatric applications (e.g., mental health)
- Psychological applications (cognitive and behavioural therapies)

ADDENDUM: KEY RESEARCH AREAS AND ADDITIONAL TEXTS

Achieving a fully functional prototype and its associated technologies required further research by the author in other vital areas that included:

- **Sensory integration:** touch-capacitive and mid-air haptics.
- **Early detection:** proprioceptive virtual session data. Early stability detection: patient composure (stroke) based on gyroscopic data. The integrated audiogram and ear training software to detect hyperacusis.
- **Prevention and Treatment:** interactive metronome, gait syncopation training to assist treatment for tinnitus and hyperacusis.
- **Neurological and peripheral systems:** proprioception, olfactory and exposure therapy, and development of hands-free ‘gestural’ interaction.
- **Other neurodiverse areas:** people with mild to severe dementia and Alzheimer’s

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1.10 Cognitive Rationale

Increased interest amongst the neurological community in developing pharmacological interventions and applications for targeting specific brain mechanisms (i.e., chemical imbalance) has become increasingly popular. Neurologists have investigated the altered effects of gamma-aminobutyric acid (GABA) (a core inhibitory neurotransmitter) for children with autism spectrum conditions (Cho, Chang and Chang, 2007; Puts *et al.*, 2017).

Cognitive studies of inhibitory drugs, such as Riluzole, restore medial prefrontal cortex (mPFC) functional connectivity to nominal levels and reverse controlled (Class-A) drug-induced suppression (Sepulveda-Orengo *et al.*, 2018; Testen *et al.*, 2018). [67] [68] Scientists are keen to obtain necessary genetic signatures through the occipital lobe (a homogenous brain area) that repeatedly occurs in high-functioning autism. Autistic individuals have a larger prefrontal cortex compared to neurotypical counterparts. [69]

1.10.1 Existing Accessible Music Technologies: SEND

Existing literature illustrates a limited amount of research relating to virtual music technologies. Virtual Reality Musical Interventions (VRMIs) may one day complement therapeutic interventions within clinical and healthcare domains.

The Special Educational Needs and Disabilities (SEND) community identifies a handful of groups actively supporting accessible music for young people with disabilities. Groups such as '*OpenUp Music*' (Henchman, 2017) have evolved slowly since 2017 to offer an accessible open orchestra programme via an established Music Education Hub (MHE).

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[67] Riluzole is a medication initiated via specialists to manage the extended life of patients with amyotropic lateral sclerosis. The medicine is used in the treatment of motor neuron disease.

[68] The mPFC is a brain region involved in the pathogenesis of depressive symptoms. It plays a crucial role in the affective and cognitive deficits in depression.

[69] Consistent results reported that using a combination of the two (PRESS and MEGA-PRESS) techniques on similar trial groups resulted in higher (peaks) concentration levels of glutamate and lower levels of GABA.

The following two examples of music technology interventions (closely resembling the proprietary systems used in this research — ARTIMIS and CiiMS) are given below: [70] [71]

1.10.1.1 Clarion

Firstly, Farrimond's Clarion (2016) is one accessible assistive music technology system successfully implemented nationally and demonstrated throughout the United Kingdom, earning widespread award-winning recognition (Open Up Music, 2020). Farrimond's near-infinite musical software instrument is inspired and named after virtuoso musician *Clarence Adoo* (Adoo, 2020; Toryoung 96, 2018). Farrimond's highly configurable setup exemplifies his long-established electronic music composition and interactive technology experience. Furthermore, the Clarion is one of only a few music technology systems to empower people with physical disabilities through electronic creative composition.

1.10.1.2 Wildcard

Secondly, the *Wildcard* (Gelsomini *et al.*, 2016, p. 479) is an example of a wearable simulated virtual storytelling system for children with neurodevelopmental disorders that has been co-designed by professionals within the healthcare domain. The *Wildcard* is a cost-effective VR interactive system that utilises existing smartphone technology that incorporates virtual elements of the narrative to facilitate patients by staying focused on the activity they can perform. This seamless learning method activates familiar behavioural abilities helpful to participants in their everyday lives. The system has provided very positive results to researchers such as Sra, Jain and Maes (2019), who have evaluated children with cognitive and emotional deficits by exploring the potential of wearable VR technologies

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[70] ARTIMIS:- *Assisted Realtime Three-dimensional Immersive Musical Intervention System* hardware and VR interface.

[71] CiiMS: *Creative immersive interactive Musical Software* application and software user interface.

EXISTING TECHNOLOGIES AND AREAS IN NEED OF FURTHER DEVELOPMENT

This section provides an overview of existing digital audio setups and music production technologies currently unaccustomed to clinical and special educational needs disabilities for neurodiverse applications. For the first time, the author introduces the *Comparison Grid* to compare applications through a wide range of audio configurations.

1.10.2 Digital Audio Workstations

Digital audio workstations (DAWs) have exponentially evolved into self-contained music studios that manage all aspects of *virtual* music production. Sound engineers and music producers support using this digital technology and streamlined workflow. [72] DAWs are used in many creative audio and music technology environments to create music. Existing configurations are available as hardware or software variants for a wide range of multimedia industry applications that include: music production, film score composition, live performances, the games industry, digital animation, and music education. [73]

DAWs are flexible tools for audio editing and feature a diverse range of advanced functionalities for multi-track recording and mastering. Emulated virtual studio technologies (VSTs) are instruments, studio effects and percussion editors that seamlessly integrate into the digital audio environments to provide a single digital workstation. [74] Next-generation music production software requires high computing power to ensure real-time automation and optimisation at higher sampling rates.

The following table highlights familiar digital audio sampling rates for digital audio applications:

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[72] Virtual music production refers to lane automation and advanced feature sets, including spatial surround sound and multi-channel mixing.

[73] Creative audio refers to recording studio environments. Music technology encompasses Live performance, DJ applications and free-improvisation music technology performance.

[74] Orchestral and synthesised sounds and effects (for pre and post-production) within the digital domain are accessible via virtual studio technologies (VST).

Table 11.

Sampling rates utilised for digital audio applications

Frequency	Application
8 kHz	Telephony — ITU-T G711 standard
16 kHz	Telephony and data reduction G722
32 kHz	NICAM, DAT and AES broadcast coding
44.056 kHz	A modified version of the 44.1 kHz frequency used to synchronise analogue to digital equipment
44.1 kHz	CD-quality sample frequency
48 kHz	AES 5: rate for professional applications
96 -192 kHz	AES 5: secondary rate for high bandwidth applications, (Dolby Digital)

Sampling frequency standards for digital audio equipment

1.10.3 Modern Music Production Tools

Compared to their analogue counterparts, many modern DAW configurations occupy a smaller footprint (physical area). Current setups have evolved into considerably lighter, more reliable, and versatile systems — offering greater flexibility. A laptop (for example) with a software sequencer, dedicated audio interface, a MIDI controller and a pair of high-quality studio monitors is sufficient for rapid music production. Furthermore, portable hardware technologies and a handful of free tools can output high-quality recordings. Alternatively, mobile and tablet apps with MIDI compatibility have become popular; their portability provides users with a more practical method of controlling the master DAW software interface via wi-fi or Bluetooth connectivity.

Whatever the toolset, to meet the requirements of premium digital audio production, software DAWs and multi-surface hardware controllers require multi-threaded core computer processors (Intel, 2021). These simultaneously process multiple audio channels and real-time audio effects (amongst other complex real-time tasks).

1.11 The Comparison Grid

The Comparison Grid correlates the features, options, advantages and disadvantages of three high-end music digital audio workstations, music Production and virtual Studio technologies and digital musical protocols (i.e., MIDI and OSC). The author's intended purpose of the Comparison Grid is to primarily illustrate the gaps within virtual and clinical applications using existing music technology systems.[75] More importantly, these comparisons demonstrate the need to develop a proof of concept in new areas and show their associated configurations and disadvantages in the given context.

The mixed reality musical intervention (Shaded in grey on ***Part 1*** of the Comparison Grid; on the following page) demonstrates the author's potential for using the system within clinical applications. For clarity, the areas of application, client profiles and features include:

- Rehabilitation
- Clinical domains
- Special Educational Needs and Disabilities (SEND)
- Remote cloud-based access
- Telehealth **(see Telehealth: Pioneering VR Technologies, page 45).**
- Virtual Reality Music

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[75] Traditional studio and live real-time performance setups can be costly, requiring dedicated audio engineers to manage and configure. Portable systems also require more extended battery life and dedicated high-quality audio interfaces.

Two-part table: Direct comparisons between mainstream Digital Audio Workstations

***Part 1:** Existing technologies and areas of development*

		Digital Audio Workstations (DAW): configurations and applications		
		Dedicated Studio DAW	**Computer DAW**	**Portable DAW**
Standard components	Display (Qty)	● (1)	○ (2+)	● (1)
	Professional audio interface	●	●	○
	MIDI (2.0)	●	○ Custom	○
	OSC	– Hardware only	○	●
	Keyboard	○	○	●
	Mixing console	●	●	●
	Monitoring (external/Internal)	○	○	○ Laptop Speaker
	Display interface	● Touchscreen	○	●
Neurodiverse applications/profiles	Studio	●	●	●
	Mixing	●	●	●
	Mastering	●	●	●
	Live performance	●	●	●
	Electronic music production	●	●	●
	Rehabilitation	X	X	X
	Clinical	X	X	X
	SEN (Special Educational Needs)	X	X	X
	Remote access (online / cloud)	● Remote for music only	X	X
	Telehealth	X	X	X
Features	**Virtual Reality music**	X	X	X
	Wi-fi connectivity	●	–	●
	Bluetooth	●	●	●
	Portability	–	–	●
	Networking	●	●	●
	Virtual Studio Technology (VST)	●	●	○
	Group music sessions	●	○	○
	Rack-mounted	–	●	–
	Small footprint	–	●	●
	Realtime improvisation	–	–	●

***Part 2:** Disadvantages of existing music technologies*

	Dedicated Studio DAW	**Computer DAW**	**Portable DAW**
Disadvantages within the context of clinical and special educational needs applications)	Requires a dedicated sound engineer	Steep learning curve (dedicated support)	Integrated hardware
	Fixed system (portability)	Rack-mounted (portability)	Difficult to upgrade
	High cost	Optional extras	Battery power
	Optional extras	Excludes display	Dedicated hardware
	Dedicated to studio use only	Supports windows DAWs only	Audio interface

Key:-
● Standard or compatible feature
○ Optional feature
— Not available/applicable
X Gaps in the field (currently unsupported for this application): areas of further investigation for this research

Within clinical and special educational needs applications, the attributes emphasise existing protocols and fundamental elements that require further attention and investigation. [76]

NOTE: Subsequent chapters address the new areas of application for the system.

1.12 Comparison Grid Links

To prime the readers' understanding of new concepts and familiarity within the areas of music technology. The author provides additional texts in **Appendix L** with an explanatory section of existing technologies within the Comparison Grid,

…

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[76] The graphical representation compares the existing DAW technologies and their potential for clinical applications. Client profiles, clinical and SEN show additional features currently not supported by existing technologies (shown in grey are highlighted in bold on the table).

INTRODUCING A MIXED REALITY MUSICAL INTERVENTION SYSTEM

The following section introduces preliminary investigations and technologies that the author contributed to the early stages of developing the mixed reality musical intervention system and accompanying protocols; throughout this research. The author made initial discoveries through a programme of independent study during undergraduate and postgraduate master's degrees, and results from the studies helped underpin further advanced research as a PhD project. [77] The successes from early discoveries influenced the author's further research in limited areas of XR, music and neurodiversity.

Early concepts and software development methods (i.e., the Bérard theory of auditory integration training) guided the exploratory stages of clinical auditory intervention. The initial results led to real pilot studies conducted at a special educational needs (SEN) school and a residential home setting. Study participants for creative and clinical musical sessions were recruited from a small group of children with ASC and one older person with moderate-stage dementia. These early studies shaped the development of a (far more primitive) multi-faceted prototype musical interface to assist people with neurodiverse conditions.

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[77] Undergraduate research BA (Hons) Creative Music Technology: Independent Creative Project 2 (ICP2) (2014 – 2017) Postgraduate Masters of Music (MMus): Composition/Creative Audio project (2018-2019)

1.13 ARTIMIS

The *'Assisted Real-time Three-dimensional Immersive Musical Intervention System'* (ARTIMIS) was conceived from an independent creative project (practical dissertation) — wholly inspired by Stelios **(see Acknowledgements: Inspired by Stelios, page iii)**.

The independent creative project was based on the previously mentioned and established Bérard Auditory Integration Training methods (Bérard and Brockett, 2011), where passive sound therapy strengthens and balances the auditory system. The author's subsequent research into speech, language and frequency modulation guided the development of an early prototype digital auditory software suite (as set out in this section). This software was developed to assist children with conditions such as hyperacusis and tinnitus. [78] [79] Resultingly, these investigation areas formed a pilot project consisting of a music-technology interface with multiple hardware and software modules.

To test their efficacy, the author demonstrated the software and hardware interfaces at the Sound Learning Centre UK to Neurodevelopmentalist Pauline Allen, whom Dr Bérard trained in France. [80] The North London site is one of only seven approved *Bérard AIT International Society* (BAITIS) centres certified to conduct Bérard *Auditory Training Intervention* (AIT).

1.13.1 Early Prototype Variants

The early prototype ARTIMIS supplementary digital intervention was modelled on existing analogue signal modulator devices (i.e., Audiokinetron and Earducator™). The two electronic hearing devices were explicitly developed to adhere to the Bérard protocol for conducting an AIT therapy session.

---

[78] Hyperacusis refers to hypersensitivity and difficulty processing sounds as they become progressively louder causing hearing distress.

[79] Auditory Integration Training (AIT) **(see Appendix I for additional texts)**

[80] The Sound Learning Centre, London, UK. Link to website

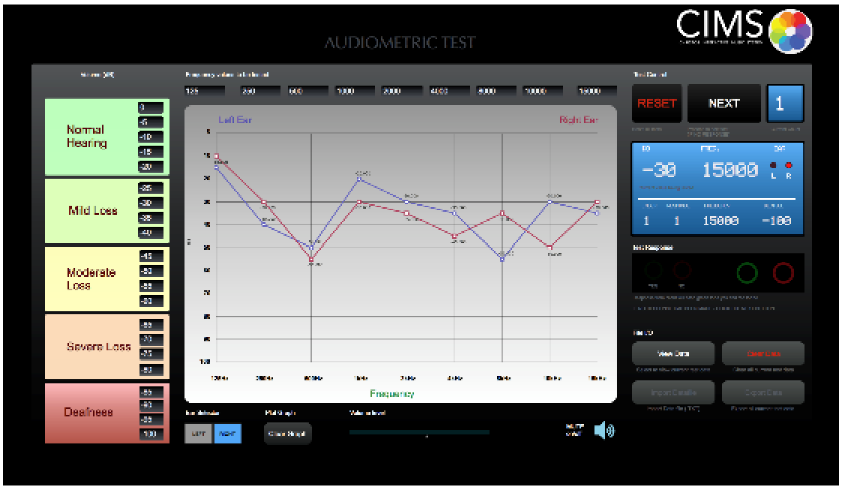


Figure 5. The originally developed audiometric software interface.

Figure 6. The original frequency-modulator software interface.

1.14 CiiMS

CiiMS [*pronounced Sims*] is the *'Creative immersive interactive Musical Software'* application; conceived from a control interface for the original piece of hardware named *"Play-board."*

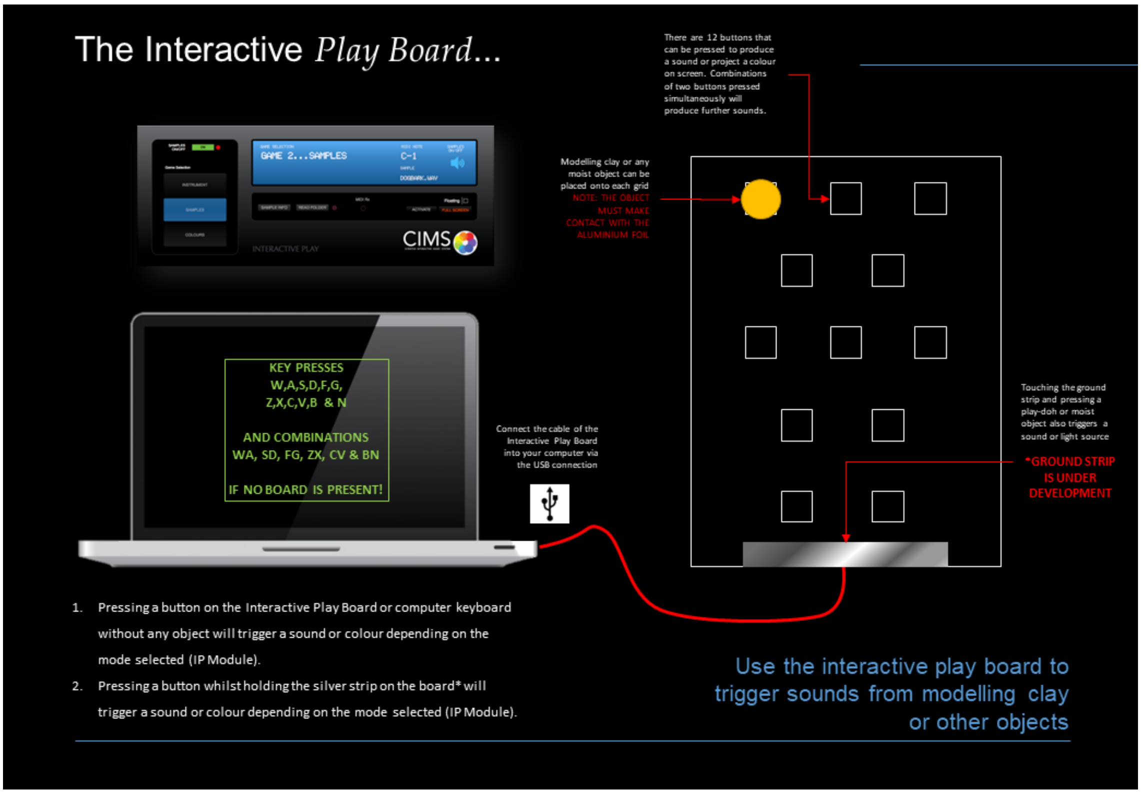
The *Play-board* features a novel interface that permits up to sixteen organic objects (e.g., a banana or modelling clay) that can be placed on the device's surface to trigger sounds and create musical arrangements. As a further layer of sensory stimulation, by striking the respective objects, their associative colour hues (from a palette of vivid colours) are displayed onto an external projector — further prompting children to interact. [81] The author initially developed the hardware interface to work directly with an earlier version of the CiiMS software by synchronising preloaded audio samples (Jay and Rosenbaum, 2015).

---

[81] The author's original *Play-board* utilises a *Makey-Makey* (Jay and Rosenbaum, 2015) circuit board interface assigned with custom MIDI assignments: Link to source.

1.14.1 Early Development and Testing of the CiiMS Interface

In 2017, the *Play-board* was superseded, and the author upgraded CiiMS with full functionality of a touch-capacitive hardware interface for clinical, creative audio and real-time compositional applications. [82] Currently, the CiiMS interface is Windows 11 (*Microsoft.com*, 2022) and macOS-compatible, the accompanying tablet application works with iOS mobile platforms (Apple Inc., 2022; *Apple United Kingdom*, 2022).



The Interactive *Play Board*...

There are 12 buttons that can be pressed to produce a sound or project a colour on screen. Combinations of two buttons pressed simultaneously will produce further sounds.

Modelling clay or any moist object can be placed onto each grid
NOTE: THE OBJECT MUST MAKE CONTACT WITH THE ALUMINIUM FOIL

KEY PRESSES
W,A,S,D,F,G,
Z,X,C,V,B & N

AND COMBINATIONS
WA, SD, FG, ZX, CV & BN

IF NO BOARD IS PRESENT!

Connect the cable of the Interactive Play Board into your computer via the USB connection

Touching the ground strip and pressing a play-doh or moist object also triggers a sound or light source

*GROUND STRIP IS UNDER DEVELOPMENT

1. Pressing a button on the Interactive Play Board or computer keyboard without any object will trigger a sound or colour depending on the mode selected (IP Module).
2. Pressing a button whilst holding the silver strip on the board* will trigger a sound or colour depending on the mode selected (IP Module).

Use the interactive play board to trigger sounds from modelling clay or other objects

Figure 6a. The interactive Play-board instruction manual

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[82] CiiMS captures audio instantaneously (i.e., in real-time) and distribute entire recordings (including music, MIDI data, and media samples) across a pre-programmed hardware interface immediately after recording.

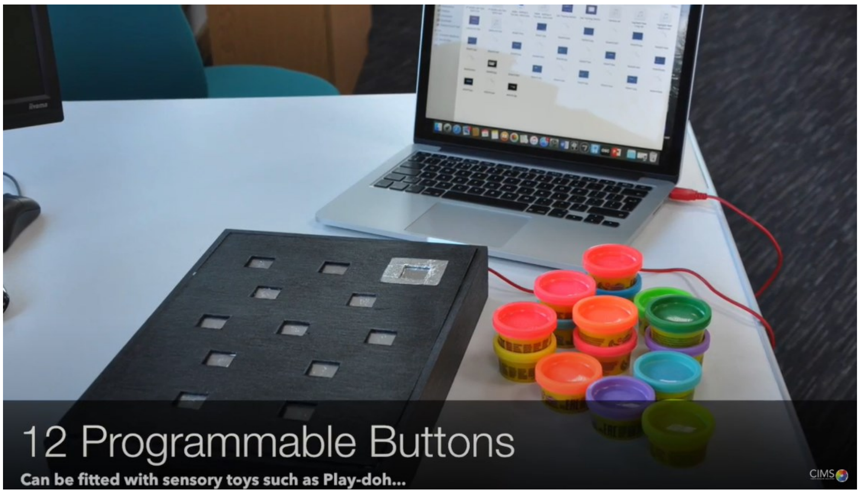
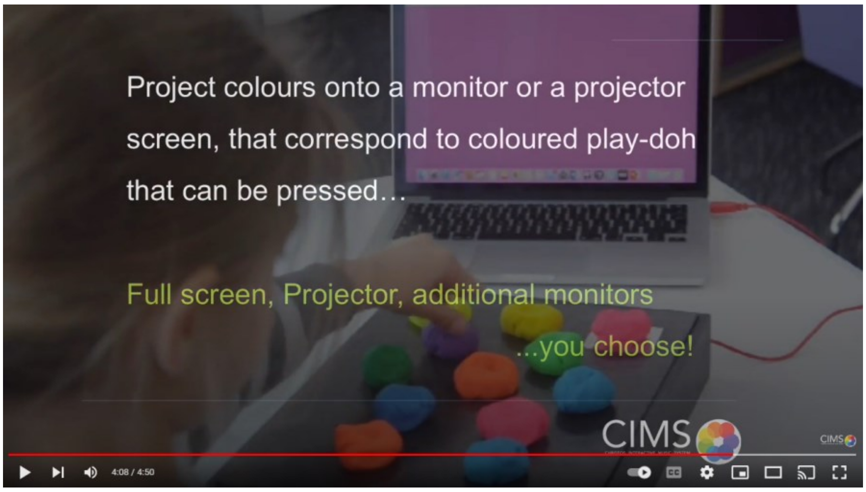


Figure 7. The "Play-board" with coloured modelling clay.



Project colours onto a monitor or a projector screen, that correspond to coloured play-doh that can be pressed...

Full screen, Projector, additional monitors ...you choose!

Figure 8. Objects with colour trigger the "Play-board".

The CiiMS technology prototype interface has been tested effectively in various real-world scenarios within three distinct areas of musical applications:

- Clinical: residential setting (NHS care home testing).
- Special Educational Needs and Disabilities (SEND): provision for children with an autism spectrum condition.
- Creative composition: real-time live performance via free improvisation (beyond musical rules or inclination).

1.14.2 Rapid Interface Techniques: *MATI*

It became apparent to the author during early prototyping stages that elderly and stroke patients presenting physically debilitating conditions (i.e., ataxia) were disadvantaged whilst composing and interacting using ARTIMIS and CiiMS. [83]
One participant found it particularly challenging whilst using a pre-programmed 'simple' setting of the CiiMS interface. The evaluation showed that the virtual assistive technology (within clinical and residential care homes) required additional large-scale testing to establish more optimised approaches to achieve a better level of interaction for restrictive movements. The author's early testing and retinal technology investigations by De Wit (1999) and Menozzi *et al.* (2001) prompted using a web-camera-based gestural input interface. [84] Consequently, the author developed a bespoke 'quick selection' eye-tracking system: *Musical sAccadic Transitional Interface* (MATI). [85]

Through subsequent evaluations of retinal assistive technology, links between efficient optical movements during a performance when selecting and tracking objects (in real-time) on screen were possible. As a result, a prototype roundel software interface and "overlay pad" were individually developed to select musical tone and harmonic key signatures. Both interfaces coincided with *Nikolay Diletsky's* (1679) circle of fifths theory (Bradbury, 2020; Music Division, 1979). [86]

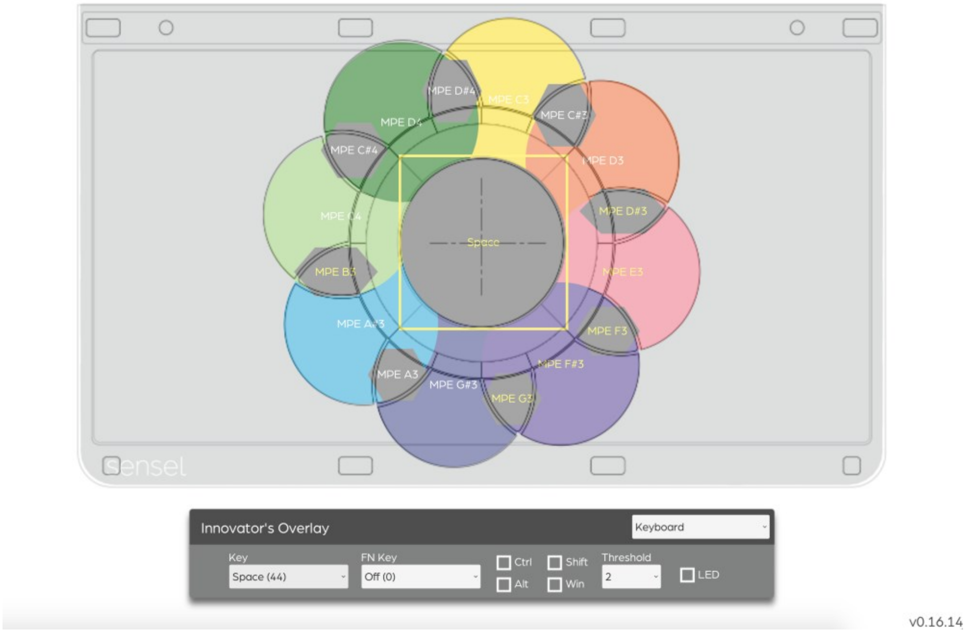
---

[83] Many residential patients experienced permanent and temporary forms of paralysis. Ataxia refers to loss of muscular control and imbalance. Associated via a lack of coordination. Link to source.

[84] The author thoroughly investigated research encompassing various modalities and alternative forms of physical control for a musical input and creative interaction.

[85] The MATI interface lets notes play optically in mid-air via a non-linear format.

[86] Idea grammatiki musikiyskoy (Moscow, 1679)



Key: Space (44)
FN Key: Off (0)
☐ Ctrl ☐ Shift
☐ Alt ☐ Win
Threshold: 2
☐ LED

Figure 9. MIDI programming: The bespoke roundel interface.

The revised interface provided participants with a considerably improved engaging experience and a significantly more effective quick selection method.

1.14.3 Critical Points During Development: Multi-Touch Interface

The author has developed CiiMS within the Max 8 (*Cycling '74*, 2022) patch-based software programming environment. It complies with MIDI MPE (MIDI Association, 2018) and supports the multi-touch capacitive surface interface (Sensel, 2017). [87] [88]
The author's software development process utilised a robust software platform (Max 8) to achieve performance testing of fully customisable interface elements that were programmed within an accompanying MIDI mapping application (*Figure 9*) (Nyboer, 2017).

---

[87] Many test patches for the Sensel interface were coded exclusively to ensure compatibility with iPad (Apple) and iPhone mobile devices. The tablet interface was developed using MIRA (Cycling '74) software application.

[88] Max 8 is a visual object-orientated programming language for prototyping music technology applications and art installations.

The following bulleted list presents the author's areas of development for the CiiMS software user interface (UI) prototype:

- Custom overlays with adaptable controllers.
- Twelve physical prototypes with "quick-access" design layouts for left-and right-handed users.
- Investigations into sustainable technologies and materials.
- A silicone base template composed of small magnets aligned along sensors. [89]
- Unique software architecture with complete customisation, including multidimensional and multi-input sources.
- MIDI Polyphonic Expression (MIDI MPE) compatible.

FILE NAME: Take 4 - 10.17 - Everyday [Ableton].wav

INPUT MODE: Eye

Tempo 160 BPM

MUTE:

dB level 0

MASTER VOL. 4

SIG. 4

Figure 10. The original CiiMS Sampler version. 2.0.1.

---

[89] The final hardware interface was vigorously tested and two versions of the software User Interface (UI) were produced.

1.14.4 Driving the Next Chapter of This Research…

In summary, the tangible results obtained during the author's post-graduate master's degree (MMus) system have laid the groundwork for substantial ongoing development at the PhD level. Early prototyping investigations' and preliminary results informed the validity and efficacy of a music technology-based intervention, pointing towards further research and development.

…

Chapter 2.
METHODOLOGY 1:

CONCEPTUAL FRAMEWORKS, RESEARCH & INTERVENTION DESIGN

2.1 Conceptual Frameworks

This chapter presents the author's comprehensive conceptual frameworks (from ideas developed throughout the literature review) as a result of Turgot's economic theory of *Diminishing Returns 1767* (Shephard and Färe, 1980). The author explains the implementation of a newly formulated *3-Stage Technical Development Process* (3S-TDP) model used throughout the preliminary research phase. [90]

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[90] The 3S-TDP model was significant in assisting the author to accumulate accurate relevant empirical data for this research.

The 3-Stage Technical Development Process (3S-TDP)

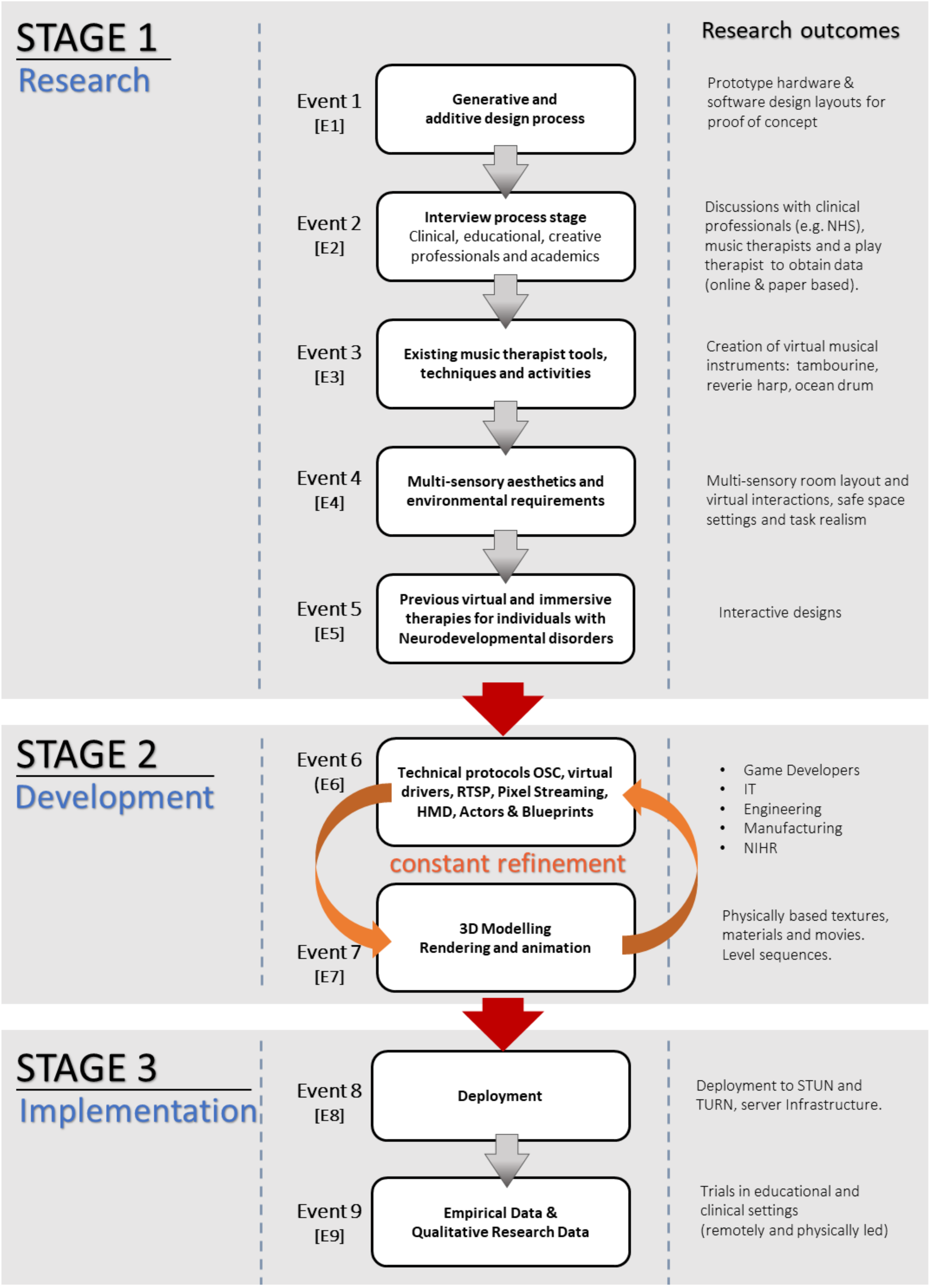


Figure 11. The 3-Stage Technical Development Process.

2.2 The 3-Stage Technical Development Process

Figure 11 illustrates the *3-Stage Technical Development Process* (3S-TDP) developed by the author. This tri-stage systematic methodology comprises nine events presented in three successive stages and has been implemented throughout the research process.

The three stages consist of:

- Stage 1 — Research
- Stage 2 — Development
- Stage 3 — Implementation

Three sequential (freely flowing) stages of the 3S-TDP are guided by individual events leading to the author's optimal research outcomes **(indicated to the right of *Figure 11*).** Construct validity methodologies, and the writer's reviews of research implementation (Sabatier, 1986) inspired the 'tri-stage' top-down technical process and structured execution plan.

NOTE: Stage 2 Development (of the 3S-TDP) is a consistently refining mechanism based on the Law of diminishing returns (in the context of the production of services).

2.3 Stage 1. Research

Stage one consists of five exploratory processes: [E1], [E2], [E3], [E4] and [E5].
These processes are referred to as Event 1 [E1] through Event 5 [E5], respectively.

2.3.1 Event 1. [E1] The 'Generative and Additive Design Process'

Event 1 [E1] of the technical development process comprises the production of design alternatives. These determine multiple preliminary concepts, such as design layouts and prototyping, for developing a virtual immersive musical interface.

2.3.2 Event 2. [E2] Interview Process Stage

> ***'An interview is made for the purpose of securing information. . . about the informant himself, or about other persons or undertakings that he knows or is interested in. The purpose may be to secure a life history,***

> *to corroborate evidence got from other sources, to secure. . . data which the informant possesses.'* **(W. Odum and Jocher, 1929)**

Event 2 [E2] details formal meetings with individuals from clinical, educational, creative and academic fields to appraise the design alternatives (as detailed in Event 1 [E1]); these establish essential concepts for the project. [91] The following table summarises individuals from various disciplines interviewed by the author during the process:

Table 12.

Interviews and discussions during preliminary research

Participant (Initials)	Professional title or discipline	Company / Institution	Discussions held	Medium	Total cumulative hours
EK	Educational Consultant and Play Therapist	SEND Training www.thesendtrainer.co.uk	Sensory Integration, lighting, and therapy room layout	Telephone conversation	1.5 hours
RH	Music Therapist		Technology and Music	Telephone conversation Zoom	45 mins 1 hour
SB	Music Therapist		Clinical interventions	Zoom	1 hour
SR	Music Therapist	Devonshire Partnership NHS Trust	Music Therapy Procedures Animals, Instruments	Zoom	3x 1 hour
AB	Senior Clinical Trial Researcher Stroke Medicine	The University of Nottingham	Gait, Stroke recovery using music therapy		
AC	Wayfinding	NIHR	Funding and proof-of-concept viability for virtual immersive devices	Telephone	3x 30 mins
SB **KA**	Research and Innovation Managers	Nottingham Hospitals NHS Trust	Presentation of an immersive device	Video	2 hours
D O'C	Engineering Technical Manager	The School of Engineering, Technology and Design Canterbury Christ Church University	Rapid prototyping techniques and manufacturing processes	In-person	1.5 hours
KA	Business Development Manager	GoPrint3D	Printing a 3D model for prototyping	Telephone conversation	2 hours
KR	Deputy Headteacher	Laleham Gap School		In-person	7 hours
MF	Undergraduate Student	CCCU Games	3D Modelling	Discord Zoom Telephone	
WH	Technician	CCCU Games	Unreal Engine 4, Virtual Reality Development	Video	
WM	Student	CCCU Music	Autism	Messenger Video	

---

[91] For this research, the author considered geographic locations, structured conversations, video conferencing, and paper-based and digital questionnaires. Concise information was obtained from respondents for future analysis to develop a series of virtual therapist tools and activities for the virtual user interface.

2.3.2.1 Interview process: key findings

The following interview was conducted with an experienced play therapist to discuss relevant areas of knowledge. The findings were as follows: [92]

Interview with Play Therapist (EK) date of interview 25th March 2020

(see Appendix I)

- EK's support with Stelios and other high-functioning autistic individuals gave the author confidence in her ability to design sensory aesthetics.
- EK advised that the proposed virtual sensory room should include soft furnishings, lighting, materials, and consideration of a safe layout.
- EK strongly recommended using interactive bubbles, waterfalls, games or virtual toys — each offering visually intense colours and themes.

NOTE: The virtual therapy prototype room layout is discussed further (see page 73). These concepts informed the author to develop a series of flashing 3-dimensional notes to synchronise to music and mimic nursery rhymes and other familiar sounds.

Key findings employed from the interview (and those conducted with other professionals) guided the design of a virtual reality musical sensory room and other virtual elements contained within a scene. The following excerpt presents essential findings from a video conference interview with an experienced Music Therapist (SR). [93]

---

[92] Emma (EK) is a qualified play therapist and accredited learning and language trainer specialising in behaviour management. Emma has over 13 years of experience supporting vulnerable children and individuals with high and low-functioning autism spectrum conditions.

[93] Sue (SR) is a music practitioner with 25 years of experience in areas of acquired brain injury, neurological music therapy and dementia client specialisms.

Interview with Music Therapist (SR) date of interview 10th April 2020

(see Appendix I)

- SR is a certified member of The British Association for Music Therapy (BAMT), a professional body for music therapists practising in the UK.
- A Southwest NHS Trust employs SR as a Music Therapist within the UK Clinical Research Facilities Network.
- During a six-month training placement in 2013, SR worked primarily as a Music Therapist. The position was to uncover positive associations between patients' responses to music.
- Through a programme of potential recovery through methods of musical activities, SR devised a series of structured sessions to allow clients (*Table 13*) freedom to express themselves freely, with opportunities for clients to pursue and develop their musical interests. Client control groups were recruited based on their connections to musical activities — prior to their injuries.

Table 13.

Example Client J. Attributes

	Nature of Injury	Impairments	Musical connection prior to injury
Client J	Brain Injury on the right side. Hemiplegia resulted from a fall of 15 feet.	Sight, mobility, immobile right-hand	Active musician with a keen interest in keyboard playing

2.3.3 Event 3. [E3] Existing Music Therapist Tools, Techniques & Activities

Event 3 [E3] assesses existing music therapy tools, techniques, and activities likely to occur during a music therapy session. This event guides the researcher in accurately reproducing proprioceptive feedback that would fundamentally appear in real-world interactions to design a virtual musical instrument. *Table 14* (on the following page) presents percussion and other instruments that a music therapist utilises.

Table 14.

Musical instruments used by a Music Therapist

Family	Instrument
Percussion	Ocean drum
	Gathering drum
	Djembe
	Bongo drums
	Tambourine
	Maracas
	Rain stick
	Wind chimes
	Metallophone
	Slit drums
	Glockenspiel
	Handbells (hand/desk bells)
	Piano
Strings	Reverie Harp
	Guitar
	Harp
	Violin

"…from my experience, practitioners have learned over many years [that], children entering a wonderworld [music room], are first greeted with robust instruments [such as a Piano]. They can play within new [physical] environments as hard or as soft as they like. [But] when you present 'real instruments' to a child, this encourages communication, interaction and expression of emotion…particularly so with autistic individuals." **Susan Rivett, NHS Trust Partnership 2020.**

2.3.3.1 Reverie harp

The Reverie Harp consists of twenty strings tuned to the key of C Major. The instrument is played by strumming strings with the tips of the fingernails to generate warm, calming pentatonic harmonics. [94] Warm sentiments and relaxation through tactile stimulation are promoted, and these characteristics are ideally suited for therapeutic environments.

2.3.3.2 Birdsong

Alongside the traditional string, brass and percussive instruments, the *Birdsong* support activity is a lifelike plush bird interlined and woven with a soft cotton filling. The toy includes a recorded sample of a bird's call emitted from a micro speaker. [95] Gripping and gently squeezing the plush toy will imitate the call of a bird's species, and the interaction promotes social engagement between the child and the toy during a therapy session. The *Royal Society for the Prevention of Cruelty to Animals* (Alsop, 2022) provides replica toys of realistic-looking birds to practitioners and educators, forming part of their education and youth intervention programme (RSPCA). [96]

NOTE: Outcomes from the interviews in Event 2 [E2] and the existing tools and techniques outlined here in Event 3 [E3] guided the author to develop personalised virtual posters within the virtual scene.

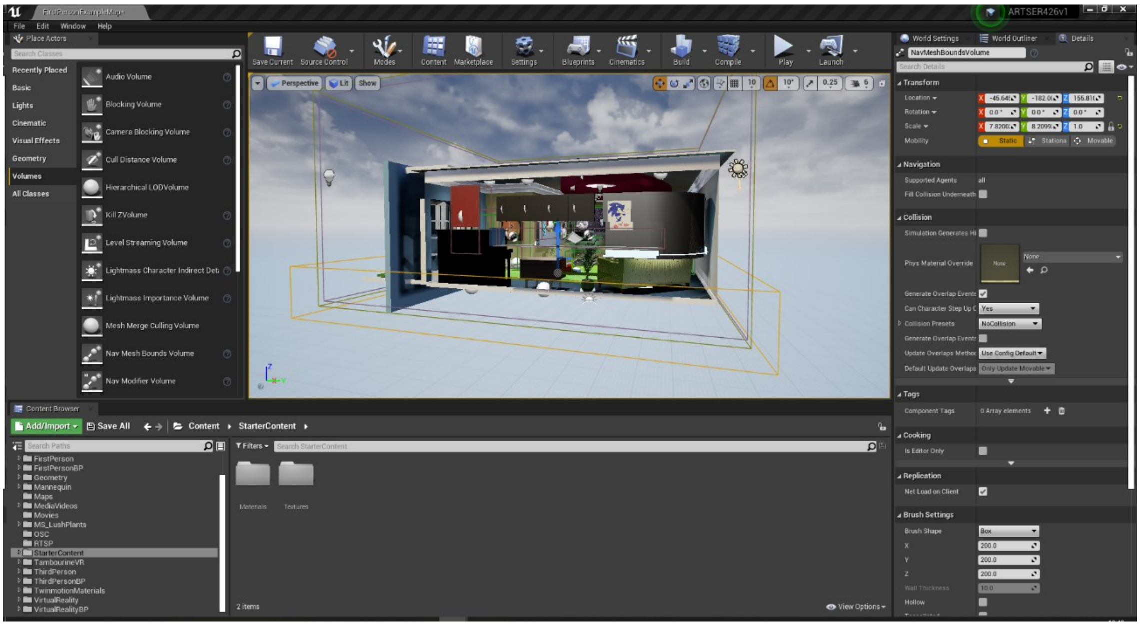
---

[94] Construction is often from solid mahogany or Baltic birch plywood face, together with a solid cherry wooden frame.

[95] The sample bird sound is recorded and saved directly to an integrated Read Only Memory (ROM) microchip.

[96] RSPCA Link to source

2.3.4 Event 4. [E4] Multi-Sensory & Environmental Requirements



NavMeshBoundsVolume

Location X -45.64 Y -182.0 Z 155.81
Rotation X 0.0° Y 0.0° Z 0.0°
Scale X 7.8200 Y 8.2099 Z 1.0
Mobility: Static
Supported Agents: all
Fill Collision Underneath: ☐
Simulation Generates Hi: ☐
Phys Material Override: None
Generate Overlap Events: ☑
Can Character Step Up C: Yes
Collision Presets: NoCollision
Generate Overlap Events: ☐
Update Overlaps Methoc: Use Config Default
Default Update Overlaps: Only Update Movable
Component Tags: 0 Array elements
Is Editor Only: ☐
Net Load on Client: ☑
Brush Shape: Box
X: 200.0
Y: 200.0
Z: 200.0
Wall Thickness: 10.0
Hollow: ☐

Figure 12. Designing the multisensory environment.

Let us now turn to Event 4 [E4] of the *3-Stage Technical Development Process* (3S-TDP). This event is intended primarily to investigate the aesthetic characteristics of all the multi-sensory environments and to guide the design of a virtual equivalent.

Firstly, the process examines clinical practitioners' or educators' requirements and activities (obtained through interviews in Event 2 [E2]) and illustrates conventional therapy sessions.

Example requirements and characteristics may include (without limitation):

- Environmental lighting and optics
- Personal space and boundaries (i.e., geofencing) [97]
- Repetition within sensory domains
- Visual cues and auditory cues

---

[97] A geofence refers to a virtual perimeter boundary based upon a real-world geographic area. The perimeter can be generated dynamically or to fit a predefined group of boundaries.

The above list exemplifies multi-sensory and somatosensory modalities that are critically important when designing a physically accurate and realistic virtual environment. *Table 15* (below) is representative of the therapeutic activities and techniques in Event 2 [E2] and Event 3 [E3] of the 3S-TDP.

Table 15.

Observed behavioural and social interactions during multisensory play

Stage	Characteristics	Social Interactions	Behavioural Interactions
Stage 1: Motivation, attention, and orientation	Intense engagement	High levels of vigilance Highly focused. Fascination with objects	Loss of self-awareness, sense of time and environmental surroundings
Stage 2: Cognitive symbolic, semantic, and imaginative	Appraisal of aesthetic objects	Meaningful interactions	Descriptive, experimental, and visual lines on inquiry
Stage 3: Affective	Emotional experience	An intense, precise feeling of cohesion	Fascination with the object and aesthetic appraisal

2.3.4.1 Design concepts for a therapeutic space

Secondly, a conceptual sketch layout (drawn to a suitable scale) is advisable to plan 3-dimensional asset locations, virtual spaces, lighting, and positioning of the CiiMS virtual musical instrument. Immersive room concepts (inspired and sketched by the author) obtained via design consultants and interviews from Event 2 [E2] and Event 3 [E3] embody a virtual therapeutic musical environment. [98]

2.3.4.2 Fundamental musical elements

Tertiary investigations into the six fundamental musical elements (rhythm, dynamics, melody, harmony, timbre, and form) guide the development and design of virtual instruments to ensure exciting musical activities within the ViMRI environment.

---

[98] The author's conceptual sketches incorporate various therapeutic activities and sensory lighting, complete with a virtual video display.

The author presents the following sensory adaptation table to demonstrate the findings of previously conducted activities:

Table 16.

Sensory adaptation table

Musical element	Sub-components	Key sensory adaptations	Commonly used MT Instruments or techniques
Rhythm	Beat and meter, pattern, repetition, tempo, and pulse	Gait, motor planning, self-regulation, entrainment	Drums, percussion
Dynamics	Nuances, human dynamics, physiological participation	Sensory stimulation, mood, and physiological effects (e.g., muscle control). Self-expression	Blowing soft or soft, thumping intensities, stomping solid or soft, clapping
Melody	Human vocal calls, auditory tracking, melodic contours, pitch discrimination, auditory tracking	Social communication, the symbolic expression of feeling, language development (prosody), calmness or excitement	Laughter, speech, staccato, screaming, shouting, groaning, lullabies, nursery rhymes
Harmony	Scale structures and resolution, additional dimension (i.e. colour), cultural, religious and community.	Induces mental guided imagery states, stimulates auditory concentration and awareness	Chanting vocal or instrumental sound patterns and chord progressions. Detection of musical elements
Timbre	Texture and sound, tonal qualities, orchestration,	Elicits emotional reaction, Verbal communication and soothing. Induces behavioural imbalance	Romantic strings, harp, xylophone, woodwind
Form	Evolution and shape, improvisation, musical development	Incites a state of anticipation, promotes imitation, organisation, repetition, and conclusion	Resting, awaiting a tune to begin, count-in, musical sampling and repeating

2.3.5 Event 5. [E5] Existing Virtual and Immersive Therapies

Event 5 [E5] is a process of investigation for analysing existing virtual or immersive therapies within clinical, educational and other (broader) virtual reality paradigms **(see Virtual Reality Treatments: Chapter 1. Literature Review, page 26).**

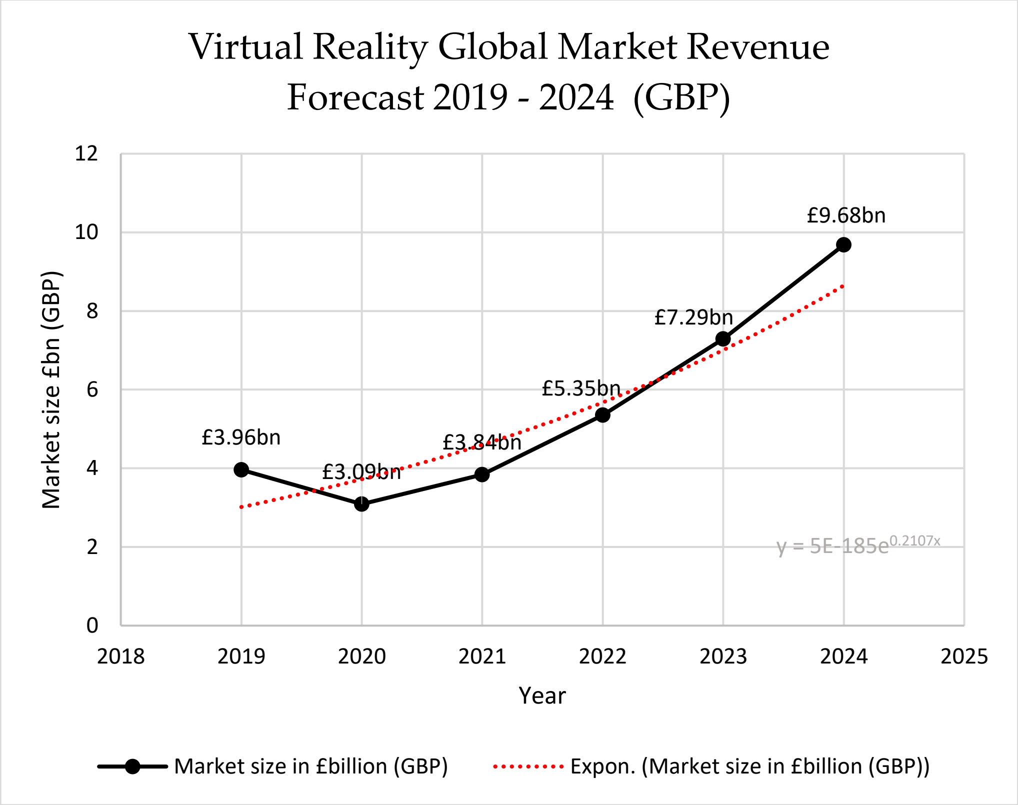


Figure 13. Estimated global market value growth - Source Statista (2022) (Alsop, T. 2021).

Virtual reality and simulated experiences have proliferated and will exponentially increase in the coming decade (Alsop, 2022). The global market share of immersive and mixed technologies applications will increase from £3.96bn to £9.68 billion by 2024. [99] These statistics represent an average increase of 36%, year on year. [100] Furthermore, the exponential increase in the improvements of VR technologies will

---

[99] Statistics obtained via the Virtual Reality (VR) dossier (Statista, 2021) Link to source.

[100] Exponential increase on chart calculation: 2022. Year 1: 39% (i.e., (5.35 – 3.84) = 1.39), Year 2: 36% (i.e., 7.29 – 5.35 = 1.36) = 1.39) and Year 3: 33% (i.e., 9.68 – 7.29 = 1.33). *Mean* average calculations.

strengthen and support the healthcare sector. Accelerated developments will also bring immersive virtual classroom experiences to educational settings.

2.4 Stage 2. Development

The development stage (referred to as Stage 2) of the author's *3S-TDP* consists of a continuously refining cycle of Stage 1 (Event 1 [E1] through Event 5 [E5]) from collaborative efforts between professionals across associated disciplines. [101] Furthermore, Stage 2 consists of events: **Event 6 [E6] and Event 7 [E7].**

The conceptual methodology in applying the top-down systematic approach during this research accelerated the development process and welcomed established theories and interventions of the natural world (observed throughout Stage 1 of the research process).

Development starts with a blueprint of ideas and forms a tangible, systematic process that becomes perpetually refined as complexity increases. The development process (i.e., Stage 2) is an external contribution to additive manufacturing, 3D animation, virtual server technology and integration of virtual IP-related devices and technology applications (Erichsen, 2010; *NewTek, Inc.*, 2020).

Event 7 [E7] of the development process considers 3D modelling for virtual reality, together with the following essential factors derived from Barr (2016):

- Overall scene complexity
- Stylistic realisations (i.e., how realistic does the scene need to mirror?)
- Real-world environment scale
- Level of detail (LOD)
- Virtual motion sickness
- Modelling tools

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[101] The author's development process was inspired by other developmental cycles, theories and grand theories of human development, including psychoanalytical (Freud) and Kohlberg's Theory of moral development (Piaget)

- File format and data exchange (i.e., software import/export)
- Mood lighting and sensory environmental lighting
- Incorporation of virtual MIDI, MPE and OSC protocols
- Polygon count

NOTE: In addition to the above listing, the author required careful planning when building the virtual musical interface for neuro-diverse communities. Particular attention to each individual's multi-sensory needs became essential during this process.

CLOUD TESTING AND HOSTING A REMOTE ViMRI

2.5 Stage 3. Implementation

The final stage involves deploying a virtual musical interface onto a virtual machine (VM) to a cloud-based infrastructure. Once hosted, the commencement of a SPiME trial can begin to obtain research data. The following describes the third stage of implementation of a 3-Stage Technical Process (i.e., Event 8 [E8] and Event 9 [E9], respectively) **(see page 65).** The following procedures test the remote capabilities of a virtual musical interface.

2.5.1 Technical Hosting Procedures

i. A virtual machine (VM) configuration is required to open a local Internet Protocol (IP) address. [102]

ii. The packaged project from the IDE software application (*Epic Games*, 2019) is transferred (copied) as an executable 3D application onto the virtual machine.

iii. The executable 3D application is executed (run) from the virtual machine.

iv. Virtual MIDI driver (Erichsen, 2010) installation is required to open the virtual audio port for two-way transmission (TX and RX) of the virtual machine. [103]

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[102] Virtual Machine (VM) refers to a virtual computer hosted by a cloud platform such as Amazon AWS (Amazon Web Services, 2022), Microsoft AZURE or Google Cloud. See example AWS EC2 configuration: Link to source

[103] TX and RX refer to MIDI transmission and reception of audio data.

v. Installation of compatible virtual machine (VM) graphics driver (GPU) software.

vi. Node.JS framework is installed and executed to establish compatibility between the server and pixel streaming encoder (OpenJS Foundation, 2009).

vii. A final 3D application appears on the virtual machine.

viii. An internet browser address allows access to the virtual machine by typing in the virtual computer's IP address (for example: (255.118.163.12)).

These processes are required to host and configure a pixel streaming session for a high-quality 3D interactive experience (cross-platform) from a virtual machine directly onto a smartphone, tablet, or web browser. [104] The benefit of using this method results in a remotely packaged data file requiring no on-site installation or user download. The final streamed VR project is directly available for the participant to interact with and remotely access (Miglio, 2019). [105] The final complication for this technical hosting requires a cloud service, such as Amazon Web Services (2022) or Microsoft AZURE (Microsoft, 2022), to configure several virtual computer services for pixel streaming solutions within the IDE. These services are required to test and host an immersive virtual software interface.

2.5.2 Conceptual Virtual Reality Musical Communications

The *Conceptual Virtual Reality Streaming Musical Environment* (ConViRS-ME *[pronounced Converse me]*) model is the result of the author's research and development surrounding technical networking and streaming protocols of existing games VR models (within information technology paradigms). The author's process model for virtual reality musical communications is presented on the following page *(Figure 14),* indicating various artificially intelligent infrastructure networking protocols and supporting cloud-based computing platforms.

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[104] The interactive experience can be uploaded directly from a Unity or Unreal Engine project.

[105] Pixel Streaming plugin is part of the Unreal Engine ver. 4.21 and upwards. This encoder works to host multiple spectators to collaborate within a presentational environment by sharing a link (IP web address).
Packaged UE4 applications can then be delivered using the Pixel Streaming system and distributed (streamed) over signalling and web servers with support from a WebRTC Proxy Server.

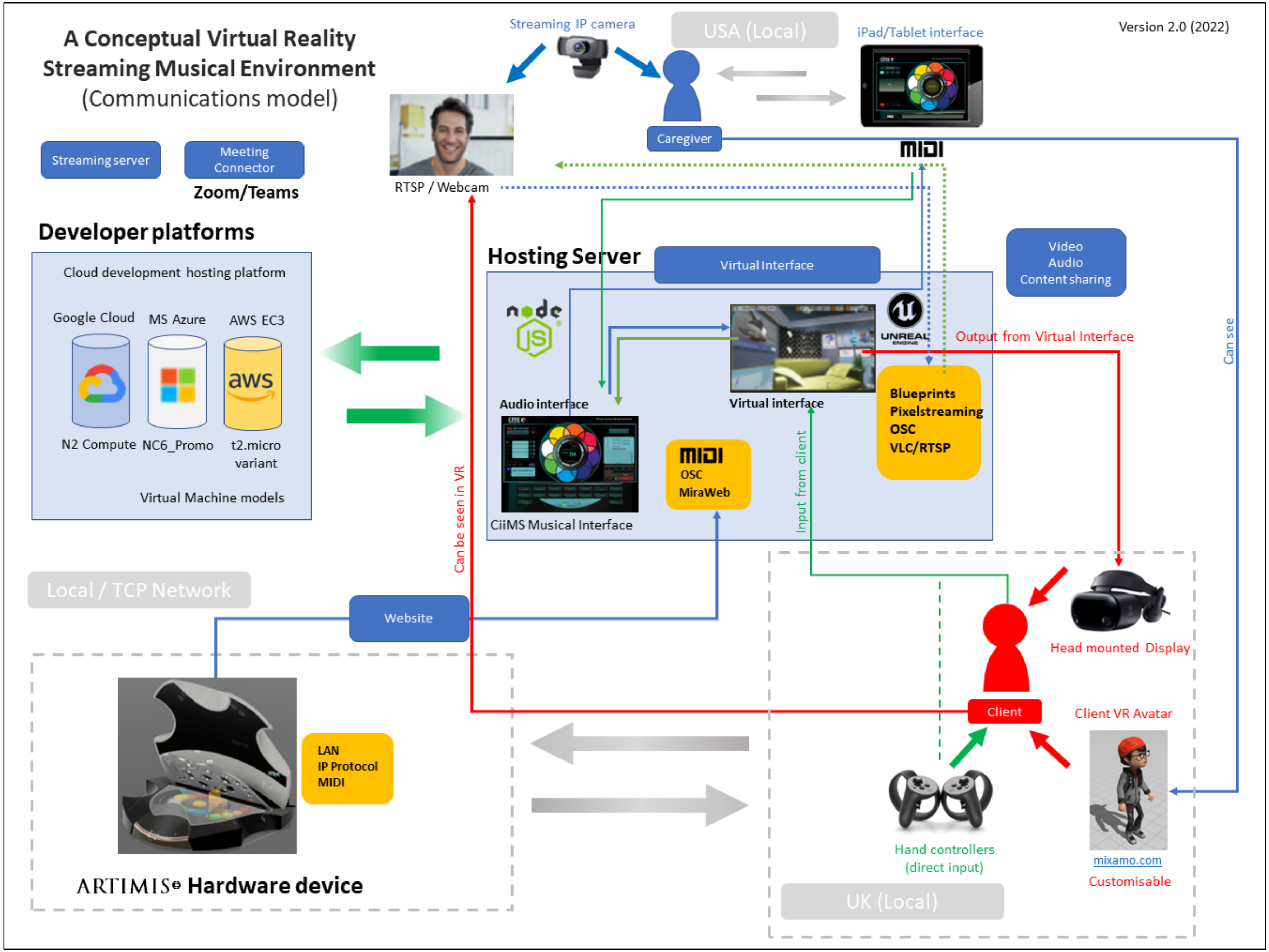

Figure 14. The Conceptual Virtual Reality Communications Model.

NOTE: During the research, the author successfully deployed the virtual reality application to a virtual machine with a remote configuration. Three cloud-based computing platforms were tested, including Amazon Web Services (AWS) (2022), Google Cloud (Google, 2022) and Microsoft Azure (2022b).

In order for a caregiver to be "virtually visible" within a 3D scene to the client during a remote session, this requires a Real-Time Streaming Protocol (RTSP) webcam (or other equivalent hardware capabilities). Physical interaction between a remotely based caregiver and the client requires dual haptic-touch hand controllers to encourage interaction and navigation around virtual objects within the scene. [106] Facilitation for the remote communications model setup requires a mobile device (e.g., a smartphone or tablet) or a personal computer (PC) with a pre-installed CiiMS software application — developed exclusively for the immersive remote scenario. [107]

2.5.3 Setup Procedures for a Remote ViMRI Session

The author's conceptual model (*Figure 14)* requires the following setup procedures:

i. For a new session, the caregiver obtains login credentials.

ii. Group therapy clients receive an invitation and password to log in to the session.

iii. A client creates a virtual avatar (cartoon) profile of themselves.

iv. A hosting server (e.g., Amazon Web Services (AWS) (2022)) company hosts the virtual software environment accessible from any worldwide location (providing an internet connection is available).

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[106] The author proposes a conceptual configuration of a physically integrated mid-air haptic and tactile feedback interface within the ARTIMIS hardware device (i.e. a tactile motion controller); provided to the user via the CiiMS software user interface. Physical somatosensory sensations would be experienced virtually by both client and caregiver from any global location.

[107] The software application requires an internet connection over a Local Area Network (LAN) developed cross-platform and compatible with macOS (Apple Inc) or Windows (Microsoft) operating systems.

NOTE: The author recommends that the audio engine and virtual interface be installed on a cloud-based server (e.g., Amazon AWS (2022)) and must be connected to relay all video, music, and all virtual communication data.

Processed data ***(from step 4)*** is relayed to the client and therapist as a real-time streaming video within the virtual reality, and audio offers interaction between client and caregiver.

v. The locally situated "on-site" ARTIMS hardware device (i.e., at a school or within a clinical setting) connects to the networked session.

vi. Physical communication is facilitated through ARTIMIS. The hardware device encourages clients to interact via a physical soft-touch interface that 'talks' to the virtual (CiiMS) interface during the session.

vii. Real-time feedback is transmitted directly to the virtual environment for a caregiver to monitor and interact with the client.

…

RESEARCH DESIGN

This section of Chapter 2: Methodology 1 provides an overview of the author's research strategy and design methodologies systematically introduced using a structured approach to the research design principles. Fundamental design choices were made during the study design process to guide the author's decisions that informed the reliability and validity of the author's research methodologies.

2.6 What is a ViMRI?

A ViMRI [*pronounced Vim-ree*] is the abbreviation for a 'Virtual immersive Musical Reality Intervention.' The author notes to the reader that it is essential to distinguish the term *immersive* within the acronym, as this does not reflect the perception of existing within a non-physical environment (usually associated with virtual reality immersion). It is therefore essential to note that the term *immersive* (within the context of a ViMRI) refers specifically to the physiological activities and the musical engagement that result from a SPiME (*Supplemental Personalised, immersive Musical Experience*) study programme **(see Chapter 2. Methodology 1, page 100 for a detailed description).** Any musical interactions that occur via the virtual music technology system; facilitate the individual's social, emotional and behavioural characteristics.

2.7 The Research Questions

The three key research questions are:

i. **What approaches can effectively facilitate engagement with technologically mediated musical interaction in immersive environments?**

ii. **Can the introduction of a local or remotely guided cloud-based immersive musical environment complement established therapeutic processes for specific types of intervention?**

iii. **Can immersive music realities influence improvement in people with an autism spectrum condition (ASC) and other neurodiverse conditions?**

2.8 Introduction and Aims of the Research

This research explores the effectiveness of a newly developed extended reality (XR) musical intervention as a complementary technology. The potential of a customisable (remotely guided) device to support people with neurodiverse comorbidities requires careful consideration of various methodological research design approaches.

The use of virtual music technologies within clinical domains remains under-researched, indicating a preference for using exploratory research methodologies.

2.9 Research Design and Fundamental Design Choices

This original research adopts innovative approaches to virtual musical composition, VR interaction, and novel virtual interfaces placed within the creative arts and humanities field. Collectively, these digital and tangible areas lend themselves to the practice-led research methods of Smith and Dean (2014).

Positivism and interpretivism research theories were examined and discarded owing to their subjective and logical binary character; however, these options were incompatible with this conceptual framework. An exploratory research methodology based on the Principles of Sociological Inquiry (Blackstone, 2012) influenced the nature of this study by identifying existing and established theories and adapting them to innovative theoretical concepts. [108] Furthermore, proposed (alternative) higher-order descriptive research approaches (containing larger datasets) for future extensive studies will determine correlation and causality.

2.9.1 Deductive Research

Principal theories investigated in the literature review throughout **Chapter 1** determined two essential factors for the author to select a viable research approach.
The author carefully considered the data (variables) and theories as two entities, which

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[108] This exploratory study sets the foundations for new knowledge of early-stage feasibility to identify variables within virtual immersive music technology paradigms.

informed the necessary level of development, implementation and analysis to guide the ambitious VR project (given the limited timescales). These served as the rationale for choosing from one of the three research approaches:

- Deductive
- Inductive
- Abductive

The criteria for deductive research methods offered the best fit for this research. A combination of established clinical and psychological theories of music technology and XR realities (within technological domains) helped to formulate new ideas. Exposure and cognitive behavioural therapy were two of these areas applied exclusively to the ViMRI phenomena.

2.9.2 Periods for Data Collection

The author chose to use a simplified longitudinal time horizon method for data collection based on the comprehensive reviews by Caruana *et al.* (2015).
This observational approach is compatible with the qualitative and quantitative (mixed) data collection methods (Rojon, 2016).

Study data included a group of high-functioning autistic children within a special educational needs setting. Data collection occurred at multiple stages over twelve weeks (with trials administered over six weeks). These design choices made by the author ensured consistency of the datasets, which would help create observations throughout the analysis phase to change individuals' perspectives that may occur over time **(outlined in the forthcoming section: Data Collection Methods, see page 97).**

The datasets for this research study were gathered via questionnaires and other established clinical score-based methods, resulting in a series of case studies for final analysis **(see page 132 Case Studies: Chapter 4. Findings & Discussion).**

Quantitative research data has been analysed using the advanced SPSS® software platform (IBM, 2022). Transcription accuracy for qualitative research data was achieved using the Nvivo analysis software (*QSR International*, 2020) to record interviews and questionnaires; leading the author to formulate five clusters from the dataset **(see pages 209-213, Qualitative Analysis of Research Findings: Chapter 4. Findings & Discussion).**

2.9.3 Informing Reliability: Research Methodologies

The author carefully considered other researchers who may wish to replicate this study to ensure the consistency and accuracy of the findings. Adhering to the same analytical procedures, data collection methodologies, and analytical techniques within this research paper is wholly achievable.

Certain biases and errors that could influence the reliability of future research studies have been analysed by the author, including:

- Participant error — session times and trial days should remain consistent.
- Participant bias — any circumstances that could produce erroneous responses (an open planned area in the presence of a parent or caregiver).
- Researcher error — interpretation of interviews and session planning (several sessions over shorter periods reduce fatigue between participants and the researcher). [109]
- Researcher bias — the influence of a researcher's interpretations and objective responses.

Let us now turn to the validity of this research.

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[109] The author experienced throughout the trials that longer sessions overstimulate autistic individuals, leading to sensory overstimulation.

2.9.4 Informing Validity

Three research modalities of validity were examined as part of the design process: [110]

- Construct validity
- Internal validity
- External validity

The author selected construct validity for its flexibility in combination with the exploratory research method. The systematic approach offers the potential to produce specific and well-established outcomes for researching an undiscovered ViMRI concept (Weir, 2005).

2.10 Data Collection Methods

This study uses inductive and deductive methods to gather qualitative and quantitative data. The following section describes the data collection methods to recruit a sample of autistic individuals and the necessary ethical measures required for a virtual reality musical intervention study. [111]

2.10.1 Research Sample

Eighteen children (*N*=18) for the *Virtual immersive Musical Reality Intervention* (ViMRI) research study were randomly selected. For resolutions, early outcomes were necessary to deliver a series of trials over six consecutive weeks. [112] [113] In addition, information packs were distributed to parents and caregivers for completion for each child to obtain participant consent **(see Appendix A: Research Consent).**

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[110] Internal validity refers to casual relationships between existing variables based upon assumptions. External validity concerns the research findings and can be generalised to other settings or groups. Construct validity offers a top-down approach to guide methodological choices and justify decisions made during the research design phase.

[111] The author's inductive methods included specific observations and repetitive patterns, forming a generalisable conclusion. The author's deductive methods were based on existing exposure therapy theories and CBT to formulate a hypothesis and validate the efficacy (of a ViMRI) from the collected data.

[112] The author's fundamental preparations (timetables and key timings) were established to ensure that child participants could visualise the proposed research study locations and seating plans.

[113] The author planned group activities using photographs and concise diagrams for each session. These were presented in an introductory session; several weeks prior to the trials commencing.

Weekly sessions were held with the deputy headteacher and other teaching professionals at a Special Educational Needs and Disabilities (SEND) school to discuss critical issues. Discussions of concern for the study included moral ethics, parent and carer consent, medical conditions, and other vital areas agreed upon in principle. [114] [115] To pre-empt any unexpected changes (that could potentially provoke social anxieties) and avoid emotional discomfort, contingencies to forewarn participants were in place. **(see Appendix C: Participant Requirements)**.

2.10.2 Ethical Clearance for Experimental Groups

This study included four individual experimental groups organised by the author with the assistance of teaching staff and classroom assistants. The support staff's first-hand experience and familiarity with each child assisted in rapid ethical clearance and safety measures **(see Appendix G: Ethics and Guidance)**. The deputy headteacher was involved throughout the entire selection process.

2.10.3 Prerequisites

The author's prerequisites for the study required the participants purporting to have a reasonable degree of musicality, virtual reality experience and a variation in autism spectrum conditions (i.e., representative of the population). Each child's abilities ranged from mild to moderate and comprised social, emotional, and behavioural interaction deficits.

2.10.4 Participant Data Collection: VIMR-Q1

Preliminary-test questionnaire

VIMR-Q1 is a preliminary-test questionnaire and joint assessment form to explore personal preferences and establish a personalised individual participant profile **(see Appendix B: VIMR-Q1 Participant Questionnaire Form)**. Critical considerations for this

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[114] Additional key issues included: security procedures, non-disclosure agreements and information technology.

[115] School staff meetings focused on guidance and implementation methods before the study design commenced.

test include special interests, fears (or specific phobias), level of technical ability, musicality, favourite colour and preferred 3-dimensional geometric shapes.

Application and criteria

VIMR-Q1 is established on the SCERTS® (Prizant *et al.*, 2006) assessment process, a reliable multi-disciplinary framework that supports therapeutic experiences to strengthen the socioemotional activities of an autistic individual. [116] Similarly, the VIMR-Q1 questionnaire closely reflects the comprehensive assessments addressed by the SCERTS® framework and evaluates vital areas of development — including:

- Social communications
- Emotional regulation
- Interpersonal (transactional) support

The VIMR-Q1 measures areas of "virtual risk" that may be associated with underlying medical conditions. [117] The assessment provides an evaluation of personal safety before using any VR equipment.

NOTE: The form VIMR-Q1 should be completed collaboratively with the child's caregiver or supporting teaching professional. [118]

2.10.5 Parent and Caregiver Data Collection VIMR-QPC

Secondary-test evaluation

VIMR-QPC, is an online evaluation form and preliminary-test questionnaire for parents and caregivers of an autistic child **(see link).** The assessment is a psychometric test modelled on the established CARS-2-ST and CARS-2-HF rating methods (Schopler

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[116] SCERTS refers to the Social Communication Emotional Regulation, and Transactional Supports for infants and young children between 1 month and six years old. The programme encourages spontaneous communication and relationships to regulate emotional arousal whilst supporting learning and engagement. These elements aid a child's progress as he or she works toward a specific goal.

[117] Medical conditions unsuitable for prolonged VR interaction epilepsy, hyperacusis and photosensitivity).

[118] Completion of this form is advised within a special educational needs (SEN), social community, or home environment.

et al., 2010). Scoring criteria for the VIMR-QPC corresponds with the CARS-2 severity group rating scale **(see Appendix K: Example *CARS-2-HF* Score Report)**. [119]

Application and criteria

Parents and caregivers for this secondary-test evaluation must indicate any areas of the complexity of behavioural and social interaction deficits. The VIMR-QPC method of assessment observes child participants in a familiar setting.

The VIMR-QPC secondary test evaluation is advantageous for researchers conducting trials to detect unnoticeable symptoms and characteristics of participants. In addition, the evaluation interprets previously exhibited deficits.

2.10.6 Teacher Assessment Participant Ratings – VIMARS 1.0 and VIMARS 2.0

Bi-directional evaluations

Virtual Immersive Autism Ratings Scales 1. and 2. **(VIMARS 1.0 and 2.0)** are pre- and post-test bi-directional (two-way) evaluation surveys. These forms are advised for completion by suitably trained professionals within a special educational needs setting **(see Appendix E: VIMARS)**.

Two-stage completion during the early and latter stages of a *Supplemental Personalised, immersive Musical Experience* (SPiME) study programme include:

i. **VIMARS 1.0 - preliminary completion**

   To be completed preceding a SPiME via direct observation within an educational or classroom setting.

ii. **VIMARS 2.0 - secondary post-completion** (on-site or remotely off-site).

   To be completed approximately three months after a SPiME programme, with the same participant sample group.

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[119] Copies of the CARS-2 form (W-472C) are available from: www.wpspublish.com

2.11 Analytical Methods

This section outlines the author's analytical methods for the study.

2.11.1 Participant Identification

A unique identification (uID) with variables enciphers sensitive information (e.g., participant names); the author used this method as a way to quickly identify each child within the study and further ensure the confidentiality of every child (pre and post-trials). [120]

Table 17.

Study participants – unique identifier (uID) design

Name, Group Number, Group Name = **Unique Identifier**

Stelios Ioannou, Group 2, Guitars = **SIG2G**

Example of the unique participant ID attributes

NOTE: This data collection methodology informed the author to implement four musically themed groups for children of mixed gender. Each group was assigned by varying social abilities (see participant questionnaire data, pages 169-177). [121] [122]

2.11.2 Participant Evaluation and Scoring Methods

Outcomes from key school meetings were instrumental in the design process for the author, who formulated the preliminary-test evaluation forms **(see prerequisites Section 2.10.3)** and online questionnaires for the data analysis phase:

- Form VIMR-Q1 — participant questionnaire and data collection form
- Form VIMR-QPC — parent and caregiver online questionnaire form
- Form VIMARS 1.0 — participant survey rating form for teaching professionals

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[120] The author developed the uID to conceal each child participant's identity during the quantitative analysis stage and post-research.

[121] The groups for this study were entitled: Violins, Guitars, Saxes and Pianos.

[122] Lesson plans, nameplates and presentations were distributed to parents and carers prior to undertaking the virtual immersive musical reality sessions consecutively over six weeks.

- Form VIMARS 2.0 — participant survey rating form for teaching professionals
- Sub-section variables and scoring criteria (ID).

2.12 Data Analysis Methods

This section presents data analysis methods undertaken by the author during the preliminary research phase. Preliminary-test evaluation forms from the bulleted list above guided the author's initial investigations of the research. **Participant Data Analysis: VIMR-Q1 (Trial 1)**

VIMR-Q1 responses

Eighteen participants (*N*=18) ** responses were recorded using questionnaires and transferred into an Excel spreadsheet (*Microsoft*, 2022). Unique individual codes (uIDs) for each participant were assigned to their responses and evaluated against a custom-designed 7-point Likert scale, as shown in the following table:

****NOTE: For consistency throughout this thesis, the author uses a capital '*N*' to represent the sample group of 18 participants (i.e., *N*=18). In statistical convention, a capitalised '*N*' usually equals the size of the population, and a lowercase '*n*' refers to the sample size.**

Table 18.

VIMR-Q1 evaluation criteria: 7-point Likert scale

Likert Score	Criteria
7	Has a particular unique interest
6	Gave multiple answers
5	Is specific about the answer
4	Answered the question
3	Single Yes answer
2	Single No answer
1	Did not answer
0	**Not applicable to the question**

The participant dataset examines credible results and divides them into categories according to the participant's ability level for their particular interests, as shown in *Table 19.*

Table 19.

ViMRI participant, pre-test evaluation questionnaire criteria

Section	Code	Question
1.1 Musical Preferences	001	What is your favourite song?
	002	Do you like to sing?
	003	Do you play any musical instruments?
	004	If yes, what do you play?
	005	Who is your favourite singer?
	006	Do you like to make music?
	007	What is your favourite instrument?
1.2 Virtual Reality (VR)	008	Do you know what Virtual Reality (VR) is?
	009	Have you ever used Virtual Reality (VR)?
	010	Do you wear glasses?
	011	Would you wear a VR Headset?
1.3 Animals and Pets	012	What is your favourite animal?
	013	Do you have a pet?
	014	If yes, what kind of pet is it?
	015	If yes, does it have a name?
1.4 Hobbies	016	Do you have a particular interest?
1.5 Colours	017	What is your favourite colour?
1.6 Geometric Shapes	018	What is your favourite 3D Shape?
2.1 Fears		**Are you fearful of the following?**
	019A	Hand Dryers?
	019B	Balloon Popping?
	019C	Loud noises?
	019D	Buzzing noises from lights?
	019E	Coffee machines?
	019F	Afraid of heights (flying or being on a bridge)?
	019G	The water at the seaside?
	019H	Flashing lights?
	019J	Falling?
	019K	What other sounds might make you jump?
2.2 Change	020	What changes would make you unhappy?

Table 19. *(Cont.)*

3.1 Technology		**Do you have any of the following technologies?**
	021A	Gaming PC
	021B	PlayStation
	021C	XBOX
	021D	Nintendo Switch
	021E	Mobile Phone
	021F	Tablet
	021G	VR Headset

The 7-point Likert scores for each question are weighted against each section (e.g., 3.1 Technology) to determine a final evaluation score **(see page 177 for a completed score table).** The results from this data can then be used to calculate a total weighted score rating for each participant's pre-test evaluation. [123] [124]

NOTE: This systematic approach ensured the author's impartial assessment of the participants and highlighted the most fundamental (and diverse) autistic traits during the data analysis phase (see Appendix B: Participant Questionnaire Form VIMR-Q1).

2.12.1 Parent and Caregiver Data Analysis: VIMR-QPC

Outcomes

The VIMR-QPC guidance compares correlations between pre-and post-ViMRI sessions. [125] Parent and caregiver data about personal child participant information is obtained during the analysis stage and considers close familiarity (between the two) for each participant. The VIMR-QPC datasets are compared and analysed with the preliminary questionnaires (VIMR-Q1) to ensure more dependable outcomes.

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[123] Musical Preferences (1.1), Virtual Reality (1.2), Animals and Pets (1.3), Hobbies (1.4), Colours (1.5), Geometric Shapes (1.6), Phobias (2.1), Change (2.2) and Technology (3.1).

[124] The final weighted average score is intended to guide future qualitative analysis and research studies.

[125] VIMR-QPC guidance: once before SPiME sessions commence (around session 2 or 3) and again following completion.

NOTE: The author's judgement in obtaining first-hand knowledge from other perspectives became critical in guiding the design of a successful Virtual immersive Musical Reality Intervention (ViMRI).

2.12.2 VIMARS 1.0 & 2.0 Guidance Scoring Methods

VIMARS 1.0 and VIMARS 2.0 digital scoring criteria are psychometric evaluation ratings modelled in line with the established CARS-2-HF criteria (Schopler *et al.*, 2010). Fifteen categories using four scores rated 1.0, 1.5, 2.5 and 3.5 are evaluated respectively to determine a (final) *total raw score*. An *initial score* is indicated for each category, followed by an autism severity rating. The final *summed score* for each assessment is calculated using a total 't-score' rating (out of a possible 45 marks). A final s*ummed score* is then evaluated against the t-score criteria using the following table:

Table 20.

VIMARS (t-Score) evaluation criteria

Evaluation	Summed score
Minimal-to-no symptoms of autism spectrum condition	**(15–27.5)**
Mild-to-moderate symptoms of autism spectrum condition	**(28–33.5)**
Severe symptoms of autism spectrum condition	**(34 and higher)**

The advantages of conducting pre, and post-assessments via VIMARS 1.0 & VIMARS 2.0 offer:

i. Observational scores are identified early during the evaluation process to inform clinical or educational professionals of any discrepancies that may require further testing.

ii. Individual scores rely on personal performance to measure progress or regression (based upon the traits of an individual's pre- and post-assessment).

iii. Observations are recorded electronically (using a smartphone or tablet device) in real-time. Results can be recalled instantaneously, at any point during a trial period.

INTERVENTION DESIGN

This section of Chapter 2: Methodology 1 presents the author's protocol for a *Virtual immersive Musical Reality Intervention* (ViMRI), together with guidelines and recommendations for administering a ViMRI. Thereafter, a S*upplemental Personalised, immersive Musical Experience* (SPiME) programme protocol and guidelines for a 2-stage virtual recording process are given.

Real-world trial sessions document six individual case studies based upon a single variation (i.e., $a - f$) of a SPiME **(see Chapter 4. Part B: Summary of Key Findings, pages 214-224).**

2.13 What is a ViMRI? A Quick Recap

A ViMRI [*pronounced Vim-ree*] is the abbreviation for a *'Virtual immersive Musical Reality Intervention.'* It is essential to distinguish the term *immersive* from the acronym, as it does not reflect the perception of presence within a non-physical environment (usually associated with virtual reality immersion).

The term *immersive* (within the context of the ViMRI) refers specifically to the physiological activities and the musical engagement resulting from a *Supplemental Personalised, immersive Musical Experience* (SPiME) study programme **(see page 100)**. Any musical interactions that occur via the virtual music technology system facilitate the individual's social, emotional and behavioural characteristics.

2.14 The ViMRI Protocol

A *Virtual immersive Musical Reality Intervention (ViMRI)* consists of six alternatives **(variants *a-f* respectively)**. Each ViMRI variant is presented during a *Supplemental Personalised, immersive Musical Experience* (SPiME). Variations are selected either as a single activity (e.g., *a*) or as collaborative activities (e.g., *a, d,* and *e*) based on the following set of criteria:

2.14.1 ViMRI Administration Criteria

a) Real-time group composition and interaction

'Trial-specific' audio samples are primarily selected to record musical compositions.[126] The samples should be selected collectively (i.e., by a group of individuals). Alternatively, the group can record real-time musical compositions. Following the pre-stage recording process (for future group engagement), composition material is re-recorded and transferred into a customised virtual reality environment.

b) Real-time solo composition and interaction

'Trial-specific' audio samples are primarily selected by the participant for a real-time solo performance to record musical compositions.[127] The final (re-recorded) solo composition material is imported into a personalised virtual reality environment.

c) Individual investigation through a personalised, immersive experience (*in-vivo*)

The in-vivo personalised, immersive experience is an internally presented virtual reality activity. This variant comprises personalised media unique to the individual based on their profile. A principal investigator guides the participant (equipped with a head-mounted display) using a haptic control interface; through a series of musical, sensory, and exploratory activities within the VR.[128]

d) Individual investigation through a personalised, immersive experience *(ex-vivo)*

The ex-vivo personalised, immersive experience is an externally presented virtual reality activity; comprising a child's personalised media (based on their profile) that is unique to the individual. An alternative '*ex-vivo*' input method (using a wireless programmable keyboard) reinforces virtual musical composition.

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[126] - The author pre-loaded samples of farmyard animals, modern samples and everyday sounds for the study trials.

[127] - 'Trial specific' refers to a pre-loaded audio file chosen for the session based on the participant's profile/preferences.

[128] - Example activities include popping bubbles, throwing balls, watching movies and listening to music.

e) **Virtual Exposure (VE) to musical fears (*in-vivo*)**

The participant is presented incrementally with their specific fear of sound or phobia while immersed in their personalised VR environment — forming part of a desensitising strategy. In certain circumstances (where permitted), the child's preferred or feared sound can be introduced to their real-life counterpart — at the end of a session. [129]

f) **Real-time group composition using immersive virtual playback**

'First level' musical compositions are recorded in real-time collectively by a group of participants, utilising the ARTIMIS hardware interface.

The performance material is linked directly to a virtual reality environment and CiiMS software interface for further group interaction to encourage a 'second level' of creativity. ***Option f represents the central concept of a ViMRI (pending future testing).***

Individual participant evaluations for any of the above variations (i.e., ***a* to *f***) are recorded on completion of each session using the form: **VIMARS IND (see Appendix E).**

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[129] For example, the author presented a real hand-dryer to a participant after their virtual session that was presented within their virtual environment.

2.15 Virtual Composition Guidelines

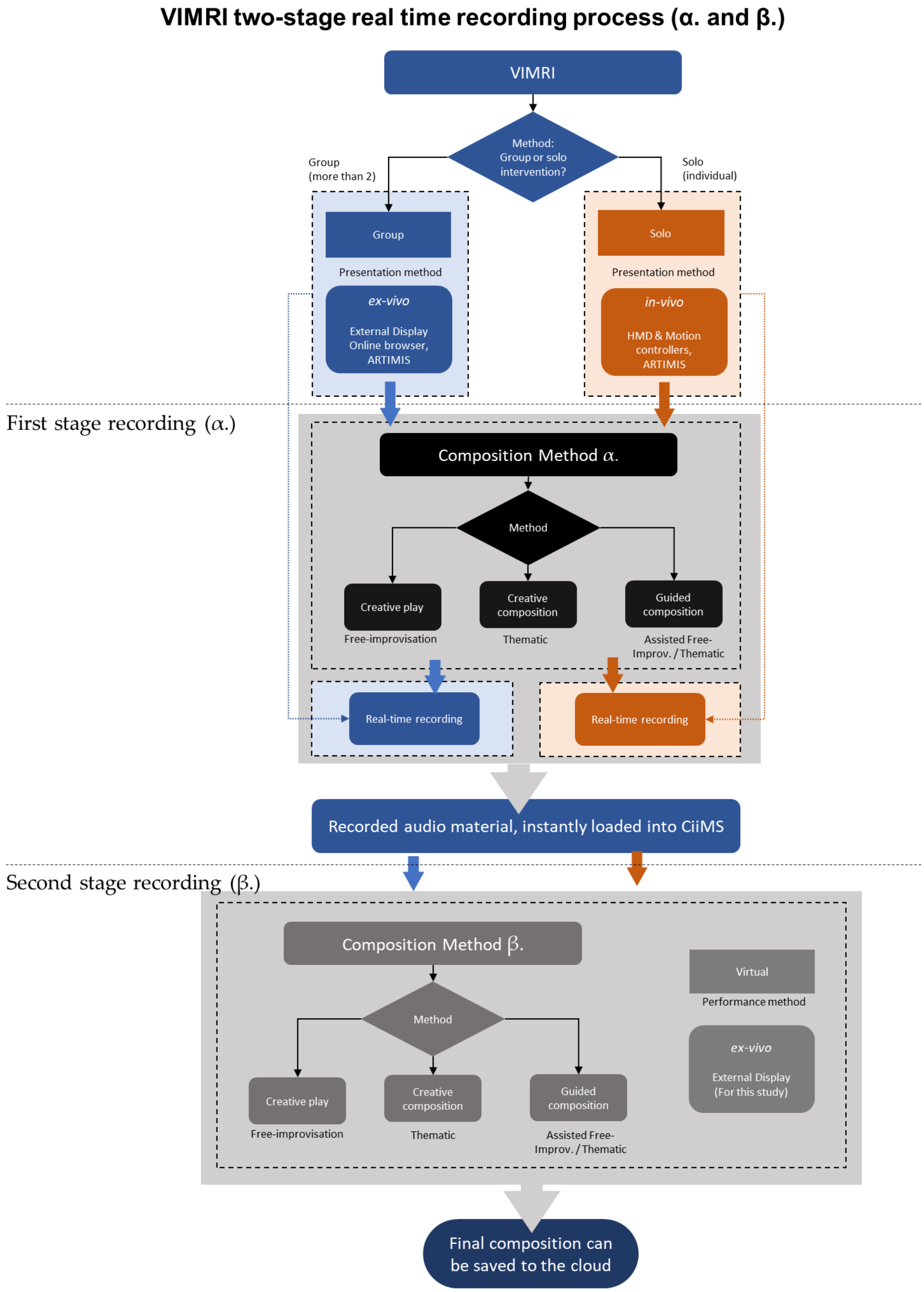

Figure 15. Virtual composition process flow chart.

The following process is the author's explanation of virtual composition within a ViMRI:

Two-stage real-time recording processes, Alpha (α.) and Beta (β.), shown in *Figure 15*, are necessary to capture musical compositions (as audio samples) via physical gestures and vocal interactions when using the ARTIMIS and CiiMS interface.

Group performance is mediated externally by a two-stage approach using capacitive touch.

1. **First stage recording - Alpha (α.)**, is guided by a group-improvised performance (programmed to record for sixteen seconds or more). Thereafter, a recorded digital audio performance is automatically re-distributed (instantaneously) — across sixteen physical touch-capacitive pads on the CiiMS hardware interface.

2. **Second stage recording - Beta (β.)**, transmits the recorded material (from α.) from the ARTIMIS interface to the CiiMS virtual reality software that is accessible to the participants. The CiiMS hardware interface bolsters interaction and composition for a final virtual piece.

The 7-stage ViMRI cyclic trial stage process

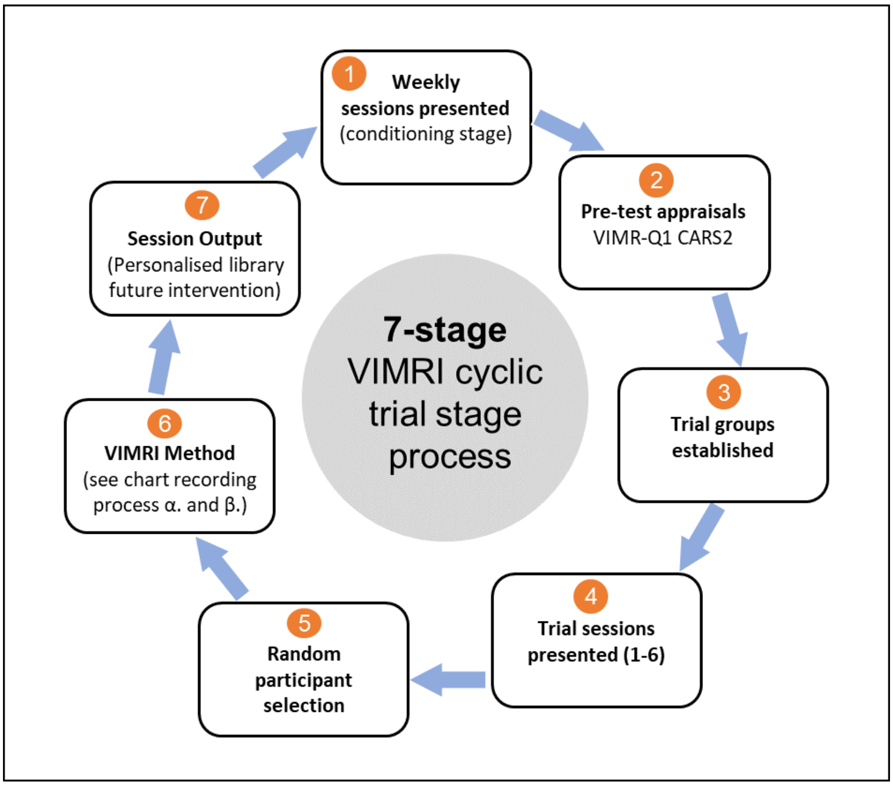

Figure 16. The 7-stage ViMRI process.

2.16 Supplemental Personalised, immersive Musical Experience (SPiME): Guidelines

The following section details the author's protocol for administering the *Virtual immersive Musical Reality Intervention*. A *Supplemental Personalised, immersive Musical Experience* (SPiME) programme consists of six sessions delivered over six consecutive weeks. These guidelines begin with a brief overview, followed by the session objectives and (in each case); a brief account of real-world outcomes. Study trials for this research were achieved within a special educational needs (SEN) environment by a group of eighteen high-functioning autistic children.

NOTE: This educational pathway exemplifies the development of a research programme for uncomplicated adaptation to other disciplines — (i.e., used as a transferrable tool).

2.16.1 Session Regulations

Supplemental Personalised, immersive Musical Experience (SPiME) study sessions should be presented at the same time each week — to encourage familiarity and similarity within the same classroom (or educational) setting. The instructional setting should remain consistent throughout the process to encourage social interaction within the group. [130]

A brief synopsis: **Session 1 to Session 4**

i. Virtual and musical activities with small participant groups of 4-5 suggest a session duration of fifty minutes.
ii. Regular intervals between virtual and musical activities suggest 5-10 minutes.
iii. Session durations for groups larger than five participants require agreement with a learning administrator.

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[130] The author ensured consistency every week by using the same suitable room layout and appointed a seating plan for each child within each group session.

iv. Virtual reality activities for each individual suggest two 5-minute sessions — intervals should last approximately three minutes each.

v. Session 5 and Session 6 are trial sessions.

vi. The trial duration should not exceed 15 minutes per session and be not less than 5 minutes.

vii. Trial sessions should include the support of a familiar teaching assistant.

A gradual approach for trial sessions should be emphasised and implemented during the study, as shown below:

Table 21.

Example session timetable

Session Date (e.g., 2021)	Session outline
Wednesday, Nov 3rd	Session 1: Virtual Immersive Music - An introduction
Wednesday, Nov 10th	Session 2: What do you like?
Wednesday, Nov 17th	Session 3: First Exploration of VIMR
Wednesday, Nov 24th	Session 4: Virtual Play
Wednesday, Dec 1st	Session 5: Virtual Immersive Music – A Customised Immersive Experience
Wednesday, Dec 8th	Session 6: Virtual Immersive Music – Exit Interviews and questionnaires
	Recommended session duration: 50 minutes

Example session timetable presented for this research study

For a full breakdown of session regulations, see **Appendix C (Participant Requirements)** and trial session presentation slides; see **Appendix M** for this study.

2.16.2 Session 1. ViMRI Introduction

2.16.2.1 Overview

Participants are introduced to the principal investigator within a classroom setting (as assigned by the school) and accompanying educating support staff to ensure consistency throughout forthcoming sessions.

The introductory session focuses on traditional and electronic music fundamentals. Children are encouraged to explore other music genres and interact (by physical means) with alternative and traditional musical instruments. This session provides an opportunity for children in a group setting to familiarise themselves with the principal investigator, acquire confidence in themselves, and progress to future sessions.

2.16.2.2 Virtual immersive music session objectives

- Introduces the principal investigator (PI)
- Presents a new virtual instrument (through video presentation)
- Emphasis on the importance of social groups
- Forthcoming sessions and programme outcome discussions
- Individual participant suitability and assessment for forthcoming sessions
- Journal completion of the session for qualitative evaluation

2.16.3 Session 2. What Do You Like?

2.16.3.1 Overview

Participants meet the principal investigator for a second time, accompanied by a familiar teaching assistant(s), to encourage likeness and repetition. Objectives for session 2 are three-way, focussing on investigations of individual interests, hobbies, and favourite colours. Activities include an introduction to 3-dimensional concepts (3D), a brief historical overview of virtual reality, its origins, and the invention of anaglyphic and stereoscopic techniques by *Sir Charles Wheatstone (1802-1875).*

2.16.3.2 A fundamental overview of 3D

Children will learn about 3D computer coordinate software by Autodesk and model some standard and extended 3D primitives. This practical session presents teachings around the user coordinate system (UCS) and depth perception **(informed by Virtual Spaces; see page 8).**

The session presents learners with the foundations concerning spatial relationships that rely on X, Y and Z axis coordinates (Owen, 2018). Children produce a sketch of their choice (using traditional methods) with various media, including pens, coloured pencils, and crayons. The final sketch is optically scanned and digitally imported into the child's personalised virtual world for forthcoming sessions and inclusion in their VR scene.

2.16.3.3 Session 2 learning criteria

The learning criteria for Session 2 are as follows:

- Investigations into participant interests
- Exploration of spatial and depth perception
- Introduction to standard and extended 3D primitives
- Historical origins of Virtual Reality
- Practical session: sketching with traditional media
- A 3D software application tutorial
- Anaglyphic processing

2.16.4 Session 3. Exploring VR

2.16.4.1 Overview

Session 3 develops the participants' understanding and knowledge of previously visited spatial relationships. Three-dimensional stereoscopic vision and depth perception prepare participants for an immersive experience — within a virtual music environment. The session's primary focus includes a demonstration of a ViMRI instrument and CiiMS technology interface (*Sensel*, 2017; *Meta*, 2020). Children are encouraged to interact with the specialised toolset freely and incrementally understand virtual proprioception (i.e., body awareness). These areas of knowledge will help participants coordinate muscular movement and identify somatosensory sensations.

Two "exploratory" virtual computer applications are available for investigation:

i. Geographical Application
ii. A virtual immersive musical reality standard template
(explicitly developed for the trial). [131]

The above virtual software applications encourage spatial and navigational learning to promote confidence in children when virtually navigating with a pair of haptic-touch motion controller joysticks (or equivalent). Finally, form VRMI-Q1 requires completion for early assessment. [132]

2.16.4.2 Session 3 requirements

A sizeable interactive screen or external display is advisable to cast the virtual environment and slide presentations. [133] Navigation using any of the following two methods includes:

- Motion controllers: manipulation and navigation around a virtual scene to interact with musical elements and objects (preferably with haptic feedback).
- A wireless programmable keypad interface. Individuals with physical disabilities or medical conditions can navigate VR using this alternative. [134]

2.16.4.3 Session 3 learning criteria

The learning criteria for Session 3 are as follows:

- Introduction to Virtual immersive Musical Realities (ViMRs)

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[131] A standard virtual template is an interchangeable environment containing media assets, 3D objects, sensory lights and audio sample sounds substituted with the individual's personal preferences for their personalised session..

[132] VRMI-Q1 Evaluates Preference, anxiety, dexterity, phobia efficacy and sense of presence.

[133] The author discovered through the trials that an external interactive screen allows for better group participation and interaction.

[134] Physical disabilities could include restrictive movements or medical conditions: photosensitivity or hypersensitivity to light.

- Exploring virtual environments
- Getting acquainted with VR equipment
- What are your personal preferences?
- Creative immersive interactive Musical Software (CiiMS): a practical session
- Musical composition using the CiiMS interface
- Sensory relaxation [135]

The author presented the above example activities to participants during the trial sessions (see slide examples, Appendix M: Presentation Material).

2.16.5 Session 4: Virtual Play

2.16.5.1 Session 4 overview

A *Virtual Play* session assesses participant confidence by first establishing familiarity between the child, the Principal Investigator (PI), and the group companions who have remained consistent throughout the previous sessions. Session 4 adopts an individualised (i.e., one-to-one) approach. Participants are interviewed to help stimulate the development and realisation of their unique virtual world.

2.16.5.2 Session 4 pre-requisites

Participants should have a completed VIMR-Q1 questionnaire for this virtual musical 'trial' session. A recommended total session duration should not exceed 20 minutes with a minimum of two 3-minute intervals (devised as appropriate).
A supporting educator or equivalent teaching assistant should be present throughout.

2.16.5.3 Session 4 assessment criteria

The assessment criteria for Session 4 are as follows:

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[135] Sensory relaxation refers to listening to the relaxing noises of birds and immersion within a virtual sensory room.

- Participants experience the immersion of a large virtual reality scene within an enclosed perimeter. The scene should incorporate *real-world* scale dimensions and heights.
- External motion controllers assist navigation (together with a numeric keypad assigned with specific functions). These interface options encourage improved somatosensory, memory and hand-eye coordination.
- Individuals should prepare for the IND trial sessions as outlined in the participant requirements letter **(see Appendix C: Form 3).**
- Musical preferences guide communication and developmental assessment.

The author devises the following guidelines (below) to assess areas of social and emotional competencies during performance assessments (inspired by Campbell and Overman (1988)).

i. **Preferences** – coloured world static objects should utilise simulated collisions acquired by the individual's favourite colour.
ii. **Anxiety** – falling virtual objects should include haptic feedback to simulate a fear of being trapped within a controlled boundary area (i.e., without an exit).
iii. **Measured competence** — individuals should experience virtual variable heights to immerse themselves on top of a simulated virtual platform for observation.
iv. **Fear of height** — 'over the edge' navigation within the virtual environment should be proportional in scale to a realistic place (e.g., a mountain or cliff top) to recreate a commanding 'virtual' view.
v. **Social Interaction** — There should be an element of "sudden" automated relocation of objects within the VR.

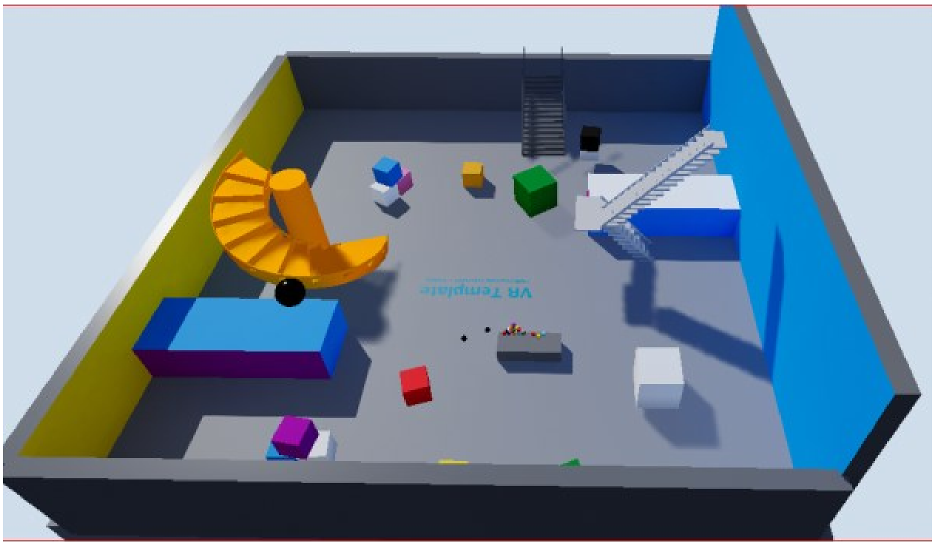

Figure 17. The virtual play template (overhead screenshot).

Figure 18. Coloured cubes and bowling balls: positioned and ready for interaction.

2.16.6 Session 5. Virtual Immersive Musical Reality (Trial Session)

2.16.6.1 Overview

Session 5 is the penultimate virtual immersive music session performed within familiar physical surroundings and an equivalent classroom setting. Trial Session 5 focuses on desensitisation. Individuals' fears and phobias are exposed through various activities to challenge music creativity and virtual engagement. [136] Virtual activities

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[136] The author refers to literature reviews surrounding Cognitive Behavioural Therapy and Exposure Therapy paradigms that influenced the decision to incorporate fears and phobia activities for session 5 - (Abramowitz et al. 2011, p. 232).

include manipulating inanimate virtual objects (e.g., a poster and 3D shapes) to invoke social stimuli and support the selective preferences of participants. Theoretical and technology-based HCI approaches guide these customised experiences and musical games **(page 24).** [137]

ViMRI Trial Variations: Session 5

Session 5 offers two trial variations:

i. ***in-vivo* – *internal immersion***: An immersive 'hybrid' experience with VR equipment (i.e., HMD and motion controllers) for interaction. Individual or group compositions are technologically facilitated externally via the dedicated (ARTIMIS) interface.

ii. ***ex-vivo* – *external immersion***: An alternative external 'immersive experience' with an interactive display for interaction. Individual or group compositions are technologically mediated externally — via a wireless numeric keypad interface connected to a dedicated (ARTIMIS) interface.

NOTE: The author's final ViMRI version will be the proof of concept. Technology advancements allow for a new exposure method like ARET (Augmented Reality Exposure Therapy). Here, the individual can be immersed within the environment (external) and interact physically using the CiiMS and ARTIMIS interfaces (Baus and Bouchard, 2014).

2.16.7 Session 6: Exit Interviews and Questionnaires

2.16.7.1 Overview

Session 6 summarises the progress of participating children in the research study. Activities performed throughout the SPiME programme are reviewed through interviews to allow individuals to express their thoughts on the study. During the final session, participants complete an exit questionnaire to establish an 'exit score' for qualitative evaluation.

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[137] Customised experiences and musical games are guided by the information captured from a participant interview session (VMRI-Q1 and VIMR-2).

Chapter 3.
METHODOLOGY 2:

DESIGN OF A SUPPLEMENTARY VR MUSIC TECHNOLOGY

Figure 19. The virtual immersive musical reality scene.

The author comprehensively explains the system exposition, including the ideas and theories used to build the unique ARTIMIS proprietary virtual interactive music system. Chapter 3: Methodology 2 provides methodologies supporting this research (established early on by the author) to assess new supplementary technologies for a (complimentary) virtual reality musical intervention. Six case studies **(see page 133)** present various permutations of the ViMRI intervention that give rise to three resulting study trials and findings (discussed in **Chapter 4** of this thesis).

NOTE: The case studies inspired the author's inception of detailed and systematic guidelines for a virtual supplemental intervention (explained in Chapter 2. Methodology 1: Intervention Design, page 95).

3.1 Design and Development of ARTIMIS and CiiMS

This section presents the author's design and development process of the ARTIMIS and the CiiMS complementary interfaces (drawing upon various stages of the *3-Stage Technical Development Process* **(page 65)**. These guided the author to conceive and develop new technologies for this research.

3.1.1 ARTIMIS: Quick Recap

ARTIMIS refers to an *'Autism Real-time Three-dimensional Immersive Musical Intervention System'* that encompasses over eight years of continuous development.
The authors' son, Stelios **(see Acknowledgements, page iii),** has inspired the development of this immersive musical intervention. ARTIMIS has been conceived to address the musical needs of individuals with high-functioning autism spectrum conditions (ASCs).

The hardware-based system incorporates a fully functional physical user interface with (highly responsive) multi-directional and haptic-feedback touch pads that facilitate musical engagement. The interface system can load preset or individual samples or record a passage of musical composition across the interface pads — near instantaneously.[138] A pre-existing touch-capacitive hardware surface (*Sensel*, 2017) allows the user to achieve a high level of interactive complexity and creativity, further enhanced by a fully interchangeable touchpad interface — customised for any given theme. Varying touch pressures control the layers of musical expression via MIDI Polyphonic Expression (MPE). Depending on the musical application, the MIDI MPE protocol assigns controllers, such as velocity, pitch, and bend. Furthermore, the interface is expandable for future assignments (according to the introduction of new technology).

A *'Creative immersive interactive Musical Software'* application (CiiMS [*pronounced Sims*]) accompanies ARTIMIS, a customised software interface developed in parallel

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[138] A passage of musical composition is determined by a preset 'recording duration' that can be selected via the CiiMS software interface.

with the hardware. The author's future intentions for the hardware and software technologies will complement established therapeutic interventions as a transferrable tool for supporting people with neurodiverse conditions.

3.1.2 User Interface

3.1.2.1 The CiiMS floral interface

The CiiMS floral© is central to the user interface (UI). A 16-segment-coloured roundel is replicated throughout the system in hardware and software forms. Initially modelled from Acrylonitrile Butadiene Styrene (ABS) **(see *Table 4*, page 29)**, the floral prototype hardware interface uses 3D plastic components. The author revisited early prototyping techniques (including additive manufacturing) to obtain original FBX file (Filmbox) format data during development. These templates were imported into a 3D computer-aided design (CAD) software application (*Autodesk*, 2022a) to reconstruct a low-level polygon floral equivalent. The author's decision to utilise the FBX-compatible file format exchange throughout the development process ensured cross-platform software compatibility. Furthermore, this format reduced total 3D modelling time and the need to re-invent or re-model individual components (by reusing the floral interface) within the virtual scene.

Figure 20. The floral multi-touch capacitive hardware interface.

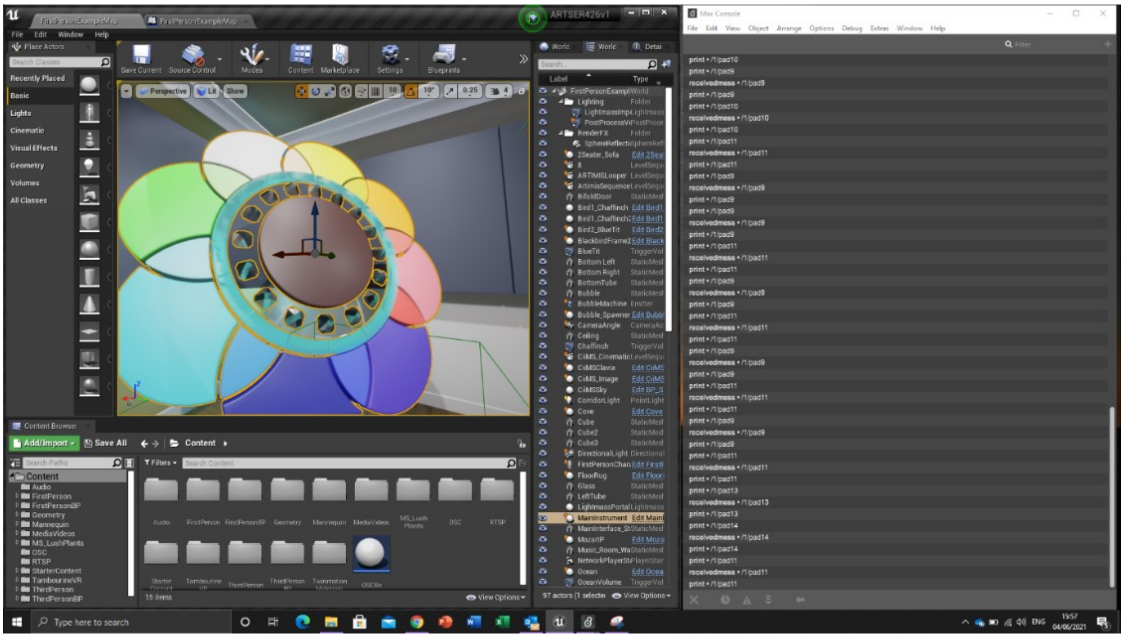

Figure 21. CiiMS 3D interface MIDI testing within Unreal Engine 4.26.2 (Epic) and Max 8 (Cycling '74).

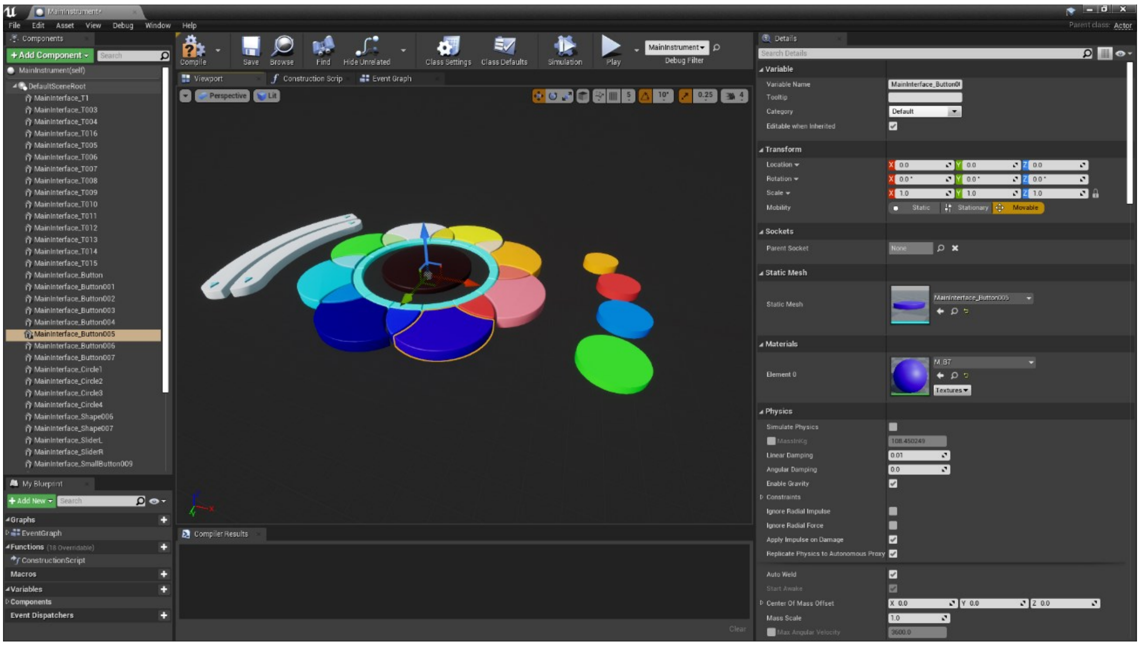

Figure 22. 3D CiiMS roundel interface within the Unreal Engine 4.26 environment (Epic, 2019).

3.1.3 The 3D Modelling Process

3.1.3.1 Low-resolution models, high-resolution images

Within virtual reality and advanced real-time computer applications, the 3D modelling process places efficiency at the forefront of the agenda.[139] A smooth surface approximation achieves clean models using low-level polygonal modelling techniques (Lohikoski and Rudén, 2013).[140] Subdivision modelling is a technique that involves the construction of 3-dimensional assets modelled at a low resolution (a block cage) and applied with higher resolution bitmap images (Holden, 2011). Many 3D programming applications (if not all) include pre-defined 'standard primitive' toolsets, including cubes, cones, cylinders, spheres, planes and prisms **(as shown in *Figure* 23).**
Standard primitives are the foundations of 3D modelling and subdivision modelling techniques.[141]

3.1.3.2 NURBS modelling

Non-Uniform and Rational B-Spline (NURBS) surface approximation comprises mathematically accurate (smooth) surfaces for creating complex, large-scale scenes or engineering applications — such as G2-level surfaces (Shiach, 2015).[142] The NURBS modelling process uses alternative methods during the 3D modelling in the form of Bézier curves (often referred to as B-splines). The author drew upon NURBS modelling throughout the development phase of the 3D interface. Due to the non-organic simplicity of the scene objects, the NURBS modelling method was trialled and considered inappropriate by the author for this application.

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[139] The author refers to efficiency as the process of optimisation of a 3-dimensional model within the games development process. The fewer polygons lead to a more efficient 3D model.

[140] Polygons refer to geometric 3-dimensional primitives.

[141] The author used the subdivision modelling process to create the VR assets. Polygonal primitives are low-resolution mesh templates with minimal vector points that can be used as a starting point for further manipulation into a more detailed model by presupposing the tri-faces (triangular) further into smaller divisions.

[142] Non-Uniform and Rational B-Spline (NURBS) modelling is used throughout the automotive industry.

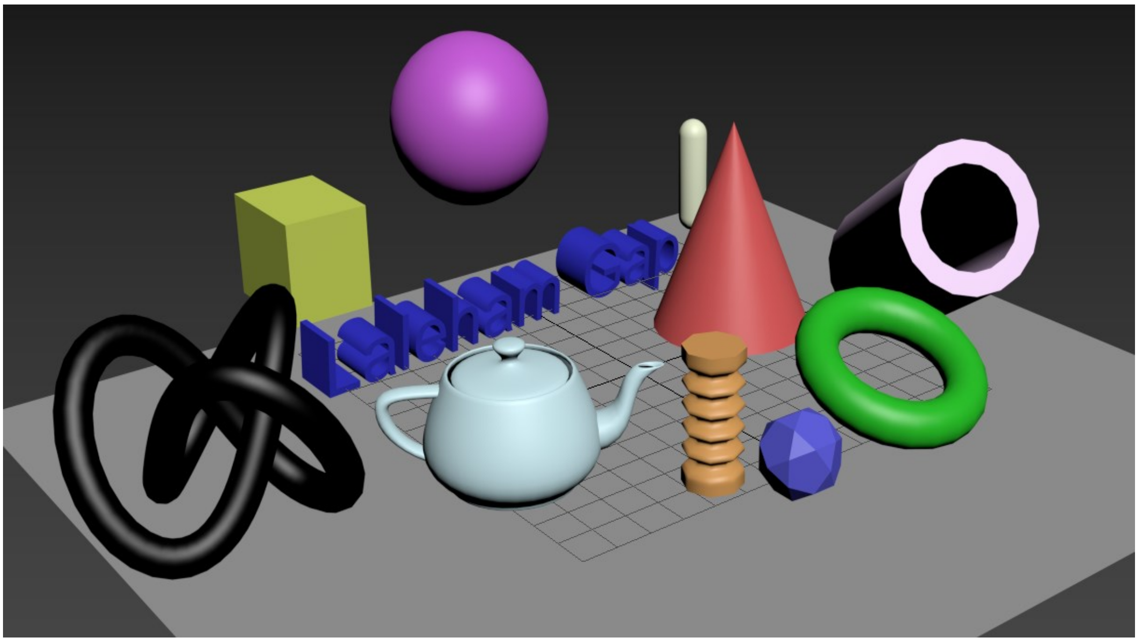

Figure 23. Standard '3D' primitives.

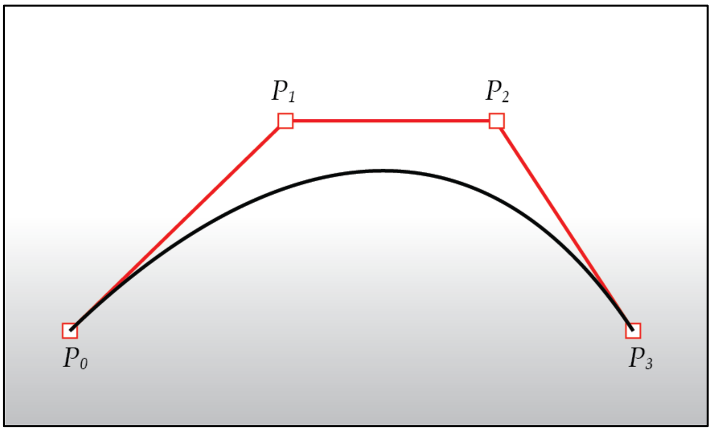

Figure 24. NURBS 'B-Spline' curve with 4-points (P_0, P_1, P_2 and P_3).

The Bézier (B-spline) equation curve of degree (*k*) is defined by:

$$S(t) = \sum_{i=0}^{n} N_{i,k}\,(t)P_i$$

3.1.4 Creating Natural Virtual Reality Scene Materials

Virtual scenes frequently require a catalogue of natural elements to create realistic materials and atmospheric effects. The author chose a suitable 3D painting software application **(see page 31)** and an alternative high-end image processing software (*Adobe Inc*, 2019) to develop the VR scene material assets.

Adobe Substance 3D (2021) is one example application for creating image scenery and virtual object and asset materials. The author cropped bitmap images and exported them directly into the Unreal Engine's (*Epic Games*, 2019) *Physically based visual material editor* [143] as a copied instance. [144] Physically based rendered (PBR) materials were instanced (copied intact from the parent) throughout the virtual scene. This methodical approach allowed for a more rapid workflow and ensured that duplicate materials were minimised and only created from the source material. Furthermore, this process guided to a more efficient final output and reduced file sizes and interdependencies of objects within the scene. Unreal Engine 4 (*Epic Games*, 2019) includes a node-based material editing environment for creating complex material networks using expression nodes.

NOTE: The toolset benefited the author for animating individual, material parameters and assets within the Unreal Engine 4 scene environment. [145] [146]

3.1.5 Software Choices for the Design of Virtual Assets

The prototyping process consists of numerous stages; visualisations initially guide a physical prototype's design. The author produced several variations of 3-dimensional computer-generated virtual assets using the *AutoCAD* Computer-Aided

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[143] Unreal Engine incorporates a node-based graphical interface to create complex shaders within a scene: Link to source

[144] In the Unreal Engine IDE, the term 'instance' within the context of a master material (referred to as the child) is a duplicate of the original material (the parent) that explicitly inherits parameters of the base materials data only.

[145] The author refers to the matinee and cinematic toolsets used to animate objects within the VR scene sequentially over a pre-determined animated time, reducing the workflow further. This workflow enabled the author to use a series of *matinee* and *cinematic sequences* to be created within the editor.

[146] The author used individual material parameters to create sensory lighting, metronome lights, bubbles and audio-visual triggers within the VR scene.

Design (CAD) software application (*Autodesk*, 2022b). A product design and manufacturing suite (*Autodesk*, 2022c) to accurately model surfaces and create a scaled representation of virtual assets within the scene was also used. All virtual assets, including virtual instruments, sensory lighting and other physical properties, were simulated and rendered within the 3ds Max (*Autodesk*, 2022a) modelling and animation environment. Digitally scanned preliminary conceptual sketches throughout the prototyping and additive manufacturing process assisted the author in forming accurate modelling templates. In addition, original sketches made during the physically based rendering (PBR) modelling stages guided the author to achieve a more significant level of detail and provide a more realistic virtual environment.

NOTE: These processes influenced the author to implement various design changes that evolved from an integrated device into a percussion instrument with holographic cameras.

3.1.6 Modelling the Virtual Instruments and Assets

3.1.6.1 The Filmbox 'FBX' format

The author chose the Filmbox (FBX) interoperable proprietary digital file format throughout the 3D modelling and animation process. Whilst developing a VR interface, a low-polygonal modelling approach became of significant value, resulting in faster regeneration times and increased performance levels within the VR headset during testing. Furthermore, maintaining a lower polygon count of the 3D objects within the scene reduced the overall file size and increased scene complexity (Walker and Walker, 2001).

3.1.6.2 Primitive shapes

Modelling virtual immersive musical assets within the 3ds Max (*Autodesk*, 2022a) environment was quickly achieved using primitive shapes. The 3D workflow involved first obtaining accurate reference images before importing models into the scenes and onto virtual scaled planer objects (work-planes) to mimic the virtual asset's physical size. The author investigated physical dimensions and materials before modelling musical instruments within a scene, and the final instruments were recreated and accurately modelled using the *Fusion 360* software application (*Autodesk*, 2022c).

A virtual scene can become extraordinarily complex. Individual assets and materials contribute to increased data sizes; this became evident during the development of the immersive musical interface. Three-dimensional models for a scene are refined at the sub-object level using pre-defined surface primitives and a series of editable mesh and modifier commands. A hierarchical stack of operations preserves the original geometry of shapes within the parametric modelling toolset whilst maintaining a low poly-count. [147]

3.1.6.3 Ethical guidance for a virtual multisensory room

The author gathered significant research in physical therapeutic environments and physiological paradigms to determine the most appropriate layout to design a virtual sensory room. Ethical guidelines and regulations become increasingly challenging when transitioning from physical to virtual reality. For example, virtual exposure therapy systems for combat-related scenarios — designed for individuals diagnosed with Post-traumatic Stress Disorder (PTSD) deliver positive outcomes (Rizzo *et al.*, 2010). [148]

NOTE: The author's discussions with a play therapist (see page 68) and multisensory considerations (previously discussed in the literature review) strongly influenced the conception of a series of virtual room layout sketches. [149]

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[147] The author's early attempts to model a virtual tambourine resulted in extremely high polygon counts (some 72,000 polys calculated). The author deemed the tessellations far too large and uneconomical during real-time scene testing and rendering. Modelling additional assets in this way would have undoubtedly produced undesirable latency.

[148] Providing clients give informed consent prior to participating in their virtual setting.

[149] Materials, space, and environmental lighting in the virtual setting were all considered prior to modelling.

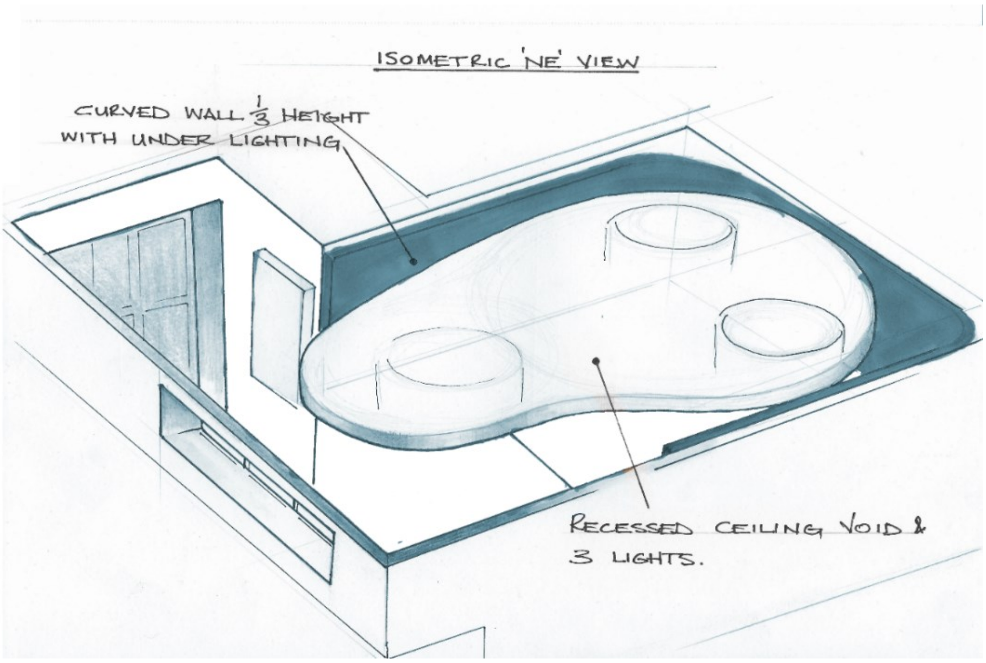

Figure 25. Isometric North East (NE) conceptual sketch layout of the VR therapy room.

3.1.6.4 Creating virtual fixtures and fittings

The author modelled realistic virtual fixtures and furnishings (i.e., carpet, walls, posters, textures, and other assets) using the 3ds Max (*Autodesk*, 2022a) software suite. UV mapping techniques ensured that high-resolution image textures applied to complex scene objects reduced the overall polygon count and improved the speed of the final VR music application. Particularly given that this is a highly time-consuming process.

3.1.6.5 Animation design

Technical, musical, and virtual concepts — through Events [E2], [E3], [E4] and [E5], respectively were formulated through the author's accomplishments of interviews together with individuals in respective areas.

NOTE: The above process guided the author's decision to develop immersive 3D sensory, behavioural, social, and emotional elements within the scene. This paved-the-way to design and develop many animations shown in the following table:

Table 22.

Animations designed for the ViMRI

Scene asset	Animation within the ViMRI scene	Inspired by (Initial)
Bird posters	Triggered when approached	(SR) music therapist — *Birdsong* NHS Trust Devonshire
Treble clef	Lights illuminate in sequence to a nursery rhyme when interaction occurs	(EK) play therapist — interview
Sensory lighting	Physically accurate IES photometric lighting profiles for realistic sensory lighting	(KB, SB) NHS Nottingham via interview
Streaming media television	Display of sensory videos, calming images and relaxing audio	(EK) play therapist and (SB) Music Therapist
Tambourine	Physically based properties trigger boxes for detection of motion of individual cymbals	(MF) Games developer (CCCU)
Illuminated virtual instrument	Buttons illuminate and depress automatically when triggered (i.e., virtual press)	Music therapists (RH, SB)
Spatial audio	Sound is applied depending on the client's position	(SR) Music therapist NHS Trust Devonshire

3.1.6.6 Lighting and environment

Lighting a 3-dimensional environment is fundamental when designing for virtual scenes, especially when rendering output appears on a head-mounted display (HMD) for the final VR experience. Particular attention was given to the ambient lighting within the scene during development to meet the sensory needs of individual participants. IES profiles contain embedded real-world lighting measurements and distributions **(see section 1.7.3: Photometric Lighting, page 32).** Many specific IES lighting profiles for light bulbs and LEDs are available to download by the manufacturer. IES profiles contain technical data attributed to lighting: falloff (attenuation), intensity (strength), lens flare and reflections — amongst the many other essential lighting attributes. These elements and their accurate parameters collectively form a photometric 3D profile (including) that can be imported and used by many 3D software applications within a scene. The ARTIMIS virtual scene utilises 16 IES spotlights, three void lights, eight recessed lights and two concealed wall lights (hidden from view).

NOTE: To ensure a physically accurate representation, the author modelled all 3D assets and assigned the correct data profiles from the Philips range of Professional Lighting Photometric Data (Philips, 2018).

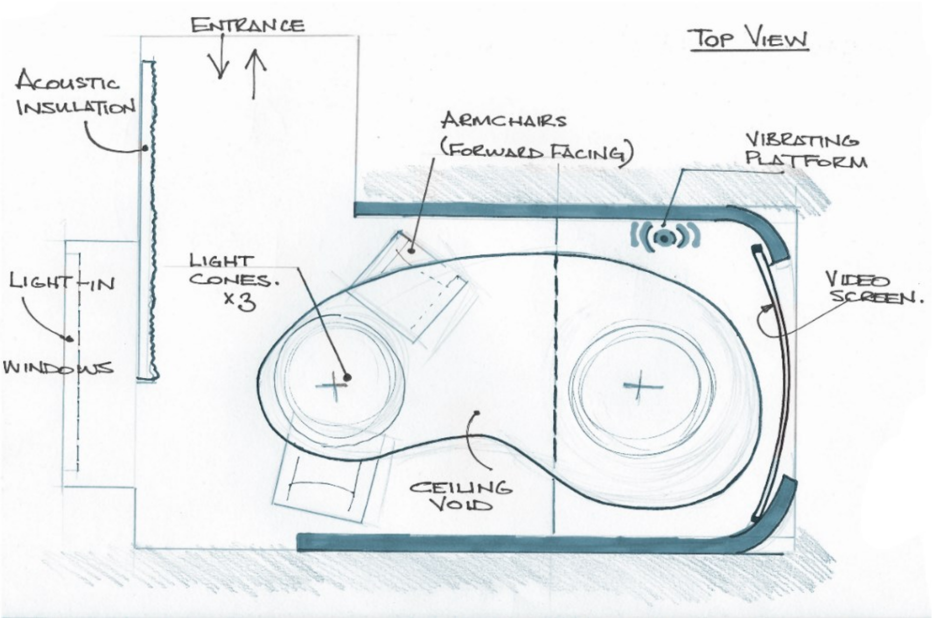

Figure 25a. A 'Bird's Eye View' conceptual sketch layout.

3.1.7 Binding Virtual Audio Within the Immersive Environment

To ensure that audio and MIDI messages can communicate successfully within a virtual reality environment (i.e., remotely over an external network or device), a master blueprint (code) requires an appropriate OSC server and client configuration for transmitting and receiving MIDI messages (within the IDE). [150] [151] Touch - Open Sound Control (Touch OSC) protocol (Hexler Limited, 2020) permits messages from within the VR environment to be transmitted and received as musical data (MIDI). This technically demanding process relies on the CiiMS software interface installed on a local machine to achieve compatibility and functionality.

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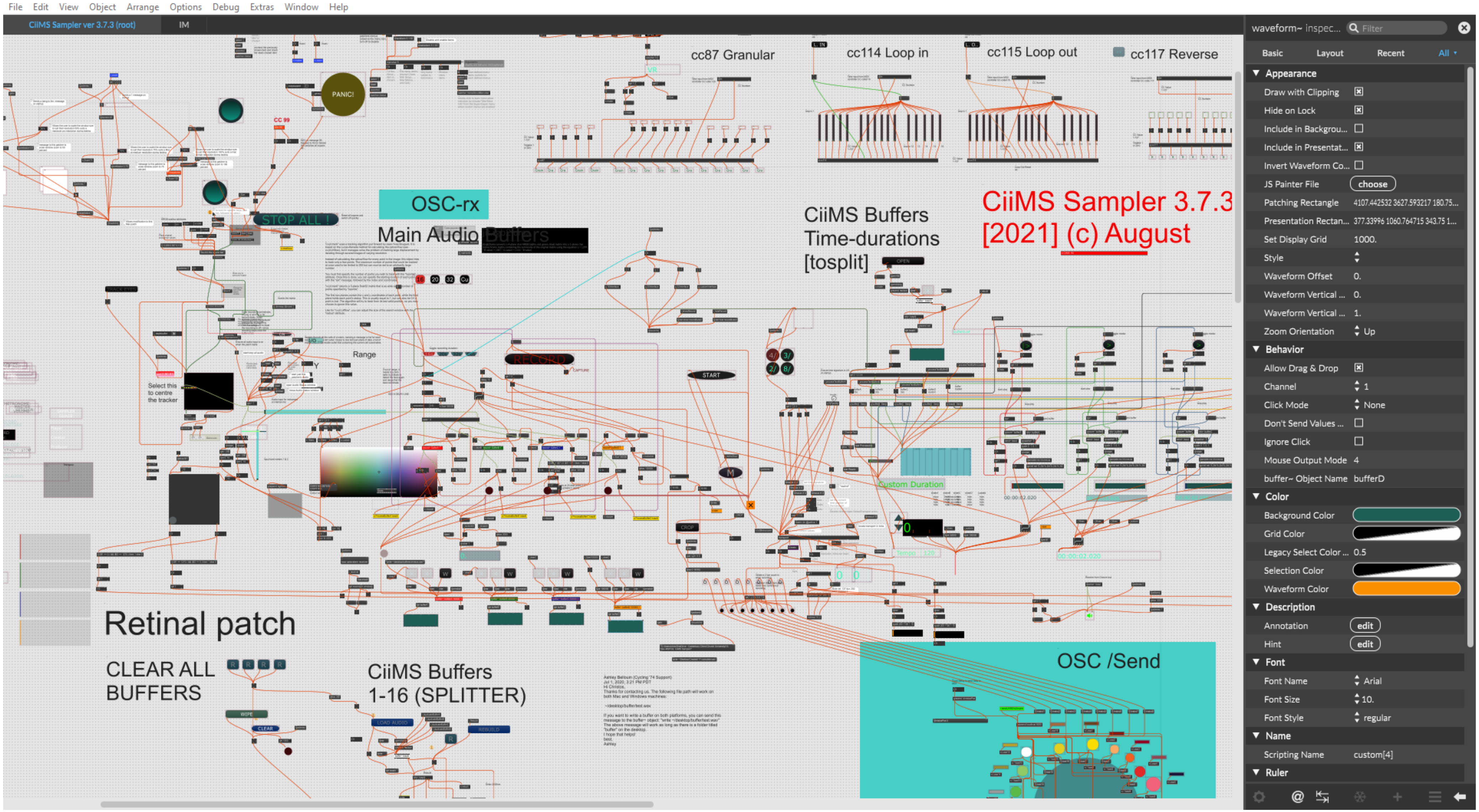
[150] Core types of an OSC Server act as the listener (receiver) for messages that are being sent from a local copy of the Unreal Engine. The OSC client, refers to the protocol for sending (transmitting) OSC messages (MIDI) via a bundle. The Unreal Engine 4 includes an OSC plugin (ver.4.26 installed for this project) available at: Link to download.

[151] The author configured the Open Sound Control (OSC) plugin for Unreal Engine 4 independently during development to establish a generic audio data connection between the virtual reality scene and the CiiMS interface.



Ashley Bellbuin (Cycling '74 Support)
Jul 1, 2020, 3:21 PM PDT
Hi Christos,
Thanks for contacting us. The following file path will work on both Mac and Windows machines:

~/desktop/buffer/test.wav

If you want to write a buffer on both platforms, you can send this message to the buffer~ object: "write ~/desktop/buffer/test.wav"
The above message will work as long as there is a folder titled "buffer" on the desktop.
I hope that helps!
best,
Ashley

waveform~ inspec... Filter

Basic | Layout | Recent | All

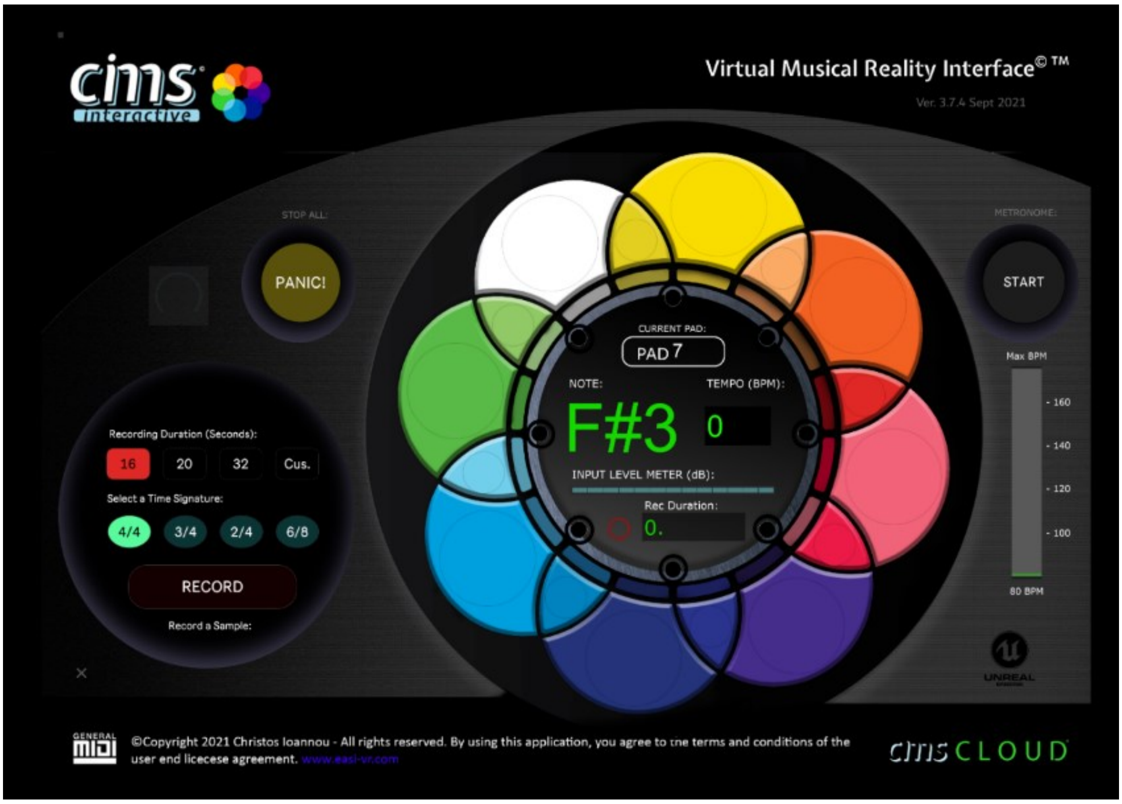
Appearance	
Draw with Clipping	☒
Hide on Lock	☒
Include in Backgrou...	☐
Include in Presentat...	☒
Invert Waveform Co...	☐
JS Painter File	choose
Patching Rectangle	4107.442532 3627.593217 180.75...
Presentation Rectan...	377.33996 1060.764715 343.75 1...
Set Display Grid	1000.
Style	
Waveform Offset	0.
Waveform Vertical ...	0.
Waveform Vertical ...	1.
Zoom Orientation	Up
Behavior	
Allow Drag & Drop	☒
Channel	1
Click Mode	None
Don't Send Values ...	☐
Ignore Click	☐
Mouse Output Mode	4
buffer~ Object Name	bufferD
Color	
Background Color	🟩
Grid Color	
Legacy Select Color ...	0.5
Selection Color	
Waveform Color	🟧
Description	
Annotation	edit
Hint	edit
Font	
Font Name	Arial
Font Size	10.
Font Style	regular
Name	
Scripting Name	custom[4]
Ruler	

Figure 26. A small regional screenshot from the Max 8 programming environment.

3.1.7.1 LoopMIDI virtual software driver

Towards the end of the software development, the author discovered that data messages between the 3D application, iPad application and MIDI software (i.e., ARTIMIS, iPad and CiiMS) were incomplete. A virtual 'loopback' port was required for installation (collectively within each software node) to allow effective virtual MIDI communication. Without this specific configuration, a virtual connection cannot be established. [152] Installing the LoopMIDI 1.0 software application (*Erichsen*, 2010) rectified this issue. [153]

NOTE: The next development phase required hosting and testing the virtual software musical interface and streaming video assets on a cloud-based virtual server.



©Copyright 2021 Christos Ioannou - All rights reserved. By using this application, you agree to tne terms and conditions of the user end licecese agreement. www.easi-vr.com

Figure 27. The mobile CiiMS tablet software interface (iPad) ver. 3.7.4 © 2021.

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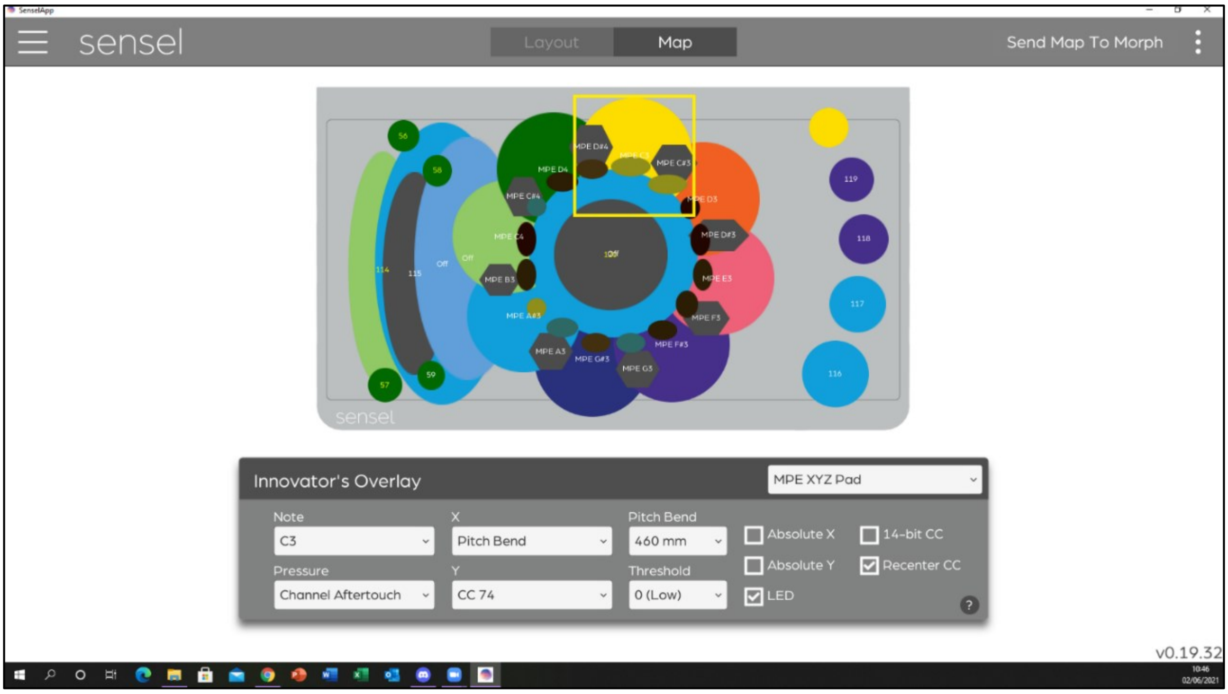
[152] The virtual MIDI configuration was a process devised by the author that presented many technical challenges. Copious research was conducted to master many fundamental principles, and a selection of protocols and programming languages (MAX, C++, Blueprints) were initiated and executed the MIDI project onto a cloud-based hosting service.

[153] The virtual LoopMIDI software cable is a virtual bridge that manages virtual communication ports once installed and configured correctly.



Innovator's Overlay
MPE XYZ Pad

Note: C3
X: Pitch Bend
Pitch Bend: 460 mm
Pressure: Channel Aftertouch
Y: CC 74
Threshold: 0 (Low)
☐ Absolute X
☐ Absolute Y
☑ LED
☐ 14-bit CC
☑ Recenter CC

Figure 28. Mapping within the MIDI MPE programme environment.

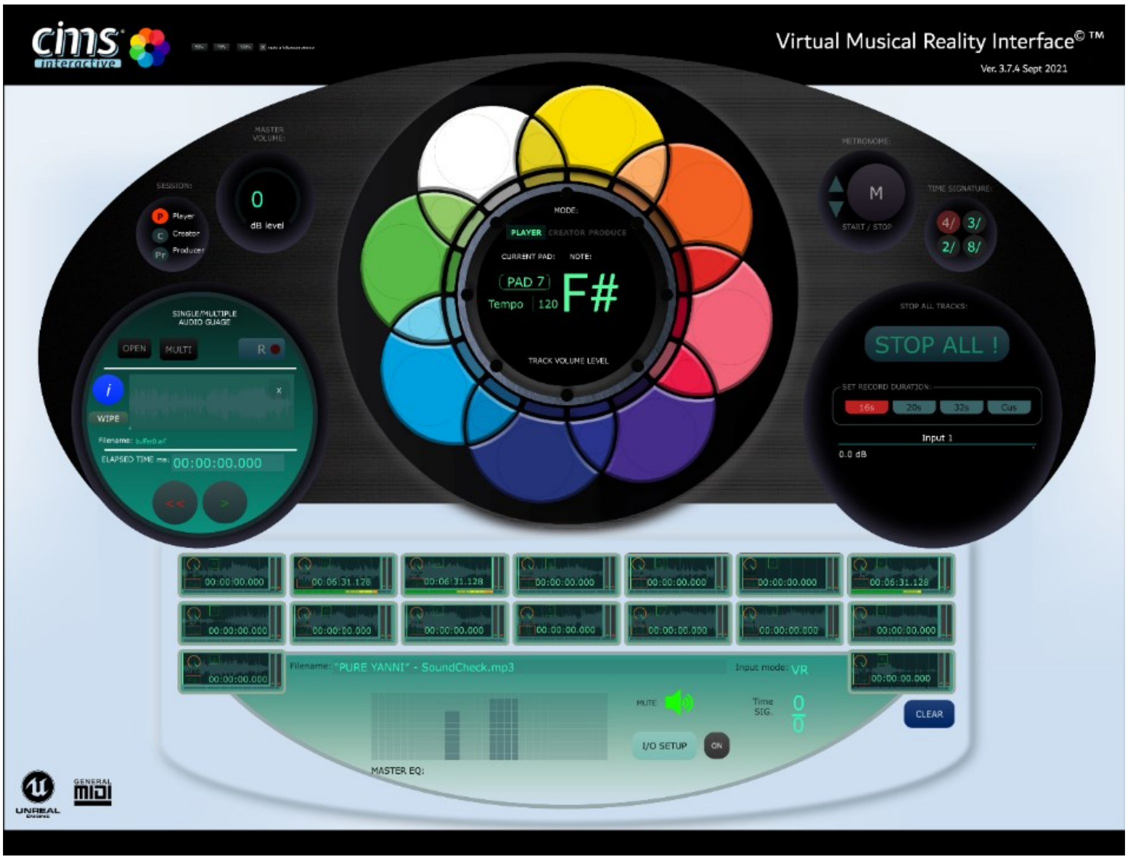


Figure 29. The desktop CiiMS interface version 3.7.4.

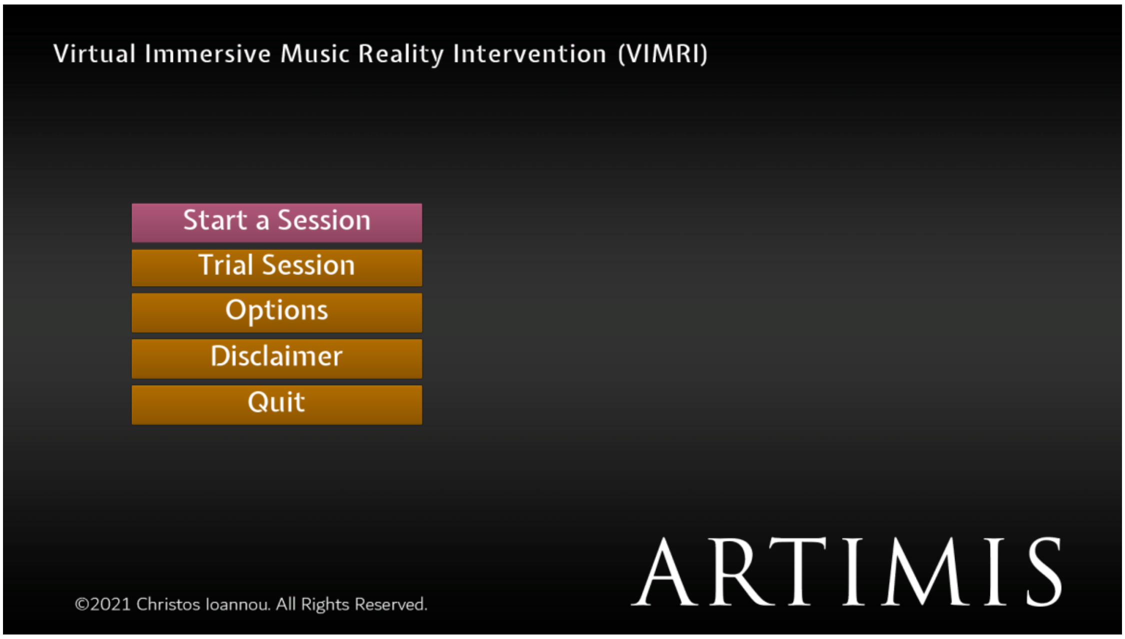


Figure 30. The ARTIMIS start-up screen: Main menu options.

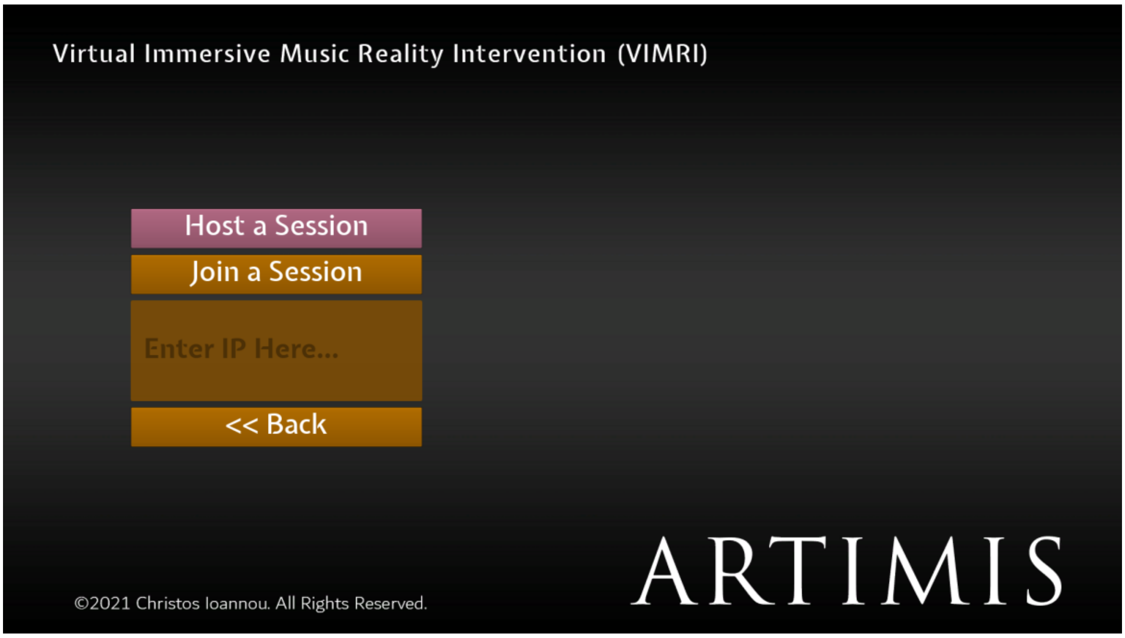


Figure 31. The host and joining sessions menu for a remote session.

Chapter 4.
FINDINGS & DISCUSSION

4.1 Trial Studies, Statistical Results & Interpretations

Chapter 4 presents the author's findings and discussions in two parts:

Part A: A systematic presentation of results summarising sample demographics of survey respondents' data and a core evaluation of the statistical analysis.[154] In addition, this part of the thesis presents a culmination of the author's six case studies and the analysis of the results. The findings demonstrate a minimal statistical significance of the impact of this research (albeit on a limited scale), requiring extensive large-scale testing.

Part B: These are the author's discussions and interpretations of the findings that refer to **Part A** of this chapter.

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[154] The author presents findings that were obtained using the CAR2-HF scoring system and newly developed VIMR scoring, to demeonstrate the similarities between the two systems.

PART A: PRESENTATION OF STATISTICAL FINDINGS

4.2 Chapter 4 Results: Introduction

Part A introduces the author's findings from an initial four-week *Supplemental Personalised, immersive Musical Experience* (SPiME) developed using a ViMRI protocol. [155]

Six case studies are presented, documenting the author's accounts, observations and outcomes of a single SPiME session. Individual studies vary from the ViMRI protocol over six weeks of research (including at least one protocol variant in each study). The author methodically presents resultant data, descriptive statistics and sample data, including inferential statistics and the core statistical methods of analysis and participant responses.

Part two of the chapter **(PART B: Discussions & Interpretation of Findings)** provides an interpretation and summary of the author's previously mentioned significant findings (in the form of discussions). Concluding results for each case study trial are reported giving an in-depth interpretation. The section concludes with a summary and evaluation of the discussions and findings of the chapter.

NOTE: The author provides the case studies with associative hyperlinks to their respective supporting video and audio material (see Appendix N for full details).

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[155] The ViMRI protocol defines (and forms part of) a *Supplemental Personalised, immersive Musical Experience* (SPiME).

4.3 Findings for Trial Study Sessions: Weeks 1 – 4

The following findings are from the author's first four sessional weeks.

4.3.1 SPiME Session 1 Outcomes

4.3.1.1 Trial study session 1; a brief account:

Week 1) Observations

The session duration was appropriate for each group size (between 4-5 children). Children used tactile fidget toys to aid soothing — resulting in undesired distractions to fellow peers during the session.

Week 1) Findings

Following re-evaluations and observations of the recorded video footage, a simplified approach for future sessions, including shorter durations, was necessary. Reduced verbal instructions were supportive, whilst visual slides would be more beneficial for future sessions.

Week 1) Outcomes

These small (but effective) changes would encourage children in all the groups to process information far more effectively — in future sessions.

(See Appendix H: Week 1. Notes).

4.3.2 SPiME Session 2 Outcomes

4.3.2.1 Trial study session 2; a brief account:

Week 2) Observations

Friendships and discussions between the children within the four groups (i.e., Violins, Pianos, Guitars, and Saxes) were transparent. Direct observations for each child within their weekly group setting displayed encouraging dialogue — noting an improvement from the previous week.

Week 2) Findings

Reduced instructions and discussions were essential in allowing the children to focus uninterruptedly during each activity. The group preferred a more empathic approach, contributing to a reduction in the information presented unnecessarily. Session 2 served as an introduction to 3-dimensional theories and stereoscopic vision for children via historical exploration. The groundwork for deploying VR technology (prior to the leading trials) was accomplished throughout this session.

Week 2) Outcomes

Participant [OSG2G] was engaged throughout the session, using a marker pen to sketch a series of accurate 3-dimensional shapes onto an interactive whiteboard.
Child [OSG2G] probed many relevant questions regarding exploring the 3D axis, parallax, and spatial relationships. Participant [FBG1V] demonstrated previous VR experience — prompting an exciting discussion regarding VR room-scale boundaries (a built-in physical perimeter safety feature). Overall, interactions and using their VR technology (by the children) were the most impressive **(see Appendix B: Data Collection Form)**. Data for early stage investigation was recorded at the end of the session using the form VIMR-Q1. **See Appendix H: Week 2. Notes**.

4.3.3 SPiME Session 3 Outcomes

4.3.3.1 Trial study session 3; a brief account:

Week 3) Observations

Several computer and information technology (IT) issues surrounding security configuration and remote wi-fi access using the school's TCP/IP network protocol.
This unfortunate scenario prevented remotely casting the session from the hosting laptop to the primary interactive display panel.

Week 3) Findings

Unforeseen early connectivity issues for the third session required alternative means. A contingency for a hard-wired connection allowed musical activities to continue (via rotation) — for each group session; children could maintain a sense of engagement and continued cheerfully unconcerned. [156]

Week 3) Outcomes

Session three encouraged musical composition, self-confidence, and physical activities. All children responded positively to the session and were motivated to develop their social skills within a secure and rewarding environment. Overall, this was a physically active session for the author and participants, with qualitative data accumulated for further analysis **(see Appendix H: Week 3. Notes).**

" [It's] nice that I can [actually] move around! " [TKG2G]

" I went through the wall! " [TKG2G]

" I wish you could sit on stuff ", [LBL3S]

" Oh My God, it's the **number 12 bus*****! …" [TKG2G]***

"[…] Mum has been on **the 12 bus*****! " [TKG2G]***

" It makes it more interesting! " [OSG4P]

" How do I pick up stuff? " [TKG2G]

" This is [actually] very fun! " [TKG2G]

" I've got it [tambourine]. " [TKG2G]

---

[156] The author used a combination of VR, frequency modulation software and music to ensure children were engaged during the sessions technical glitch.

4.3.4 SPiME Session 4 Outcomes

4.3.4.1 Trial study session 4; a brief account:

Week 4) Observations

The following observations during session four include:

- Case [TMG4P] appeared fully engaged in the session and was pleased to reveal her preference for acquiring a similar VR headset for personal use.
- Child participant [NCG1V] could not participate using a head-mounted VR headset because of medical difficulties. [157]
- [NCG1V] became angry when her routine became habitually altered.
- Subject [CFG1V] started the SPiME trials as a tranquil and unengaging individual. By session 4, it was clear she became more confident — after immersion within the ViMRI environment.
- Child [FBG1V] was the only participant who reached the highest point of the virtual platform during a "fear of heights" activity — although he did not appear frightened when leaning over the unbounded virtual ledge beneath him — within the VR.

Week 4) Findings

Children with a VIMR-Q1-Session weighted overall score of 400 or above showed improved social interaction. Social engagement intensified between individuals and their fellow students during exhilarating reactions. A casting dongle (Google, 2019) via a universal serial bus (USB) was substituted to ensure a more stable wireless connection to share VR content on a large interactive display. [158]

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[157] The author used an external laptop with an alternative VR 'equivalent' application. This substitution included an installed software version of ARTIMIS utilising a wireless keypad interface to navigate the interface.

[158] The author's decision to use an external casting device provided a 'mixed-reality' immersive experience, bypassing the connectivity issues that had previously failed during session 3.

Week 4) Outcomes

Learning experiences and shared knowledge of utilising secured TCP/IP and information technology networked configurations led to a significantly more organised and fluid setup. Session 4 presented many individual cases of children with social communication impairments **(see Appendix H: Week 4. Notes)**.

Q. Would you be more scared in real life?…

" I guess so. " [FBG1V]

4.3.5 SPiME Sessions 5 and 6 Outcomes

For comprehensive findings and documentation of Session 5, see Case Study 5, **page 155** and **page 222**. **(See Appendix H: Week 5. Trial Notes)**.

For comprehensive findings and documentation of Session 6, see Case Study 6, **page 160** and **page 223**. **(See Appendix H: Week 6. Notes)**.

4.4 Case Studies

The following section presents six individual case studies documenting a *Supplemental Personalised, immersive Musical Experience* (SPiME). Each study presents a variation of a *Virtual immersive Musical Reality Intervention* (ViMRI) administered to children with an autism spectrum condition within a Special Educational Needs and Disabilities (SEND) setting.

ETHICS NOTE: Three weeks before the trial studies, the author ensured that all child participants and their parents/carers were well informed regarding their voluntary participation and fully prepared for the studies. The author sent a comprehensive package of visual presentations and documentation via post for their consent. The package consisted of:

- Permission letters explaining the proposed study with the option to withdraw at any point.
- Parent and carer consent forms
- Participant consent forms
- Letter of consent from the school permitting the child participant's footage and media to be used by the author **(see Appendix A: Research Consent).**
- A comprehensive lesson plan; outlining each session and detailed requirements and procedures for each participant (including prerequisites for participation).
- Approved health and safety risk assessment and ethics application to conduct trials within a special educational needs and disabilities (SEND) setting **(see Appendix G: Ethics and Guidance).**

The following case studies presented by the author consider the following attributes:

i. Sessions adhere to a variation of administration criteria — explained in the ViMRI protocol **(see pages 95-97)**. [159]

ii. Individual case studies present an overview outlining the purpose and activities of the study. All observations are unbiased in their approach.

iii. Respective results (including the approaches and processes) for each case study are referenced and presented with descriptive and inferential statistics.

A summary of key findings, interpretations, discoveries and conclusions for the case studies are available in **Part B** of this chapter **(see Chapter 4. Discussion and Interpretation of Findings: pages 214 - 224).**

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[159] The criteria and protocols forming part of this research were designed by the author before the study trials commenced.

Case Study 1. Variations of a *Supplemental Personalised, immersive Musical Experience* (SPiME) for children with an autism spectrum condition: Group composition study.

4.4.1.1 Purpose

Teaching professionals assigned children (aged 11 to 14) of varying gender and musical ability to one of four named study groups. [160] A principal investigator (the author) presented six *Supplemental Personalised, immersive Musical Experience* (SPiME) sessions to the children within a familiarised classroom setting. New and exciting music technologies (including virtual concepts) were introduced gradually during the study.

A *'Creative immersive interactive Musical Software' (CiiMS)* mediated the sessions by combining a fully customisable digital musical interface (ARTIMIS), and virtual reality musical concepts were introduced gradually throughout the SPiME. The purpose of the study is for children with newly found creative and virtual composition skills (in a group setting) to express themselves better when facilitated by virtual music technology. The study aims were:

i. Evaluate the impacts of group musical interaction through a fully customisable interface installed with tailored musical preferences.

ii. Assess the technology's effectiveness as a supplementary therapy tool (e.g., encouraging children to make informed choices within a social group setting).

iii. Help improve areas surrounding self-confidence facilitated by group musical participation.

---

[160] The author named the four study groups for this study: Violin, Pianos, Saxes, and Guitars.

4.4.1.2 Activities

The study presents four activities:

Creative play, creative composition, guided composition and music *follow-my-lead* — based on the popular game *Simon* (Hasbro, 2020).

4.4.2 Activity 1. Creative Play

Methods

Participants first choose from a list of pre-loaded audio samples to guide the creative play activity. A creative composition from the audio material is performed in real-time using the CiiMS capacitive-touchpad interface **(see The CiiMS Floral Interface, page 119)**. Once all group participants are comfortable performing together, a final version of the musical arrangement is digitally recorded and transferred directly into the CiiMS software interface.

Subjects

James [JWG2G] and Lenny [LBL2G] are 11 years old. The two children interacted closely during their six-week trial and were paired together (without encouragement) by their similarities. Through the author's direct observation and results from pre-evaluations — monitored throughout their weekly sessions — [JWG2G] and [LBL2G] both presented varying degrees of social and emotional challenges. Often, the children would make socially inappropriate comments and explicit references.

Throughout the Creative play session, the two children were encouraged to use their creativity and experimental composition techniques. James and Lenny jointly selected sounds from a set of modern audio samples and began to perform — using a combination of the sixteen force-touch sensitive pads — on the CiiMS interface.

🔊 **Appendix N. > Case Study 1 > Activity 1 Creative Play > Audio Recording > Link to Audio**

Figure 32. Participants [JWG2G] and [LBL2G] interacting with ARTIMIS during a Creative Play (group) session.

4.4.3 Creative Play Observations

Lenny [LBL2G] directed the session with an initial decision to interact. James [JWG2G] was apathetic and unengaged until observing a demonstration of the technology. James was encouraged to listen to a 'guitar strum' that triggered a persuasive response. Various hand gestures were used during the performance whilst recording in real-time using the CiiMS hardware interface.

🎬 **Appendix N. > Case Study 1 > Activity 1 Creative Play > Link to video**

4.4.4 Activity 2. Creative Composition (Stylianos)

Methods

A creative composition is achieved by adjusting musical parameters relating to tempo, meter, and rhythm. One of four recording durations and preferences of the CiiMS software interface is selected before a performance. [161] The objectives of activity two during the session were to record freely improvised vocals and percussive sounds supported by physical bodily interactions. [162] Similarly, as the creative play activity (i.e., activity 1), musical composition is continuously recorded in real-time by a dedicated

---

[161] The recording durations were: 15 seconds, 30 seconds, 60 seconds, or an unlimited duration.

[162] External recordings were via an external microphone for this study.

‘**creator mode’** preset on the software interface. A further (final) digitally recorded performance is captured through the capacitive-touch interface and played back.

Subjects

Stylianos [SIG2G], a 14-year-old boy with social and emotional deficits, presented himself as a knowledgeable individual with a personal interest in technology, animation, and virtual 3D concepts. Thomas [TKG2G], aged 12 (and a close friend of Stylianos), was diagnosed with early childhood *Attention Deficit Hyperactivity Disorder* (ADHD) at the age of 5. The two children were part of the Guitars group.

Thomas presented himself as a hesitant individual throughout the sessions and displayed extensive, consistent characteristics associated with ADHD. Some of Thomas’ tendencies included: hyperactivity, inattentiveness, shouting mid-session and impulsiveness.

4.4.5 Creative Composition Observations

When prompted to select from one of the four-session activities, the children instantly preferred recording their musical compositions — over the pre-loaded musical material. Stylianos looked towards his zipper for percussive interaction and used vocals to mimic beatboxing as his rhythmic tool. Thomas required a level of persuasion to interact vocally during the activity, which was encouraged by referencing his favourite “number three bus”. The boys selected a musical sample duration of 32 seconds prior to recording.

Appendix N. > Case Study 1 > Activity 2 Creative Composition > Link to video

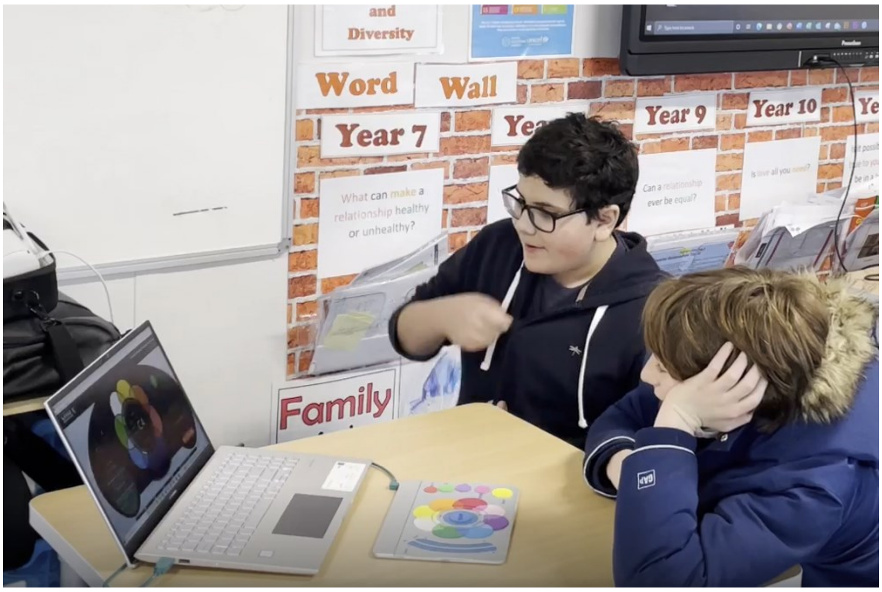

Figure 33. Stylianos [SIG2G] and Thomas [TKG2G]: during a creative composition group session.

4.4.6 Activity 3. Guided Composition (Millie, Sonny, and Robyn)

Methods

This session amalgamates activities from the *Creative composition* and *Creative play* activities (i.e., Activity 1 and Activity 2) to encourage real-time recording via guided improvisation techniques — within a group setting. Guided composition focuses primarily on supporting children musically with lower levels of social interaction and those with a generalised anxiety disorder. The session relies on instructional prompts and turn-taking techniques — guided by scene assets from personal preferences —from the participants' questionnaire VIMR-Q1-Session **(see Session 3. Exploring VR, page 103)**.

Subjects

Robyn [RNG3S], aged 11, had a range of associated social impairments; these proved significantly challenging for her whilst socialising within the group. Robyn presented herself as a happy individual (almost masking her condition). Sonny [SLG3S], aged 12, was diagnosed with Asperger's Syndrome and struggled with reciprocal social interactions. Many of the traits associated with Sonny's [SLG3S] condition during earlier sessions were clear to the author. These included local interests and the repetition of routine.

Millie [MMG3S] (aged 11) was identified with a variety of comorbidities from an early age (and, like Robyn), masked many of her symptoms exceptionally well.

Guided Composition Outcomes

Children from the Saxes group chose between singing or clapping to the beat of a metronome. Prior to beginning recordings for the session, several ideas were shared by the children; when asked who would like to sing; Millie responded:

> ***"…I'm not singing. I am too embarrassed." [MM3GS]***

Sonny resolutely emphasised to the group his intention to supervise, and Robyn made minimal eye contact with Millie during their conversations. As a result, Robyn chose (for the pair) to sing during the session.

After considerable speculation amongst the group, Millie shouted out that her preference to participate would be to clap during recording. Physical gestures supported her decision. During the recording, the children all participated in clapping activities.

The author quotes the following reactions from the children's musical 'call and responses' during the sessions (see Appendix H: Weekly Session Notes).

"What's your favourite thing, Millie… what's your favourite thing?"

Response: " …Unicorn"

"What's your favourite thing, Robyn… what's your favourite thing?"

Response: [Roars]

"What's your favourite thing, Sonny… what's your favourite thing?"

Response: "…Computer"

Concluding the performance, the music technology audio interface triggered an automated response, distributing all recorded material as individual samples — across sixteen-touch capacitive interface pads. Further musical improvisations shaped the final composition.

Figure 34. Participants [RNG3S], [SLG3S] and [MMG3S] during a guided composition session.

Appendix N. > Case Study 1 > Activity 3 Guided Composition > Link to video and audio

4.4.7 Activity 4. Follow-My-Lead (Riley and Tory)

Methods

Participants listen to a selection of 'pre-determined' thematic sounds. The instructor initially presents audio using a remote interface or tablet via a CiiMS software that displays corresponding coloured pads — pressed by the instructor — on a separate screen, triggering a personalised sound. When prompted, children take turns and press a matching colour pad (of the instructors) using their interface — a corresponding sound acknowledges a correct response. The musical *'follow my lead'* activity initiates turn-taking and is based upon the concept from the electronic game "Simon Says" (Hasbro, 2020) — albeit without the concept of elimination from the game.

Subjects

Riley [RUG2G] presented as an introverted and knowledgeable 11-year-old individual who expressed his ability to play the Ukulele from a young age**.** Even though he delivered himself well during the trial sessions, Riley had limited verbal communication. Riley's diagnosis confirms an ASC and selective mutism. [163] Tory [THG2G] (aged 12) was diagnosed with a low level of understanding — requiring adult support and supervision to manage his communication and unpredictable behaviour throughout the school day. The pair reported fear of loud noises (suggesting hyperacusis), and both had an exceptionally superior level of technological understanding.

Follow-My-Lead Outcomes

Observation

Because of time restrictions, the session was delivered rapidly and began using the CiiMS touchpad interface with pre-loaded audio samples. The children were asked to experiment by hitting the touchpads randomly to trigger multiple sounds. After a short practice, the boys were asked, "how would you like to make your music?" Tory appeared slightly puzzled. Physiological reactions were observed to the triggered sound responses (i.e., hitting the table and tapping their feet). Correct instructions were mimicked using physical gestures. Eye contact was evident throughout the session — particularly by Tory — who awaited confirmation (by the supervisor) after each correctly pressed pad.

Physical interaction was abundant during the session. Whilst using the CiiMS gestural interface (supported by the colourful floral interface sensory pads), the haptic feedback of the ARTIMIS interface was vital to encouraging the children during the musical activity. In addition, instantaneous feedback from the CiiMS software sampler interface gave the children complete control.

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[163] Riley and Tory were part of the Guitars group.

Figure 35. Tory and Riley react to a correct response during a turn-taking session.

Appendix N. > Case Study 1 > Activity 4 > Guided Composition > Link to video file

Case Study 2.

A Virtual Reality *Supplemental Personalised, immersive Musical Experience* (SPiME) for children with an autism spectrum condition: Solo composition study via ex-vivo exposure.

The following case study introduces a virtual reality environment as a further dimension, forming the criteria of a *Supplemental Personalised, immersive Musical Experience* (SPiME). The activities throughout the trial encouraged free expression through various creative composition techniques — facilitated by a digital musical interface and supporting *'Creative immersive interactive Musical Software' (CiiMS).*

This research study was conducted in a regular classroom between the author and children diagnosed with a high-functioning autism spectrum disorder. The trial aimed to achieve conclusions to strengthen the premise of using a customisable virtual immersive musical reality interface. The investigations emphasise the importance of informed choice-making to improve self-confidence — through solo musical participation.

4.4.7.1 Activities

Case Study 2 presents a creative composition within a virtual environment:
b) Real-time solo composition and interaction (see page 96, ViMRI protocol).

4.4.8 Activity 1. Virtual Composition (Timothy)

Methods

Creative composition methods are employed to record a passage of musical material in real-time using free improvisation musical logic. A participant first selects musical parameters for this session through choice, and the personalised preferences for the virtual environment are gathered (before the activity) from interviews and questionnaire forms **(see Appendix B).**

The ex-vivo virtual environment session is presented (cast) onto a large interactive display screen and conducted without a virtual reality headset. Real-time responses for the session are made by participants using a capacitive ARTIMIS touch interface to encourage the respondent to immerse themself in the virtual musical reality. Navigating and interacting with the personalised environment supports the musical composition process.

Subject

On the first encounter, Timothy [TBG4P] presented himself as a polite 12-year-old boy. Timothy's deficits were so remarkably well masked that his evaluations required assessment via the VIMR-Q1-Session and CARS-HF questionnaires.

The recorded results depicted a more precise picture to the author, and it was evident that combined with his mild-to-moderate diagnosis of autism spectrum condition, Timothy's challenges were predominantly related to changes in routine and social communication deficits. Before the trial activity, Timothy had never experienced virtual reality, nor was he appropriately adaptable to musical activities. Timothy had expressed a fear of heights and (more positively) a passion for farmyard animals.

Observation

Several inconsistent and inappropriate gestural interactions were observed throughout the session through subconscious stimulation (Proteus Effect) whilst using the VR. Timothy's engagement achieved creative composition with the sixteen-segment coloured roundel floral pads (mimicked within the VR). From a physiological perspective, the texture of the sensory soft foam pads provided instant feedback.

Subject [TBG4P] observed a strong preference for imitating sounds orally rather than using the instrument when he performed musically. Timothy uttered verbally (i.e., spouts of stimming), and there were several echolalic responses during successful contact through interactions whilst using the interface.

Navigating Timothy's virtual scene (within his boundary zones) triggered sounds from personalised images, and the visual feedback from the CiiMS software interface was instantaneous. [164]

Figure 36. The VR activity was presented (ex-vivo) onto a large interactive display screen.

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[164] The software interface independently monitored various note names, colours, and pad numbers via MIDI data.

Figure 37. Participant [TBG4P] makes involuntary vocals during a real-time composition.

Figure 38. [TBG4P] interacts with the new ARTIMIS haptic-touch interface.

🎬 🔊 **Appendix N. > Case Study 2 > Link to video file**

Case Study 3.

A Virtual Reality *Supplemental Personalised, immersive Musical Experience* (SPiME) for children with an autism spectrum condition: Solo composition study via VR exposure.

A sample of eighteen high-functioning autistic children (*N*=18) was randomly selected to participate in a *Supplemental Personalised, immersive Musical Experience* (SPiME) over six successive weeks. Two boys (aged 11 and 12) from the sample each participated in an individual virtual reality solo composition study. Over six weekly sessions, observations and Childhood Autism Rating Scale, Second Edition (CARS-2-HF) measurements showed that both boys' total weighted scores were within the upper range of the CARS-2-HF scale rating.[165] [166] Scores for the *Fears* category (i.e., Participant Questionnaire Form VIMR-Q1, Section 2.1 (019c)) reported fear of loud noises **(see pages 169-177 for participant results).**

A prerequisite for participation in the study required that the individuals presented various chronic impairments, determined via the total weighted scores from the author's newly developed participants' VIMR-Q1-Session form.[167] Virtual immersive Musical Reality Intervention (ViMRI) score ratings for both boys presented technologically savvy attributes — each with a higher-than-normal degree of VR experience. A diverse quantity of quantitative and observational analysis (collected during week six of the trial sessions) led the author to develop a personalised virtual reality environment for each child. The purpose of this study sought to measure two outcomes:

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[165] Weighted scores were determined by the results of VIMR-Q1-Session and CARS-HF questionnaires.

[166] Children scoring within the higher severity group range of CARS-2 often demonstrated an increase level of social anxiety; from the fifteen categories associated with high functioning autism spectrum condition.

[167] The author selected participants with impairments and attention deficits captured during previous sessional activities using forms VIMARS 1.0 and VIMARS 2.0 **(See Appendix E).**

i. Physiological and psychological responses of children diagnosed with significantly higher levels of an autism spectrum condition during participation of a SPiME.

ii. Evaluate a ViMRI's capability to desensitise a fear or anxiety of a child with an ASC.

4.4.8.1 Methods

Children were immersed (in-vivo) with the assistance of a virtual reality headset within their personalised musical environments. Motion controllers were adapted to navigate around a virtual musical sensory room (pre-loaded onto an *Oculus* VR headset (Meta, 2022)) and linked directly to a physical CiiMS virtual musical software interface. The virtual musical reality environments were conceived from a virtual software template and edited individually by the author — using the custom attributes of each child's profile (outlined in *Table 23* below).

Table 23.

Virtual reality environment assets: template overview

Assets	Attributes
Video	Personal video file
Treble clef and notes	Pre-loaded sounds and flashing lights
Picture frames	Interchangeable photos and posters
3D objects	Playable within the VR
CiiMS Instrument	Spheres, Cubes, Pyramids

The individual sessions (IND) were then presented within a familiar weekly location and classroom setting and supported by the author using a written transcript **(see Appendix D: Transcripts)**. The objectives of the ViMRI during the *Supplemental*

Personalised, immersive Musical Experience (SPiME) sessions sought to immerse children within their personalised environments.

4.4.9 Subject 1. Lorenzo [LHB4P]

Lorenzo presented himself as a considerate 12-year-old boy with a passion for *Star Wars: Episode IV - A New Hope* (1977), art, and military guns. During the first session, Lorenzo was drawn instantly to a box of fidget toys (religiously used throughout his sessions as a comfort object).

Observations

Lorenzo was fastened into the VR equipment comfortably and indicated lots of bodily gestures — throwing objects and bending down to reach a pair of virtual drumsticks and various 3D objects. Lorenzo presented himself with good coordination skills. However, he demonstrated poor physical balance within the constrained boundary. Verbal responses were minimal during the session, and Lorenzo did not answer any questions. Lorenzo's favourite music video, '*My Heart Will Go On*' (Céline Dion, 1997), ensured he was entertained during the session.

Due to a technical malfunction, the virtual reality headset failed to connect to the school's network. The occurring fault (mid-way through the session) demonstrated that Lorenzo showed a high level of patience while waiting for the equipment to reconnect. Lorenzo participated in a fear test and a virtual poster navigation activity during his session. However, Lorenzo could not comprehend his instructions correctly. By the end of the session, there were physical signs of loss of balance *(Figure 40)*, leaving him somewhat confused. The session was suspended prematurely as a safety precaution.
Lorenzo walked away confidently, with a smile on his face.

Figure 39. [LHB4P] interacting during a SPiME session.

Figure 40. The author assists participant [LHB4P] with the VR equipment.

Appendix N. > Case Study 3 > Subject 1 [LHB4P] > Link to video file

4.4.10 Subject 2. Luka [LMG4P]

Luka (aged 11) had been diagnosed with autism and presented himself as a headstrong individual with a superfluous technological ability. Luka had an exceptional talent for memory recall, reflected by his meticulous attention to detail, mathematical ability, and expert knowledge of general detailed specifications.

Observations

Further observations throughout the trial indicated Luka's tendency to shout out involuntary phrases repeatedly and impersonate others in his social setting. Luka threw himself to the ground in a series of coordinated involuntary movements in what appeared to be a comfort mechanism. The teachers reported these echolalic and physical attributes to have caused many social obstacles (particularly around his peers) who do not always comprehend him.

Luka required constant supervision throughout the day as he did not drink enough water. Because of the excessive nature of his severe autistic characteristics, the teachers advised the author to ensure Luka could be allowed a reduced session time before the trials began. A shorter twenty-minute learning interval was agreed upon — as prolonged lessons would be difficult for Luka to sustain his attention.

4.4.11 ViMRI Study 1. [LMG4P]

Observations

Luka spearheaded a very encouraging start to the session. Interactions included throwing virtual cubes, 3-dimensional cones and rolling virtual balls around his personalised scene. Many of Luka's interactions during the trial session required little help; he appeared fascinated by his virtual hands, looking at them inquisitively. Luka attempted to collect virtual rolling balls and struggled to grasp and manipulate the various simulated virtual objects of varying sizes.

Occasionally, Luka escaped the Oculus guardian boundary (this defined the physical, virtual area); however, he later appeared to make positive use of navigating around the scene whilst using alternative methods. [168] Luka's fast-paced session was handled graciously in response to many rapidly presented (quick-fire) instructions. Around halfway through the trial session, Luka altered his virtual locomotion strategy

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[168] The Guardian is a precautionary safety measure for users to set up virtual boundaries that appear when a participant approaches near the edge of a play area. Link to source.

(navigation method) from physical movements to a stationary approach. The joystick controls — integrated with the motion controllers — aided his navigation.

"Oh, this is scary!" (Time 0:05), "Oh, that's cool!" (Time 0:27)

"Ball on the floor… That's cool!" (Time 1:39)

"It's a hoover." (Time 3:09)

(Single word answers repeating) "A and B…", "Monkey!", [LMG4P]

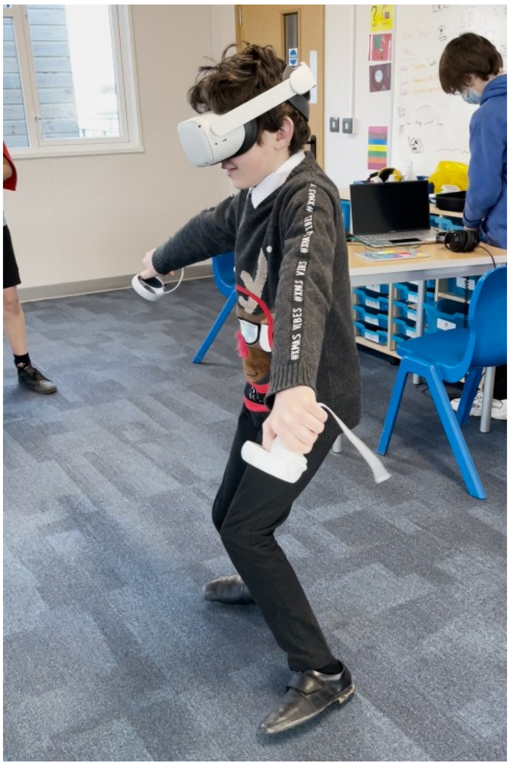

Figure 41. The moment Luka [LMG4P] used the haptic controllers to trigger his favourite song whilst dancing to his routine.

NOTE: The most superlative experience during all research observations occurred when Luka unmasked how to physically trigger his favourite song within the virtual scene.

🎬 **Appendix N. > Case Study 3 > Subject 2 [LMG4P] > Link to video file**

Case Study 4:
Investigations of an individualised immersive musical experience (ex-vivo) for an autistic child, supported by a Virtual immersive Musical Reality Intervention (ViMRI)

4.4.12 Study Overviews

Nicky had a history of disturbances to light exposure (part of her sensory processing disorder) within the sample group and was clinically diagnosed with a high-functioning autism spectrum condition. Teachers and parental observations reported that flickering lights and high-intensity luminous patterns were triggers for previous reactions. The historical occurrences had not developed into severe illnesses, nor had they triggered spontaneous seizures (although reported symptoms included intermittent headaches, dizziness, and nausea). Nicky did not have a clinical diagnosis of epilepsy; however, individual consent was provided by caregivers to participate in the study beforehand. [169] [170]

An alternative ex-vivo study uses an opposite methodological approach to its counterpart, the 'in-vivo' study (i.e., Case Study 3 differs with two children internally immersed within their personalised musical environments, wearing a virtual reality headset and aided by motion controllers). In contrast, this study presents an externally immersive and interactive experience to a participant via a large (50″) external interactive display linked directly to the ARTIMIS hardware and CiiMS virtual musical software interface. User input for this study was provided remotely (via a pre-configured numerical keypad) and pre-programmed to access multiple navigational controls for the interactive experience (replacing the traditional motion controllers for navigating around the VR). The ex-vivo (external exploration) session was delivered within a familiar setting (per the 'in-vivo experiment'). The author's objectives for this Virtual immersive Musical Reality Intervention

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[169] The author refers to Harding et al. (2014), a paper reviewed prior to the trials. The study primed his knowledge of epilepsy and photosensitive seizures — prior to the study.

[170] The frequency (speed) of flashing lights most likely to cause seizures varies from person to person. Flashing lights most likely to trigger seizures fall between 5 to 30 flashes per second (Hertz).

(ViMRI) were to immerse Nicky within her unique personalised environment; facilitated by musical participation.

4.4.13 *Ex-vivo* Subject. Nicky [NCG1V]

Teachers' reports confirmed that several aspects of Nicky's school life were challenging and required adult supervision to assist with her management during class time. Nicky cleverly masked her emotions; this was evident through weekly observations and an innate ability to participate during the sessions, giving multiple-word answers.

During her time with the Pianos group, Nicky participated voluntarily by playing an acoustic and an electric violin and listening to high-frequency sounds — presented through a set of closed-back headphones. Nicky responded admirably to questions during her weekly presentations.

Observations

During the externally presented immersive musical experiments, Nicky presented rigid bodily postures, limited head movements and localised eye contact. Responses to verbal instructions were accurately received whilst navigating using a numeric keypad interface. Sessions for externally presented ViMRI were better suited to a seated position because of the wireless numeric keypad interface. Nicky's responses were acknowledged, although she required constant prompting throughout the session. The focus of the session was influenced by observing a mirrored display through the laptop computer screen — rather than using an intended large interactive screen. Another notable observation was the postural swaying of her legs, whilst listening to her favourite piece of music.

NOTE: The author positioned the technology element on a desk directly in front of Nicky; this facilitated her positive engagement throughout the session.

Appendix N. > Case Study 4 > Link to video

Case Study 5:

Managing hypersensitivity in ASC to sounds and anxiety disorders: A Virtual immersive Musical Reality Intervention - desensitisation (ViMRI-d) study.

4.4.14 Study Overview

Four high-functioning autistic children (aged 11) were selected randomly from a study group of eighteen participants to trial a virtual immersive musical reality intervention — by desensitisation (ViMRI-d). The study is derived from established methods of graded exposure.

Traditionally, exposure therapies (ETs) are utilised by practitioners to treat anxiety disorders to help overcome various psychological and physiological fears and phobias.
A ViMRI-d simulates this intervention by first targeting the individual's source of fear — obtained through their personalised profile — established from pre-test questionnaires **(see VIMR-Q1-Session)** and observations throughout a six-week *Supplemental Personalised, immersive Musical Experience* (SPiME). Gradual and repeated exposure within a personalised virtual music environment to a source of fear over a series of sessions assists in de-sensitisation. Through virtual exposure, the key sources of anxiety, feared objects (or frightening situations), can be confronted 'head-on' by replicating a real-world scenario. These virtual confrontations are designed to enhance the individual's quality of well-being.

The following study documents an account of two practical ViMRI-d intervention sessions administered during a SPiME group session — quotes from other children who undertook comparable interventions support these findings.

4.4.14.1 Methods

Children were randomly selected from one of four SPiME musical groups (i.e., the Violins, Guitars, Saxes, or Pianos) to form an overall sample group of eighteen children. Before the desensitisation study, weekly sessions *(Table 24)* were conducted in a consistent location and classroom setting to meet each child's individual needs. Familiar teaching assistants supported each study group (led by a programme of virtual and musical activities) with the principal investigator (i.e., author) each week.

Table 24.

SPiME session programme

Session	Title	Session Outlines
Session 1:	Virtual immersive Music Introduction (ViMRI)	• A taster session of what is to come… • Electronic music and traditional instruments. • Play with some musical instruments. • This session will last for no longer than 50 minutes.
Session 2:	What do you like?	• Discover more about your interests. • Learn about 3D and 3D shapes. • Learn about the history of VR equipment. • Draw a poster of your choice. • Draw some 3D shapes on the computer.
Session 3:	First Exploration of ViMRI	• What is a ViMRI • Exploring virtual worlds. • Listen to relaxing music. • Fill in a questionnaire (5 short questions).
Session 4:	Virtual Play	• Walk around a virtual scene. • Combat any fear of heights. • Play a VR game. • The session will last no longer than 50 minutes.
Session 5:	Virtual Immersive Music: A Customised Immersive Experience	• Immerse yourself in your own customised, immersive musical environment (you designed from Session 4). • Introduce your familiar images and sounds.
Session 6:	Exit Interviews and Questionnaires	• Re-visit all the new things you have learned. • Discuss how ViMRI has helped you. • Complete some questionnaire sheets. • Have some fun!

Four children from a trial group of eighteen were selected randomly using the author's newly devised VIMRI-Q1-Session pre-test evaluation method to assess their suitability for this study. Three participants (from the overall trial group) were identified as having higher-than-average levels of fear in multiple areas (*Mean* = 26.3, highest score = 35).

4.4.15 Subject 1. Millie [MMG3S]

Millie received her diagnosis of Sensory Processing Disorder (SPD) independently from her Autism Spectrum Condition (ASC) at age six. A medical assessment based on the ICD-11 for Mortality and Morbidity Statistics (WHO, 2022) classified Millie's Generalised Anxiety Disorder (GAD) as an associated limitation with intellectual functioning in ASC. [171] Millie was assigned to the 'Saxes' group and presented as articulate. Like many other female participants, Millie had a superlative ability to conceal her feelings and emotions and had previously experienced VR.

Throughout the trial sessions, Millie systematically strengthened connections with her female peers. Support staff revealed Millie had a deficient level of social understanding. Millie's sensory difficulties became apparent to the author through several weeks of observation between his familiarisation through the SPiME tuition. One example was her inability to be easily confused and misinterpret instructions (using lower-level language) during musical activities.

NOTE: Millie received an overall VIMR-Q1-Session score rating of 31.6 and a CARS-2-HF summed score rating of 31 (see page 94, VIMARS 1.0 & 2.0 Guidance Scoring Methods). These scores would correspondingly indicate an evaluation of mild-to-moderate levels of behaviour.

Observations

Millie integrated tightly within her social group, presenting an extraordinarily high level of critical thinking and practicality. Particularly in the introductory, 3D and musical sessions (i.e. the first three weeks of the trials).

4.4.16 Synopsis

The following synopsis was noted in week six towards the end of the study, leading up to the ViMRI-d:

Week 1.

- Participation and investigation using electric and acoustic violins.
- Incoherent attention span.
- Sustained and constant fidgeting.
- Hyper-focused (throughout the trial activities).

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[171] The author refers to Section 6A02.3 of the ICD-11 manual for Mortality and Morbidity Statistics (Ver: 02): Link

- Habitually inquisitive, always asking relevant and intriguing questions.

Week 2.

- Preference to sitting at the front of the classroom, at the same desk, for each session.
- Consistent body posture — preferred facing her peers (never towards the tutor).
- Fidgeting with objects (e.g., with a name badge).
- Swinging legs throughout presentations or instructions.
- Curiosity about 3D technology paradigms.

Week 3.

- Nurturing and caring personality traits towards her peers.
- Assisted children in turn-taking activities (within her group).

Week 4.

- Exclusive within her group.
- Millie demonstrated physical spins and "punches into mid-air" whilst navigating her personalised VR activity.
- Excelled by obtaining the highest point within a virtual reality environment (unaided) during a combined group activity.

Week 5.

- Absent from the session.

Week 6.

- Millie was preoccupied continuously during her ViMRI-d and responded favourably to guided instructions. The disconnect between the virtual headset and the school's computer network configuration was lost several times during the session, with unexpected dropouts.

Test 1. The Hand Dryer

Using varying levels of intensity and duration, an audio sample ‘hand dryer’ was presented (nine times in succession). At first, Millie appeared startled; however, this was counteracted by the author forewarning her about future presentations. Millie gradually became accustomed to the random simulated sounds through a repeated pattern of presentation.

> ***“It just startled me!… it was fine!” Millie, Aged 11***

The author observed physiological responses, including an abundance of postural actions (i.e., bending and kneeling). Millie appeared content within her ‘virtual environment’ — physically reaching her arms into mid-air several times and shouting with joy. [172]

> ***“Yippee.” Millie, Aged 11 (time 1:33)***

Towards the end of her study presentation, Millie was encouraged to use an authentic (physical) air dryer and taken to a nearby restroom, where she cautiously engaged without any issues.

> ***“It’s even better now!” Millie, Aged 11***

🎬 **Appendix N. > Case Study 5 > Link to video file**

4.4.17 Test 2. The Siren

Millie navigated toward a specific virtual location of an instructional poster for the task. Left and right motion controllers were assigned to trigger and cancel noises quickly as she began to trigger her personalised samples (unchallenged) with some intentional prompts. Millie appeared confused at first, acting more positive once the sounds were familiarised.

🎬 **Appendix N. > Additional Footage > Link to video file**

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[172] Once the author observed that Millie was familiar with the audible presentations, he gradually increased the volume level until around halfway through the test.

Case Study 6:

Real-time group composition and immersive virtual interaction study; for children with an autism spectrum condition (ASC)

4.4.18 Background

Four high-functioning children with an autism spectrum condition (ASC); identified with varying social and emotional deficits were selected to participate in a real-time group composition study using a virtual immersive musical reality intervention (ViMRI). Reactive real-time musical composition approaches (using a technologically mediated musical interface) in a classroom setting were used to evaluate a virtual intervention and newly developed protocol.

This study confirms a previously trialled external ViMRI group intervention method to evaluate the software and hardware technologies required for a virtual performance — currently at mid-stage development.

The author favoured a previously verified ex-vivo virtual musical composition method **(see pages 96 and 97 for a description of variation d and f; criteria for this study)**. The selected trial group was pre-conditioned by five taught *Supplemental Personalised, immersive Musical Experience* (SPiME) sessions, and each session sought to apprise the immersive music technology whilst the author observed a small group of children. Musical compositions were created through virtual music improvisation.

4.4.18.1 Preconditioning

Preliminary tests and ratings of musical and social preferences for the four sample respondents were conducted prior to this study. Five successive PowerPoint (*Microsoft,* 2022a) presentations and virtual musical activities followed. These helped pre-condition the group and familiarise them with a ViMRI setup. The following account is of the group's creative virtual composition session:

4.4.19 Virtual Composition Outcomes

Observation

Children aptly performed *Happy Birthday* whilst singing directly into the ARTIMIS prototype device. Vocals and body percussion sounds continuously accompanied 'free improvisations' until the recording was complete. After the initial first stage recording process, **α.** **(see 2.15 Creative Virtual Composition Guidelines, pages 98-99),** the children looked at each other in amazement (time reference 1:27). Second stage (virtual) recording **β.** was demonstrated to the group for them to interact inside the VR world. Compositions continued uninterrupted, and children used various unique creative musical expressions.

🎬 **Appendix N. > Case Study 6 > Link to video and audio**

…

4.5 Descriptive Statistics

The following section summarises the sample demographics of survey respondents' data and core evaluations of the statistical analysis of the six case studies from the previous section (Section 4.4). [173] The early statistical significance and impact of the following results indicate a need for the research to be expanded on a significantly broader scale.

4.5.1 Sample Demographics: Survey Respondents' Data

Eighteen (*N*=18) high-functioning autistic children with an Educational Healthcare Plan (EHCP) were selected to receive six consecutive weeks of a *Virtual immersive Musical Reality Intervention (*ViMRI). The total sample size included twelve male (*N*=12) and six female (*N*=6) participants aged between eleven and thirteen years (*Mean=11.3*). Six children (male = 5, female = 1) had musical abilities and could play musical instruments. Fourteen children had previous experience using a virtual reality device.

4.5.2 Participant Group Sample Statistics

Table 25.

ViMRI group sample (N = 18)

			Unique ID	Group	Age	Plays a musical instrument	Previous VR experience
Gender	Male	1	FBG1V	Group 1-Violins	11	Yes	Yes
		2	SIG2G	Group 2-Guitars	13	No	Yes
		3	RUG2G	Guitars	11	Yes	Yes
		4	THG2G	Guitars	12	No	Yes
		5	TKG2G	Guitars	12	No	Yes

---

[173] Demographic examples refer to: age, race, ethnicity, gender and education.

Table 25 *(Cont.)*

	6ssss		JWG3S	Group 3 - Saxes	11	Yes	Yes
	7		LBL3S	Saxes	11	Yes	Yes
	8		SLG3S	Saxes	11	No	Yes
	9		TBG4P	Group 4-Pianos	12	No	No
	10		OSG4P	Pianos	11	No	Yes
	11		LHB4P	Pianos	11	Yes	Yes
	12		LMG4P	Pianos	11	No	Yes
	Total	*N*	12	12	12	12	12
		Mean			11.42	1.75	1.08
		Std. Deviation			.669	.622	.289
Female	13		ESG1V	Group 1 - Violins	11	Yes	No
	14		CFG1V	Violins	11	No	Yes
	15		NCG1V	Violins	12	No	No
	16		TMG1V	Violins	11	No	No
	17		RNG3S	Group 3 - Saxes	11	No	Yes
	18		MMG3S	Saxes	11	No	Yes
	Total	*N*	12	12	12	12	12
		Mean			11.17	1.83	1.50
		Std. Deviation			.408	.408	.548
Sample	*N*		18	18	18	18	18
	Mean				11.33	1.78	1.22
	Std. Deviation				.594	.548	.428

4.5.3 Participant Survey Scores

A final participant questionnaire on the following page *(Table 26)* presents findings from a survey of children's reactions, recording their enjoyment and likelihood of participating in future sessions. One child was absent during the final trial session.

NOTE: The sub-table on the following page presents results based on the SPiME group and gender.

Table 26.

Participant survey scores (form SC1)

Participant ID.	Group	SPiME Group	Gender	How much have you enjoyed the SPiME sessions (on a scale of 1 to 10)? **	How would you feel if you could have a weekly session (on a scale of 1 to 10)? **
FBG1V	1	Violins	Male	10	10
NCG1V	1	Violins	Female	8	8
CFG1V	1	Violins	Female	7	3
ESG1V	1	Violins	Female	10	10
TMG1V	1	Violins	Female	10	10
TKG2G	2	Guitars	Male	10	10
THG2G	2	Guitars	Male	6	10
RUG2G	2	Guitars	Male	Absent	Absent
SIG2G	2	Guitars	Male	8	10
JWG3S	3	Saxes	Male	10	10
SLG3S	3	Saxes	Male	10	10
LBL3S	3	Saxes	Male	10	10
MMG3S	3	Saxes	Female	10	10
RNG3S	3	Saxes	Female	10	10
TBG4P	4	Pianos	Male	10	10
OSG4P	4	Pianos	Male	10	5
LHB4P	4	Pianos	Male	9	10
LMG4P	4	Pianos	Male	10	10

** Results obtained using a Likert Scale (1 lowest score, ten highest score)

scored five or less	0	2
scored between 5 and 9	5	3
scored full marks 10	12	14
Mean average score	9.29	9.18

4.5.4 Participant Success Rate Pie Chart

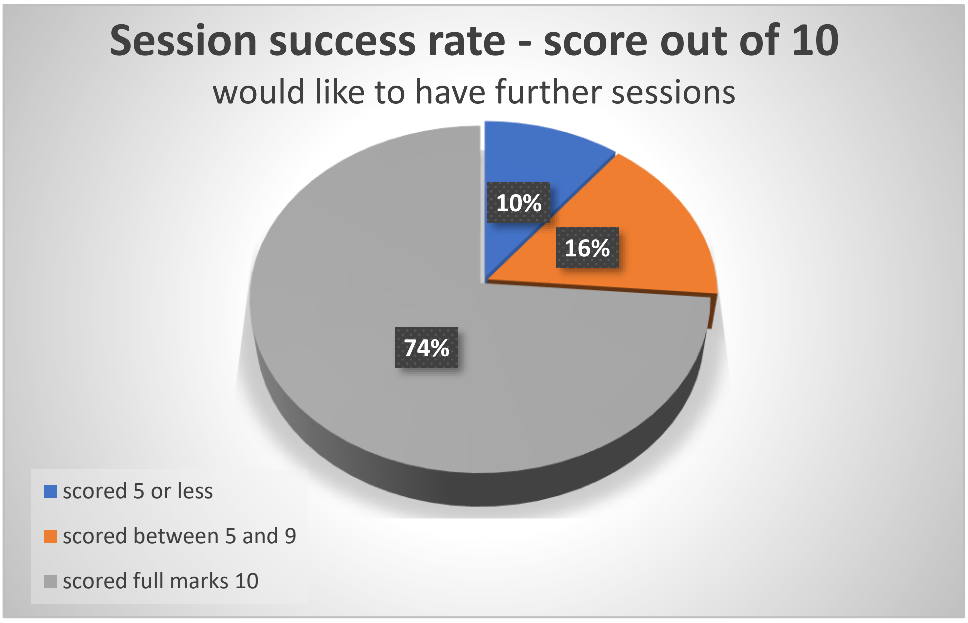

Figure 42. 74% of participants agreed they would like to continue with future SPiME sessions.

4.5.5 Participant Enjoyment Pie Chart

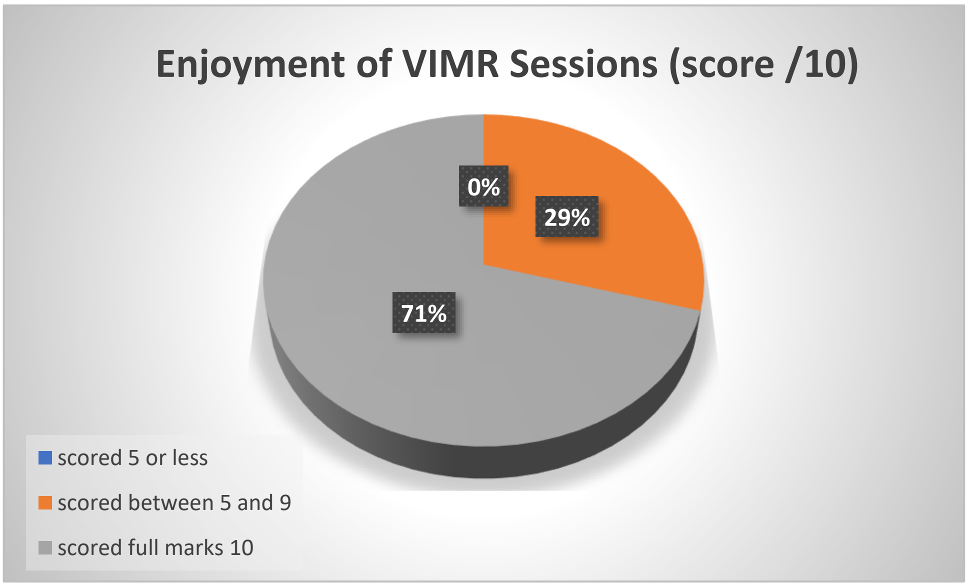

Figure 43. 71% of participants scored the SPiME sessions 10 out of 10, and 0% scored less than 5.

4.5.6 Individual Participant Test Score Results [SIG2G]

Table 27.

Participant [SIG2G] *scores (by criteria)*

	Scores	% Weightings
Total Score	**96**	**100**
Weighted Total	2.77	
(Score x Weighted Total)	265.9	
Final Score	**26.6**	
Sections by score & weightings (%)		
1.1 Musical Preferences	19	14
1.2 Virtual Reality (VR)	12	8
1.3 Animals and Pets	6	4
1.4 Hobbies	4	5
1.5 Colours	4	3
1.6 Geometric Shapes	4	2
2.1 Fears	25	32
2.2 Change	4	10
3.1 Technology	18	22
Total score	**96**	**100**

Results for participant SIG2G demonstrate a final ViMRI participant score of 26.6. Data describes weightings in musical preference, VR, fear, and technology.

Results from [SIG2G]'s favourite categories from the above dataset inspired individual preferences for the author to develop the participant's unique personalised ViMRI experience.[174] The results from each category for *Stylianos* (1.1 – 3.1) guided the

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[174] Additional assets were developed by the author from the results of [SIG2G]'s musical genre, colour, animals, pets, favourite 3D shapes and preferred hobbies.

author's conceptualisation of individual media assets for the personalised virtual music reality environment (e.g., posters, videos, and images). [175]

4.5.7 Participant Responses: Scoring Criteria

The following pages present responses for each child participant recorded by the author using the form VIMR-Q1-Session (on following pages 169-177). The author assigned each response for each category of the 7-point Likert scale from the following table:

Table 28.

Scoring Criteria for VIMR-Q1-Session responses (7-point Likert)

Test score	Criteria
7	Has a particular unique interest
6	Gave multiple answers in response to the question
5	Is specific about the answer to the question
4	Answered the question
3	Single 'Yes' answer
2	Single 'No' answer
1	Did not answer the question
-	**Not applicable to the question**

Procedures for scoring criteria:

i. Responses are assigned a weighted score (out of 100).

ii. Each participant receives an individual **test score,** rated against the above Likert scale criteria (i.e., 0 – 7), depending on the variability of the response given.

iii. Total participant test scores for each individual are calculated.

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[175] - The technique of producing 3D and virtual media assets based on the results of individual profiles was replicated by the author for all the participants.

iv. Individual **test scores** are multiplied by their corresponding **weight** for a final total average **weighted sum score**

v. The outcome of step 4 is multiplied by the sum of the participants' test score (Score x Weighted sum score total). The output is divided by 10 to provide a reasonably sized Final score compared to a CARS-HF score.

4.5.8 Calculating the test scores (step-by-step)

Example calculation provided by participant [SIG2G]:

Participant [SIG2G] received a test score total of **96** and a total weighted sum score of 277. [176]

Calculation 1:

(The weighted sum score of 277 is a percentage out of 100% — therefore, divide by 100).

Result:

265.92

(The actual weighted average of 2.885 is not used in this formula (i.e., 277 ÷ 96)

Calculation 2:

The resulting calculation is divided by 10 to give the Final Score.

265.92 ÷ 10 = 2.659

Final Score for [SIG2G] = 26.6 (to one decimal place)

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[176] Total weighted sum score of 277 is calculated: (4x2) + (3x1) + (2x2) + (0x5) + (4x1) + (2x2) + (4x1) etc. for each section.

Group 1 - Violins

Participant Questionnaire Dataset Responses - (Form VIMR-Q1)

Canterbury
Christ Church
University

XR, music and neurodiversity: Design and application of new mixed reality technologies that facilitate musical intervention for children with autism spectrum conditions.

9am - 9:50am	Child's Identifier:	[ESG1V]	[FBG1V]	[CFG1V]	[NCG1V]	[TMG1V]
	Year Group:	7	7	7	7	7
	Age:	11	11	11	12	11
	Group:	1	1	1	1	1

Section	Code	Question	Response	Score	Weight %	Response	S	%	Response	S	%	Response	S	%	Response	S	%
1.1 Musical Preferences	001	What is your favourite song?	Imagine Dragons - Believer	4	2%	Courtesy Call - Nightcore	4	2%	Addicted - Jorja Smith	4	2%	Silence - Marshmello	4	2%	Closer - The Chainsmokers	4	2%
	002	Do you like to sing?	Yes (sometimes without an audience)	4	1%	No	2	1%	Depends	4	1%	Yes	3	1%	Yes	3	1%
	003	Do you play any musical instruments?	Yes	3	2%	Yes	3	2%	No	2	2%	No	2	2%	No	2	2%
	004	If Yes, what do you play?	Piano & Ukulele	6	5%	Saxophone & Ukulele (lessons)	6	5%	N/A	0	5%	N/A	0	5%	N/A	0	5%
	005	Who is your favourite singer?	Gary Lightbody (Snow Patrol)	4	1%	Nightcore	4	1%	Don't Know	1	1%	KSI	4	1%	Ed Sheeran	4	1%
	006	Do you like to make your own music?	Yes	3	2%	Never tried	4	2%	No	2	2%	Yes	3	2%	Yes	3	2%
	007	What is your favourite instrument?	Piano	4	1%	Flute	4	1%	N/A	0	1%	Keyboard	4	1%	Electric Guitar	4	1%
1.2 Virtual Reality	008	Do you know what Virtual Reality is?	Yes	3	3%	Yes	3	3%	Yes	3	3%	Yes	3	3%	Yes	3	3%
	009	Have you ever used Virtual Reality?	No	2	2%	Yes	3	2%	Yes	3	2%	No	2	2%	No	2	2%
	010	Do you wear glasses?	No	2	1%	Yes	3	1%	No	2	1%	No	2	1%	No	2	1%
	011	Would you wear a VR Headset?	Yes	3	2%	Yes	3	2%	Yes	3	2%	Yes	3	2%	No	2	2%
1.3 Animals and Pets	012	What is your favourite animal?	Cat	4	1%	Eagle	4	1%	Cat	4	1%	Cat	4	1%	Wolf	4	1%
	013	Do you have a pet?	Yes	3	1%	No - allergic to most animals	4	1%	Yes	3	1%	Yes	3	1%	Yes	3	1%
	014	If Yes, what kind of pet is it?	Cat	4	1%	N/A	0	1%	2 Cats, 1 Dog	4	1%	Guinea Pigs x2	4	1%	Bird	4	1%
	015	If Yes, does it have a name?	Bill Bill	4	1%	N/A	0	1%	Spots & Patch. Amber the dog	4	1%	Carrot & Rocket	4	1%	Mary	4	1%
1.4 Hobbies	016	Do you have a special interest?	Gaming, Minecraft, planning Cat Café when adult	6	5%	I like lots of things	4	5%	Anime	4	5%	Football, Maths, Art	6	5%	Crafting	4	5%

9am - 9:50am		Child's Identifier:	[ESG1V]			[FBG1V]			[CFG1V]			[NCG1V]			[TMG1V]		
		Year Group:	7			7			7			7			7		
		Age:	11			11			11			12			11		
		Group:	1			1			1			1			1		
Section	**Code**	**Question**	**Response**	**Score**	**Weight %**	**Response**	**S**	**%**	**Response**	**S**	**%**	**Response**	**S**	**%**	**Response**	**S**	**%**
1.5 Colours	**017**	What is your favourite colour?	**Purple**	**4**	**3%**	Green	4	**3%**	Black	4	**3%**	Blue	**4**	**3%**	Black	**4**	**3%**
1.6 Geometric Shapes	**018**	What is your favourite 3D Shape?	**Sphere**	**4**	**2%**	**Cone**	**4**	**2%**	**None**	**4**	**2%**	**Cube**	**4**	**2%**	**Cube**	**4**	**2%**
2.1 Fears		**Are you scared of any of the following?**															
	019A	Hand Dryers?	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	019B	Balloon Popping?	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	019C	Loud noises?	**Dentist, loud music, blender**	**5**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	019D	Buzzing noises from lights?	**Yes**	**3**	**3%**	**Maybe**	**4**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	019E	Coffee machines?	**No, just annoying**	**4**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019F	Afraid of heights (flying or being on a bridge)?	**No (flying), heights (outside) possibly (zero fear?)**	**5**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	019G	The water at the seaside?	**Waves crashing & cannot swim**	**4**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**
	019H	Flashing lights ?	**No**	**1**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019J	Falling?	**Extremely**	**4**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	019K	What other sounds might make you jump?	**Scream, music suddenly starting, sirens**	**4**	**5%**	**Loud motorbike**	**4**	**5%**	**N/A**	**0**	**5%**	**A loud crash / a sudden squeak**	**5**	**5%**	**Loud Bang, Knocking**	**6**	**5%**
2.2 Change	**020**	What changes would make you unhappy?	**Being in a different environment and the toilet not flushed**	**5**	**10%**	**Not seeing friends (Jack)**	**4**	**10%**	**Don't know**	**4**	**10%**	**Change of event (Sport) change of team**	**6**	**10%**	**Changes to your day at short notice**	**5**	**10%**
3.1 Technology		**Do you have any of the following?**															
	021A	Gaming PC	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	021B	PlayStation	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	021C	XBOX	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	021D	Nintendo Switch	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	021E	Mobile Phone	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	021F	Tablet	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	021G	VR Headset	**No**	**2**	**4%**	**No**	**2**	**4%**	**No**	**2**	**4%**	**No**	**2**	**4%**	**No**	**2**	**4%**
		Test score total		**125**	**100%**		**109**	**100%**		**90**	**100%**		**111**	**100%**		**106**	**100%**
		Weighted sum score		**3.67**			**3.22**			**2.46**			**3.25**			**3.02**	
		Score x Weighted sum score total		**458.8**			**351.0**			**221.4**			**360.8**			**320.1**	
		Final Score		**45.9**			**35.1**			**22.1**			**36.1**			**32.0**	

Group 2 - Guitars

Participant Questionnaire Dataset Responses - (Form VIMR-Q1)

Canterbury Christ Church University

XR, music and neurodiversity: Design and application of new mixed reality technologies that facilitate musical intervention for children with autism spectrum conditions.

10am - 10:50am		Child's Identifier:	[SIG2G]			[RUG2G]			[THG2G]			[TKG2G]		
		Year Group:	9			7			7			7		
		Age:	13			11			12			12		
		Group:	2			2			2			2		
Section	**Code**	**Question**	**Response**	**Score**	**Weight %**	**Response**	**S**	**%**	**Response**	**S**	**%**	**Response**	**S**	**%**
1.1 Musical Preferences	001	What is your favourite song?	Smooth Criminal - Michael Jackson	4	2%	Hall of Fame	4	2%	The Phantom of The Opera 25th Aniv.	5	2%	I don't have one	1	2%
	002	Do you like to sing?	Yes	3	1%	No	2	1%	Yes	3	1%	Yes	3	1%
	003	Do you play any musical instruments?	No	2	2%	Yes	3	2%	No	2	2%	No	2	2%
	004	If Yes, what do you play?	N/A	0	5%	Ukulele	4	5%	N/A	0	5%	Not answered	1	5%
	005	Who is your favourite singer?	Michael Jackson	4	1%	Imagine Dragons	4	1%	Toby goes through phases of obsessively listening to a piece of	4	1%	Not answered	1	1%
	006	Do you like to make your own music?	No	2	2%	No	2	2%	No	2	2%	No	2	2%
	007	What is your favourite instrument?	I don't have one	4	1%	Ukulele	4	1%	Electric keyboard and Guitar	6	1%	Drums	4	1%
1.2 Virtual Reality	008	Do you know what Virtual Reality is?	Yes	3	3%	Yes	3	3%	Yes	3	3%	Yes	3	3%
	009	Have you ever used Virtual Reality?	Yes	3	2%	Yes	3	2%	Yes	3	2%	Yes	3	2%
	010	Do you wear glasses?	Yes	3	1%	Yes	3	1%	No	2	1%	No	2	1%
	011	Would you wear a VR Headset?	Yes	3	2%	Yes	3	2%	Yes	3	2%	Yes	3	2%
1.3 Animals and Pets	012	What is your favourite animal?	Dog	4	1%	Huskey Dog & Hamsters	5	1%	Wolf & Elephant	6	1%	I don't have one	1	1%
	013	Do you have a pet?	No	2	1%	Yes	3	1%	Yes	3	1%	No	2	1%
	014	If Yes, what kind of pet is it?	N/A	0	1%	Hamster, Fish, Cat & Dog	4	1%	Dog & Tortoise	6	1%	N/A	0	1%
	015	If Yes, does it have a name?	N/A	0	1%	Skittles, Jay & Marley	4	1%	Lola and Shelley	4	1%	N/A	0	1%
1.4 Hobbies	016	Do you have a special interest?	I like to go on walks	4	5%	Football	4	5%	Lego, History, Playing on Nintendo Switch PS4	4	5%	London Busses	4	5%

10am - 10:50am		Child's Identifier:	[SIG2G]			[RUG2G]			[THG2G]			[TKG2G]		
		Year Group:	9			7			7			7		
		Age:	13			11			12			12		
		Group:	2			2			2			2		
Section	**Code**	**Question**	**Response**	**Score**	**Weight %**	**Response**	**S**	**%**	**Response**	**S**	**%**	**Response**	**S**	**%**
1.5 Colours	**017**	What is your favourite colour?	**Blue**	**4**	**3%**	**Blue**	4	**3%**	**Orange & Yellow**	6	**3%**	**RED**	**4**	**3%**
1.6 Geometric Shapes	**018**	What is your favourite 3D Shape?	**Sphere**	**4**	**2%**	**Pyramid and Sphere**	**6**	**2%**	**Rectangular Prism**	**4**	**2%**	**Sphere**	**4**	**2%**
2.1 Fears		**Are you scared of any of the following?**												
	019A	Hand Dryers?	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	019B	Balloon Popping?	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	019C	Loud noises?	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	019D	Buzzing noises from lights?	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019E	Coffee machines?	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019F	Afraid of heights (flying or being on a bridge)?	**Yes (flying)**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	019G	The water at the seaside?	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes (fear of tides)**	**3**	**3%**	**No**	**2**	**3%**
	019H	Flashing lights ?	**No**	**2**	**3%**	**Does not like them**	**4**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019J	Falling?	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	019K	What other sounds might make you jump?	**Ambulance siren**	**4**	**5%**	**A loud bang, shouting**	**6**	**5%**	**Storm, thunder, Toby doesn't want to talk about this.**	**6**	**5%**	**N/A**	**0**	**5%**
2.2 Change	**020**	What changes would make you unhappy?	**Change in order**	**4**	**10%**	**If someone says that we are going somewhere, then I can't go**	**5**	**10%**	**Most**	**4**	**10%**	**Not answered**	**1**	**10%**
3.1 Technology		**Do you have any of the following?**												
	021A	Gaming PC	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**
	021B	PlayStation	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	021C	XBOX	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	021D	Nintendo Switch	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	021E	Mobile Phone	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	021F	Tablet	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	021G	VR Headset	**Yes**	**3**	**4%**	**Yes**	**3**	**4%**	**No**	**2**	**4%**	**No**	**2**	**4%**
			Test score total	**96**	**100%**		**119**	**100%**		**117**	**100%**		**76**	**100%**
			Weighted sum score	**2.77**			**3.44**			**3.14**			**2.06**	
			Score x Weighted sum score total	**265.9**			**409.4**			**367.4**			**156.6**	
			Final Score	**26.6**			**40.9**			**36.7**			**15.7**	

Group 3 - Saxes

Participant Questionnaire Dataset Responses - (Form VIMR-Q1)

XR, music and neurodiversity: Design and application of new mixed reality technologies that facilitate musical intervention for children with autism spectrum conditions.

11am - 11:50am		Child's Identifier:	[RNG3S]			[JWG3S]			[MMG3S]			[LBL3S]			[SLG3S]		
		Year Group:	7			7			7			7			7		
		Age:	11			11			11			11			11		
		Group:	3			3			3			3			3		
Section	**Code**	**Question**	**Response**	**Score**	**Weight %**	**Response**	**S**	**%**	**Response**	**S**	**%**	**Response**	**S**	**%**	**Response**	**S**	**%**
1.1 Musical Preferences	**001**	What is your favourite song?	**Don't know**	**2**	**2%**	**Straight out a Compton - Ice Cube Esy E**	**4**	**2%**	**Get Cool - Stray Kids**	**4**	**2%**	**Humans - Imagine Dragons**	**4**	**2%**	**None given**	**1**	**2%**
	002	Do you like to sing?	**Yes**	**3**	**1%**	**No**	**2**	**1%**	**Yes**	**3**	**1%**	**Yes - When I am on my own**	**5**	**1%**	**Yes**	**3**	**1%**
	003	Do you play any musical instruments?	**No**	**2**	**2%**	**Used to**	**3**	**2%**	**No**	**2**	**2%**	**Yes**	**3**	**2%**	**No**	**2**	**2%**
	004	If Yes, what do you play?	**N/A**	**0**	**5%**	**Drums & Guitar**	**4**	**5%**	**N/A**	**0**	**5%**	**Ukulele, Guitar, Sticks**	**4**	**5%**	**N/A**	**0**	**5%**
	005	Who is your favourite singer?	**Don't know**	**2**	**1%**	**Esi E**	**4**	**1%**	**Jess Glyn**	**4**	**1%**	**Imagine Dragons**	**4**	**1%**	**I don't have a favourite singer**	**4**	**1%**
	006	Do you like to make your own music?	**Sometimes**	**4**	**2%**	**No**	**2**	**2%**	**Yes**	**3**	**2%**	**Yes**	**3**	**2%**	**No**	**2**	**2%**
	007	What is your favourite instrument?	**Don't know**	**2**	**1%**	**Drums**	**4**	**1%**	**Keyboard**	**4**	**1%**	**Guitar**	**4**	**1%**	**Not sure**	**4**	**1%**
1.2 Virtual Reality	**008**	Do you know what Virtual Reality is?	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	009	Have you ever used Virtual Reality?	**Yes**	**3**	**2%**	**Yes**	**3**	**2%**	**Yes**	**3**	**2%**	**Yes**	**3**	**2%**	**Yes**	**3**	**2%**
	010	Do you wear glasses?	**Yes**	**3**	**1%**	**No**	**2**	**1%**	**Yes**	**3**	**1%**	**No**	**2**	**1%**	**No**	**2**	**1%**
	011	Would you wear a VR Headset?	**Yes**	**3**	**2%**	**Yes**	**3**	**2%**	**Yes**	**3**	**2%**	**Yes**	**3**	**2%**	**Yes**	**3**	**2%**
1.3 Animals and Pets	**012**	What is your favourite animal?	**Dog and Fox**	**6**	**1%**	**Bearded Dragon Lizard**	**5**	**1%**	**Dog**	**4**	**1%**	**Donkey**	**4**	**1%**	**Cat**	**4**	**1%**
	013	Do you have a pet?	**Yes**	**3**	**1%**	**Yes**	**3**	**1%**	**No**	**2**	**1%**	**Yes**	**3**	**1%**	**Yes**	**3**	**1%**
	014	If Yes, what kind of pet is it?	**Dog**	**4**	**1%**	**Lizard**	**4**	**1%**	**N/A**	**0**	**1%**	**Rabbits & Cats**	**6**	**1%**	**Dog**	**4**	**1%**
	015	If Yes, does it have a name?	**Lily**	**4**	**1%**	**Coco**	**4**	**1%**	**N/A**	**0**	**1%**	**Snowy, Lola**	**6**	**1%**	**Lilly**	**4**	**1%**
1.4 Hobbies	**016**	Do you have a special interest?	**Computer games**	**4**	**5%**	**Computers & Technology**	**4**	**5%**	**Singing / Musical Theatre**	**4**	**5%**	**Playing Playstation**	**4**	**5%**	**Technology**	**4**	**5%**

11am - 11:50am		Child's Identifier:	[RNG3S]			[JWG3S]			[MMG3S]			[LBL3S]			[SLG3S]		
		Year Group:	7			7			7			7			7		
		Age:	11			11			11			11			11		
		Group:	3			3			3			3			3		
Section	**Code**	**Question**	**Response**	**Score**	**Weight %**	**Response**	**S**	**%**	**Response**	**S**	**%**	**Response**	**S**	**%**	**Response**	**S**	**%**
1.5 Colours	**017**	What is your favourite colour?	**Red**	**4**	**3%**	**Blue**	**4**	**3%**	**Pink**	4	**3%**	**Blue**	**4**	**3%**	**Blue**	**4**	**3%**
1.6 Geometric Shapes	**018**	What is your favourite 3D Shape?	**Cylinder**	**4**	**2%**	**Cube**	**4**	**2%**	**Cone**	**4**	**2%**	**Come**	**4**	**2%**	**I don't Know**	**2**	**2%**
2.1 Fears		**Are you scared of any of the following?**															
	019A	Hand Dryers?	**No but I don't like it**	**2**	**3%**	**No**	**2**	**3%**	**A little**	**4**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	019B	Balloon Popping?	**No but I don't like it**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**
	019C	Loud noises?	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Sometimes, depends on noise**	**5**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**
	019D	Buzzing noises from lights?	**No but I don't like it**	**2**	**3%**	**Irritates Me**	**3**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019E	Coffee machines?	**No but I don't like it**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	019F	Afraid of heights (flying or being on a bridge)?	**No**	**2**	**3%**	**Sort of**	**4**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**
	019G	The water at the seaside?	**No**	**2**	**3%**	**Loud but likes**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019H	Flashing lights ?	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019J	Falling?	**No**	**2**	**3%**	**Yes - Wildwood Climbing frame**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**
	019K	What other sounds might make you jump?	**I don't like fireworks or hand dryers & sirens**	**6**	**5%**	**Fire engine**	**5**	**5%**	**Banging, Sirens, Motorbikes**	**6**	**5%**	**Toaster**	**4**	**5%**	**Unexpected noises**	**4**	**5%**
2.2 Change	**020**	What changes would make you unhappy?	**Most of them**	**4**	**10%**	**Don't know**	**2**	**10%**	**Sudden changes**	**4**	**10%**	**Don't know**	**2**	**10%**	**Any**	**4**	**10%**
3.1 Technology		**Do you have any of the following?**															
	021A	Gaming PC	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	021B	PlayStation	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	021C	XBOX	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**
	021D	Nintendo Switch	**No**	**2**	**3%**	**Used to**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	021E	Mobile Phone	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	021F	Tablet	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	021G	VR Headset	**No**	**2**	**4%**	**No**	**2**	**4%**	**Yes - Playstation VR**	**3**	**4%**	**No**	**2**	**4%**	**No**	**2**	**4%**
			Test score total	**101**	**100%**		**109**	**100%**		**104**	**100%**		**113**	**100%**		**101**	**100%**
			Weighted sum score	**2.81**			**2.94**			**3.04**			**2.91**			**2.80**	
			Score x Weighted sum score total	**283.8**			**320.5**			**316.2**			**328.8**			**282.8**	
			Final Score	**28.4**			**32.0**			**31.6**			**32.9**			**28.3**	

Group 4 - Pianos

Participant Questionnaire Dataset Responses - (Form VIMR-Q1)

Canterbury Christ Church University

XR, music and neurodiversity: Design and application of new mixed reality technologies that facilitate musical intervention for children with autism spectrum conditions.

12am - 12:50am		Child's Identifier:	[TBG4P]			[OSG4P]			[LHB4P]			[LMG4P]		
		Year Group:	7			8			7			7		
		Age:	11			12			11			11		
		Group:	4			4			4			4		
Section	**Code**	**Question**	**Response**	**Score**	**Weight %**	**Response**	**S**	**%**	**Response**	**S**	**%**	**Response**	**S**	**%**
1.1 Musical Preferences	001	What is your favourite song?	Happy - Pharrell Williams	4	2%	Just Can't Wait to be King	4	2%	Titanic - Celine Dion My Heart Will Go On	4	2%	Daft Punk - Better, Faster, Stronger	4	2%
	002	Do you like to sing?	No	2	1%	Yes	3	1%	Yes	3	1%	Yes	3	1%
	003	Do you play any musical instruments?	No	2	2%	No	2	2%	Yes	3	2%	No	2	2%
	004	If Yes, what do you play?	N/A	0	5%	N/A	0	5%	Piano	4	5%	N/A	0	5%
	005	Who is your favourite singer?	I don't have one	4	1%	Not answered	1	1%	Not answered	1	1%	Not answered	1	1%
	006	Do you like to make your own music?	No	2	2%	No	2	2%	Maybe	2	2%	He has a good musical ear	5	2%
	007	What is your favourite instrument?	Guitar	4	1%	Drums	4	1%	Piano	4	1%	Leo would probably like drums & keyboard	4	1%
1.2 Virtual Reality	008	Do you know what Virtual Reality is?	No	2	3%	Yes	3	3%	Yes	3	3%	Yes	3	3%
	009	Have you ever used Virtual Reality?	No	2	2%	Yes	3	2%	Yes	3	2%	Yes	3	2%
	010	Do you wear glasses?	Yes	3	1%	Yes	3	1%	No	2	1%	No	2	1%
	011	Would you wear a VR Headset?	Yes	3	2%	Yes	3	2%	Yes	3	2%	Yes	3	2%
1.3 Animals and Pets	012	What is your favourite animal?	Squirrel	4	1%	N/A	0	1%	Cat, Dog, Bird	6	1%	Monkey	4	1%
	013	Do you have a pet?	Yes	3	1%	Yes	3	1%	Yes	3	1%	Yes	3	1%
	014	If Yes, what kind of pet is it?	African Land Snail	4	1%	Dog & 2 Cats	4	1%	2 Dogs, 1 Cat	4	1%	Cat	4	1%
	015	If Yes, does it have a name?	Shelly	4	1%	Luna, Benny & Betty	6	1%	Bebe, Rocket, Rascle	6	1%	Martha	4	1%
1.4 Hobbies	016	Do you have a special interest?	Cricket, Football and Darts	6	5%	Playing my Xbox or Oculus VR	6	5%	Trains & Electronics	6	5%	Geography - Especially Cities & Google Earth. Japan	5	5%

12am - 12:50am		Child's Identifier:	[TBG4P]			[OSG4P]			[LHB4P]			[LMG4P]		
		Year Group:	7			8			7			7		
		Age:	11			12			11			11		
		Group:	4			4			4			4		
Section	**Code**	**Question**	**Response**	**Score**	**Weight %**	**Response**	**S**	**%**	**Response**	**S**	**%**	**Response**	**S**	**%**
1.5 Colours	**017**	What is your favourite colour?	**Orange**	**4**	**3%**	Green	4	**3%**	**RED**	4	**3%**	**Blue**	**4**	**3%**
1.6 Geometric Shapes	**018**	What is your favourite 3D Shape?	**Sphere**	**4**	**2%**	**Cube**	**4**	**2%**	**Cone**	**4**	**2%**	**Cube**	**4**	**2%**
2.1 Fears		**Are you scared of any of the following?**												
	019A	Hand Dryers?	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**
	019B	Balloon Popping?	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019C	Loud noises?	**No**	**2**	**3%**	**Sometimes**	**5**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	019D	Buzzing noises from lights?	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019E	Coffee machines?	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019F	Afraid of heights (flying or being on a bridge)?	**Heights (Yes)**	**3**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	019G	The water at the seaside?	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019H	Flashing lights ?	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**
	019J	Falling?	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	019K	What other sounds might make you jump?	**Not answered**	**1**	**5%**	**Not answered**	**1**	**5%**	**Spooking me**	**4**	**5%**	**Barking Dogs**	**4**	**5%**
2.2 Change	**020**	What changes would make you unhappy?	**Not answered**	**1**	**10%**	**Not answered**	**1**	**10%**	**Not answered**	**1**	**10%**	**Stopping something I'm enjoying or changing activity**	**4**	**10%**
3.1 Technology		**Do you have any of the following?**												
	021A	Gaming PC	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	021B	PlayStation	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**
	021C	XBOX	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	021D	Nintendo Switch	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	021E	Mobile Phone	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**	**Yes**	**3**	**3%**
	021F	Tablet	**Yes**	**3**	**3%**	**No**	**2**	**3%**	**Yes**	**3**	**3%**	**No**	**2**	**3%**
	021G	VR Headset	**No**	**2**	**4%**	**Yes**	**3**	**4%**	**Yes**	**3**	**4%**	**No**	**2**	**4%**
		Test score total		**96**	**100%**		**96**	**100%**		**111**	**100%**		**103**	**100%**
		Weighted sum score		**2.38**			**2.46**			**2.94**			**2.86**	
		Score x Weighted sum score total		**228.5**			**236.2**			**326.3**			**294.6**	
		Final Score		**22.8**			**23.6**			**32.6**			**29.5**	

Groups 1 - 4

VIMR-Q1-Session Dataset: Comprehensive Results for all Participants

XR, music and neurodiversity: Design and application of new mixed reality technologies that facilitate musical intervention for children with autism spectrum conditions.

Canterbury Christ Church University

Participant details							Scores				VIMR-Q1 Criteria								
Identifier uID	LG-SIS (Total Raw Score)	OBSV-SIS Change during observation	Age	Year group	Gender	Group	Weighted sum score	Test score	Score x weighted sum score total	Final Score	1.1 Musical Preferences 14%	1.2 Virtual Reality (VR) 8%	1.3 Animals and Pets 4%	1.4 Hobbies 5%	1.5 Colours 3%	1.6 Geometric Shapes 2%	2.1 Fears 32%	2.2 Change 10%	3.1 Technology 22%
ESG1V	**30.0**	↑	11	7	F	**G1**	3.67	125.0	458.8	**45.9**	28	10	15	6	4	4	35	5	18
FBG1V	**29.5**	→	11	7	M	**G1**	3.22	109.0	350.9	**35.1**	27	12	8.0	4	4	4	28.0	4	18
CFG1V	**35.5**	↓	11	7	F	**G1**	2.46	90.0	221.4	**22.1**	13	11	15.0	4	4	4	18.0	4	17
NCG1V	**32.5**	↓	12	8	F	**G1**	3.25	111.0	360.8	**36.1**	20	10	15	6	4	4	29.0	6	17
TMG1V	**33.0**	↑	11	7	F	**G1**	3.02	106.0	320.1	**32.0**	20	9	15	4	4	4	31.0	5	14
SIG2G	**28.5**	↑	13	9	M	**G2**	2.77	96.0	265.9	**26.6**	19	12	6	4	4	4	25	4	18
RUG2G	**40.5**	↓	11	7	M	**G2**	3.44	119.0	409.4	**40.9**	23	12	16	4	4	6	29	5	20
THG2G	**31.5**	↓	12	8	M	**G2**	3.14	117.0	367.4	**36.7**	22	11	19	4	6	4	30	4	17
TKG2G	**31.0**	↑	12	8	M	**G2**	2.06	76.0	156.6	**15.7**	14	11	3	4	4	4	18	1	17
RNG3S	**26.0**	→	11	7	F	G3	2.81	101.0	283.8	**28.4**	15	12	17	4	4	4	25	4	16
JWG3S	**32.5**	↓	11	7	M	G3	2.94	109.0	320.5	**32.0**	23	11	16	4	4	4	29	2	16
MMG3S	**31.0**	↑	11	7	F	G3	3.04	104.0	316.2	**31.6**	20	12	6	4	4	4	32	4	18
LBL3S	**35.5**	↓	11	7	M	G3	2.91	113.0	328.8	**32.9**	27	11	19	4	4	4	24	2	18
SLG3S	**34.5**	↓	11	7	M	G3	2.80	101.0	282.8	**28.3**	16	11	15	4	4	2	28	4	17
TBG4P	**34.0**	↑	11	7	M	G4	2.38	96	228.5	**22.8**	18	10	15	6	4	4	21	1	17
OSG4P	**31.0**	↑	12	8	M	G4	2.46	96	236.2	**23.6**	16	12	13	6	4	4	22	1	18
LHB4P	**48.5**	↓	11	7	M	G4	2.94	111	326.3	**32.6**	21	11	19	6	4	4	25	1	20
LMG4P	**43.0**	↓	11	7	M	G4	2.86	103	294.6	**29.5**	19	11	15	5	4	4	24	4	17
Mode average	48.50		13				3.67	125.0	458.8	**45.9**	28	12	19	6	6	6	35	6	20
Mean average	33.8		11.33				2.9	104.6	307.2	**30.7**	20.1	11.1	13.7	4.6	4.1	4.0	26.3	3.4	17.4
Standard Deviation	5.459		0.594				0.391	11.510	71.695	**7.176**	4.425	0.873	4.750	0.916	0.471	0.686	4.675	1.614	1.378

4.6 Inferential Statistics VIMR-Q1

The following section presents the author's inferential statistical data gathered from the VIMR-Q1-Session in the following order:

VIMR-Q1-Session: Inferred statistical results

- Statistical summary (VIMR-Q1-Session): Responses for fears and a sense of presence.
- Test results (VIMR-Q1-Session): Fear & sense of presence by gender.
- Observed differences (VIMR-Q1-Session): Total pre-test and post-test scores.

VRMI-Q1-Session: Collective results

- Overall responses (VIMR-Q1-Session) test results and statistical significance.
- Overview of results (VIMR-Q1-Session).

4.6.1 VIMR-Q1-Session: Inferred Statistical Results

Table 29.

Statistical summary (VIMR-Q1-Session): responses to fears and a sense of presence

	Cases excluded		**Cases excluded**		**Total cases**	
	N	**Per cent**	***N***	**Per cent**	***N***	**Per cent**
Pre-test score Total before VIMR-Q1-Session	18	100.0%	0	0.0%	18	100.0%
Post-test score Total after VIMR-Q1-Session	17	94.4%	1	5.6%	18	100.0%

Total sample size (N=18)

VIMR-Q1-Session: comparison table between pre- and post-test-score results.

The total VIMR-Q1-Session: Tested (*N*=17) sample size is 94.4%. Untested (*N*=1) is 5.6%

Table 30.

Test results (VIMR-Q1-Session): fears & sense-of-presence (by gender)

Gender		Pre-test score total (by the participant)	Post-test score total (by the participant)
Male	Mean	27.50	28.55
	N	12	11
	Std. Deviation	4.034	2.841
Female	Mean	24.17	28.67
	N	6	6
	Std. Deviation	3.430	2.582
Total	Mean *(M)*	**25.72**	**24.12**
	N	**18**	**17**
	SD	**2.824**	**3.480**

i. Mean pre-test average score by male participant is *M* = 27.50, *N* = 12 (participants). The standard deviation is *SD* = 4.034.

ii. Mean post-test average score by male participant was *M* = 28.55, *N* = 11 (participants). The standard deviation is *SD* = 2.841 (Mean change >1.05) (SD change 1.193).

iii. The mean pre-test average score by female participants is *M* = 24.17, *N*=6 (participants). The standard deviation is *SD* = 3.430.

iv. Mean post-test average score by female participant: *M* = 28.67, *N* = 6 (participants). The standard deviation is *SD* = 2.582 (Mean change <0.848) (*SD* change 0.848).

Table 31.

Observed differences (VIMR-Q1-Session): total pre- and post scores

Gender		Pre-test score total (participant)	Post-test score total (participant)
Male	Mean	27.50	28.55
	N	12	11
	Std. Deviation	4.034	2.841
Female	Mean (*M*)	24.17	28.67
	N	6	6
	Std. Deviation	3.430	2.582
Total	**Mean**	**26.39**	**28.59**
	N	**18**	**17**
	Std. Deviation	**4.075**	**2.671**

i. Total mean pre-test average score is *M* = 26.39, *N* = 18 (participants).
   The standard deviation is *SD* = 4.075.

ii. Total mean post-test score is *M* = 28.59, *N* = 17 (participants).
    The standard deviation is *SD* = 2.671 (Mean change >2.20) (*SD* change 1.193).

4.6.2 VRMI-Q1-Session: Collective Results

Presented below are the collective statistical results for the VRMI-Q1-Session:

Table 32.

Overall responses (VIMR-Q1-Session) test results and statistical significance

		Paired Differences					95% Confidence Interval		
Part 1)	**Pre and Post-Test Analysis**	**Pre score**	**Post score**	**Sample Size (*N*)**	**Mean**	**Std. Deviation**	**Lower**	**Upper**	**Cross Zero**
	Preferences (Likes)	85	104	17	-1.353	1.057	-1.896	-0.809	No -
	Preferences (Dislikes)	89	52	17	1.882	1.867	0.922	2.842	No +
	Anxiety (Pre and Post)	81	19	17	3.353	1.455	2.605	4.101	No +
	Dexterity	74	106	17	-2.118	2.147	-3.222	-1.014	No -
	Fear Efficacy	57	101	17	-2.706	2.312	-3.895	-1.517	No -
	Sense of Presence	89	104	17	-1.176	1.380	-1.886	-0.467	No -
	Total Pre- & Post	**475**	**486**	**17**	**-2.118**	**4.91**	**1.191**	**-4.642**	**Yes**

		Effect size				Sig. (2-tailed)	Cohen's d			
Part 2)	**Pre and Post-Test Analysis**	***t value***	**df**	**t at df**	**> CV**	**p Value**	**mean / SD**	**Effect Size***		**Statistical Significance**
	Preferences (Likes)	5.277	16	2.120	Yes	0.000075	-1.280	0.63509	Large	Yes p < .05
	Preferences (Dislikes)	4.157[177]	16	2.120	Yes	0.000742	1.008	0.51924	Large	Yes p < .01
	Anxiety (Pre and Post)	9.500	16	2.120	Yes	0.000000055805839	2.304	0.84941	Large	Yes p < .10
	Dexterity	4.066	16	2.120	Yes	0.000898	-0.986	0.50818	Large	Yes p < .05
	Fear Efficacy	4.825	16	2.120	Yes	0.000187	-1.170	0.59267	Large	Yes p < .05
	Sense of Presence	3.515	16	2.120	Yes	0.002871	-0.852	0.43573	Medium	Yes p < .10
	Total Pre- & Post	**1.778**	**16**	**2.120**	**No**	**0.094411**	**-0.431**	**Small**		**No p < .05**

Cross Zero: No +	The range falls above Zero
Cross Zero: No-	Does not cross zero: Range falls below Zero

* Small effect = 0.2, Medium effect = 0.5 Large effect = 0.8

> CV = is the t value greater than the *Critical Value* at 16 degrees of freedom (2.120)

---

[177] Where a negative *t-value* (effect size) is shown, this is indicative of which group has been entered first by the author. It is safe to ignore the negative test for a Cohen's d test sample size of all post-test's where *N*=17.

4.6.3 Overview of Results (VIMR-Q1-Session)

- The findings for pre-tests and post-tests in each category have significant probability values (*p*-values). These are statistically (and significantly) different (Cohen's d posits a large effect size in each case).

- Overall findings for the total values of the pre-test and post-test results are not significantly different (Cohen's d postulates a small effect size that is not significant).

4.7 Inferential Statistics VIMR-Q2

The author presents inferential statistical data (gathered from the VIMR-Q2-Session) in the following order (for the reader's reference):

VIMR-Q2-Session: Inferred statistical results

- Statistical summary (VIMR-Q2-Session): Social interaction responses (total participants).
- VIMR-Q2-Session: Pre-test and post-test case summaries.
- Mean comparison test results (session VIMR-Q1-Session and VIMR-Q2-Session).

VRMI-Q2: Descriptive statistical results

- Paired samples t-Test comparisons: VIMR-Q2-Session and VIMR-Q1-Session.
- Correlation coefficients between pre-test and post-test results (VIMR-Q2-Session).

VRMI-Q2: Collective results

- Overall responses (VIMR-Q2-Session) test results and statistical significance.

Additional findings:

Individual trial (IND-2-Session): Statistical findings

- Results of individual responses for individualised guided discovery & fears: IND-2-Session.

Fears: fear of heights

- Participants' fear of heights: Section 2.1 of the VIMR-Q1 form (code 019f) **(see Chapter 4. Findings, page 190)**.
- Fear of heights pre- and post-analysis comparisons.
- Fear of heights was recorded prior to the ViMRI intervention (Session 4).
- Fear of heights recorded post ViMRI intervention (Session 4).

4.7.1 VIMR-Q2-Session: Inferred Statistical Results

READERS' NOTE: Pre-test results for the VIMR-Q2-Session dataset ensure continuity and accuracy. The author has used two test variables (anxiety) to conduct a paired t-test.

A slight change from VIMR-Q1-Session differs only in substituting the variable 'Sense of presence' (to test self-awareness for each individual) with the 'Social interaction' variable. [178]

Table 33.

Statistical summary (VIMR-Q2-Session): social interaction responses (total participants)

	Cases					
	Included		Excluded		Total	
	N	%	*N*	%	*N*	%
Pre-test score total before *VIMR-Q2*-Session	18	100.0%	0	0.0%	18	100.0%
Post-test score total after *VIMR-Q2*-Session	16	88.9%	2	11.1%	18	100.0%

Comparison of included and excluded cases for VIMR-Q2-Session

- Total Sample size for test (*N* = 17) 94.4%, Untested (*N* = 1), 5.6%.
- The above table indicates the total sample size (pre and post-session), *N* = 18.
- In the second trial (VIMR-Q2-Session), the participant totals were reduced to 16 children due to unforeseen exclusions (88.9%).

---

[178] The author's test for social interaction included a visual strategy designed to test for exchanges (i.e., call and response) and other minor differences (details) for the children to observe within their VR.

Of the two exclusions (11.1%), one child was absent from an illness, and the second child's test ceased prematurely due to a depleted battery. [179]

Table 34.

VIMR-Q2-Session: pre-test and post-test case summaries

Participant No.		Pre-test total per participant	Post-test total per participant	Gender
	1	34	29	Male
	2	26	14	Female
	3	21	34	Female
	4	26	27	Female
	5	20	29	Female
	6	30	27	Male
	7	22	24	Male
	8	24	30	Male
	9	26	34	Male
	10	27	29	Male
	11	26	35	Male
	12	27	35	Male
	13	22	32	Female
	14	25	29	Female
	15	28	24	Male
	16	28	31	Male
	17	27	**.	Male
	18	19	*.	Male
Total	***N***	**18**	**16**	**18**

A breakdown of cases by gender and individual totals: based on the Likert Scale scores for trial 2.

a. Limited to the first 100 cases.

** Depleted battery towards the end of the session

* Absent from session

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[179] The VR equipment sustained continuous use during the trials and therefore did not have sufficient power to complete the session.

Previous test scores **(see results from *Table 30,* page 179, for example)** present interesting comparisons when considering the study's excluded participants.

Table 35.

Mean comparison test results (VIMR-Q1-Session and VIMR-Q2-Session): fears & sense of presence

Gender		Pre-test score total by the participant	Post-test score total by the participant	Pre-test score total by participant	Post-test score total by participant
Male	Mean	27.50	28.55	26.50	29.80
	N	12	11	12	10
	SD	4.034	2.841	3.778	4.077
Female	Mean	24.17	28.67	23.33	27.50
	N	6	6	6	6
	SD	3.430	2.582	2.658	7.064
Total	Mean	26.39	**28.59**	25.44	**28.94**
	N	18	**17**	18	**16**
	SD	4.075	2.671	3.698	5.285

Comparisons of the total mean pre-test and post-test scores for VIMR-Q1-Session and VIMR-Q2-Session (by the participant)

The author points out similarities between sessions VIMR-Q1-Session and VIMR-Q2-Session: 28.59 compared to 28.94. [180]

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[180] The author points out the scores are comparable even with one absent participant (i.e., *N*=17 against *N*=16).

4.7.2 VIMR-Q2-Session: Descriptive Statistical Results

Similar to VIMR-Q1-Session, a paired sample t-Test using the VIMR-Q2-Session Dataset for anxiety (post-and pre-test) within the second session gives the following results:

Table 36.

Paired samples t-Test comparisons: VIMR-Q2-Session and VIMR-Q1-Session

		Mean	*N*	Std. Deviation	Std. Error Mean
VIMR-Q2-Session **(VIMR-Q1-Session)**	Anxiety (Pre-test)	4.53 **(4.47)**	17	1.419	.344
	Anxiety (Post-test)	1.24 **(1.12)**	17	.664 **(.485)**	.161 **(.118)**

Pre- and post-test anxiety results — VIMR-Q2=Session and ***VIMR-Q1-Session (shown in brackets)***

Table 37.

Correlation coefficients pre-test and post-test results (VIMR-Q2-Session)

		N	Correlation	Significance
VIMR-Q2-Session	Anxiety (Pre-test) & Anxiety (Post-test)	17	.390	.122

Output correlation (.390) to calculate the effect sizes for the following table *(Table 38).*

4.7.3 VRMI-Q2-Session: Collective Results

Pooled results for the VRMI-Q2-Session test are:

Table 38.

Overall responses (VIMR-Q2-Session): test results and statistical significance

		Paired Differences					**95% Confidence Interval**		
Part 1)	**Pre and Post-Test Analysis**	**Pre-score**	**Post-score**	**Sample Size (N)**	**Mean**	**Std. Deviation**	**Lower**	**Upper**	**Cross Zero**
	Preferences (Likes)	85	102	17	-1.235	1.855	-2.189	-0.282	No -
	Preferences (Dislikes)	89	72	17	0.765	2.488	-0.515	2.044	Yes
	Anxiety (Pre and Post)	81	21	17	3.294	1.312	2.620	3.969	No +
	Dexterity	74	80	17	-0.412	3.906	-2.420	1.597	Yes
	Fear Efficacy	57	85	17	-1.765	3.289	-3.456	-0.074	No -
	Social Interaction	72	105	17	-2.176	2.325	-3.372	-0.981	No -
	Total Pre- & Post	**458**	**465**	**17**	**-3.187**	**6.635**	**-6.723**	**0.348**	**Yes**

		Effect size				**Sig. (2-tailed)**	**Cohen's d**			
Part 2)	**Pre and Post-Test Analysis**	**t Value**	**df**	**t at df**	**> CV**	**p Value**	**mean / SD**	**Effect Size***		**Statistical Significance**
	Preferences (Likes)	2.746	16	2.120	Yes	0.014363	-0.666	0.32032	Small	Yes $p < .05$
	Preferences (Dislikes)	1.267	16	2.120	No	0.223288	0.307	0.09118	Small	No $p < .01$
	Anxiety (Pre and Post)	10.354	16	2.120	Yes	00000001.6883	2.511	0.8701400	Large	Yes $p < .05$
	Dexterity	0.435	16	2.120	No	0.669626	-0.105	0.01169	Small	No $p < .05$
	Fear Efficacy	2.212	16	2.120	Yes	0.041829	-0.537	0.23419	Small	Yes p < .10
	Social Interaction	3.86	16	2.120	Yes	0.001386	-0.936	0.482190	Small	Yes p < .10
	Total Pre- & Post	1.921	16	2.120	No	0.073878	-0.480	0.18741	Small	Yes p < .10

Cross Zero: No +	Does not cross zero. However, the range falls above Zero
Cross Zero: No-	Does not cross zero. However, the range falls below Zero

* Small effect = 0.2, Medium effect = 0.5 Large effect = 0.8

> CV = is the t value greater than the Critical Value at 16 degrees of freedom (2.120)

4.7.4 Overview of Results (VIMR-Q2-Session)

- Findings for the pre-test and post-tests: Preferences (Likes), anxiety, fear efficacy and social interaction have significant *p*-values and are statistically different.

- Cohen’s d confirms the effect sizes for 4 out of 6.

- The overall findings, however, for the total values of the Pre- and Post-test results are significantly different even though Cohen’s d posits a small effect size

4.7.5 Individual Trial (IND-2): Statistical Findings

Table 39.

Results of individual responses for guided discovery & fears: IND-2

		Paired Differences					95% Confidence Interval		
Part 1)	**Pre and Post-Test Analysis**	**Pre score**	**Post score**	**Sample Size (*N*)**	**Mean**	**Std. Deviation**	**Lower**	**Upper**	**Cross Zero**
	Preferences (favourite images)	98	115	18	-0.944	1.162	-1.522	-0.367	No -
	Preferences (favourite video)	100	102	18	-0.111	0.471	-0.346	0.123	Yes
	Anxiety (Sound 1)	94	48	13	1.462	2.665	-0.149	3.072	Yes
	Anxiety (Sound 2)	81	52	13	0.538	2.47	-0.954	2.031	Yes
	Dexterity	71	108	18	-2.056	2.388	-3.243	-0.868	No -
	Fear Efficacy (Virtual Reality)	78	66	18	0.667	3.068	-0.859	2.192	Yes
	Total Pre- & Post	522	491	13	-7.69	4.986	-3.782	2.244	Yes

		Effect size				Sig. (2-tailed)	Cohen's d			
Part 2)	**Pre and Post-Test Analysis**	**t Value**	**df**	**t at df**	**> CV**	**p Value**	**mean / SD**	**effect size***		**Statistical Significance**
	Preferences (favourite images)	**-3.449**	**17**	2.110	Yes	**0.003064**	-0.812	0.426433	Small	Yes p <.01
	Preferences (favourite video)	**-1**	**17**	2.110	No	0.331333	-0.236	0.058824	Small	No p >.01
	Anxiety (Sound 1)	**1.977**	**12**	2.179	No	0.071439	0.549	0.262167	Small	No p >.01
	Anxiety (Sound 2)	**0.786**	**12**	2.179	No	0.447164	0.218	0.053177	Small	No p >.01
	Dexterity	**-3.652**	**17**	2.110	Yes	0.001973	-0.861	0.454616	Small	Yes p <.01
	Fear Efficacy (Virtual Reality)	**0.922**	**17**	2.110	No	0.369452	0.217	0.050450	Small	No p >.01
	Total Pre- & Post	-0.556	12	2.179	No	0.588248	-1.542	0.027335	Small	No p <.10

Cross Zero: No +	Does not cross zero. Range falls above Zero
Cross Zero: No-	Does not cross zero. Range falls below Zero

* Small effect = 0.2, Medium effect = 0.5 Large effect = 0.8

> CV = is the t value more significant than the Critical Value at 12 and 17 degrees of freedom (2.179, 2.110, respectively)

4.7.6 Overview of Results (Individual trial IND-2)

- A sample size of all post-test (*N*=17).
- The findings for trial 3 (IND-2) indicate that the p-values are small and, although they appear statistically significant, Cohen's d posits a small effect size for preference to favourite images and dexterity.
- The quantitative findings overall of the total values for trial 3 (IND 2) posits a small effect size: the *p*-value is lower than .01, as shown in bold **0.003064**

4.7.7 Results: Participant's Fear of Heights

Table 40.

Participants with a fear of heights: Section 2.1 (code 019f)

Participant ID.	Group	Age	Gender	Fear of Height
FBG1V	1	11	Male	1
NCG1V	1	12	Female	1
CFG1V	1	11	Female	2
ESG1V	1	11	Female	2
TMG1V	1	12	Female	1
TKG2G	2	12	Male	2
THG2G	2	12	Male	2
RUG2G	2	11	Male	1
SIG2G	2	13	Male	1
JWG3S	3	11	Male	1
SLG3S	3	11	Male	1
LBL3S	3	11	Male	2
MMG3S	3	11	Female	1
RNG3S	3	11	Female	2
TBG4P	4	12	Male	1
OSG4P	4	11	Male	2
LHB4P	4	12	Male	1
LMG4P	4	11	Male	2

Questions for each variable correspond to a range of scores on the Likert Scale: [181] [182]

Score: 1 – 3 = no, to little effect.
4 = neutral response (neither agree nor disagree).
5 – 7 = medium to high effect.

Table 41.

Fear of heights pre- and post-analysis comparisons

	Fear of heights	No fear of heights	Sample size	Did not participate
Prior to the test	11	7	18	-
Post-test	6	11	17	0
Change	5	6	1	
SD	3.54	2.83		

---

[181] The answers on the higher end of the continuum (5-7) indicate a strong agreement with the question.

[182] The author used reverse scoring for some variables. For example, a high trait (or construct) such as perfectionism would measure high on the variable (perfection) for some participants. However, this construct would also answer low on the scale (i.e., perfect all the time, 1, rather than not perfect, 7).
Quantitative data was reverse coded using SPSS software (IBM, 2021).

Table 42.

Fear of heights: recorded prior to ViMRI intervention (Session 4)

				Yes Response				*No* Response					
	Total Sample Size *(N)*	**Test Group**	**Per Child**	**Male**	**Female**	**%**	**Yes**	**Male**	**Female**	**%**	**No**	**Total of the sample tested:**	**Untested %**
	18	18	5.55%	7	4	61.1%	**11**	5	2	38.9%	**7**	100%	0%
Male	12	12		39%	22%	61.1%		27.8%	11.1%	38.9%		100%	
Female	6	6											

Table 43.

Fear of heights: recorded post ViMRI intervention (Session 4)

				Yes Response				*No* Response					
	Total Sample Size *(N)*	**Test Group**	**Per Child**	**Male**	**Female**	**%**	**Yes**	**Male**	**Female**	**%**	**No**	**Total of the sample tested %**	**Untested %**
	18	18	5.55%	3	3	33.3%	**6**	8	3	61.1%	**11**	94%	6%
Male	12	12		16.7%	16.7%	33.3%		44.4%	16.7%	61.1%		94%	
Female	6	6											

4.8 Core Statistical Analysis

The author presents testing methods to assess the findings' internal consistency and reliability.

4.8.1 Reliability of Composite Measures Overview: Data Check

Multiple Likert scale-based measures were combined to capture one construct (composite measure). These received similar internal consistency ratings. However, as the Likert scales for this research are newly developed (i.e., by the author on a personal level), not all internal consistency can be guaranteed. Therefore, assessing the reliability of each composite measure requires a recognised statistical test score reliability method.

Cronbach's alpha (Forero, 2014) is one commonly used (reliable) internal consistency scale measure. The survey design for this research is fundamentally multiple questionnaires (i.e., VIMARS 1.0 and 2.0, Q1, Q2) scored using a pre-conceived Likert scale. The concern for inter-reliability of mean differences — between two groups (i.e., those with musical preferences and those with fears) — required more suitable methods for this dataset. A Cohen's D test (Cohen and Lea, 2004) was deemed the most appropriate formula to measure and demonstrate the variables combined (i.e., from the two groups that were more or less saying the same thing). Furthermore, the results from the reliability testing (using composite measure methods) could calculate an effect size with a paired sample t-test **presented in this next section**.

4.9 The Paired Sample *t*-Test

For a "*within-subjects design*", the author consistently conducted a paired samples *t*-Test analysis (in three parts) using the IBM SPSS statistical software (2021) to compare pre-and post-test *mean* values from the study results by obtaining two scale variable measurements of the same sample (e.g., anxiety). [183] The resulting output when conducting a paired-samples *t*-Test analysis with SPSS software provides three statistical outputs:

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[183] A *within-subjects design* can sometimes be referred to as '*repeated measures design*'. The author used this method to compare related measures (from a group of the same participants) between opposing conditions. Similar to a placebo in medical testing.

Descriptive statistics paired correlation coefficients and inferential statistics.[184] [185] The inferential statistics output from an SPSS calculation *(highlighted in Table 47)* provides a *t*-value, the degrees-of-freedom (*df*) and a significance value that correspond to critical values against a *t*-Distribution Table **(see Appendix J: Qualitative Data)** to determine the **first part** of a statistical significance test. [186]

The author presents data from *Table 47* as an example calculation:

t value = 9.500 is greater than the critical value of 2.120 within the *t*-Distribution Table at 16 *df (alpha 0.05)*. Inclusion criteria for the test:

Table 44.

Correlation coefficients: pre- and post-test results (IND-2)

		N	Correlation	Significance
Pair 1	**Anxiety (Pre-test) & Anxiety (Post-test)**	17	.096	.714

Note: The output correlation (0.96) is required to calculate the effect size in Table 39.

Table 45.

Descriptive statistics trial 1: Anxiety

		Mean	*N*	Std. Deviation	Std. Error Mean
VIMR-Q1-Session	Anxiety (Pre-test)	4.47	17	1.419	.344
	Anxiety (Post-test)	1.12	17	.485	.118

Descriptive Anxiety statistics include the "standard error" of the mean for each variable (pre- and post-test anxiety)

---

[184] Descriptives refer to *Mean* value (*M*), sample size (*N*), Standard deviation (*SD*) and standard error of the *Mean* for each variable.

[185] *Correlation coefficient* between the two variables of the test (e.g., pre and post-anxiety) to calculate the effect size.

[186] The analysis using SPSS was conducted via the software menu: **Analyze>Compare Means>Paired-Samples T-Test**. Variables from the current analysis were selected for the *Mean* comparison (e.g., pre and post-anxiety) and OK was selected to display the resultant data.

4.9.1 Cohen's *d*

The Cohen's *d* formula calculates the effect size and measures the practicality and significance of collective results for VRMI-Q1-Session and VRMI-Q2-Session and the Individual trial IND-2 statistical findings **(see Table 33. page 183 and Table 39. page 189)**.

$$d = \frac{mean_D}{SD_D}$$

Where 'd' is the differences of paired sample values (i.e., pre-and post-test virtual reality trial results).

The effect sizes of the quantitative measure of magnitude and the difference (*D*) between the two mean test results for anxiety (i.e., pre and post-intervention) are calculated. The sample group for this study contributes to equal size (*N*=18).

Effect size calculation:

$$2.304 = \frac{3.353}{1.455}$$

(3.353 ÷ 1.455 = *d* 2.304)

By referring to the Cohen's *d* effect size classification table of results *(see Table 46),* The interpretation for the above result is a large effect size (i.e., a large magnitude) of >0.8. In this case, **2.304.**

Table 46.

Cohen's d: effect size classifications

Effect size	*'d'*
Small	0.2
Medium	0.5
Large	0.8

4.9.2 Paired Sample t-test VIMR-Q1-Session: Anxiety

Table 47.

Trial 1 anxiety: statistical significance

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Anxiety (Pre and Post Tests)	3.353	1.455	.353	2.605	4.101	9.500	16	<.001 (see p.197)

The inferential statistics P value corresponds to 9.500 with 16 degrees of freedom **(see appendix J for Student's t-Distribution Table for two-tail test critical values**).**

By observing the above results, the pre-test and post-test Mean (*M*) values are statistically and significantly different *(Table 47).*

In particular:

i. **Part 1 test result:** The recorded *t* value = 9.500 is greater than the critical value for 16 degrees of freedom *df* = 2.120.**

ii. **Part 2 test result:** The recorded *p*-value of **0.000000055805839** is significantly lower than the 0.05% fishers value (Fisher, 1918).

iii. **Part 3 test result:** Lower and Upper 95% confidence intervals do not cross zero (i.e., both upper and lower values are above and on the same side of zero).

4.9.3 Paired Sample t-Test VIMR-Q2-Session: Anxiety

Table 48.

Trial 2 anxiety: statistical significance

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Anxiety (Pre and Post Tests)	3.294	1.312	.318	2.620	3.969	10.354	16	<.001

In inferential statistics, the p-value corresponds to 10.354 with 16 degrees of freedom, demonstrating a small effect.

When observing comparisons between the pre-test and post-test scores **(Sig. (2-tailed) scores of *Table 47 and 48*),** the author's findings for anxiety once again demonstrate a statistical significance (i.e. $p < .001$)

i. The recorded confidence t value of 10.354 is greater than the critical value for 16 degrees of freedom *(df)* (2.120) (Students t-Distribution table: **see Appendix J**)

ii. The recorded p-value is **0.000000016883** — significantly smaller than the 0.05% fishers value (Fisher, 1918).

iii. Lower and Upper 95% Confidence intervals do not cross zero and similarly fall within the upper and lower values (limits) on the same side of zero.

The Cohen's *d* formula calculates the effect sizes of the quantitative measure of magnitude and the difference (*D*) between the two *Mean* test results for anxiety (i.e., pre- and post-intervention). The sample group for this study contributes to an equal size (*N*=18) rather than a sample population **(see NOTE page 91).** The results are as follows:

3.294 / 1.312 = *d* 2.511.

Similarly, to test VIMR-Q2-Session, these results posit a large effect size — displaying a greater magnitude of > 0.8.

4.10 Case Study Findings

The following section presents the findings for each of the six case studies.

4.10.1 Case Study 1. Activity 1: Creative Play

Throughout six sessions, James [JWG2G] and Lenny [LBL2G] appeared to develop better self-awareness and the two children were comparably matched intellectually. Their pre-test scores were coincidentally similar on both scoring systems (32.5, 35.5 CARS-2-HF and 24.0, 23.0 VIMR), respectively, as shown in the following table:

Table 49.

Case study 1. participants' test results: creative play

Model	Score	JWG2G	LBL2G
VIMR	LG-SIS	24.0	23.0
CARS-2-HF	Raw	32.5	35.5
	t-score	49	53
	Percentile	46	62

Results from the pre-test and session scores were variable.

Raw scores (i.e., unaltered data from the test observations) indicated a CARS t-score of 49 and 53 positioned them both within the mild-to-moderate levels of behaviour of autism. James (Drums & Guitar) and Lenny (Ukulele, Guitar, Sticks) received musical training; each had a previously moderate experience using virtual reality.

4.10.2 Case Study 1. Activity 2: Creative Composition

CARS-HF scores for Stylianos [SIG2G] and Thomas [TKG2G] were 28.5 and 31.0, respectively (*Table 50*), indicating a *t-score* of 43 and 46 **(highlighted in bold in Table 50),** indicating mild-to-moderate levels of behavioural impairments.

Table 50.

Case study 1. participants' test results: creative composition

Model	Score	SIG2G	TKG2G
ViMRI	LG-SIS	26.6	15.7
	Musical Preferences	19	14
CARS-2-HF	Raw	28.5	31
	t-score	**43**	**46**
	Percentile	24	35

4.10.3 Case Study 1. Activity 3: Guided composition

Raw CARS-HF scores for this group of 26.0, 34.5 and 31.0, corresponding to t-scores of 38, 51 and 46 (respectively). The results in *Table 51* classify low-to-moderate levels of behaviour impairments for the children in this group.

As confirmed in the following table:

Table 51.

Participants' Social Interaction Scores (SIS): guided composition

Model	Score	**RNG3G** (Robyn)	**SLG3G** (Sonny)	**MMG3G** (Millie)
ViMRI	LG-SIS	**28.4**	**28.3**	**31.6**
	Change	**4**	**4**	**4**
CARS-2-HF	Raw	**26.0**	**34.5**	**31.0**
	t-score	38	51	46
	Percentile	12	54	35
Autism rating		Low-mild	Mild-moderate	Mild-moderate

4.10.4 Case Study 1. Activity 4: Follow-My-Lead (Riley and Tory)

CARS-HF scores of 40.5 and 31.5 signify *t*-scores for the pair of 60 and 47. These results classify Riley [RUG2G] within the severely impaired level of impairment and Tory [THG2G] nearer to the mild-to-moderate levels of behavioural impairments. Higher scores of 29 and 30 *(Table 52),* highlighted in bold for fears, confirmed hypersensitivity to loud noises.

Table 52.

Participants' Social Interaction Scores (SIS): ViMRI* v *CARS-2

Model	Score / Category	RUG2G	THG2G	Weighted score%
ViMRI	LG-SIS	**30.5**	**22.5**	-
	1.1 Musical Preferences	23	22	14
	1.2 Virtual Reality (VR)	12	11	8
	1.3 Animals and Pets	16	19	4
	1.4 Hobbies	4	4	5
	1.5 Colours	4	6	3
	1.6 Geometric Shapes	6	4	2
	2.1 Fear	**29**	**30**	32
	2.2 Change	5	4	10
	3.1 Technology	20	17	22
CARS-2-HF	Raw	**40.5**	**31.5**	
	t-score	60	47	
	Percentile	84	38	
Result		**Severe**	**Mild-mod.**	

Correlations between RUG2G and THG2G's VIMR and CARS-2-HF results are evident in their adjacent total scores (30.5 / 40.5 and 22.5 / 31.5), with an overall mean difference of 9.5.

4.10.5 Case Study 2. Activity 1: Virtual Composition (Timothy)

Correlations between the VIMR scores and CARS-HF scores indicated the participant had a mild-to-moderate level of behavioural impairments and a lower level of '2.2 Change' **(see pages 169-177)** social-emotional understanding (CARS-HF= 2.5). A fear score of 21 is closely associated with a fear of heights, falling, and hypersensitivity to noises and sounds. These scores were all relatively low.

Table 53.

Individual participant (CARS-2-HF) pre-test results: [TBG4P]

	Description	Scores
CARS-2-HF Category	1. Social-Emotional Understanding	2.5
	2. Emotional Expression and Regulation of Emotions	2.5
	3. Relating to People	2.5
	4. Body Use	2.5
	5. Object Use in Play	3.5
	6. Adaptation to Change/Restricted Interests	2.5
	7. Visual Response	1.5
	8. Listening Response	2.5
	9. Taste, Smell, and Touch Response and Use	2.5
	10. Fear or Anxiety	2.5
	11. Verbal Communication	1.5
	12. Nonverbal Communication	1.5
	13. Thinking/Cognitive Integration Skills	2.5
	14. Level and Consistency of Intellectual Response	1
	15. General Impressions	2.5
	Raw score	**34**
	t-score	**51**
	Percentile	**54**

A t-score of 51 classified [TBG4P] inside the mild-to-moderate levels of autism behavioural impairments.

Table 54.

Individual participant (ViMRI) pre-test results: **[TBG4P]**

ViMRI Category	Score	% Weighting
1.1 Musical Preferences	18	14
1.2 Virtual Reality (VR)	10	8
1.3 Animals and Pets	15	4
1.4 Hobbies	6	5
1.5 Colours	4	3
1.6 Geometric shapes	4	2
2.1 Fears	21	32
2.2 Change	1	10
3.1 Technology	17	22
Total	**96**	**100**
Weighted total	2.38	
Score x weight total	228.5	
Final Score	22.8	

4.10.6 Case Study 3: Participant 1. Preliminary Test Results

The author's discussions with the teaching assistants reported that Lorenzo [LHB4P] experienced difficulties with relationships and had experienced friendship breakdowns (leaving him feeling disheartened by other people). Many of these negative attributes significantly impacted the participants' social skills, resulting in higher levels of sensitivity and lower levels of trust. Lorenzo's diagnosis of ASC reflected his struggles to follow verbal instructions. Often, adults would repeat or explain events using different approaches to help Lorenzo better comprehend.

Table 55.

Participant 1: **LHB4G** ***(CARS-2-HF) preliminary test results***

CARS-2-HF Category	Score	Mean Ave.
1. Social-Emotional Understanding	3.5	2.6
2. Emotional Expression and Regulation of Emotions	3.5	2.7
3. Relating to People	3.5	2.9
4. Body Use	3.5	2.4
5. Object Use in Play	3.5	2.4
6. Adaptation to Change/Restricted Interests	3.5	2.9
7. Visual Response	2.5	1.7
8. Listening Response	2.5	2.0
9. Taste, Smell, and Touch Response and Use	2.5	2.1
10. Fear or Anxiety	3.5	2.6
11. Verbal Communication	3.5	1.5
12. Nonverbal Communication	3.5	1.8
13. Thinking/Cognitive Integration Skills	3.5	2.3
14. Level and Consistency of Intellectual Response	2.5	1.2
15. General Impressions	3.5	2.7
Raw score	**48.5**	**33.8**
t-score	**>70**	49.1
Percentile	**>97**	46.2

LHB4G was the sole child (within the sample group) to receive a t-score above the maximum threshold of >70.

Lorenzo was the only child (within the sample group) to receive a t-score above the maximum threshold of >70. A CARS-2-HF score of 60 would suggest a high level obtained when behaviour has been rated severely abnormal in all 15 categories of the test. A percentile of >97 indicates nearer to the 100 per cent limit.

Table 56.

Participant 1: LHB4G—ViMRI preliminary test results

ViMRI Category	Score	% Weighting
1.1 Musical Preferences	21	14
1.2 Virtual Reality (VR)	11	8
1.3 Animals and Pets	19	4
1.4 Hobbies	6	5
1.5 Colours	4	3
1.6 Geometric shapes	4	2
2.1 Fears	25	32
2.2 Change	1	10
3.1 Technology	20	22
Total	**111**	**100**
Weighted total	2.94	
Score x weighted total	326.3	
Final Score	**32.6**	

Lorenzo's VIMR rating was average for the trial. A final score of 32.6 included a slightly raised mean average score of 21 (i.e., mean=20.1) for musical preferences within the group.

4.10.7 Case Study 3: Participant 2 Preliminary Test Results

A higher-than-average *t-score* of 63 (comparable to participant 1) within the sample group indicated a higher-level rating of a severely abnormal level of behaviour. Lorenzo's percentile score of 90 was second only to Luka's within the group.

Table 57.

Participant 2: **LMG4P** *(CARS-2-HF) preliminary test results*

CARS-2-HF Category	Score	Mean Ave.
1. Social-Emotional Understanding	3.5	2.6
2. Emotional Expression and Regulation of Emotions	3.5	2.7
3. Relating to People	3.5	2.9
4. Body Use	2.5	2.4

Table 57. *(Cont.)*

5. Object Use in Play	3.5	2.4
6. Adaptation to Change/Restricted Interests	3.5	2.9
7. Visual Response	2.5	1.7
8. Listening Response	1.5	2.0
9. Taste, Smell, and Touch Response and Use	2.5	2.1
10. Fear or Anxiety	3.5	2.6
11. Verbal Communication	2.5	1.5
12. Nonverbal Communication	2.5	1.8
13. Thinking/Cognitive Integration Skills	3.5	2.3
14. Level and Consistency of Intellectual Response	1	1.2
15. General Impressions	3.5	2.7
Raw score	**43**	**33.8**
t-score	**63**	49.1
Percentile	**90**	46.2

4.10.8 Case Study 3: Participants 1 & 2 Preliminary Test Result Comparisons

The following table presents ViMRI comparisons between participants' preliminary-test results.

Table 58.

Participants ViMRI preliminary test result comparisons

ViMRI Category	LMG4P (Lorenzo)	**LHB4P** (Luka)	**Difference**	**% Weighting**
1.1 Musical Preferences	19	21	-2	14
1.2 Virtual Reality (VR)	11	11	-	8
1.3 Animals and Pets	15	19	-4	4
1.4 Hobbies	5	6	-1	5
1.5 Colours	4	4	-	3
1.6 Geometric shapes	4	4	-	2
2.1 Fears	24	25	-1	32
2.2 Change	4	1	+3	10
3.1 Technology	17	20	-3	22
Total	**103**	**111**	**-8**	**100**
Weighted total	**2.86**	**2.94**	**.08**	
Score x weighted total	**294.6**	**326.3**	**31.7**	
Final Score	**29.5**	**32.6**	**3.1**	

LMG4Ps ViMRI rating was slightly lower than the average mean=30.7 for this trial that recorded a final score of 29.5.

4.10.9 Case study 4: Participant ViMRI-Q1 Group Test-Score Comparisons

Evidenced by the author through prolonged observations, the verbal responses of Nicky and her peers of similar age presented critical indicators of selective mutism. Nicky received a slightly lower-than-average CARS-2-HF score of 32.5. (group *Mean* = 33.8). This score categorises Nicky within the range of 28-35.5, indicating a mild-to-moderate level of autistic behaviour. A t-score value of 49 (0.1) was lower than the average score of 49.1; as shown in the following table:

Table 59.

Trial group pre-test comparisons

	Group 1 (G1V)					**Group 2 (G2G)**				**Group 3 (G3S)**					**Group 4 (G4P)**				***Avg.***
ID	ES	FB	CF	**NC**	TM	SI	RU	TH	TK	RN	JW	MM	LBL	SL	TB	OS	LHB	LM	
Gender	F	M	F	F	F	M	M	M	M	F	M	F	M	M	M	M	M	M	
Raw	30	29.5	35.5	32.5	33	28.5	**40.5**	31.5	31	26	32.5	31	35.5	34.5	34	31	**48.5**	**43**	33.8
t-score	45	44	53	49	50	43	60	47	46	38	49	46	53	51	51	46	>70	63	49.1
Percentile	31	28	62	46	50	24	84	38	35	12	46	35	62	54	54	35	>97	90	46.2

The author scored subjects within the trial group (N=18) using the VIMR-Q1-Session pre-test evaluation method.

4.10.10 Case Study 5. VMRI-Q1-Session: Participant Fear Test Comparisons

Three of the four children scored (*Mean* = 26.3) in all aspects of fears (Section 2.1). The author noted that participants' fears and comparative scores for trial 1 were higher-than-average.

Table 60.

Participants fear score comparisons

Code	Are you scared of the following?	% Weight	TMG1V	Score	MMG3S	Score	JWG3S	Score	LBL3S	Score
019A	Hand Dryers?	3%	Yes	3	Yes	4	No	2	Yes	3
019B	Balloon Popping?	3%	Yes	3	Yes	3	No	2	No	2
019C	Loud noises?	3%	Yes	3	Sometimes	5	Yes	3	No	2
019D	Buzzing noises from lights?	3%	Yes	3	No	2	Irritates Me	3	No	2
019E	Coffee machines?	3%	No	2	No	2	No	2	Yes	3
019F	Afraid of heights?	3%	Yes	3	Yes	3	Sort of	4	No	2
019G	Water at the seaside?	3%	Yes	3	No	2	Loud but likes	2	No	2
019H	Flashing lights?	3%	No	2	No	2	Yes	3	No	2
019J	Falling?	3%	Yes	3	Yes	3	Yes - Climbing frame	3	No	2
019K	What sounds make you jump?	5%	Loud Bang, Knocking	6	Banging, Sirens, Motorbikes	6	Fire Engine	5	Toaster	4
	Totals	**32%**		**31**		**32**		**32**		**24**

Notes:

i. *The total weighted score for fear is 32% out of 100%.*
ii. *Three child participants scored above the average (31,32, 32).*
iii. *One participant scored 24*
iv. *There were two male and two female participants.*

4.10.11 Comparison of statistical significance for trials

Comparisons and significance for anxiety, dexterity, and preferences (likes and choices made) for trial 1 (VIMR-Q1), trial 2 (VIMR-Q2) and trial 3 (IND-2) were consistent between trials.

Table 61.

Comparisons of significance and effect size

Trial	Findings	*p* Value	Effect value and size		Statistical significance
VIMR-Q1	Preferences (Likes)	0.000075	0.63509	Large	Yes *p* < .05
	Anxiety	0.000000055805839	0.84941	Large	Yes *p* < .01
	Dexterity	0.000898	0.50818	Large	Yes *p* < .05
	Sense of presence	0.002871	0.43573	Medium	Yes *p* < .01
VIMR-Q2	Preferences (Likes)	0.014363	0.32032	Small	Yes *p* < .05
	Anxiety	0.00000016883	0.8701400	Large	Yes *p* < .00001
	Fear efficacy	0.041829	0.23419	Small	Yes *p* < .01
	Social interaction	0.001386	0.482190	Small	Yes *p* < .01
IND-2	Preferences (Likes)	0.003064	0.426433	Small	Yes *p* < .01
	Anxiety	0.071439	0.262167	Small	No *p* > .01
	Fear efficacy	0.369452	0.050450	Small	No *p* > .10
	Dexterity	0.01973	0.454616	Small	Yes *p* < .10

Some statistical probability (p) values were indicatively low (examples highlighted in black) their effect sizes (highlighted in grey) implied a greater statistical significance: p < . 01 and p < .00001 @ alpha α = .05 (t-Distribution table)

4.11 Qualitative Analysis of Research Findings

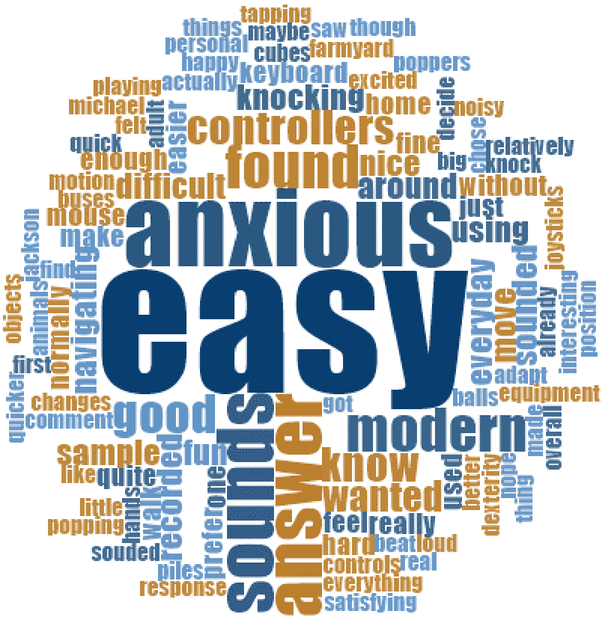

Figure 44. Thematic qualitative analysis: word occurrences from the author's findings.

4.11.1 Thematic Analysis

Qualitative analysis for VIMARS, VIMR-Q1-Session (trial 1), VIMR-Q2-Session (trial 2) and IND-2 (trial 3) data were categorised into five clusters using the NVIVO (*QSR International*, 2020) software application, resulting in a thematic analysis. These results favourably confirmed the following for a *Virtual immersive Musical Reality Intervention* (ViMRI) through a *Supplemental Personalised, immersive Musical Experience* (SPiME) — over six weeks.

Cluster 1 - Decision Making		Cases
a)	Children favoured creating their compositions	4
b)	Choices reinforced using reasoning	6
c)	Neutral decision or choice	21

d)	Adverse decisions made regarding choices	0
e)	Positive decision or choice	11
f)	Required adult assistance to make an informed choice	1
g)	Capable of making choices independently	5

Cluster 2 - Understanding and expressing emotions - Social interaction		Cases
a)	A small minority (*N*=2) of children had a preference for navigating around the VR scene using alternative methods (keyboard and mouse)	2
b)	Activities during the SPiME promoted gross-motor skills (balance, coordination, body awareness, reaction times)	0
c)	Dexterity (generalisable)	20
d)	Difficulty using the equipment (dexterity)	17
e)	Guided discovery improved after completing practice sessions (an inductive approach to learning)	5
f)	Navigation was complex - VR boundary restricts the physical movement area	1
g)	Social interaction	1
h)	Virtual Reality immersion promotes emotional development through play	2

Cluster 3 - Emotional interaction		Cases
a)	A SPiME sparks creativity and emotional interaction - further testing is required to determine the effects of expressing emotions in larger groups	19
b)	Significantly reduced anxieties whilst using VR besides a ViMRI	32
c)	Children's sound responses to their fears (hypersensitivity) are distracted whilst using VR	20
d)	Creating music using a CiiMS pad is an enjoyable experience	21
e)	Promotes emotion and insight	21
f)	Personal experiences for video immersion help to develop meaningful emotions; stimulating emotional, immersive interaction	20
g)	Fear of heights whilst within the VR makes children feel safe	17
h)	Fear of sound virtual reality immersion - multiple presentation attempts help with desensitisation	20

Cluster 4 - Rigid and repetitive behaviours		Cases
a)	The feeling of change (position of the objects) within a VR scene decreases anxiety	19
b)	Personal preferences promote familiarity	4

Cluster 5 - Virtual Immersive environments		Cases
a)	Exposure to favourite Images and personal preferences within VR improves emotional wellbeing	20
b)	Reduces the level of fear of heights considerably	19
c)	Did not answer	1
d)	Concerns for a small percentage	6
e)	Simulation provides a level of realism to encourage somatosensory perception and sensorimotor processing	17
f)	VR experience least liked (specified by group)	17
g)	Unable to navigate to a specific point	1
h)	Hair getting in the way	1
i)	HMD - Equipment	1
j)	Interacting with certain objects	2
k)	Learning to use the equipment	1
l)	Nothing - liked everything	5
m)	Ceased working - technical	2
n)	Unsure	2
o)	VR experience most liked (specified by group)	22

p)	Ease of use	1
q)	Everything	2
r)	Exploration	4
s)	Fun	1
t)	Falling off the cliff	1
u)	Interface	1
v)	A new world - escapism	2
w)	Not at all worried	1
x)	Picking things up	1
y)	Playing with things not used before	1
z)	Realism	1
aa)	Unsure?	1
bb)	ViMRI promotes a sense of self	4
cc)	Additional comments	20

PART B: DISCUSSION & INTERPRETATION OF FINDINGS

4.12 Introduction

Part B (Chapter 4) interprets six case studies and critical findings analysed by the author in **Part A** **(page 126, Chapter 4: FINDINGS & DISCUSSION).** The results provide the reader with interpretations and conclusions describing each case study's implications and significance. A summary provides an overview to help answer the original research questions.

4.13 Restating the Aims

To assist the reader, the author presents the three key research questions for reference:

i. **What approaches can effectively facilitate engagement with technologically mediated musical interaction in immersive environments?**

ii. **Can the introduction of a local or remotely guided cloud-based immersive musical environment complement established therapeutic processes for specific types of intervention?**

iii. **Can immersive music realities influence improvement in people with an autism spectrum (ASC) and other neurodiverse conditions?**

4.14 Summary of Key Findings

Case Study 1 Discussions: Composition Methods

The following summarises the author's critical findings for the Creative Play Session:

4.14.1 Creative Play (James and Lenny)

Interpretation

Both children responded exceptionally well to their guided instructions. It was clear to the author that through joint participation and observed bodily responses (whilst reacting to percussive and rhythmic sounds) that the pair each presented musical drumming abilities.

Conclusion

James [JWG2G] and Lenny [LBL2G] had lots of fun during their creative play session, and enjoyment was abundant. These children had built a rapport during previous sessions. The familiarity with one another and their tutor helped strengthen their social interaction and sessional engagement.

4.14.2 Creative Composition (Stylianos and Thomas)

Interpretation

Stylianos [SIG2G] and Thomas [TKG2G] engaged in unison. The two children responded very well to their instructions, taking full advantage of the gestural interface and experimenting using various interactive techniques. Stylianos made a robust decision to use his zipper for 'beat boxing'; this was a quick-fire composition technique used to improvise during the session.

Conclusion

At the end of their session, both children expressed their elation. The boys were positively receptive to using rapid and innovative methods of musical composition.
This creative composition session provided effective methods by assisting in regulating the children's behavioural and emotional mood states. The ARTIMIS interface functionality further enhanced their engagement when the children could listen to their recording once it had finished. [187]

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[187] Playback was instantaneous once the recording had finished without waiting.

4.14.3 Guided Composition (Millie, Sonny and Robyn)

Interpretation

Using turn-taking combined with preferential questions allowed the children to use music to speak informally through social participation and musical interaction. The group became far more enthusiastic by involving clapping to encourage physical interaction. The results from the performance were observed by emphatic laughter and excitement — after the group recording activity. These positive responses encouraged further creativity and articulation.

Conclusions

This activity shows that individuals with low levels of understanding and self-regulation have the opportunity to perform musical composition through a support-guided composition programme. Furthermore, a supervisor can successfully mediate and strengthen this by using music technology.

- Adding a multi-capacitive interface (i.e., ARTIMIS) with various sensory pressures persuades new creative sounds — forming part of the ViMRI concept.
- Manipulating musical samples using a unique interface operates as a further dimension of physical interaction to encourage dexterity.
- Collaboratively, the group was encouraged to participate and have fun, encouraging discussion between the participants.

4.14.4 Musical 'Follow-My-Lead' (Riley and Tory)

Interpretation

An initial demonstration of the circular interface and pads using unlimited combinations of direction and motion preoccupied the children. Using eye contact was Tory's mechanism for seeking mutual approval from his peers to express their correct assumptions. Tory interpreted his answers succinctly — without sufficient explanation or supporting visual evidence when questioned. Many physical movements and gestures in reaction to positively identifying correct sounds included clenched fists and jittering movements. Positive emotions were further evident when a sample sound was activated correctly.

Conclusion

This session further establishes the concept of using a physical, digital musical interface with haptic feedback, proving that it can be highly beneficial to assist social group interactions. There was an improved level of communication between '*child and instructor*' over a more extended period. Social turn-taking through musical participation supported by visual aids helped promote sensory integration whilst encouraging eye contact.

4.14.5 Case Study 2 Discussion: Virtual Composition (Timothy)

Interpretation

After demonstrating the musical interface, Timothy was uncompromising in creating the music (his way). Timothy's body language interprets this subconsciously by mimicking the musical sounds (presented as actions). The Discovery of personalised objects within the scene encouraged reassurance, particularly when Timothy memorised a trigger position to activate virtual objects of interest.

- Physical responses to each pad pressed (on the interface) strengthened the decision to compose his music.

  Echolalic actions were significantly high.

Conclusion

Adding a virtual environment combined with any ViMRI activity adds a further dimension to musical composition. The circle of fifths interface arrangement (developed by the author) encouraged expressiveness, and the ARTIMIS interface layout successfully met the performer's needs. Timothy's expressive and imaginative composition was observed first-hand through his originality via musical engagement. This complementary approach holds the potential to support sensory processing deficits that commonly result in the breakdown of communication through speech and language development.

Case Study 3 Discussions: An *in-Vivo* Experience

4.14.6 Participant 1: Lorenzo [LHB4P]

Interpretation

Interpretations from this session alluded to Lorenzo [LHB4P] establishing complete familiarity when using the equipment and navigation menus of the personalised interface. Lorenzo's (exceptional) ability to learn rapidly using his knowledge and experiences of VR systems (and previous session tutorials) helped his social anxieties within an incomprehensible environment.

- Lorenzo became withdrawn and fell into his imaginary world during numerous sessions, and a personalised VR environment was an excellent substitute to transport him to a new safe place.
- Lorenzo heard many sounds during the session, demonstrating confusion and responding with many slow bodily motions.
- Assistance during the sessions guided Lorenzo to make informed choices based on his poor responses — most evident when instructed during a virtual fear test.
- A large smile on Lorenzo's face suggested that he thoroughly enjoyed the session (a satisfying observation made by the author during the research).

"Where is it?... Where is it going? Where has the character gone?" Lorenzo, aged 11

Conclusion

To conclude, the importance for Lorenzo to feel supported during his trial session by the adults surrounding him was achieved by carefully explaining many of the instructions beforehand. Lorenzo's sense of stability and trust over the six-week trial period were strengthened through the SPiME, making him feel protected.

- Lorenzo's confidence flourished throughout the SPiME sessions.
- A strong bond during a technical malfunction with his peers was evident.

- A fluid transition relayed contentment by a large smile at the end of the session. Virtual Reality HMD and motion-controller input interfaces were appealing to Lorenzo.
- The teaching assistant became emotional, and Lorenzo hugged her at the end of his trial to express his gratitude.

4.14.7 Participant 2: Luka [LMG4P]

Interpretation

Luka [LMG4P] became wholly engrossed in his virtual world. The Unreal engines (UE4) software constraints (i.e., physics) — used to develop the virtual environment — successfully impacted physical interactions between Luka and virtual objects within the scene. Feedback from weighted balls and friction between the virtual floor (for example) provided real-world haptic simulation (mimicking physical objects).

Whilst observing his own 'virtual hands,' Luka's proprioception was further heightened by his physiological responses. As a result, many more dynamic interactions and a stronger sense of awareness were encouraged. Luka moved out of his guardian boundary, which obliged physical help to correct his position inside the desired safe play area. This particular scenario encouraged Luka to make an informed decision based on his restricted movements and alternative methods of virtual mobility. These movements required motion-controlled joysticks to make small 45-degree increments.

Conclusion

Findings from this 'in-vivo' investigation demonstrated several vital points.
First, a ViMRI session allows children like Luka to express themselves through 'one-to-one' supervision — within a uniquely personal space at a time of convenience.
Second, the immersive virtual experience substitutes an actual sensory room and integrates many interactive musical elements and personal preferences to occupy a small physical footprint. Third, such attributes would be more difficult to implement during a taught session — particularly within a large classroom group.

Of equal importance, this trial focussed on a single individual presenting undivided attention to express himself verbally and physically. Conversing using single-word answers (i.e., ‘A’ and ‘B’, ‘Monkey’, and ‘Hoover’) would not have been prompted if such an opportunity for a ViMRI within a SPiME session had been made available. Personalised attributes of favourite colours helped influence Luka’s decisions to pick up his favourite objects and the repetitive physical actions of his interactions.

In short, this study successfully emphasised cognition, learning new tasks and strengthening psychological skills and physiological dexterities.

> ***‘ []…with others doing this, he could join in, but not independently.***
> ***…or being so happy.’ Teaching assistants' response, 2021***

Given that Luka has many social and emotional barriers to overcome, Luka danced to his favourite song, *Harder, Better, Faster, Stronger* (Daft Punk, 2001), with a pre-prepared dance routine — never seen before.

4.14.8 Case Study 4 Discussion: an *ex-Vivo* Experience

Interpretation

Nicky [NCG1V] exhibited many associated symptoms of nonverbal communication deficits — particularly around selective mutism and social developmental disabilities. Limited facial expressions interpreted an absence of interest presented throughout the activity. Constant prompting for two-way interaction was characteristic of masking any abnormalities. Nicky's postural instability and limited eye contact were evident throughout this session. Her non-verbal cues incited overriding responses to the social changes she perceived within her new virtual environment.

Conclusion

During the first encounter (Week 1), Nicky had limited interactions within the group — presenting herself as a competent individual. As the only female participant, this case study establishes girls' innate ability to mask their autistic traits better; consequently, girls with ASC become misdiagnosed.

Various physiological disabilities and neurological effects of the appropriate use of alternative VR interface methods (i.e., ex-vivo) point toward a need for further research into alternative external VR navigation methods. Furthermore, extended investigations are essential for people with photosensitive conditions such as epilepsy.

The study evaluated the placement of autistic individuals within a new environment — where neurodiversity is not always fully understood. Relying on postural instability (i.e., stimming and repetitive behaviours) demonstrates a need to present neurotypical social behaviours to their counterparts. This case study provides an opportunity to test a colourful interface's portability and visual aesthetics through the facilitated engagement of an alternative wireless numeric keypad.

4.14.9 Case Study 5 Discussion: A ViMRI-d

Interpretation

Millie's [MMG3S] responses to verbal instructions were cautious. Many of her difficulties processing combined multi-sensory inputs were reactions to anxiety and feeling overwhelmed. These are critical indicators of an SPD prognosis.

Millie moved into her virtual location whilst preparing for her fear test; this was another striking example of desensitisation within the VR environment — in response to a natural physiological 'Fight or flight reaction — towards a perceived threat.

Many subconscious reflexes (i.e., spinning around, physically bending, and combined shouting during her virtual tasks) alluded to proprioceptive 'over-responsive' feedback. These intense responses functioned as a form of sensory stimulation.

Conclusion

This study investigated multiple virtual immersion cases within a personalised virtual reality music environment. These allude to graded exposure methodologies — characteristic of exposure therapy. In addition, repetitive, systematic exposure to known fears (i.e., within a child's personalised virtual environment) established effective intervention. Millie's curiosity grabbed her attention; more importantly, her tailored musical VR environment was unique to her individual preferences. This experiment was preceded by conditioning each participant and supporting them via an informed programme of weekly sessions (i.e., the SPiME) to educate and familiarise them with their surroundings.

Millie is one example from a group of children in the study (in addition to 3 participants from the entire sample *N*=18) who were administered a virtual intervention and then presented with real-life equivalencies. This isolated incident demonstrates significant probability within the findings, which further substantiates that a ViMRI-d is an effective form of desensitisation to treat hypersensitivity to sound (i.e., phonophobia).

4.14.10 Case Study 6 Discussion: Virtual Composition

The scores obtained from the participant, parent, and carer questionnaires guided the author to design a series of *Supplemental Personalised, immersive Musical Experience* (SPiME) sessions. These sessions intend to fulfil the needs of the children's levels of social interaction and musical abilities.

Interpretation

Coincidentally, participant [TBG4P] celebrated his birthday on the day of the session. The first stage of recording: **α. (see 2.15 Virtual Composition Guidelines – First stage recording - Alpha (α.), pages 98-99)**, was captured via the ARTIMIS hardware interface. Instructions were reiterated to the group to encourage them to compose additional musical material. To the children's surprise, the results from **α.** (Alpha), triggered a positive response to encourage experimental composition further using the touchpads. Further instructions to the group regarding the forthcoming stage **β.** (Beta) recording encouraged various interactions whilst establishing a new recording duration, and the group performed for a second successive time.

At this stage, new musical compositions within the VR environment using the CiiMS hardware interface were completed, verifying the efficacy of the prototype interface during the trial.

Conclusion

Until this session, the author's preliminary ground-breaking virtual group music session had not been tested collectively in a real-world setting. [188] Furthermore, musical interaction was spontaneous and supported using the newly developed music technology. The author's pilot study established a platform to test the creative virtual composition methods using physical means within a group setting. Subsequently, the trial was an opportunity to test real-time external abilities on-site. A large display proved advantageous for the group session in which participants collectively visualised and interacted with the virtual interface. This trial's efficacy and successful outcomes have

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[188] The author developed the CiiMS hardware and software interface independently (from one another) during a pandemic scenario.

independently verified the writer's scope for further development of a cloud-based application — with the potential to harness (real-time) digital healthcare technologies.

4.15 Summary

The author demonstrates through the case studies that the ARTIMIS interface and its functionalities provided musical facilitation. To summarise:

1) The author directly obtained pre-test data for each participant's Childhood Autism Rating Scale (VIMR-QPC equivalent) from a parent or carer.
2) Through their observations, the children's teachers recommended that the author determine pre-score ratings and individual variables.
3) Children for the research study were introduced to virtual (solo and group) musical activities.
4) The author and teaching staff interviewed participants at the end of the six-week sessions by completing exit questionnaires.
5) To ensure continuity and accuracy of recorded data sets within the study, quantitative and qualitative analysis was measured and evaluated using a paired samples *t-test* (from pre and post-test variables).
6) The author analysed correlations for equivalence between pre and post-sample means.
7) The author further evaluated and interpreted parameter effect sizes and statistical significances using Cohen's D standard deviation.[189]

Please see Appendix H for detailed notes on the six weekly session findings.

Fundamentally, this research aims to demonstrate the efficacy of a ViMRI. The author will use the original findings from these studies to conduct longer-term research to contribute to new and exciting areas of virtual assistive technologies within clinical and Special Educational Needs and Disabilities (SEND) domains.

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[189] A measure of effect size, the most familiar form being the difference between two means (M_1 and M_2) expressed in units of standard deviations: Jacob (Jack) Cohen (1923–98) Statistical Power Analysis for the Behavioural Sciences (1969, 1988)oxford reference.com

Chapter 5.
CONCLUSION

The concluding chapter of the thesis summarises the key contributions and rationale to satisfy the intentions of the author's original research questions. Discussions surrounding observations, trial findings and study investigation limitations are presented. In addition, the author assimilates the outcomes of this mixed research methodology approach with recommendations for future research.

5.1 Overview

Throughout this research, the author has tested the feasibility of a newly developed complementary Virtual immersive Musical Reality Intervention (ViMRI) concept (comprising six alternatives a-f respectively) to support high-functioning autistic individuals within a special educational needs and disabilities (SEND) setting. At its core, the author's contribution to new knowledge is the amalgamation of virtual reality and immersive music technologies in a neurodiverse context.

The author's objective was to develop new creative and educational environments, motivated by real-world results in a series of trials. The author devised a robust design protocol, a curricular music VR programme, and a process of virtual composition guidelines **(see page 99)**. These fruitions each led to the administration of a *Virtual immersive Musical Reality Intervention* (ViMRI) supported by a rigorously coordinated *Supplemental Personalised, immersive Musical Experience* (SPiME), each facilitated via a multi-faceted music technology, hardware, and software interface.

Consequently, by implementing a newly developed system for personalised and supplemental VR music intervention, the findings indicate the potential for improvement in social interaction, dexterity, anxieties, and other comorbid autism spectrum condition (ASC) deficits.

The ARTIMIS (*Autism Real-time Three-dimensional Immersive Musical Intervention System)* and CiiMS (*Creative immersive interactive Musical Software)* are original software and hardware technologies. [190] The author developed these to facilitate musical interactions (based on the personal profiles of high-functioning autistic participants) and has sought to test their efficacy within an educational neurodiverse setting to further a proof-of-concept. [191]

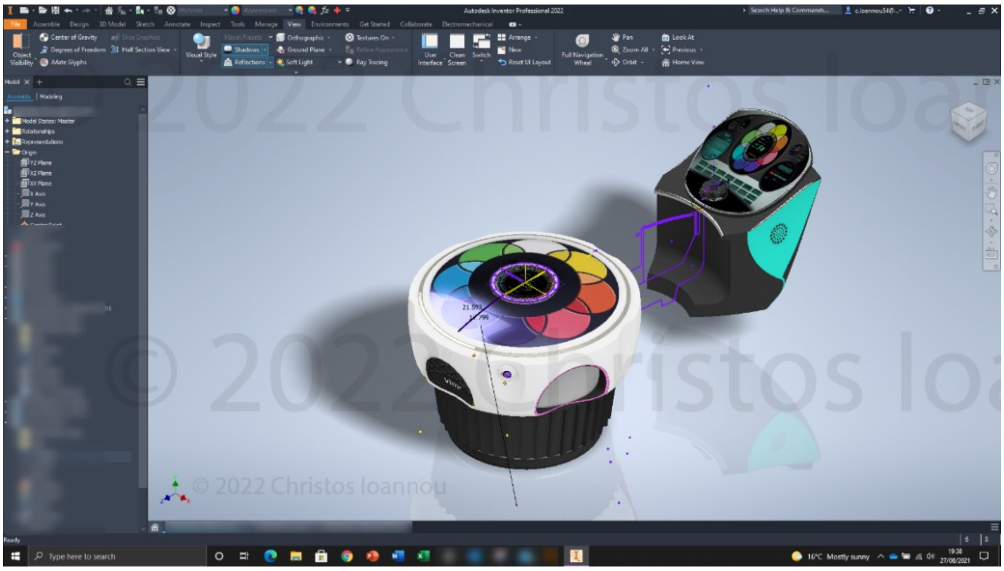

Figure 45. The ARTIMIS Proof-of-concept and module pre-installed with the CiiMS interface.

Figure 46. Screenshot of a personalised ViMRI (Note: CiiMS interface within the VR).

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[190] ARTIMIS is a hardware-based physical user interface with multi-directional haptic touch-capacitive pads. Musical engagement is facilitated through the interface via a multi-level response with the ability to load or record a personal passage of a musical composition — near instantaneously.

[191] The ViMRI protocol forms part of the *Supplemental Personalised immersive Musical Experience* (SPiME).

Here are the original questions for this research:

i. **What approaches can effectively facilitate engagement with technologically mediated musical interaction in immersive environments?**

ii. **Can the introduction of a local or remotely guided cloud-based immersive musical environment complement established therapeutic processes for specific types of intervention?**

iii. **Can immersive music realities influence improvement in people with an autism spectrum condition (ASC) and other neurodiverse conditions?**

Based upon the original questions and investigations (set out in the introduction of this thesis) and the development of a proposed VR music technology system, the author believes this research has yielded findings of potential significance for the area of research.

Qualitative and quantitative data analysis from the research findings indicates that high-functioning children with an autism spectrum condition (ASC) participated in a (consistently-led) six-week *Supplemental Personalised, immersive Musical Experience* (SPiME) programme presenting notable improvements in specific areas — when administered with a ViMRI. These findings have been evidenced and documented within the thesis by the author throughout six individual case studies **(see Chapter 4. Part A: 4.4 Case Studies),** each of which is accompanied by audio-visual documentation.

The Case Study findings further indicate that the proof-of-concept technology system presented in this research, accompanying software, hardware and associated protocols developed by the author (CiiMS and ARTIMIS), constitute a contribution to the area of technologically assisted arts-based intervention in clinical settings.

An overall summary of key quantitative and qualitative indicators (shown in the following texts) contributes to the early signs and strong indications of efficacy:

Firstly, the critical quantitative indicators:

1) 90% success rate for *Supplemental Personalised, immersive Musical Experience* (SPiME) sessions: Participants would like to have further sessions. 74% scored full marks, and 16% scored between 6 and 9 out of 10.

2) Trial sessions 1 and 2 were consistent in their findings, positing a reduction in anxieties and a large effect size of statistical significance. [192]

3) Trial 1 questionnaires indicate that autistic individuals with a high preference for musical activity scored highly during the trials.

4) The established CARS-2-HF rating and assessment were used as a basis for the author to develop assessment tools for personalised virtual reality-based participant evaluation and scoring methods **(see page 90).** For example, participants **[LHBG2G]** and **[LMG3G]**, who were each evaluated as having severe ASC symptoms in the CARS-2-HF, scored correspondingly in a VIMARS (the author's) system.

5) The pre-and post-test scores for trial sessions 1 and 2 (VIMR-Q1/Q2) demonstrated an improvement in areas of fear and sense of presence. [193]

6) Pre and post-test scores for trial session 3 (IND-2) showed a significant improvement for participants in their fear of heights. [194]

7) The assignment of personalised media assets (implemented into each VR music scene by the author), such as photos, videos, and musical elements for a participant's ViMRI (based on their profiles), facilitated and prolonged their engagement: a noticeable improvement in social interaction through choice. [195]

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[192] Trial session 1 (VIMR-Q1) anxiety p-value 0.000000055805839, effect size = 0.84941 (large), $p < .01$
Trial session 2 (VIMR-Q2) anxiety p-value 00000001.6883, effect size = 0.8701400 (large), $p < .00001$

[193] Trial session 1 (VIMR-Q1) pre-test score 26.39, post-test score 28.59 (difference + 2.20). *SD* change -1.404.
Trial session 2 (VIMR-Q2) pre-test score 25.44, post-test score 28.94 (difference + 3.50). *SD* change +1.587

[194] Trial session 3 (IND-2) Pre-test participants with a fear of heights = 11, post-test participants = 6 (difference = 4).
Trial session 3 (IND-2) Pre-test participants who did not fear heights = 7, post-test participants = 11 (difference = 5).

[195] Probability (*p*) value noted in trial session 3: IND-2 (0.003064 $p < .01$)

8) Post-test scores indicate significantly reduced levels of children's anxiety and a significant improvement in levels of dexterity. As demonstrated post-trials:

- Trial session 1 showed a reduction in anxiety of 76.5%. [196]
- Trial session 1 showed an improvement in dexterity by 43.2%. [197]
- Trial session 2 showed a reduction in anxiety of 74.1%. [198]
- Trial session 2 showed a slight improvement in dexterity by 8.1%. [199]

In addition to these quantitative findings, the author discovered many other significant **key-qualitative** indicators (demonstrated below), recorded by implementing variations of a *Virtual immersive Musical Reality Intervention* (ViMRI). The author documents these findings within the case studies of this research **(see pages 209-213 for a complete breakdown of each qualitative cluster)**. Notable key points include:

Cluster 1: Improvements in decision making (total occurrences = 48)

Children favoured creating personalised musical compositions rather than using preset songs with the system.

- Participants' logical choices are reinforced using reasoning.
- Participants make informed choices independently.

Cluster 2: Understanding and expressing emotions - Social interaction (occurrences = 48)

- Improvements in dexterity.
- Improvements in guided discovery.
- VR music promotes emotional development through immersive play (Axline, 1990).

Cluster 3: Emotional interaction (total positive occurrences = 170)

- A SPiME sparks creativity and emotional interaction. [200]
- VR music immersion offered distraction for children with hypersensitivity.

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[196] Pre-test anxiety score *Mean* = 81, post-test anxiety score *Mean* = 19 (difference – 62). 62 ÷ 81 = 76.543%

[197] Pre-test dexterity score *Mean* = 74, post-test dexterity score *Mean* = 106 (difference +32). 106 ÷ 74 = 43.24%

[198] Pre-test anxiety score *Mean* = 81, post-test anxiety score *Mean* = 21 (difference – 60). 60 ÷ 81 = 74.074%

[199] Pre-test dexterity score *Mean* = 74, post-test dexterity score *Mean* = 80 (difference +6). 80 ÷ 74 = 8.108%

[200] Further testing is required to determine the effects of expressing emotions in larger groups.

- Fear of specific sounds (experienced through virtual reality immersion) is reduced via desensitisation.

Cluster 4: Rigid and repetitive behaviours (total positive occurrences = 23)

- The feeling of change (i.e., positioning of objects) within a VR scene reduces feelings of anxiety.
- Personal preferences within a VR music environment promote familiarity.

Cluster 5: Rigid and repetitive behaviours (total positive occurrences = 158)

- Simulation provides a level of realism to encourage somatosensory perception and sensorimotor processing.
- Participant exposure to a favourite image via personal media (based on their profile) within the VR music environment improves emotion.

The qualitative analysis findings made by the author show that children with an ASC (involved during the SPiME and trial sessions) demonstrated notable improvements in specific areas. The findings indicate that this proof-of-concept technology system is promising and needs further development. This first section acknowledges the writer's original intentions to question 3:

iii. Can immersive music realities influence improvement in people with an autism spectrum condition (ASC) and other neurodiverse conditions?

NOTE: The author highlights week 6 (see pages 320-323 specifically) with participant [MMG3S] as an example (that is indicative) of this system's virtual exposure desensitisation.

Millie's **[MMG3S]** cautious engagement with an authentic hand-dryer was made entirely possible through virtual exposure therapy desensitisation techniques. Desensitisation was achieved by random simulated sounds and repeated patterns of presentation within the music VR via the ARTIMIS system **(see Case Study 5: Managing hypersensitivity in ASC, pages 155-159).**

Subject **[LMG4P]** improved his sense of awareness and ability to express himself verbally and physically; these improvements were ameliorated and encouraged through his virtual physiological responses.

> ***'[]…with others doing this, he could join in, but not independently. …or being so happy.'*** **Teaching assistant response, 2021**

5.1.1 Evaluation of Functionalities: ARTIMIS and CiiMS

Qualitative and quantitative evidence in the findings demonstrate a significant benefit when using the '*Assisted Real-time Three-dimensional Immersive Musical Intervention System'* (ARTIMIS) together with the *'Creative immersive interactive Musical Software'* (CiiMS) application and adhering to a newly developed ViMRI protocol through a (consistently led) SPiME programme, within a familiar setting.

Although, as previously stated, some statistical probability values were indicatively low, their effect sizes implied a greater statistical significance. The SPiME session findings support these, as seen in observations and outcomes analysis **(see page 208, Table 61 for an example).** There is compelling evidence of possible effect within several divergent areas.

The proprietary system achieves this through a user experience that incorporates one-to-one (participant and caregiver) interaction. This setup promotes a shared experience whilst delegating complete control of the session to the presenter or caregiver. People with an autism spectrum condition vastly prefer familiarity (sameness); hence, the design of the supplementary intervention uses established technologies. As outlined in the literature review **(see page 13, for example),** virtual realities are proven to provide a safe space for autistic individuals and encourage a better understanding of other people; this impacts positive communication in real-world scenarios. Furthermore, virtual environments are more sympathetic toward an autistic individual's fervent dislike to change — digitally warming towards recognition.

Through research conducted by existing play and music therapists who established the optimal design of "a soothing counselling space" (Pearson, M., & Wilson, H., 2012), the author conducted many interviews with a diverse range of clinical (and non-clinical) professionals **(see pages 68-69** and **Appendix I)**. The resulting discussions contributed to the author’s design of the personalised individual virtual experience using the interviewee’s advice; to base the VR experience upon a participant's unique profile.

From a more technical perspective, the *Assisted Real-time Three-dimensional Immersive Musical Intervention System (*ARTIMIS) facilitates improvements in dexterity, behaviour, and preferences (likes and dislikes) through musical participation. A customisable and fully interchangeable haptic-touch capacitive physical interface prompts individuals to manipulate sounds and create new sonic ideas — whilst providing real-time sensory interaction. Accompanied by the *'Creative immersive interactive Musical Software'* (CiiMS), which has also undergone continued development and refinement throughout this research, the software interface complements the hardware setup offering instantaneous recording (of audio material) and playback of "user-specific samples" tailored to a participant's unique individual session. The author's custom-developed CiiMS software interface encourages turn-taking via group participation or solo experimental recording through an instantly familiar and counterintuitive user interface. In addition, the availability of CiiMS on cross-platform and mobile devices; offers future expandability and prospective development.

However, the author's most significant breakthrough in the software interface (which has undergone its preliminary large-scale testing throughout this research) is the innate ability to integrate seamlessly through customised multidimensional and multi-input sources — using the existing (and widely available) MIDI Polyphonic Expression protocol (MIDI Association, 2018). MIDI is the digital "developers standard" for musical data specification and has supported the author in implementing musical VR activities within the virtual reality (simulated) environment.

In terms of supporting children with fears and their social interactions, a gradual approach to virtual exposure intensity and duration of the audio presentation was achieved using the author’s bespoke software and hardware interfaces. A locally-based information technology setup (deployed within an educational network environment) required high-security measures to implement this research. Resultingly, the remote capabilities of a virtual musical interface were successfully hosted — operating on a cloud-based infrastructure **(see page 77, section 2.5: Stage 3. Implementation).** The successful developments point toward further future testing of remote capabilities for clients and caregivers — using a virtual musical supplementary intervention.

Evaluations of the functionalities of the system (ARTIMIS and CiiMS) present strong relationships and early indications that support the author's intentions for question 2:

> **ii. Can the introduction of a local or remotely guided cloud-based immersive musical environment complement established therapeutic processes for specific types of intervention?**

5.2 Contributions to The Field

The following contributions in music and neurodiversity have collectively resulted in the design and application of a new mixed reality technology to facilitate musical intervention for children with an ASC. The author's achievements include:

i) **ViMRI:** Development of a *Virtual immersive Musical Reality Intervention (ViMRI)* protocol consisting of six administrative alternatives **(variants *a-f* respectively; outlined below).** A ViMRI variant may be presented as a single activity (e.g., *a*) or as a combination of more than one activity from the following list:

   a) Real-time group composition and interaction
   b) Real-time solo composition and interaction
   c) Individual investigation through a personalised, immersive experience (*in-vivo*)
   d) Individual investigation through a personalised, immersive experience (*ex-vivo*)
   e) Virtual Exposure (VE) to musical fears (*in-vivo*)
   f) Real-time group composition using immersive virtual playback

ii) **SPiME:** Introduction of a *Supplemental Personalised, immersive Musical Experience* (SPiME) programme and protocol delivered over six consecutive weeks. Individual sessions of a personalised music programme allow consistent presentations to groups of high-functioning autistic individuals within a special educational needs and disabilities (SEND) environment.

iii) **Development of two-stage real-time recording processes:** Alpha (**α.**) and Beta (**β.**) **(see diagram on page 98)**, capturing musical samples via physical gestures and vocal interactions.

iv) **ARTIMIS:** The *Autism Real-time Three-dimensional Immersive Musical Intervention System'* builds upon the author's eight years of continuous development and refinement. A unique proprietary virtual interactive music system featuring a fully functional physical user interface with multi-directional, multi-level touch response and tactile-haptic feedback.

v) **CiiMS:** *The 'Creative immersive interactive Musical Software'* application (CiiMS [*pronounced Sims*]) is a virtual software interface and transferrable tool that comprises a 16-segment-coloured roundel; to support people with neurodiverse conditions.

vi) **Testing remote capabilities for a cloud-based infrastructure:** A virtual musical interface through a *Conceptual Virtual Reality Streaming Musical Environment* mode to facilitate the potential for future physical interaction between a remotely-based caregiver and client (i.e., interacting and navigating around objects within a virtual music scene).

vii) **New evaluation and assessment outputs:** The following research outputs, scales and measures were conceived as a result of this study and formulated specifically for a *Virtual immersive Musical Reality Intervention* (ViMRI):

- VIMR-Q1 preliminary-test questionnaire and joint assessment form explore personal preferences and establish a personalised individual profile. VIMR-Q1 has derived from the transactional, family-centred approach to enhancing children's communication and socioemotional abilities with ASC (Prizant *et al.*, 2003).

Their peer-reviewed SCERTS® assessment process is a reliable multi-disciplinary framework supporting therapeutic experiences to strengthen the socioemotional activities of an autistic person.

- VIMR-QPC assessment psychometric test and questionnaire for parents and carers modelled on widely accepted CARS-2-ST and CARS-2-HF rating methods (WPS).

- VIMARS 1 and VIMARS 2 *Virtual Immersive Autism Ratings Scales* 1 and 2. Preliminary and secondary post-completion bi-directional (two-way) digital scoring evaluation surveys detect the severity of symptoms modelled with associated CARS-2-HF criteria.

- *3-Stage Technical Development Process* (3S-TDP) — a tri-stage systematic approach consisting of nine events in stages: Stage 1 research, Stage 2 development, and Stage 3 implementation **(see page 65).** Each stage is guided by individual events that arrive at optimal research outcomes. Examples include:

    - Determining preliminary design concepts for prototyping a virtual immersive musical interface.

    - The interview process comprises formal meetings with individuals from clinical, educational, creative, and academic fields to formally appraise design alternatives.

    - 3D virtual reality models, including stylistic realisations, mood lighting and sensory environmental lighting.

    - Incorporation of virtual MIDI, MPE and OSC protocols.

5.2.1 Comparison Grid Revisited

Principally introduced by the author in the methodology chapter **(see page 52),** the original Comparison Grid aims to "fill the gaps" of currently unsupported virtual and musical technologies for clinical applications by comparing existing Digital Audio Workstations (DAWs) within the neurodiverse paradigms. The Comparision Grid verifiably demonstrates areas of existing and further investigations conducted throughout the research study, each supported by the immersive virtual music technology system. The bespoke hardware and software interfaces applied using a ViMRI protocol (administered through a SPiME programme to children with high-functioning autism spectrum conditions) are contributions (however small).

These approaches facilitate effective engagement when using a technologically mediated musical intervention. The author addresses the original intentions of question 1, which states:

i. **What approaches can effectively facilitate engagement with technologically mediated musical interaction in immersive environments?**

An updated version of the Comparison Grid following the author's research is presented on the following page.

Revisited comparisons: DAWs, ARTIMIS *and CiiMS (link to the previous version)*.

Part 1:
Existing technologies versus virtual immersive music technology applications

		Digital Audio Workstations (DAW): configurations and applications			OUTCOMES OF THIS THESIS: VR Immersive music technology interface and applications	
		Dedicated Studio DAW	**Computer DAW**	**Portable DAW**	**ARTIMIS©**	**CiiMS ©**
Standard components	Display (Qty)	● (1)	○ (2+)	● (1)	● (1) VR	○
	Professional audio interface	●	●	○	●	–
	MIDI (2.0)	●	○ Custom	○	● MIDI MPE	● MIDI MPE
	OSC	–	○	●	●	●
	Keyboard	○	○	●	SENSEL (Haptic touch)	Retinal VR/OSC
	Mixing console	●	●	●	○	●
	Monitoring (external/Internal)	○	○	○ Laptop Speaker	Induction VR surround	External via ARTIMIS
	Display interface	●	○	●	Multi-touch haptic interface	○ Tablet/mobile
Neurodiverse applications/ Profiles	Studio	●	●	●	●	●
	Mixing	●	●	●	●	●
	Mastering	●	●	●	●	●
	Live performance	●	●	●	●	●
	Electronic music production	●	●	●	●	●
	Rehabilitation	x	x	x	●	●
	Clinical	x	x	x	●	●
	SEN (Special Educational Needs)	x	x	x	●	●
	Remote access (online / cloud)	●	x	x	●	●
	Telehealth	x	x	x	●	○
Features	**Virtual Reality music**	x	x	x	●	●
	Wi-fi connectivity	●	–	●	●	●
	Bluetooth	●	●	●	●	○
	Portability	–	–	●	●	●
	Networking	●	●	●	●	●
	Virtual Studio Technology (VST)	●	●	○	●	○
	Group music sessions	●	○	○	●	●
	Rack-mounted	–	●	–	–	–
	Small footprint	–	●	●	●	●
	Realtime improvisation	–	–	●	●	●

Part 2: Advantages of virtual music technologies

	VR Immersive music technology interface and applications
Advantages within the context of clinical and special educational needs applications)	Portable system and remote intervention for special educational needs and disabilities domains
	Rapid real-time recording and retinal control
	Gaps in the field that are currently unsupported in DAWs have been identified throughout this research study
	Proof of concept expandable into many other spheres
	Supported by a programme of educational presentations via a SPiME

Key:-
● Standard or compatible feature
○ Optional feature
— Not available/applicable
X Gaps in the field (currently unsupported for this application): areas investigated by this research

5.2.2 Study Limitations

The following section of this conclusion is the author's critical reflection on the areas and shortcomings of this study. Some unique key constraints discussed include:

- Significant impacts of the study, emerging during a global coronavirus pandemic.
- Interviews and discussions with music therapists yielded scepticism surrounding a technology-based music system.
- Alternative presentation methods for VR — wearing a head-mounted display.
- Limitations and accessibility to information technology (IT) security infrastructures.

The author proceeded with caution upon encountering disruptions caused by the unexpected worldwide coronavirus pandemic. All necessary conceptual developments and technologies to roll out the author's intentions to conduct trials did not materialise in time. Many issues relating to evolving technologies (i.e. mid-air haptics), remote infrastructure, and high bandwidth were still emerging and in their infancy.
An incomplete solution required a concerted effort towards achieving a solution given a limited timescale for the deployment to test a working prototype. Configurations of virtual audio using existing Open Sound Control (OSC) and virtual MIDI Polyphonic Expression (MPE) specifications, formed essential requirements for connectivity and scalability.

The pandemic imposed excessive strain on medical trusts, universities, and educational institutions, causing a delay in established collaborations. Consequently, the development and arranged trials required to gather data analysis results were significantly impeded. Health and safety, risk assessments and ethical approval were all suspended until the uncertainty of lockdown had eased.

More positively, however, these disruptions brought their advantages. Each offered a unique opportunity to develop a virtual reality software interface with remote features — than was initially expected. The author adapted new computer technologies and programming skills to code blueprints for communication with open sound control (OSC) protocols via MIDI programming **(see Appendix F)**. This unprecedented (pandemic) scenario enabled Stelios **(see**

Acknowledgements) to fully engage daily with the research. Stelios became influential in the research and development of the immersive software interface and the author's guidance — something that would not be possible under normal circumstances.

5.2.2.1 Music therapist criticisms

The qualitative collection of elicit research data during the early stages of the author's investigations yielded some criticism — particularly during the interview process (discussed in the next part of this conclusion). Professionals in select research and development areas helped guide the success and development of a proof of concept for qualitative research further down the line.

The author believes that any researcher's responsibility should consider both negative and positive feedback (i.e., first-hand), mainly when obstacles cannot always be observed with clarity. The music therapy community was the most sceptical group, showing concern regarding a digital virtual musical intervention device. Feedback from this group suggested that a technologically mediated intervention would add a layer of complexity to the therapeutic process. Sharda *et al.* (2018) justifiably point out the values of music therapy throughout their review. The author acknowledges that the active and receptive characteristics associated with a high level of musicianship require many years of training at the postgraduate level. [201]

5.2.2.2 Limitations of realistic VR development

Virtual reality animation and scene development necessitate a high degree of computing power required at a cost. Often this requires multi-core processors coupled with high-capacity random access memory (RAM) to meet the requirements of a VR-capable machine. For this study, the author utilised an integrated (commercially available) (Meta, 2022) VR headset to present 18 individually personalised ViMRI experiences. The development process is time-consuming and requires a separate source build of the Unreal Engine version (*Epic Games*, 2019) **(see Appendix F: Development).**

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[201] Two-thirds of music therapist's who were interviewed by the author, asserted a preference for more traditional methods and instruments instead of a self-contained virtual technology session.

This study utilised android-studio SDK version 3.5.3 (Google Developers, 2019). [202] Additionally, a cloud-based installation requires a C++ software server script and associative editor target files to deploy the runtime version successfully. [203] Vast amounts of storage space to compile, package and develop each VR session equates to 135GB (gigabytes) in file size; 500MB (megabytes) of allocated storage space should be available for each build on a VR headset.

High specification standard protocols for third-party computer hardware are developed by NVIDIA (2022). Their guidelines ensure that VR development for real-time rendering engines such as Unreal Engine (*Epic Games*, 2019) and Unity Pro (*Unity Technologies*, 2021) provides the developer and end-user with a rich and immersive experience.

The author's determination to develop the ARTIMIS system using an integrated development environment (IDE) such as Unreal Engine 4 (*EPIC Games*, 2019) rather than Unity or other alternative IDEs offered significant benefits to the speed of development for this project. Cutting-edge animation tools and trigger events were conceived by casting Blueprints (snippets of code) to the assets (objects) to create events — perfectly suitable for virtual immersive musical experiences and generative installations. Interactive assets were animated using the Unreal Engine 4 cinematics and matinee tools; objects were triggered by exposing variables within a blueprint.

In the context of immersive VR development, implementing proprioception and multimodal feedback positively impacted the children in the trials. Furthermore, synthetic feedback would undoubtedly be a welcome addition to musical applications to support therapeutic, rehabilitative, and creative applications. The prototype attributes of this system recognised the need for an expandable portable and modular offering — where accessibility for individuals in constrained healthcare settings can be restricted.

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[202] Android studio version 3.5.3 windows IDE version is required to deploy an executable target file to the Oculus Quest 2 VR headset. 64-bit version 191.6010548-windows 3.5 December 5, 2019 Available at: Link to source

[203] C++ Script files are required to upload the target source file onto a virtual machine hosted on a cloud platform such as Amazon AWS.

In addition to the technological virtual reality limitations, more fundamental issues exist when presenting VR as an individual activity or to larger groups of people. The study has informed characteristics evident to those with an autism spectrum condition or neurodevelopmental disorder, including:

- Children cannot always wear a VR headset for extended periods and require regular intervals between sessions.
- Group session participation is restricted with a VR headset — requiring an external display or network with a reliable, secured connection.
- The prevalence of epilepsy amongst autistic individuals (with clinical diagnosis or symptoms) indicates that in-vivo experiences are unsuitable.

Ordinarily, these are features associated with VR and its applications; however, the future development of ARTIMIS hopes to counter these issues through the *Conceptual Virtual Reality Streaming Musical Environment* model and alternative 3D projection technologies (HYPERVSN, 2022).

Fundamental information technology (IT) and security issues required further investigation by the author for the ViMRI to be more accessible. Week two of the SPiME was held within a SEND school setting and emerged as chaotic **(see Appendix H).** During setup, the author experienced issues with the virtual reality casting (i.e., connecting and sharing the experience with other participants) through the school's wireless wi-fi network infrastructure. Security issues prevented the schools' wireless network from discovering the VR equipment, and consequently, the HMD was disconnected from a large interactive display screen for the group to see. The author used alternative methods to present the experience and rotated the group activities around each child to keep them entertained and consistently participating.
As a contingency, a third-party Chrome (Google, 2019) casting device for the VR music session allowed the exercise to become accessible again.

Qualitative and quantitative data collected from 18 individuals provided a dataset of unique characteristics; these generalised the results (skewed heavily to a demographic of high-functioning autistic children) and did not reflect the broader population. Nevertheless (despite these limitations) and beyond the factors, there lies a certainty and need to develop this early stage further and provide a foundation for future resources.

5.3 Next Steps: Future Discussions

The author makes the following brief recommendations to take this research further into future studies.

Current management approaches for people living with ASC, such as music therapy, are linked closely to those of VR and the outcomes of using a supplemental immersive music technology device. Considering these, the author believes there are two very plausible options moving forward: either there is room for expansion to include VR in the existing and established approaches or the need for a multi-disciplinary approach.

VR is currently not being used in music therapy. One example of a successful embedded Virtual and Augmented Reality resource delivered to students providing effective interaction and active learning in educational environments is Class VR (Christou, 2010; Avantis Systems, 2017). One of the recommendations is for a multi-disciplinary approach to upskilling professional practitioners who work with people with ASC to integrate a ViMRI into their regular practice or to work alongside specialist VR practitioners. The advancement of VR, its associated web technologies (since the early investigations of this research), and cost reductions have given cause for remote-based virtual reality classrooms and educational content.

Learning through an established VR system provokes discussions amongst children of varied abilities and impacts children and students to consider their own experiences. Furthermore, virtual reality immersion enables an in-depth understanding of the curricular topics. The potential of a remotely-based musical system such as ARTIMIS and CiiMS could undoubtedly be used in less traditional classroom settings for home-schooling (by informal educators and parents). Music lessons and creative composition through a customised curriculum could offer accessibility to all levels of the educational system in the UK, including early years education, preschool, primary school, secondary school, and higher education.

The most significant attribute that sets this system apart from others previously mentioned is the utilisation of a customised user interface. Future (longer-term) administration of a SPiME within alternative educational systems will open up opportunities for testing a ViMRI with children of varying abilities and other ASC traits.

Many significant technical, clinical, and commercial obstacles are currently restricting the potential to introduce this proof-of-concept into ASC domains. Examples include:

- Funding for cutting-edge technology and equipment to develop a haptic interface.
- Qualified patent attorneys to obtain Intellectual property for patents of individual technologies.
- Freedom to Operate (FTO). IP and patent file protection are only in clinical and educational (SEND) applications.
- Funding to employ healthcare, specialist professionals, or outsourcing may not be part of the network of collaborators (for example, additive manufacturing; prototype materials such as specialist carbon fibre materials).

The risks proposed for future research are significantly mitigated when a wealth of experienced, accessible contacts and support networks (see following bullet points) are available to reduce development costs where strategies are in place:

- An extensive network of academic professionals
- Expressions of interest from NHS Trusts to assist with future trials and protocols

5.4 Concluding Summary

Since early research commenced in 2018, the project pace has rapidly advanced and Virtual Reality Musical Interventions (VRMIs) have (remarkably) remained in their infancy. Higher functioning individuals with neurodevelopmental conditions presented in this study have shown a restricted preference for wearing HMD equipment over extended periods. The author notes that VR nurtures positive behaviour patterns and encourages sameness to facilitate a child's musical engagement. These findings support autistic individuals in investigating new concepts, ideas, and compositional methods.

Introducing autonomous, virtual, and mixed music realities — delivered as clinical interventions within medical settings — would offer economical and viable solutions. The Nottingham University's NHS Trust (NUH) has a dedicated and established research infrastructure to deliver large-scale VR studies and raised an expression of interest. NUH believe trials could be configured remotely to relay data from a virtual user interface and indicate whether any significant cost reductions could make a viable and effective (direct) intervention. To achieve this proposal, real-world testing and patient and public involvement are essential.

A multi-player (or larger group VR) setup allowing multiple participants to connect to a single session remotely and interact individually with a caregiver requires further testing. The author has approached clinical organisations keen to investigate the possibilities of a technologically facilitated immersive musical intervention for various healthcare applications.

This research points to further developing a ViMRI concept and expanding it into different spheres. Continuous research of a multi-faceted and fully working 'proof-of-concept' will no doubt require granular analysis to reinforce further studies with larger sample sizes. Results from this study hope to guide future investigations and evaluate the impacts of administering a newly developed technologically mediated musical intervention.

With clinical and professional support, expertise and future financial investment, the author credibly foresees a version of his fully working "patient ready" and "clinically tested device" (if backed by expert collaborators) is achievable within 3-4 years of this research date (October 2026). A prototype device with a cloud-based software infrastructure evolving from the outcomes of this research will pioneer the breakthrough of a supplemental virtual musical intervention to accompany already existing (and accredited) therapies within the UK. [204] Currently, there is an absence of any similar technological device that competes in clinical (neurodiverse), creative, or educational spheres.

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[204] Existing accredited therapies refer to music therapy, psychodynamic therapy, cognitive behavioural therapy and exposure therapy.

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APPENDICES

Appendix A.

Research Consent

Participant Consent Forms (Parent and Caregivers)

Canterbury
Christ Church
University

PARTICIPANT CONSENT FORM [FORM 1]

Title of Project: **A technologically facilitated Virtual Immersive Musical Reality Intervention (VIMRI) for educational, clinical and creative applications.**

Name of Researcher: Christos Ioannou - principal investigator

Contact details:

Address:

Faculty of Arts and Humanities,
Canterbury Christ Church University,
North Holmes Road,
Canterbury,
Kent,
CT1 1QU

Tel: **01227 767700**

Email: **c.ioannou54@canterbury.ac.uk**

Please cross initial box

1. I confirm that I have read and understand the participant information form **[form 3]** for the above project and have had the opportunity to ask questions. ☐
2. I confirm that I would agree to any audio and/or visual recordings (backs of heads only). ☐
3. I understand that any personal information that I provide to the researchers will be kept strictly confidential and in line with the University Research Privacy Notice ☐
4. I understand that my child's participation is voluntary and that they are free to withdraw their participation at any time, without giving a reason. ☐
5. I agree for (name)______________________________to take part in the above project. ☐

Name of Child Participant:	Date:	Signature:
Name of person taking consent:	Date:	Signature:
Researcher:	Date:	Signature:

Copies: 1 for participant 1 for the researcher

Special Educational Needs Letter of Consent

Canterbury
Christ Church
University

PARTICIPANT CONSENT FORM [FORM 2]

Title of Project: **A technologically facilitated Virtual Immersive Musical Reality Intervention (VIMRI) for educational, clinical and creative applications.**

Name of Researcher: Christos Ioannou - principal investigator

Contact details:

Address:

Faculty of Arts and Humanities,
Canterbury Christ Church University,
North Holmes Road,
Canterbury,
Kent,
CT1 1QU

Tel: **01227 767700**

Email: **c.ioannou54@canterbury.ac.uk**

Please put a cross in the box

1. I have been told about the project and understand what it is about. ☐
2. It would be ok for the back of my head and music to be recorded in the session ☐
3. I understand that I can leave at any time, without giving a reason If I do not like the session. ☐
4. I agree to take part in the project ☐

Name of Child Participant:	Date:	Signature:
Researcher:	Date:	Signature:

Copies: 1 for participant 1 for researcher

LALEHAM GAP SCHOOL
Ozengell Place, Ramsgate, Kent CT12 6FH
Tel: (01843) 570598
Email: secretary@lgs.kent.sch.uk
Website: www.lgs.kent.sch.uk

13-12-21

To Whom it may concern,

We are happy to confirm that any video or media footage of the participating children (including images), that are created in the Virtual Immersive Musical Reality (VIMR) trials for Mr Christos Ioannou can be used with full consent.

This has been agreed in writing by the parents / carers who have each signed a participation form—prior to the trials commencing.

Kind regards

Mrs K Reeves
Deputy Head

Appendix B.

Data Collection Form

Participant Questionnaire: Form VIMR-Q1

Canterbury
Christ Church
University

PARTICIPANT QUESTIONNAIRE FORM [FORM VIMR-Q1]

Title of Project: **A technologically facilitated Virtual Immersive Musical Reality Intervention (VIMRI) for Individuals with Autism Spectrum Disorder: feasibility study.**

Please write your name:		
Which group are you part of?	**1 / 2 / 3 / 4 / 5**	000
Date:		
1.1 Musical Preferences		
What is your favourite song?		001
Do you like to sing?	Yes / No	002
Do you play any musical instruments?	Yes / No	003
If Yes, what do you play?		004
Who is your favourite singer?		005
Do you like to make your own music?		006
What is your favourite instrument?		007
1.2 Virtual Reality (VR)		
Do you know what Virtual Reality is?	Yes / No	008
Have you ever used Virtual Reality (VR)?	Yes / No	009
Do you wear glasses?	Yes / No	010
Would you wear a VR Headset?	Yes / No	011
1.3 Animals and Pets		
What is your favourite animal?		012
Do you have a pet?	Yes / No	013
If Yes, what kind of pet is it?		014
If Yes, does it have a name?		015
1.4 Hobbies		
Do you have something you really like? A special interest?		016
1.5 Colours		
What is your favourite colour?		017
1.6 Geometric Shapes		
What is your favourite 3D Shape?		018

2.1 Phobias		
Are you scared of any of the following?		019
Hand Dryers		019A
Balloon Popping		019B
Loud noises		019C
Buzzing noises from lights		019D
Coffee machines		019E
Afraid of heights (Flying or being on a bridge)		019F
The water (at the seaside)		019G
Flashing lights		019H
Falling		019J
What other sounds might make you jump?		019K
2.2 Change		
What changes would make you unhappy?		020
3.1 Technology		
Do you have any of the following: Games PC PlayStation XBOX Nintendo SWITCH Mobile phone Tablet VR Headset		021 021A 021B 021C 021D 021E 021F 021G

Appendix C.

Participant Requirements

Participant Information Form and Trial Study Information (Form 3)

Technologically facilitated Virtual Immersive Musical Reality Intervention (VIMRI) for educational, clinical and creative applications.

PARTICIPANT INFORMATION [FORM 3]

A research study is being conducted at Canterbury Christ Church University (CCCU) by ***Mr Christo Ioannou (Principal Researcher)***

Please refer to our Research Privacy Notice for more information on how we will use and stor your personal data.

Background

The main aim of this study is to produce a working prototype 'virtual and immersive musical device' that will be used to find out what kind of approaches can effectively help high functioning autistic people engage with musical and virtual interactions to improve their social and behavioural wellbeing.
This will be achieved by immersing the individuals within a Virtual Musical Reality setup (VR).

The Study will introduce new unseen physical and virtual music technologies into therapeutic, educational and creative settings to find out if these music technologies can improve the lives of people with Autism Spectrum Disorder (ASD) and People with Dementia.

This is an unfunded research project in collaboration with Laleham Gap School who have agreed for a group of students to participate in this study.
All Ethical clearance and Risk Assessments have been institutionally approved (evidence of this can be provided upon request).

What will you be required to do?

Participants in this study will be required to attend a series of six Virtual Music Reality sessions at Laleham Gap School over a minimum period of 6 weeks. The sessions will introduce them to the principal researcher (Mr Christos Ioannou), to ensure they are familiar with him before continuing with further sessions.
Christos has previous experience in running sessions at Laleham Gap of a similar nature and has also served as a classroom assistant at Palm Bay Primary school. As part of safeguarding, the school has
agreed to provide two Teaching Assistants with whom the children are familiar.

The research itself will be non-invasive and will include the voluntary use of a domestic Virtual Reality Headset that adheres to commercial Health & Safety Guidance as set out at oculus.com/warnings. The main study will also include an interactive whiteboard for those Individuals who do not wish to wear the headset. This gives those an alternative to view the virtual world on a larger interactive screen (as used by Laleham Gap in traditional teaching settings).
The teaching assistants (TA's) will be able to monitor all interactions in class and while a headset is used, they will be able to monitor the virtual reality activity through the large interactive screen.

A classroom layout image will be provided once the individuals for this study have been recruited and given to each individual 1 week before the first session. Positioning of students, TAs and the large interactive screen will be clearly laid out. TAs will observe the classroom

sessions and screen activity to ensure clarity of the setup and avoid confusion.
The parent/carers of the child are encouraged to show this setup to the pupils to avoid any element of surprise.

All clinical and personal information for these sessions will be securely stored within a folder with password protection and backed onto a secured data location.

The sessions are outlined below:

Session 1: Virtual Immersive Music – An introduction
Participants will meet Christos for the first time in a classroom assigned by Laleham Gap School who will be accompanied by the Teaching Assistants (TBC). The session aims to introduce electronic music and traditional instruments (such as a violin). This session is a taster session for the children
to familiarise themselves with Christos and allow the children to have a play with musical instruments! The session will last for no longer than 20 minutes.

Session 2: Interests: What do you like?
Participants will meet Christos for the second time in the classroom/space previously used for session one (assigned by Laleham Gap School). Participants will be accompanied by the same Teaching Assistants (TBC) as session one to ensure likeness and familiarity. The second session aims to find out more about the child's interests (their likes and dislikes). The child will be asked to draw a picture of their choice and this will be used as a 3D image for their own customised virtual world. The session will last for no longer than 20 minutes.

Session 3: First Exploration of VR (VIMR)
Participants will meet Christos for the third time. The third session aims to introduce (for the first time) an immersive musical environment and instrument that the children
can interact with. Each child will be encouraged to explore the virtual world and participate on a large interactive screen using an iPad/tablet or keyboard to navigate around the scene to play musical games, listen to relaxing noises of birds and immerse themselves in a virtual sensory room.
The session be expected to last between 25-30 minutes. And all safeguarding has been secured

Session 4: Virtual Play
Participants will meet Christos for the fourth time to expand on their knowledge of VR and immersive music. This session aims to design an individual session for each child by gathering their preferences based on their questionnaires and discussing with Christos what they would like to see within their own virtual world. The session will last no longer than 15 minutes and will be a 'one-to-one' basis with the support of a Teaching Assistant. All Safeguarding for this session will be secured and General Data Protection Regulation (GDPR) will be observed.

Session 5: Virtual Immersive Music – Customised Immersive Experience (Exposure Therapy)
Participants will meet Christos for the fifth time to immerse themselves in their, by now, customised immersive musical environment. This session aims to study how the individuals respond to their preferences whilst introducing some triggers in the form of images or sounds via exposure therapy.
This session is designed around the practises of Behavioural and Exposure Therapies to determine how (in relation to the child's triggers) will be introduced. The TA together with

display) or on an interactive whiteboard. The session will be in 2 parts consisting of 8 minutes each with a 5-minute break in between. The session be expected to last 21 minutes and likely to be on a one-to-one basis with the support of a TA.

Session 6: Virtual Immersive Music – Exit Interviews and questionnaires
Participants will meet Christos for the sixth time to immersive themselves in their customised immersive musical environment. This session aims to study how the individuals respond to their preferences whilst introducing any phobias or sounds via exposure therapy.
There will be two options for either a full immersive VR experience: using a head-mounted display, or using an interactive white-board. The session will be in 2 parts; consisting of 8 minutes each with a 5-minute break in between. The session be expected to last 21 minutes and likely to be on a one-to-one basis with the support of a TA.

For each of the above mentioned sessions, informed consent of the following is required by the parent/carer and the child:

1) Interaction with a virtual scene; images will be displayed on an interactive whiteboard.
As the child becomes familiar with the scenery, they can progress to using a headset if they wish. The upgrade to the headset is entirely voluntary. The headset will be an Oculus Quest 2 branded device, featuring eye blockers (rubber surrounds) complete with various sized interchangeable soft foam facial interfaces (to protect the child's cheekbones). The Headset is fully adjustable to fit many sizes and will be provided with a premium head strap. The unit will be sanitised between each child's use via alcohol based antiseptic cleaning solution and sufficiently dried before next use.

2) Participants will be asked to draw a picture of their favourite interest and will be asked what they dislike to serve as a basis for exposure therapy (in the virtual environment).

3) Participants will be asked to listen to music of their choice. The music or sounds will be gradually introduced; starting at a low volume level and presented on professional quality closed-back headphones with a built-in sound limiter.

4) Participants attendance for each session will be no longer than the specified time of each session (above). Children are free to leave at any time.

5) Children will be asked to participate in a group of no more than 6 in a room with Christos and Teaching Assistants.

6) Audio from the sessions will need to be recorded to use for documenting this research, solely for the use of this project only.

7) Consent for video evidence of one short recorded session (1 minute clip) that would be captured backs of heads and audio will be recorded for research purposes only.

<u>To participate in this research, you must</u>:

- Have a diagnosis of an Autism Spectrum Disorder.
- Attend Laleham Gap School.
- Be between the ages of 8 years and 15 years of age.
- Should **NOT** have a history or have experienced severe headaches to photosensitive lights.
- Should **NOT** have any Symptoms or a diagnosis of any epileptic related condition

Procedures

Children will be asked to complete an online questionnaire (a paper-based version will also be available). Sessions will be presented on site at Laleham Gap School, during normal school hours. Participants will be asked about their likes and dislikes to help produce a customised virtual world.

This information will be used to compile a customised virtual world where they will be able to experience for themselves to help them musically express their emotions and generally have a great time having fun!

Feedback

The final session will ask participants to complete or write about their experience and this will be used to gather vital information about the research. Feedback forms will be sent to the parents/carers participants prior to completing to ensure their child would be happy with the content.

Confidentiality and Data Protection

The following categories of personal data (as defined by the General Data Protection Regulation (GDPR)) will be processed:

- Gender
- Age
- Diagnosis
- Social Skills
- Communication Ability
- Phobia or fear

We have identified that the public interest in processing the personal data is:

- It is necessary for the processing of such personal data to obtain quantitative and qualitative results to determine the ranges of efficacy (effectiveness) and how this study effects social interaction when immersed in a technologically mediated musical system . Personal data will be used only by the principal researched to gather data. For the purposes of any written academic documentation of future publishing of papers, names will not be used (Student A,B,C etc.).

Data can only be accessed by, or shared with:

- The principal researcher and the University. Christos Ioannou can access the data inside the organisation; and any co-researchers; however, the parent/carer would be contacted prior to any data being used for other than this specified trial. In addition, supervisory and examiner led access will be required as a minimum. Third party organisations may be contacted (with your consent) to examine results of this trial, however they may not share the data. No data will be transferred outside of the European Economic Area (EEA).

The identified period for the retention of personal data for this project:

The length of time personal data will be kept for will be no longer than 6 months from the end of the PhD study that is currently due to finish around September 2022. For the purposes of data

- research. This only applies to personal data and may be different from the retention period for other research data.
  Where such data is required for other external purposes, permission from the parent / carer will be requested by Mr Christos Ioannou.

If you would like to obtain further information related to how your personal data is processed for this project please contact Mr Christos Ioannou, c.ioannou54@canterbury.ac.uk

You can read further information regarding how the University processes your personal data for research purposes at the following link: Research Privacy Notice - https://www.canterbury.ac.uk/university-solicitors-office/data-protection/privacy-notices/privacy-notices.aspx

Dissemination of results

Prior to commencing the trials, it is unknown, how the results of the study will be published or otherwise disseminated. The final PhD thesis will be published in the CCCU library and will be advised at the exit interview session

Process for withdrawing consent to participate

The child is free to withdraw these trials at any time, written consent of your child's participation in this research project would be advised at any time without having to give a reason. To do this the child can opt out during the session by telling their teaching assistant/teacher or Christos who would send an email to the parent/carer indicating the withdrawal from this study.

You may read further information on your rights relating to your personal data at the following link: Research Privacy Notice - https://www.canterbury.ac.uk/university-solicitors-office/data-protection/privacy-notices/privacy-notices.aspx

Any questions?

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Appendix D.

Transcripts

Individual Trial Investigation Transcript

ViMRI-d Session Transcript Participant [MMG3S]

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INDIVIDUAL VRMI TRIAL INVESTIGATION TRANSCRIPT
[FORM IND-1]

Title of Project:	**A technologically facilitated Virtual Immersive Musical Reality Intervention (VIMRI) for Individuals with Autism Spectrum Disorder: feasibility study.**

Using all the skills that the children at Laleham Gap have learned throughout the sessions (i.e. familiarity, consistency of environment and technology), this 15-minute trial has been designed to measure how successful a Virtual Reality Musical Intervention (VRMI) could be when it is utilised by supporting high functioning autistic individuals.

This Trial transcript has been divided into two parts:
Firstly, a VR headset will be used in Test 1 for a 5-minute walk-around and experimental session. This will be followed by Test 2, which utilises a specially developed musical software interface and SENSEL pad with which the child will use to create music.

Test 1.

5 minutes of Interactive VR Session using a Head Mounted Display (HMD)

Guided Discovery (5 minutes)

1. Firstly, I'd like you to walk around the scene to investigate the VR world and have a look around.
2. You will see some of your favourite images on the wall and I would like you to press the A / B buttons when you stand in front of them to change the images around.
3. On the floor, you will see some 3D shapes that we talked about and I'd like you to walk up to them. Using the hand controller grips, press each button to grab the 3D objects or ball and throw them around. You will also see a Tambourine on a table, you can pick this up or use the stick on the floor to hit the tambourine with to play a sound.
4. You would have seen the large TV screen in the room, if you would like to walk up to the screen and watch your favourite song!
5. On the wall side near to the TV, you will see some musical notes, press the bottom MC button (Z) and this will start some more music.
6. Walk up to the bubbles and get into a comfortable position, I would like you to stand there and just listen look around.

Phobia (1 minute)

1. Once everything has stopped, I'd like you to walk around the corner near to the piano and you will see a poster on the wall. I would like you to press the left button and listen to the sound. Then I would like you to press the right button and listen to the sound.

Test 2.

5 minutes of VRMI using the CiiMS Instrument on a screen

Musical Interaction (5 minutes)

https://www.autismeastmidlands.org.uk/wp-content/uploads/2016/10/Musical-interaction-an-introduction.pdf

Musical Interaction is an interactive approach primarily for developing social and communication skills. It was developed AT Sutherland House in Nottingham, where it has been successfully used for autistic pupils to engage them in conversation and promote social Interaction. This version uses a technologically mediated software interface and VR environment to facilitate improvisation.

Shared Play and Fun and Choice making (5 minutes)

1. Firstly, I'd like you to choose from one of the following sample folders; we are going to have some fun playing the sounds using the CiiMS instrument. You can use the pads in any direction or pressure to play different sounds to experiment with!

    - Farmyard Animals
    - Modern Samples
    - Everyday Sounds

Joint Activity with a familiar adult to develop social relationships and turn taking

2. Using the numeric keypad, I will press a button, and I would like you to press the corresponding pad on the Instrument. If you get this correct, the pad will light up, and you will hear the same sound as I pressed.

Expression of emotion and personality through musical play/composition (5 minutes)

3. Now, let's have a go at recording some music or clapping a rhythm to record a new song When the metronome begins, I would like you to sing or clap a beat for 20 seconds. Once it has finished, we will create a new song from your recording.

Individual Questionnaire for the session

Each child will be asked a series of open-ended questions to answer for the session. The questions are weighted and will be used for qualitative data analysis to determine the results of the trial.

Transcript of VRMI -d session between Christos Ioannou and MMG3S 1/12/2021 Time 11:07am

Time	**Transcript**
2:58	**Christos:** So, Molly, if you can start walking towards the […] piano for me at the back of the room… We should be able to hear this everyone in the class, we don't need a visual… Are you there? I'm just going to turn this music off…oh there you go . Right if you just take your hands off the button and what I would like you to do is…this button at the top …press that button …So what I would like you to do is walk up to the… Can you hear that noise?
3:33	**MMG3S**: Yeah
3:35	**Christos:** What's that noise?
3:39	**MMG3S**: Erm, either a car or a motorbike …oh, I'm scared !
3:41	**Christos:** You're scared?
3:42	**Christos:** Tell me; when you listen to motorbikes, usually when you are not in the VR world, are you quite scared of motorbikes?
3:50	**MMG3S**: No, my dad takes me riding on his motorbike all the time .
3:54	**Christos:** OK, if you press the other button on the other side of the handset at the top…
3:57	**MMG3S**: Uh!
3:59	**Christos:** You should see another button opposite on the other side right at the top where you press the motorbike button [on the opposite side]; the other handset
4:10	**MMG3S**: Oh
4:11	**Christos:** So, if you press this button, that stops it and if you press this button … So, what I'd like you to do is, press that button for me when you're ready …and you'll hear a sound
4:20	**MMG3S**: OK
4:23	**Christos:** What is that sound?
4:23	**MMG3S**: Um…either a fire engine, police car or ambulance !
4:28	**Christos:** And is that a sound that you usually don't like to hear

4:32	**MMG3S** : Yeah, ambulances and [like] doctor's offices make me paranoid
4:37	**Christos:** Yeah? So, when you hear the ambulance sound? Do you get scared usually?
4:43	**MMG3S** : Sometimes yeah, especially when it's really, really loud!
4:47	**Christos:** So, listening to the sound of the ambulance and the siren in the VR world, does that make you scared?
4:54	**MMG3S** : Er, Kind of because [like] I can't really tell where it's coming from and if [like] it's going to burst into this room at any point!
5:04	**Christos:** [Yeah] But you are hearing it aren't you? you're not terrified to hear it because you are pressing the button a few times… That's [absolutely] fantastic, so what I would like to do finally, is walk up to the bubbles for me
5:17	**MMG3S** : OK
5:19	**Christos:** And I'm sorry you can't see this (…we will for the other children), are you at the bubbles ?
5:22	**MMG3S** : Yeah
5:23	**Christos:** Now if you press the button that's marked 'B' I think? or 'A'? (There you go), [if you just let go of that], Can you hear a sound?
5:34	**MMG3S** : No?
5:36	**Christos:** Can you hear some music?
5:37	**MMG3S** : Oh yeah, yeah, yeah!
5:38	**Christos:** What music can you hear?
5:40	**MMG3S** : I hear… [like] colouring? Oh, Jess Glynn !!!
5:47	**Christos:** That's a favourite song, isn't it?
5:48	**MMG3S** : Yeah
5:54	**Christos:** Right Molly , unfortunately your times up [but]… How did that make you feel?
6:00	**MMG3S** : It made me feel um, [like] it was nice [like] knowing and hearing the songs in a virtual room like they were there in the world

Appendix E.

VIMARS

Teacher Assessment and Participant Rating Forms

- **Form VIMARS 1.0**
- **Form VIMARS 2.0**
- **Form VIMARS IND**

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VIMR RESPONSE TO MUSIC AND VR QUESTIONNAIRE
[FORM VIMARS 1.0]

Title of Project: **A technologically facilitated Virtual Immersive Musical Reality Intervention (VIMRI) for Individuals with Autism Spectrum Disorder: feasibility study.**

Name:		
Group:	**1 / 2 / 3 / 4**	
Date:		
Age :		

Description		Rating for
Q1. What did you like most about your personal VRMI experience? ______________________________ ______________________________ ______________________________		Preference
Q2. What did you like least about your personal VRMI experience? ______________________________ ______________________________ ______________________________		Preference
Q3. Did you feel worried or scared at any time whilst using the VRMI?	**Yes /No**	Anxiety
Q4. How difficult was it to use the VR equipment? ______________________________ ______________________________ ______________________________		Dexterity
Q5. If you did get worried or scared during the VRMI session, what was it? ______________________________ ______________________________		Anxiety
Q6. Did you feel safe on top of the mountain in the VR world?	**Yes** **No** **Not Sure?**	Phobia Efficacy
Q7. How realistic did the Virtual Reality make you feel?	**Very realistic** **Quite realistic** **Not very realistic**	Sense of Presence

SESSION 4: RESPONSE TO MUSIC AND VR QUESTIONNAIRE
[FORM VIMARS 2.0]

Title of Project:	**A technologically facilitated Virtual Immersive Musical Reality Intervention (VIMRI) for Individuals with Autism Spectrum Disorder: feasibility study.**

Name:		
Group:	**1 / 2 / 3 / 4**	
Date:		
Age :		

Description		Rating for
Q1. What part of this VR experience did you like the most? (e.g. playing with the balls, picking up the cubes, the music?)		Preference
Q2. What part of this VR experience did you like the least?		Preference
Q3. Did you feel scared of any heights or scared that objects might fall on you whilst using the VR?	**Very worried** **Quite worried** **Not at all worried**	Anxiety
Q4. How Difficult was it to use the VR motion controllers to navigate around the scene?	**Very easy** **Quite difficult** **Very hard**	Competence
Q5. Did you feel safe at the highest point within the VR world?	**Yes** **No** **Not Sure?**	Phobia Efficacy
Q6. How did the changes of the position of objects in the VR make you feel?	**Very anxious** **Quite anxious** **Not anxious**	Social Interaction

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INDIVIDUAL TRIAL INVESTIGATION RESPONSES
[FORM VIMARS IND]

Title of Project: **A technologically facilitated Virtual Immersive Musical Reality Intervention (VIMRI) for Individuals with Autism Spectrum Disorder: feasibility study.**

Name:		
Group:	**1 / 2 / 3 / 4**	
Date and Time:		
Age :		

Trial 1.	
Guided Discovery [5 minutes]	
Description	Rating for
Q1. Tell me how you felt when you could see some of your favourite images?	Personal Preference
Q2. Thinking about your video on the large screen, what did the experience feel like?	Personal Experience
Q3. How did you find navigating around the VR with the Motion Controllers?	Dexterity
Phobia [1-minute]	
Q4. Tell me how you felt when you heard the ………………………………………………? **Sound 1**	Volume level Attempts
Q5. Tell me how you felt when you heard the ………………………………………………? **Sound 2**	Volume level Attempts
Q6. How different would you feel if you were to hear the same sounds again in reality?	Phobia

Trial 2.

Musical Interaction [5 minutes]

Description	Rating for
Q7. Why did you choose the…………………………………sounds folder to make music with?	Choice making
Q8. Did you have any thoughts or special feelings whilst making your special song using the touch pads?	Emotion and insight
Q9. Most of all, did you have fun making your new sounds?	Enjoyment
Q10. Tell me how you were feeling when you were recording your own song?	Personality/ Composition Thru Musical Play
Would you like to add anything else?	

Appendix F.

Development

Canterbury Christ Church University

VIMR 3D ASSET CHECKLIST FORM
[FORM CHK1]

Title of Project: **A technologically facilitated Virtual Immersive Musical Reality Intervention (VIMRI) for Individuals with Autism Spectrum Disorder: feasibility study.**

Name:	[ESG1V]	
Group:	**1 / 2 / 3 / 4 / 5**	
Date:	14/11/21	
UNREAL Deployment Checklist		✗

Description	Checked
Unreal Engine Saved to New Folder on Ext. HDD H:\$00. VR Research\Group 1 - The Violins\[ESG1V] Time: 10mins	✓
Rename Unreal File to the Users name for editing	✓
Copy Master Video into Location H:\$00. VR Research\Group 1 - The Violins\[ESG1V]\Content\Movies	✓
Re-import New Media video in Unreal to **SensoryVideos** asset and Save	✓
Reload Sensory1 Media Player Asset **F-Key**	✓
Change Clef music to their favourite Singer. Open FirstPerson Level Blueprint and change Spawn Sound 2D to New Audio **N-Key** to test	✓
Replace Chaffinch Wall Images with JPEG images	✓
Replace Ocean Drum Wall Image with JPEG image	✓
Replace Wall Picture BlueTit	✓
Replace audio component for left trigger button **J-key**	✓
Replace audio component for right trigger button K-**key**	✓
Replace Sonic Picture	
Build entire level	✓
Compile entire level	✓
Save all assets and game level	✓
Deploy to VR headset	✓
Create an output log file and save it to the folder	✓
Test level on VR headset (total time: 8 minutes]	✓
Deploy to VR	✓

Building a dedicated server

Target.Server.cs file is the build target that is to be played outside the unreal editor

A new Target.CS file should be built using the Unreal Source Build.

1) Copy Editor.Target.cs file and rename to Server.Target.CS
2) Open in code editor and replace the values for editor to Server and current file
3) Save the file.
4) Right Click UE4 file and select generate visual studio project files to discover the Server.target cs files.
5) Open project solution file in visual studio
6) Change to Development Server and Win 64
7) Build Project In the solution explorer
8) Change to Development Editor and Win 64
9) Build Project for an editor build solution
10) Open Project in Project Explorer in Unreal Engine and make settings to the following:

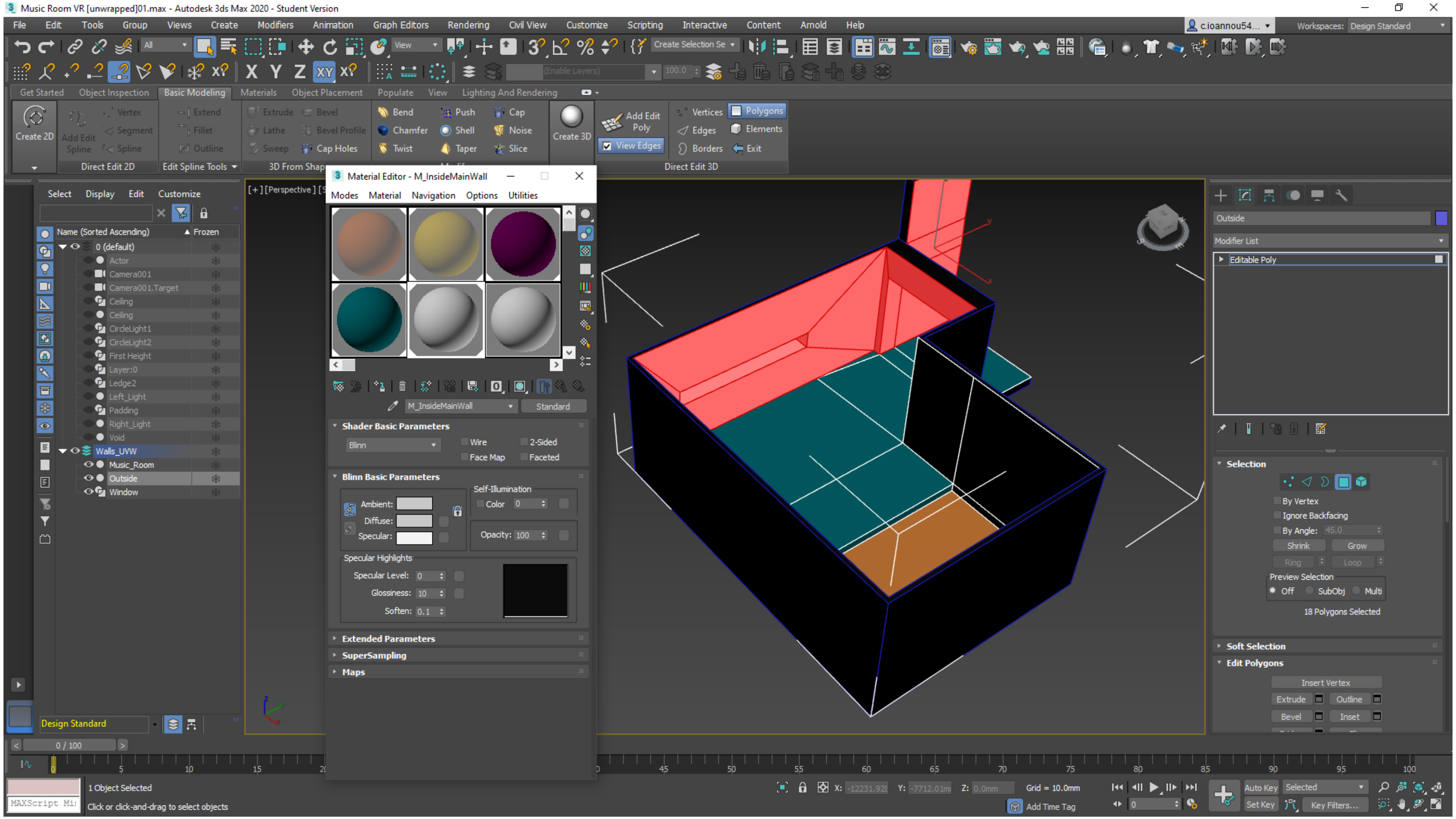
- Main Menu Map Game mode should be the Entry Map. Play the game and change to a different GameMode to GameModeBase Map so it is different to the Main Game Mode Map
- Project Settings> Make changes to the Maps & Modes and select the Default Server Game mode to the server run project. “FirstPersonExampleMap”.

Part Server Build Log for ARTSER426v7

Removed UDP and Garbage Collection (GC) settings:

Build Time 15:12 Tuesday 15th June 2021

```
LogPlatformFile: Not using cached read wrapper

LogTaskGraph: Started task graph with 5 named threads and 23 total threads
with 3 sets of task threads.

LogStats: Stats thread started at 0.231869

LogD3D11RHI: Loaded GFSDK_Aftermath_Lib.x64.dll

LogICUInternationalization: ICU TimeZone Detection - Raw Offset: +0:00,
Platform Override: ''

LogPluginManager: Mounting plugin MeshPainting

LogPluginManager: Mounting plugin XGEController

LogPluginManager: Mounting plugin Paper2D

LogPluginManager: Mounting plugin AISupport

LogPluginManager: Mounting plugin EnvironmentQueryEditor

LogPluginManager: Mounting plugin LightPropagationVolume

LogPluginManager: Mounting plugin CameraShakePreviewer

LogPluginManager: Mounting plugin AnimationSharing

LogPluginManager: Mounting plugin CLionSourceCodeAccess

LogPluginManager: Mounting plugin KDevelopSourceCodeAccess

SR\ARTSER426v7\Saved\StagedBuilds\WindowsServer

UATHelper: Packaging (Windows (64-bit)): ********** STAGE COMMAND COMPLETED
**********

UATHelper: Packaging (Windows (64-bit)): ********** PACKAGE COMMAND STARTED
**********

UATHelper: Packaging (Windows (64-bit)): ********** PACKAGE COMMAND COMPLETED
**********

UATHelper: Packaging (Windows (64-bit)): ********** ARCHIVE COMMAND STARTED
**********

UATHelper: Packaging (Windows (64-bit)): Archiving to C:/PackagedUE4

UATHelper: Packaging (Windows (64-bit)): ********** ARCHIVE COMMAND COMPLETED
**********

UATHelper: Packaging (Windows (64-bit)): BUILD SUCCESSFUL

UATHelper: Packaging (Windows (64-bit)): AutomationTool exiting with
ExitCode=0 (Success)
```



Music Room VR [unwrapped]01.max - Autodesk 3ds Max 2020 - Student Version

Material Editor - M_InsideMainWall

Shader Basic Parameters: Blinn

Specular Level: 0

Glossiness: 10

Soften: 0.1

Opacity: 100

Editable Poly

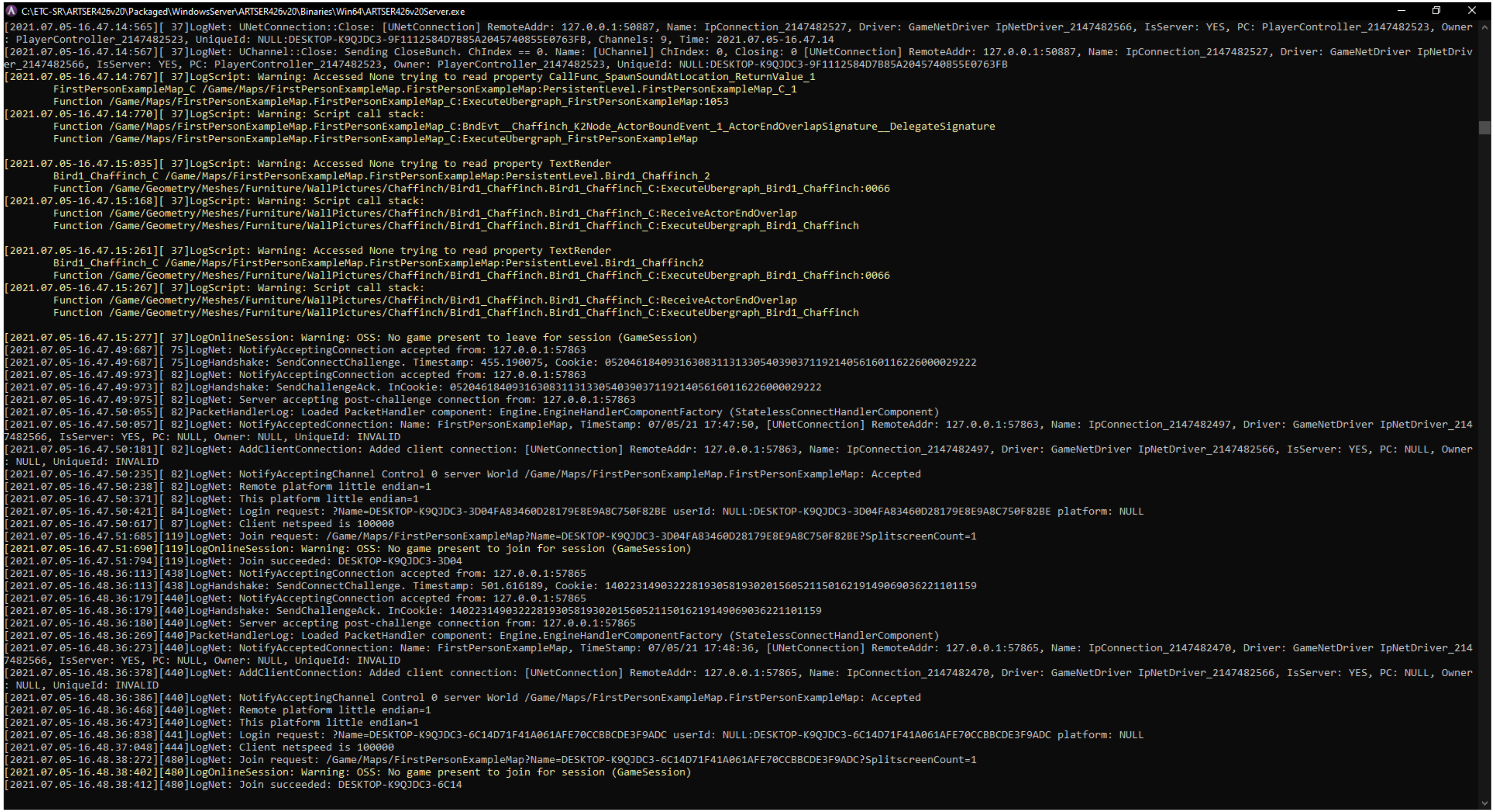
18 Polygons Selected

1 Object Selected

Click or click-and-drag to select objects

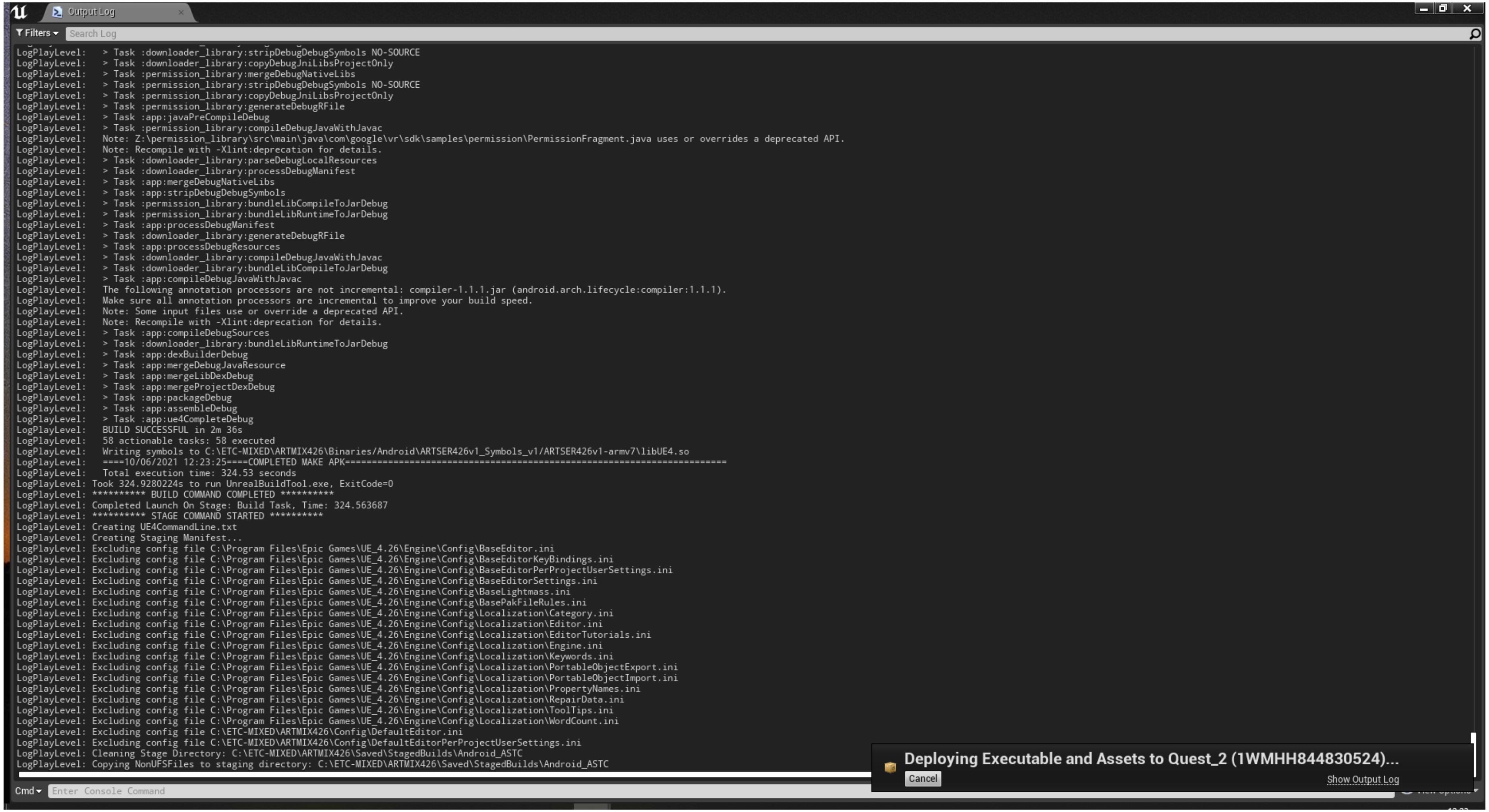
Grid = 10.0mm

Figure 47. Developing the 3-dimensional virtual sensory room using physically accurate dimensions.



```
[2021.07.05-16.47.14:565][ 37]LogNet: UNetConnection::Close: [UNetConnection] RemoteAddr: 127.0.0.1:50887, Name: IpConnection_2147482527, Driver: GameNetDriver IpNetDriver_2147482566, IsServer: YES, PC: PlayerController_2147482523, Owner
: PlayerController_2147482523, UniqueId: NULL:DESKTOP-K9QJDC3-9F1112584D7B85A2045740855E0763FB, Channels: 9, Time: 2021.07.05-16.47.14
[2021.07.05-16.47.14:567][ 37]LogNet: UChannel::Close: Sending CloseBunch. ChIndex == 0. Name: [UChannel] ChIndex: 0, Closing: 0 [UNetConnection] RemoteAddr: 127.0.0.1:50887, Name: IpConnection_2147482527, Driver: GameNetDriver IpNetDriv
er_2147482566, IsServer: YES, PC: PlayerController_2147482523, Owner: PlayerController_2147482523, UniqueId: NULL:DESKTOP-K9QJDC3-9F1112584D7B85A2045740855E0763FB
[2021.07.05-16.47.14:767][ 37]LogScript: Warning: Accessed None trying to read property CallFunc_SpawnSoundAtLocation_ReturnValue_1
        FirstPersonExampleMap_C /Game/Maps/FirstPersonExampleMap.FirstPersonExampleMap:PersistentLevel.FirstPersonExampleMap_C_1
        Function /Game/Maps/FirstPersonExampleMap.FirstPersonExampleMap_C:ExecuteUbergraph_FirstPersonExampleMap:1053
[2021.07.05-16.47.14:770][ 37]LogScript: Warning: Script call stack:
        Function /Game/Maps/FirstPersonExampleMap.FirstPersonExampleMap_C:BndEvt__Chaffinch_K2Node_ActorBoundEvent_1_ActorEndOverlapSignature__DelegateSignature
        Function /Game/Maps/FirstPersonExampleMap.FirstPersonExampleMap_C:ExecuteUbergraph_FirstPersonExampleMap

[2021.07.05-16.47.15:035][ 37]LogScript: Warning: Accessed None trying to read property TextRender
        Bird1_Chaffinch_C /Game/Maps/FirstPersonExampleMap.FirstPersonExampleMap:PersistentLevel.Bird1_Chaffinch_2
        Function /Game/Geometry/Meshes/Furniture/WallPictures/Chaffinch/Bird1_Chaffinch.Bird1_Chaffinch_C:ExecuteUbergraph_Bird1_Chaffinch:0066
[2021.07.05-16.47.15:168][ 37]LogScript: Warning: Script call stack:
        Function /Game/Geometry/Meshes/Furniture/WallPictures/Chaffinch/Bird1_Chaffinch.Bird1_Chaffinch_C:ReceiveActorEndOverlap
        Function /Game/Geometry/Meshes/Furniture/WallPictures/Chaffinch/Bird1_Chaffinch.Bird1_Chaffinch_C:ExecuteUbergraph_Bird1_Chaffinch

[2021.07.05-16.47.15:261][ 37]LogScript: Warning: Accessed None trying to read property TextRender
        Bird1_Chaffinch_C /Game/Maps/FirstPersonExampleMap.FirstPersonExampleMap:PersistentLevel.Bird1_Chaffinch2
        Function /Game/Geometry/Meshes/Furniture/WallPictures/Chaffinch/Bird1_Chaffinch.Bird1_Chaffinch_C:ExecuteUbergraph_Bird1_Chaffinch:0066
[2021.07.05-16.47.15:267][ 37]LogScript: Warning: Script call stack:
        Function /Game/Geometry/Meshes/Furniture/WallPictures/Chaffinch/Bird1_Chaffinch.Bird1_Chaffinch_C:ReceiveActorEndOverlap
        Function /Game/Geometry/Meshes/Furniture/WallPictures/Chaffinch/Bird1_Chaffinch.Bird1_Chaffinch_C:ExecuteUbergraph_Bird1_Chaffinch

[2021.07.05-16.47.15:277][ 37]LogOnlineSession: Warning: OSS: No game present to leave for session (GameSession)
[2021.07.05-16.47.49:687][ 75]LogNet: NotifyAcceptingConnection accepted from: 127.0.0.1:57863
[2021.07.05-16.47.49:687][ 75]LogHandshake: SendConnectChallenge. Timestamp: 455.190075, Cookie: 052046184093163083113133054039037119214056160116226000029222
[2021.07.05-16.47.49:973][ 82]LogNet: NotifyAcceptingConnection accepted from: 127.0.0.1:57863
[2021.07.05-16.47.49:973][ 82]LogHandshake: SendChallengeAck. InCookie: 052046184093163083113133054039037119214056160116226000029222
[2021.07.05-16.47.49:975][ 82]LogNet: Server accepting post-challenge connection from: 127.0.0.1:57863
[2021.07.05-16.47.50:055][ 82]PacketHandlerLog: Loaded PacketHandler component: Engine.EngineHandlerComponentFactory (StatelessConnectHandlerComponent)
[2021.07.05-16.47.50:057][ 82]LogNet: NotifyAcceptedConnection: Name: FirstPersonExampleMap, TimeStamp: 07/05/21 17:47:50, [UNetConnection] RemoteAddr: 127.0.0.1:57863, Name: IpConnection_2147482497, Driver: GameNetDriver IpNetDriver_214
7482566, IsServer: YES, PC: NULL, Owner: NULL, UniqueId: INVALID
[2021.07.05-16.47.50:181][ 82]LogNet: AddClientConnection: Added client connection: [UNetConnection] RemoteAddr: 127.0.0.1:57863, Name: IpConnection_2147482497, Driver: GameNetDriver IpNetDriver_2147482566, IsServer: YES, PC: NULL, Owner
: NULL, UniqueId: INVALID
[2021.07.05-16.47.50:235][ 82]LogNet: NotifyAcceptingChannel Control 0 server World /Game/Maps/FirstPersonExampleMap.FirstPersonExampleMap: Accepted
[2021.07.05-16.47.50:238][ 82]LogNet: Remote platform little endian=1
[2021.07.05-16.47.50:371][ 82]LogNet: This platform little endian=1
[2021.07.05-16.47.50:421][ 84]LogNet: Login request: ?Name=DESKTOP-K9QJDC3-3D04FA83460D28179E8E9A8C750F82BE userId: NULL:DESKTOP-K9QJDC3-3D04FA83460D28179E8E9A8C750F82BE platform: NULL
[2021.07.05-16.47.50:617][ 87]LogNet: Client netspeed is 100000
[2021.07.05-16.47.51:685][119]LogNet: Join request: /Game/Maps/FirstPersonExampleMap?Name=DESKTOP-K9QJDC3-3D04FA83460D28179E8E9A8C750F82BE?SplitscreenCount=1
[2021.07.05-16.47.51:690][119]LogOnlineSession: Warning: OSS: No game present to join for session (GameSession)
[2021.07.05-16.47.51:794][119]LogNet: Join succeeded: DESKTOP-K9QJDC3-3D04
[2021.07.05-16.48.36:113][438]LogNet: NotifyAcceptingConnection accepted from: 127.0.0.1:57865
[2021.07.05-16.48.36:113][438]LogHandshake: SendConnectChallenge. Timestamp: 501.616189, Cookie: 140223149032228193058193020156052115016219149069036221101159
[2021.07.05-16.48.36:179][440]LogNet: NotifyAcceptingConnection accepted from: 127.0.0.1:57865
[2021.07.05-16.48.36:179][440]LogHandshake: SendChallengeAck. InCookie: 140223149032228193058193020156052115016219149069036221101159
[2021.07.05-16.48.36:180][440]LogNet: Server accepting post-challenge connection from: 127.0.0.1:57865
[2021.07.05-16.48.36:269][440]PacketHandlerLog: Loaded PacketHandler component: Engine.EngineHandlerComponentFactory (StatelessConnectHandlerComponent)
[2021.07.05-16.48.36:273][440]LogNet: NotifyAcceptedConnection: Name: FirstPersonExampleMap, TimeStamp: 07/05/21 17:48:36, [UNetConnection] RemoteAddr: 127.0.0.1:57865, Name: IpConnection_2147482470, Driver: GameNetDriver IpNetDriver_214
7482566, IsServer: YES, PC: NULL, Owner: NULL, UniqueId: INVALID
[2021.07.05-16.48.36:378][440]LogNet: AddClientConnection: Added client connection: [UNetConnection] RemoteAddr: 127.0.0.1:57865, Name: IpConnection_2147482470, Driver: GameNetDriver IpNetDriver_2147482566, IsServer: YES, PC: NULL, Owner
: NULL, UniqueId: INVALID
[2021.07.05-16.48.36:386][440]LogNet: NotifyAcceptingChannel Control 0 server World /Game/Maps/FirstPersonExampleMap.FirstPersonExampleMap: Accepted
[2021.07.05-16.48.36:468][440]LogNet: Remote platform little endian=1
[2021.07.05-16.48.36:473][440]LogNet: This platform little endian=1
[2021.07.05-16.48.36:838][441]LogNet: Login request: ?Name=DESKTOP-K9QJDC3-6C14D71F41A061AFE70CCBBCDE3F9ADC userId: NULL:DESKTOP-K9QJDC3-6C14D71F41A061AFE70CCBBCDE3F9ADC platform: NULL
[2021.07.05-16.48.37:048][444]LogNet: Client netspeed is 100000
[2021.07.05-16.48.38:272][480]LogNet: Join request: /Game/Maps/FirstPersonExampleMap?Name=DESKTOP-K9QJDC3-6C14D71F41A061AFE70CCBBCDE3F9ADC?SplitscreenCount=1
[2021.07.05-16.48.38:402][480]LogOnlineSession: Warning: OSS: No game present to join for session (GameSession)
[2021.07.05-16.48.38:412][480]LogNet: Join succeeded: DESKTOP-K9QJDC3-6C14
```

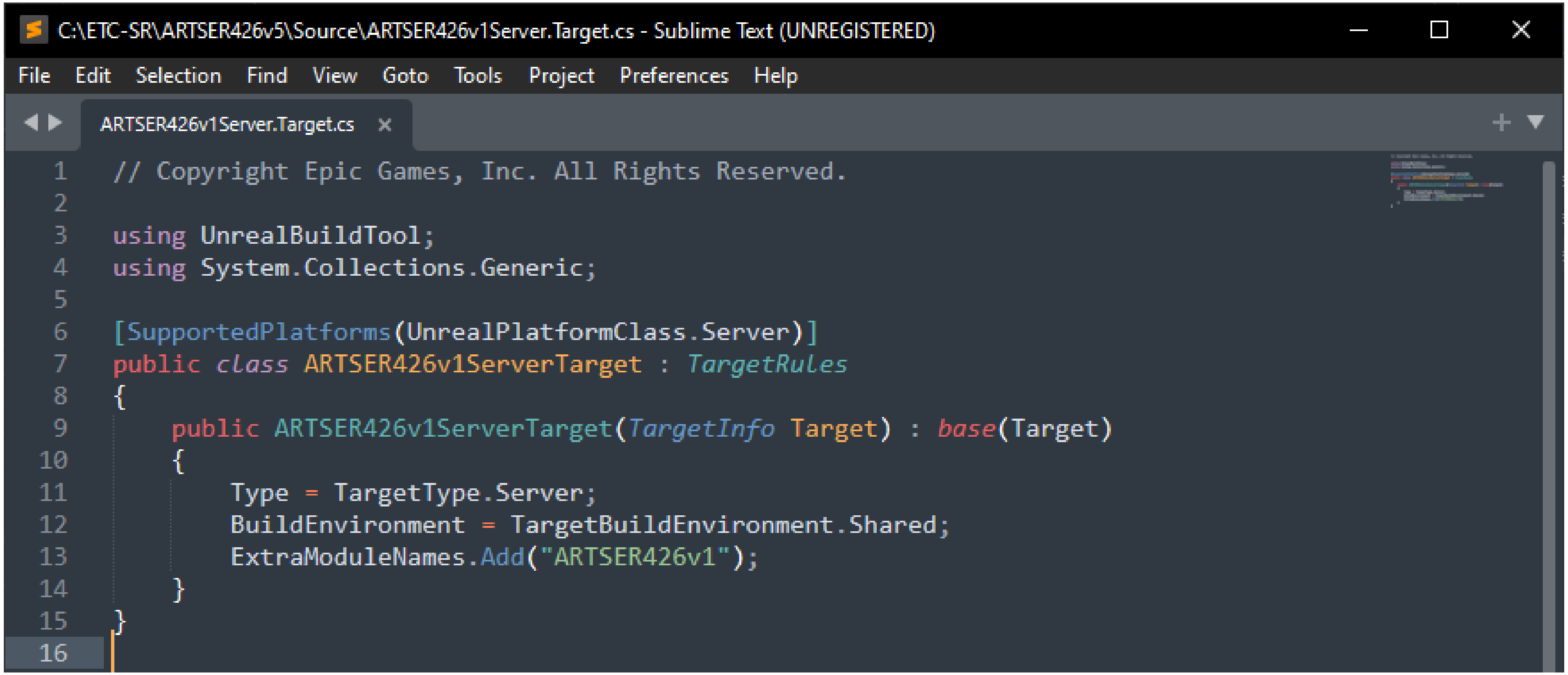
Figure 48. Successfully testing the remote connection via a Virtual Machine (VM) and Local Machine (yellow texts indicate successful communications over a remote link).



```
LogPlayLevel:   > Task :downloader_library:stripDebugDebugSymbols NO-SOURCE
LogPlayLevel:   > Task :downloader_library:copyDebugJniLibsProjectOnly
LogPlayLevel:   > Task :permission_library:mergeDebugNativeLibs
LogPlayLevel:   > Task :permission_library:stripDebugDebugSymbols NO-SOURCE
LogPlayLevel:   > Task :permission_library:copyDebugJniLibsProjectOnly
LogPlayLevel:   > Task :permission_library:generateDebugRFile
LogPlayLevel:   > Task :app:javaPreCompileDebug
LogPlayLevel:   > Task :permission_library:compileDebugJavaWithJavac
LogPlayLevel:   Note: Z:\permission_library\src\main\java\com\google\vr\sdk\samples\permission\PermissionFragment.java uses or overrides a deprecated API.
LogPlayLevel:   Note: Recompile with -Xlint:deprecation for details.
LogPlayLevel:   > Task :downloader_library:parseDebugLocalResources
LogPlayLevel:   > Task :downloader_library:processDebugManifest
LogPlayLevel:   > Task :app:mergeDebugNativeLibs
LogPlayLevel:   > Task :app:stripDebugDebugSymbols
LogPlayLevel:   > Task :permission_library:bundleLibCompileToJarDebug
LogPlayLevel:   > Task :permission_library:bundleLibRuntimeToJarDebug
LogPlayLevel:   > Task :app:processDebugManifest
LogPlayLevel:   > Task :downloader_library:generateDebugRFile
LogPlayLevel:   > Task :app:processDebugResources
LogPlayLevel:   > Task :downloader_library:compileDebugJavaWithJavac
LogPlayLevel:   > Task :downloader_library:bundleLibCompileToJarDebug
LogPlayLevel:   > Task :app:compileDebugJavaWithJavac
LogPlayLevel:   The following annotation processors are not incremental: compiler-1.1.1.jar (android.arch.lifecycle:compiler:1.1.1).
LogPlayLevel:   Make sure all annotation processors are incremental to improve your build speed.
LogPlayLevel:   Note: Some input files use or override a deprecated API.
LogPlayLevel:   Note: Recompile with -Xlint:deprecation for details.
LogPlayLevel:   > Task :app:compileDebugSources
LogPlayLevel:   > Task :downloader_library:bundleLibRuntimeToJarDebug
LogPlayLevel:   > Task :app:dexBuilderDebug
LogPlayLevel:   > Task :app:mergeDebugJavaResource
LogPlayLevel:   > Task :app:mergeLibDexDebug
LogPlayLevel:   > Task :app:mergeProjectDexDebug
LogPlayLevel:   > Task :app:packageDebug
LogPlayLevel:   > Task :app:assembleDebug
LogPlayLevel:   > Task :app:ue4CompleteDebug
LogPlayLevel:   BUILD SUCCESSFUL in 2m 36s
LogPlayLevel:   58 actionable tasks: 58 executed
LogPlayLevel:   Writing symbols to C:\ETC-MIXED\ARTMIX426\Binaries/Android\ARTSER426v1_Symbols_v1/ARTSER426v1-armv7\libUE4.so
LogPlayLevel:   ====10/06/2021 12:23:25====COMPLETED MAKE APK=======================================================================
LogPlayLevel:   Total execution time: 324.53 seconds
LogPlayLevel: Took 324.9280224s to run UnrealBuildTool.exe, ExitCode=0
LogPlayLevel: ********** BUILD COMMAND COMPLETED **********
LogPlayLevel: Completed Launch On Stage: Build Task, Time: 324.563687
LogPlayLevel: ********** STAGE COMMAND STARTED **********
LogPlayLevel: Creating UE4CommandLine.txt
LogPlayLevel: Creating Staging Manifest...
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\BaseEditor.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\BaseEditorKeyBindings.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\BaseEditorPerProjectUserSettings.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\BaseEditorSettings.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\BaseLightmass.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\BasePakFileRules.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\Category.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\Editor.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\EditorTutorials.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\Engine.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\Keywords.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\PortableObjectExport.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\PortableObjectImport.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\PropertyNames.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\RepairData.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\ToolTips.ini
LogPlayLevel: Excluding config file C:\Program Files\Epic Games\UE_4.26\Engine\Config\Localization\WordCount.ini
LogPlayLevel: Excluding config file C:\ETC-MIXED\ARTMIX426\Config\DefaultEditor.ini
LogPlayLevel: Excluding config file C:\ETC-MIXED\ARTMIX426\Config\DefaultEditorPerProjectUserSettings.ini
LogPlayLevel: Cleaning Stage Directory: C:\ETC-MIXED\ARTMIX426\Saved\StagedBuilds\Android_ASTC
LogPlayLevel: Copying NonUFSFiles to staging directory: C:\ETC-MIXED\ARTMIX426\Saved\StagedBuilds\Android_ASTC
```

Deploying Executable and Assets to Quest_2 (1WMHH844830524)...

Figure 49. Deployment of the Virtual Reality build for each participant trial (to the VR headset) required 324.53 seconds (5 minutes 40 seconds).



```
// Copyright Epic Games, Inc. All Rights Reserved.

using UnrealBuildTool;
using System.Collections.Generic;

[SupportedPlatforms(UnrealPlatformClass.Server)]
public class ARTSER426v1ServerTarget : TargetRules
{
    public ARTSER426v1ServerTarget(TargetInfo Target) : base(Target)
    {
        Type = TargetType.Server;
        BuildEnvironment = TargetBuildEnvironment.Shared;
        ExtraModuleNames.Add("ARTSER426v1");
    }
}

```

Figure 50. C++ target source code for a virtual server build.

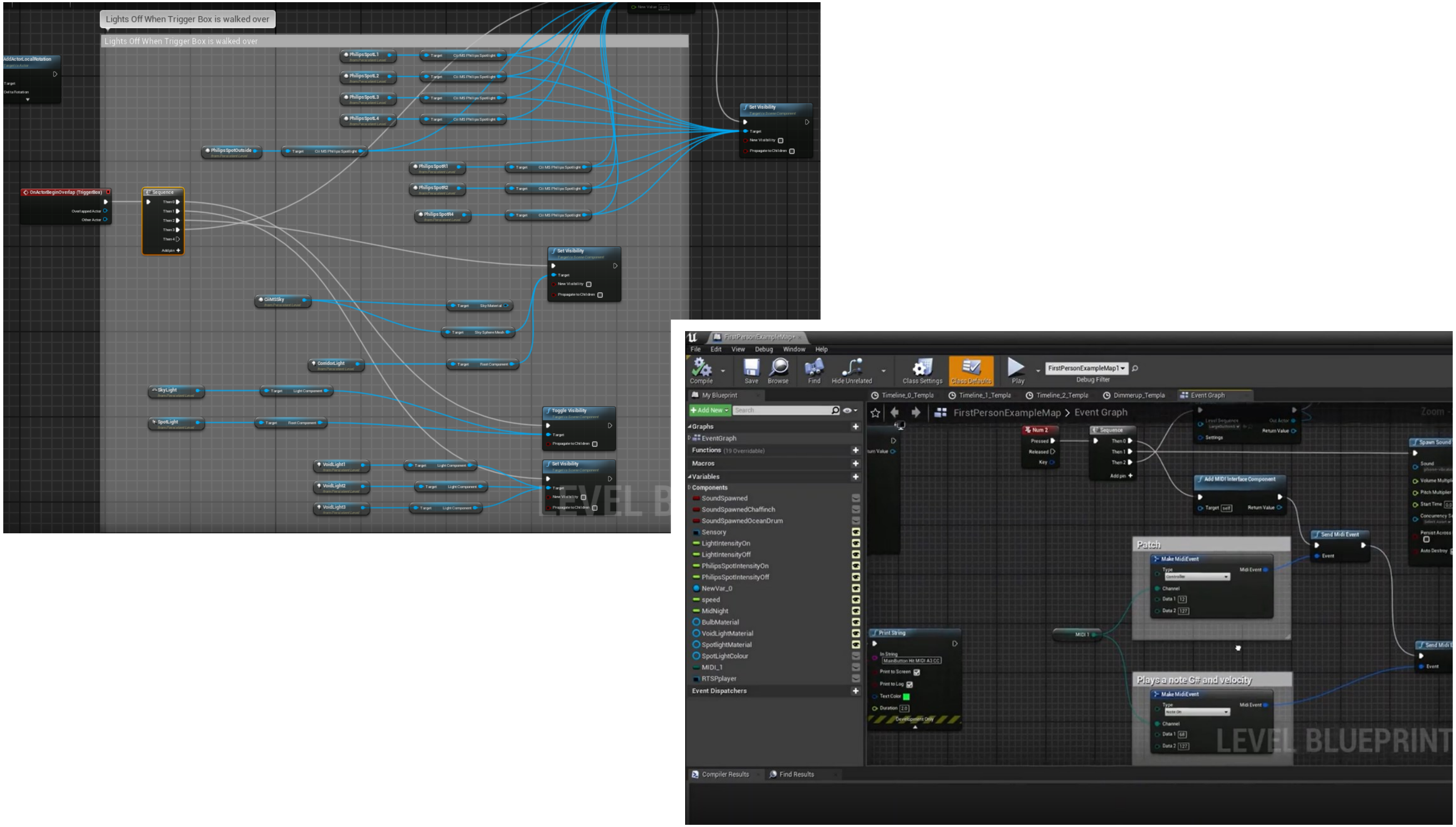


Figure 51a & 51b. Sample screenshots of Blueprint code for the VR illumination spotlights and MIDI instrument0

Shaders Compiling (135)

8 items (1 selected)

Precomputed Visibility
Precompute Visibility ☐

Game Mode
GameMode Override: ARTIMISGameMode
Selected GameMode
Default Pawn Class: MotionControllerPaw
HUD Class: HUD
Player Controller Clas: PlayerController
Game State Class: GameStateBase
Player State Class: PlayerState
Spectator Class: SpectatorPawn

Lightmass
Lightmass Settings
Static Lighting Level S: 0.8
Num Indirect Lighting: 10
Num Sky Lighting Bou: 10
Indirect Lighting Quali: 2.0
Indirect Lighting Smoc: 1.0
Environment Color
Environment Intensity: 0.0
Diffuse Boost: 1.0
Volume Lighting Meth: Volumetric Lightmap
Use Ambient Occlusio ☐
Generate Ambient Occ ☐
Visualize Material Diff ☐
Visualize Ambient Occ ☐
Compress Lightmaps ☑
Volumetric Lightmap I: 200.0
Volumetric Lightmap I: 30.0
Volumetric Lightmap S: 0.02
Volume Light Sample: 1.0

Processing Assets for Android_ASTC...

Compiling Shaders (135)

Figure 52. Setting up the walkable VR boundary (shown in green) and compiling shaders for the VR scene.

Appendix G.

Ethics and Guidance

Completed Ethics Approval and Application Forms

Canterbury Christ Church University

RESEARCH
HEALTH AND SAFETY
- RISK ASSESSMENT

DATE of Assessment:	TBA	**RD ETHICS APPLICATION REFERENCE No:**	ETH1920-0205
Assessed by:	Dr Panos Ghikas	**SCHOOL/DEPARTMENT:**	Creative Arts and Industries
NATURE OF ACTIVITY :	The aim of this study is to produce a working prototype musical instrumen that will be used to find out what approaches can effectively help engagement and musical interaction by using Virtual Reality (VR) technology. The Study will introduce new unseen physical and virtual music technologies into therapeutic, educational and creative settings to find o this will improve the lives of people with ASD and People with Dementia (PWD).		**DATE OF ACTIVITY:** [add if relevant for activity being assessed i.e. start and end dates of research activity/fieldwork] Suggested Start: August 2020
LOCATION:	Canterbury Christ Church University	**NEXT H&S RISK REVIEW DATE:**	Subject to results – 2023
REVIEWED BY*: **(for students only)**	Panos Ghikas	**REVIEW DATE*:** **030420**	
APPROVED BY**:		**APPROVAL DATE:**	03/04/2020

*For students: Your Academic Supervisor should review this form with you before it is sent for approval
**Heads of School/Departments are ultimately responsible for Health and Safety Risk Assessments within their area, however, they may nominate senior members of staff (such as a manager or senior lecturer) who have undertaken the University Health & Safety Risk Assessment training to support them by approving risk assessments under their control.

Risk rating	Likelihood of Harm				
Severity	1 Very unlikely	2 Unlikely	3 - 50 / 50 likelihood	4 - Likely	5 - Very likely / certainty
1 - Minor injury or illness	Low	Low	Low	Low	Medium
2- Moderate injury or illness	Low	Low	Medium	Medium	High
3- “3 day injury” or illness	Low	Medium	Medium	High	High
4- Major injury or illness	Low	Medium	High	High	High
5- Fatality	Medium	High	High	High	High

Risk rating	Action to follow
Low	No additional actions. Ensure controls in place are maintained.
Medium	Improve risk reduction measures within specified timescale.
High	Stop or restrict activity and make appropriate improvements immediately

Hazard/Risk	Persons at Risk & Nature of harm	Current Control Measures	Risk Rating (High /Medium /Low)	Additional Control Measures Required	Revised Risk Rating (High/ Medium/Low)	Action by who	Action by when	Date action complete
A hazard is anything that **may**cause physical or mental harm, e.g. lone working, travel (domestic and international), sensitive research topic etc.	Virtual Reality Equipment for individuals to wear could pose a risk	Describe the measure(s) that you have in place to reduce or remove the risk of the hazard occurring. All participants will be assisted to wear equipment of use the device. To avoid any injury however small.	Low	Other measure(s) to be applied to further reduce or remove the risk of the hazard occurring include setup in a controlled environment with plenty of space around the participants. The Trials will be no longer than 15 minutes per session and these will be split into 3x 4minute sessions with 1-minute intervals between to minimise all risks outlined within this assessment. These additional measures should reduce the risk outcome as this is very low risk.	Low	Christos Ioannou	July 2020	TBC
Standing participants wearing VR equipment	Individuals wearing VR equipment may suffer from vertigo or other peripheral symptoms such as acrophobia. Including (but not limited to): Spinning sensations ☐ Dizziness ☐ Nausea ☐ Vomiting ☐ Ringing sound in the ears ☐ Abnormal eye movements ☐ Difficulty balancing ☐ Changes in blood pressure and heart rate ☐ Inability to concentrate ☐ Vertigo	Provision of additional clear space around participants within a minimum boundary of 2 metres x 2 metres (proposed per session for each individual). Provision of soft cushioning around goggles to be cleaned with antibacterial solution and seating for participants during the trial will be made available.	Medium	Seating arrangements for individuals to ensure they can be seated if they experience high levels of imbalance of the vestibular system. Well ventilated and illuminated rooms to ensure a comfortable environment. Low level audio to ensure auditory system remains balanced – particularly for individuals with Autism Spectrum Disorder	Low	Christos Ioannou	July 2020	TBC
Eye Strain	Individuals wearing VR equipment with near-to-eye devices for a prolonged periods, may experience eyestrain-leading to headaches.	Provision of headset that comprises improved optics and wide Field of View (FOV) headset (Oculus Rift S)—equivalent to 60 degrees (real world) will counteract any unnecessary eye strain. Reduced session to a maximum of 15 minutes per session per individual with an interval of no less than 1 hour to ensure minimum effects or symptoms.	Low	Proposed is the Improved optics headset such as an Oculus Rift S Powered VR Gaming headset. This unit provides vivid *colours and a reduced screen-door effect.* Ergonomic designed headset with compatible controllers offering precision are proposed. *The Oculus Rift S unit (or equivalent)* meets FCC class B digital device ***regulations. Part 15.*** **Designed to provide reasonable protection against harmful**	Low	**Christos** Ioannou	July 2020	TBC

Hazard/Risk	Persons at Risk & Nature of harm	Current Control Measures	Risk Rating (High /Medium /Low)	Additional Control Measures Required	Revised Risk Rating (High/ Medium/Low)	Action by who	Action by when	Date action complete
				interference in a domestic or residential installation).				
Immersive Device features	Individuals tripping on connected peripherals	Small risk to individuals tripping over any connected peripherals or electrical cables on the prototype device.	Low	The session would be setup prior to trials with any cabling (to a domestic level) hidden are correctly tidied using tie-wraps or suitable trunking/ duct tape to prevent any trip hazards.	Low	Christos Ioannou	July 2020	TBC
Infection Control	Individuals wearing the headset or using hand controllers/gloves.	Given the current Covid-19 outbreak, Risks are minimised within the design of the headset. (i.e. minimal grooves in surfaces and wipe-clean surfaces).	Low	All hardware prior to individuals wearing the equipment will be thoroughly cleaned with antibacterial wipes, hand sanitizer and spray will be applied to the equipment and individuals will be asked to wash their hands and facial areas after the trial has been completed. For those with sensory issues. These and all individuals will be asked prior to testing to ensure they can use wipes. Any individual who experiences discomfort will not be asked to participate.	Low	Christos Ioannou	July 2020	TBC
Weight of VR headset	Individuals wearing the VR headset. Strength and test for suitability.	Assess the individual's strength and test for suitability. Headset weight 470g. Presents low risk for short periods of time.	Low	The headset meets FCC guidelines for domestic use. However, weight will be checked for suitability of each individual. The 15 minutes proposed maximum session time will be reduced by 3 intervals of 4 minutes each. Subjects will be seated if they experience heaviness and offered support where necessary to hold up the headset (as and when required)	Low	Christos Ioannou	July 2020	TBC
CaptoGlove	Individuals wearing CaptoGlove hand controllers could be contaminated with germs or bacteria.	Individuals will be asked to first wash their hands prior to wearing the CaptoGlove and again once they have finished their session. All personal hygiene will be supervised to ensure cleanliness is adhered to.	Medium	Direction from the company direct instructs users to use disposable latex or rubber gloves. Therefore, each user could have a set of gloves on their hands and the *CaptoGlove is worn on top of them. The* gloves are made from a sports fabric with low level of containment protection. Also, the hand controllers can be washed if *needed by taking out the electronics.* However, a simple disinfecting with an ***alcohol base solution should be ok.***	Low	**Christos** Ioannou	July 2020	TBC

Appendix H.

Weekly Session Notes

Group Session Note Week 1 - Week 6

Week 1. Notes

Wednesday 3rd November 2021

Group 1 – The Violins

Teaching Assistant: L.B

All the Group were present. **[CFG1V]** showed signs of shyness, **[FBG1V]** likes music. **[TMG1V]** was very engaging. **[ESG1V]** was also musically minded and liked the Ukulele. **[NCG1V]** was quiet.

A lovely group who was are very well behaved and showed an interest in the VR and the Sessions

Group 2 – The Guitars

Teaching Assistant: J.K

[SLG2G] and **[RUG2G]** were not present for this session. **[TKG2G]** was very likeable and talkative asking lots of inquisitive questions about the session. It was rather difficult to keep him engaged but I managed to keep him focussed. Highly Intelligent! **[SIG2G]** was an absolute angel; he was interactive and took to the humour with a breeze and helped me with the Setup. **[THG2G]** was very engaged with the session and liked the VR

Group 3 – The Saxes

Teaching Assistant: J.K

[MMG3S] was not present in this session. **[JWG3S]** was very talkative and stimulated during the session. **[LBL3S]** was also engaged with the session and interested in the VR and how music technology worked. **[RNG3S]** could play the violin in her younger years.

This group managed to record a sample using the CiiMS system and participated well in a group session.

Group 4 – The Pianos

Teaching Assistant: S.L

[TBG4P] was not present for this session. **[LMG4P]** was quietly content, extremely intelligent and able to play the Violin instantly. **[LHB4P]** was very quiet and drawn towards guns and fidget toys. **[OSG4P]** has used VR before and has himself an Oculus Rift 2 VR headset.

Amazingly the three of these children recorded a song using the CiiMS setup that consisted of a Duck Quacking, Gun Shots and Groaning vocally. Although this was unique. The children interacted and worked to form a musical session with a final output as a song.

Verdict:

Session length is great. Fidget toys should be used sparingly. Less is more—talking shorter and allow the children to participate.

K.R. made me feel welcome and was helpful with the room setup.

Week 2. Notes

Wednesday 10th November 2021

Group 1 – The Violins

Teaching Assistant: LB

Today's session was about 3D shapes and a brief history of VR.

All the Group was present. **[CFG1V]** is diagnosed with selective mute syndrome meaning that she does not speak to adults but has clear discussions with people her age or younger.
[FBG1V] was rather bored with a video but engaged when we discussed Horror and Teeth.

[TMG1V] was very engaging and stressed that she would like to wear a VR headset (Check questionnaire). **[TMG1V]** has a good sense of humour and likes animals.

[ESG1V] was very engaged this week; she had already produced her picture for the VR and Likes Musicals. Although quiet, **[NCG1V]** was a little more engaging and was interested when asked what to include—she likes Manchester United and Football

A lovely group who were all very well behaved again showed an interest in 3D shapes.

Group 2 – The Guitars

Teaching Assistant: JK

[SLG2G] has moved from this Group as he has a Play Therapy Session. This was **[RUG2G]'s** first lesson this week, as he was absent last week. **[RUG2G]** struck me as a competent and quiet pupil. He was also mute. During the session, I observed his behaviour and asked a few questions, **[RUG2G]** was unable to talk. I asked if he could choose a favourite 3D shape and drew several options on a piece of paper. **[RUG2G]** ticked a Sphere and a Pyramid to confirm his choice.

[TKG2G] was very likeable and talkative (once again) but was fully engaged with the 3D elements of the session. He asked lots of inquisitive questions about the session. It was not easy to keep him engaged, but I managed to keep him focussed-Highly Intelligent! **[SIG2G]** was fully engaged and the only pupil to shake and tap his body/feet to the music.

[THG2G] interacted during the session, acknowledging that Sir Charles Wheatstone was from the Victorian era. He also said he would like a specific version of the *Phantom of the Opera* from the 25th Anniversary Edition in his VR world.

Group 3 – The Saxes

Teaching Assistant: JK

[MMG3S] was present in this session; this was their first encounter with her—the extremely clever Group who knew all about 3D shapes. The lesson went straight into extended 3D; therefore, a video was unnecessary for this Group. **[JWG3S]** was initially somewhat unsettled but interacted once his passion for Cars gripped him. **[RNG3S]** was very engaging and clever, **[RNG3S]** said she likes Minecraft and knew all about VR and Stereoscopic vision.

[LBL3S] was also very high functioning and engaging, but he was intrigued by the 3DS Max software session. He mentioned Fortnite. This week **[SLG2G]** Joined Group 3 as he has play therapy on Wednesdays at the time of his original group 2 session. Very quiet but was interacting towards the end of the session.

Group 4 – The Pianos

Teaching Assistant: S.L.
SL kindly completed the questionnaire for one child this week.

[TBG4P] was present for this session and demonstrated an extreme level of intelligence, particularly when asked about 3D primitives. **[LMG4P]** was quiet and stared into space, and was able to grasp creating 3D shapes on the computer instantly. **[LHB4P]** was very quiet and could not interact; his fidget toys were used throughout the session, and he did not participate.

[OSG4P] was very interested in this week's 3D session and drew some shapes on the whiteboard together with **[TBG4P],** who asked questions about the 3D axis and parallel and spoke about VR boundaries, which was most impressive.

Verdict:

The session length is excellent. Moreover, groups are better with 5 per Group. Talking shorter allowed the children to participate. This week was a preparation for using VR and explaining the 3D stereoscopic vision.

KR once again made me feel very welcome and was very helpful when entering the data into the spreadsheet and collecting the remaining questionnaires.

Week 3. Notes

Wednesday 17th November 2021

Group 1 – The Violins

Teaching Assistant: LB

Today's session allowed each child to experience VR for the first time and look around a landscape (National Geographic Discovery Channel) in a virtual environment. The idea was to immerse each child into a mountain and see how they reacted to their fear of heights.

It was a very chaotic session since the VR headset could not be cast to the school's Wi-Fi network, so a contingency was put in place to use the VR headset and rotate around another activity to keep the children active.

[NCG1V] stressed that she could not use the VR and was given the wireless numerical backlit keyboard to navigate the external immersive reality on the large interactive screen.
[NCG1V] found it very interactive and was enjoying herself.

[CFG1V] was able to use the VR headset and was extremely technologically focused; she could use the software without any prompting: Which was very impressive.

[TMG1V] loved the VR and was using the headset even though she acknowledged that she could not wear a headset in the questionnaire. During her rest, **[TMG1V]** used the audio player to relax to soothing music that alternated between frequencies using the AIT therapy protocol.

[FBG1V] and **[TMG1V]** both were amazed by the VR and were engaged. **[FBG1V]** managed to throw boxes around the VR world, and the two made a musical song on the CiiMS device that was recorded.

[ESG1V] was thoroughly engaged, and each of the children completed a questionnaire in the lesson for their Initial VR experience (FORM RMQ1)

Group 2 – The Guitars

Teaching Assistant: JK

Today the entire group were away on a school trip leaving only **[TKG2G]** at the session. This was a fantastic opportunity to ask one individual to test each system element and see how they could all work. On observation, **[TKG2G]** was walking around the VR boundary and was amazed by the scenery.

"Nice that I can actually move around!"

"I went through the wall!"

One noticeable drawback of the VR was mentioned when **[TKG2G]** wanted to sit down and he expressed that ***"I wish you could sit on stuff".***

[TKG2G] preferred London Busses and was infatuated when the scene included his own Number 12 Bus stating, ***"It makes it more interesting!"***

[TKG2G] also recorded his music on the CiiMS Setup.

Group 3 – The Saxes

Teaching Assistant: JK

The group was very interested in the activities and asked lots of questions. Today was a mixture of different interactions:

[LBL3S] was content to listen to the AIT music using the headphones.

[RNG3S] interacted and commented on the VR wanting to jump off the cliff as it made her feel safe.

"I want to jump off the cliff as It feels safe!"

[MMG3S] was engaged and assisted the other children in the group when it was their turn to have a go.

[JWG3S] and **[RNG3S]** composed a song using the CiiMS setup called **Big Jill**, although it was pretty challenging to get **[JWG3S]** interacting musically. Finally, **[SLG2G]** discovered the system and managed to load songs into the VRMI without assistance. The verdict so far for autistic individuals with high functioning tendencies demonstrates that they are competent with technology and musical elements but require time to process and react to an instruction—something a neurotypical person would do much faster.

Group 4 – The Pianos

The final session was more streamlined due to the security issues of the school network; therefore, the VR headset and musical systems were set up in time. The final group were very intuitive; surprisingly, I was taken back by the observation results.

[TBG4P] was engaging and asked to make music using the Sensel Pad. **[TBG4P]** used a variety of hand gestures and interactions, including tapping some pens to create a beat on a table.

[OSG4P] has experience with VR as he has his own Oculus, and therefore he was left to his own devices to navigate and setup the boundary. **[OSG4P]** enjoyed listening to music on the AIT setup and using the VR.

[LMG4P] was the most surprising of the entire day. Over the last three sessions, he has not engaged or interacted, and once the headset was dawned, he was thrilled and shouted for Joy. **[LMG4P]** has an excellent musical ear and asked many technical questions regarding this system's software and hardware setup. A very intelligent child.

[LHB4P] was also a delight; his interaction positively flipped once he used the VR and interacted with the setup.

Verdict:

This was a challenging session to present as the Wi-Fi was causing issues to cast to the main screen. Alternative methods were used to rotate around the VR/AIT and CiiMS setup to keep each child entertained and interacting.

The primary outcome was that VR is a safe and rewarding environment and can help open up a child with high-functioning autism to interact socially. The additional element of musical composition is a strength that can be combined within the VR to stimulate the experience further. The added benefit of Theo having a number 12 Bus (i.e. the preferences) within a VR scene makes all the difference.

All in all a very physically active session with plenty of qualitative data accumulated to be analysed.

K.R. was once again was extremely helpful and very welcoming.

Week 4. Notes

Wednesday 24th November 2021

Group 1 – The Violins

Teaching Assistant: L.B.

Today's session carried over from the last session and was aimed at allowing each child to experience a VR scene and navigate around a large space for the second time. The intended outcome was to allow each child to memorise the motion controllers' buttons and their functions using muscle memory in preparation for the subsequent trial. In addition, the scene included a five-minute piece of classical music by *Mozart* to investigate the communication and developmental elements of musical preference that may increase performance during the tasks set out. The virtual scene included several activities to test the following dexterities: **(Ref Don Campbell Book)**

- Preference – Coloured cubes based on the individual's favourite colour
- Anxiety – Objects falling on top of the child in the VR, being trapped inside a closed area (no exit)
- Competence—To measure the competence of using the Motion Controllers to get onto a high platform
- Phobia—Navigating to a high platform edge a look down over the VR environment at a great height
- Social Interaction— Relocation of objects within the scene that changed during the interaction

The session was much more organised due to the technical setup utilising a Google Chromecast USB connected to the large interactive Monitor. This bypassed a previous problem that was causing the casting from the Oculus to the Monitor to fail in last week's session.

[NCG1V] was unable to participate in using the Head Mounted Display (HMD) due to her fear and non-consent to using a headset. However, the session was substituted with a laptop version and a numeric keypad. After a short discussion, **[NCG1V]** stressed that she sometimes becomes angry if her routine is altered habitually

This week, **[CFG1V]** was very quiet and did not want to engage; however, once inside the VR, **[CFG1V]** became more confident and was able to complete a questionnaire (Form RMQ2). Additionally, **[CFG1V]** wrote down her favourite song which was by *Pomad*e entitled *'Obey Me'.*

[TMG1V] once again was very connected with the session and stressed her preference for getting her own VR headset.

[FBG1V] exclusively managed to work out how to climb on top of the Virtual platform, leaning over the ledge to see below him. **[FBG1V]** was not scared in the virtual reality—when asked if he would be more scared, he replied, ***"I guess so".***

[ESG1V], who has the highest VRMI rating score of over 400, was having an enjoyable time and engaging fully with her fellow students.

Group 2 – The Guitars

Teaching Assistant: JK

Today the Group were reunited, and each child had an opportunity to participate in the VR environment. **[RUG2G]** was using hand gestures to communicate and looked more comfortable with my approach to the session this week. **[RUG2G]** gave his thumbs up and said his favourite colour was white.

[TKG2G] has a very low attention span diagnosis and was intrigued with the VR The FM AIT music was used to keep **[TKG2G]** settled and worked well.

[SIG2G] was excellent and involved with the entire session. Pointing out to the other children how to use the motion controllers and was the only other child to step onto the high platform within the VR.

Group 3 – The Saxes

Teaching Assistant: JK

The Group were all very hyper today. Both **[MMG3S]** and **[RNG3S]** were having an enjoyable session and **[RNG3S]** managed to work out how to navigate onto the platform.

"It feels very unnerving on top of this high ledge"

[JWG3S] was the only child who did not have the preference questionnaire completed. The session was used to ask him questions about his personal preferences to build his Virtual Reality in time for next week's session. Most of the session **[JWG3S]** was content creating a series of 3D objects and using the animation functions to create a bouncing ball.

[LBL3S] was once again very involved with the VR and was anxious to leave the session early to go to his Maths lesson.

Group 4 – The Pianos

Teaching Assistant: SL

The Group had limited numbers in this week's session as **[LMG4P]** was absent. **[OSG4P]** and **[TBG4P]** were able to engage and use the motion controllers comfortably. **[LHB4P]** was withdrawn throughout the session and did not want to participate when asked. He agreed towards the last 5 minutes of the session; unfortunately, the Oculus headset's battery had depleted by this time. **[LHB4P]** was left without a turn.

Due to the nature of the short intervals and frequent usage from each child, this left very little charging time between sessions for the VR equipment.

Verdict:

This session rectified the Wi-Fi issue that prevented the casting. The rotational system around the VR/FM AIT was helpful in keeping each child occupied. The primary outcome was achieved. The children are now familiar with using a VR system to navigate and can safely use the equipment for periods of no more than 5 minutes without getting nauseous.[LHB4P] and [JWG3S] will have VR environments for the next session with individual preferences. [LHB4P] will have a numerical keyboard input and Jaydan a VRMI setup.

Week 5. Notes

Wednesday 1st December 2021

Group 1 – The Violins

Head Teacher: K.R.

Today's session was the first part of the main trials the children have all been leading up to.

Two groups were trialled.

The proposed outcome was to let each child experience their own virtual immersive musical reality with their own preferences and gradually introduce their sounds into the scene using the hand controllers to see how they would react within a virtual world. A second part of the Trial was designed to compose a piece of music using samples of choice or improvised samples.

The musical interaction would be used to test both technological and turn-taking (cognitive/music immersion and exposure using repetitive phobias in the form of sounds being played until the sounds were recognised as not a problem.

Only [CFG1V] and [NCG1V] managed to have a complete turn on the VR

Group 2 – The Guitars

Teaching Assistant: JK

The second session was much more successful and organised. Each child had a turn within their own VR.

[SIG2G] was in charge of using the video playback and setup of the video resolution for the session. **[RUG2G]** was highly responsive to the instructions and happy being immersed in the world. The familiarity of the room and the surroundings, including myself, increased **[RUG2G]** confidence. Listening to the song *'Believer'* **[RUG2G]** was immersed entirely and happy. His one-word answer summed up the experience.

"Happy"

[THG2G] was a little apprehensive about navigating around the scene and was fully

Verdict:

This session got off to a rather bad start; the IT technology and secure infrastructure configured within an educational / school setting generally prevent wi-fi public connections connecting with ease compared to a domestic home setup. The Trial was set up using the same configuration a day before at home to ensure everything worked as it should and perfectly. Thanks to K. R. for supplying her continuous beverages and supporting me during the sessions.

Week 5. Trial Notes

Wednesday 1st December 2021

Cases of loud noise: 5

Cases of dizziness: 0

Stepping out of Boundary: 1 Case Theo (TKG2G)

Group 1 – The Violins

[TMG1V] was listening to her favourite song.

Only [CFG1V] and [NCG1V] managed to have a total turn on the VR

[FBG1V] was able to respond well to the instructions regarding his interactions, ***"George Washington"*** pretending to play the piano whilst the VR controllers.

At that point, he listened to his sounds and was curious. ***"I wonder what is happening";*** in response to the hand dryer audio sample of the triggered virtual scene. **[FBG1V]** was not uncomfortable at any time.

[CFG1V] is generally unable to speak to adults or interact. When asked if she liked the music, **[CFG1V]** nodded in agreement. Her ability to interact was reasonable and **[CFG1V]** reacted well to instructions. Dexterity was excellent when throwing 3D shapes, and **[CFG1V]** reacted well to her favourite song by (once again) nodding to acknowledge her preference. A non-verbal Individual.

Phobia task: **[CFG1V]** reacted well to the instructions and when pressed the first button

"Birds" and ***"Nothing"***

[NCG1V]: Unable to use the VR headset, this was a test to see how the external Immersion would work. ***"I've been quiet for so long".***

When asked if **[NCG1V]** liked her pictures, **[NCG1V]** nodded. My favourite colour response to Blue was just a nod.

Some entirely accurate instructions were given, and **[CFG1V]** responded extremely well by nodding emphatically to her favourite music.

Although this test did not use an HMD, the immersive experience had a similar effect.
Deputy Headteacher KR presented the questionnaire, and **[CFG1V]** responded well.

Group 2 – The Guitars

[RUG2G] is diagnosed as a selective Mute. Throughout the five sessions, I have observed **[RUG2G]** to be very quiet but "switched on". It is apparent from his questionnaires and scores that he is a knowledgeable individual and can respond to physical requests. **[RUG2G]** cannot verbally interact. During the trial, **[RUG2G]** responded precisely to the instructions.
When asked about the large TV screen in the Room, he responded ***"Yes"*** to his favourite song.

[RUG2G] is very capable and can easily place himself within the VR world. **[RUG2G]** could switch the images over using the motion controllers — a task other children found more challenging to achieve.

[RUG2G] nodded to the hand dryer, and the loud noises did not phase him.

In the end, given the time we have spent together, and his ability to become comfortable, **[RUG2G]** responded to a hand gesture by giving a high-five!

[THG2G] has presented himself throughout the sessions as a quiet and reserved individual who interacted well in each lesson. After rebooting the VR Headset, the Interactive virtual screen achieved sound during this observation.

[TKG2G] could say his name when asked (ADHD).

"OMG the 149…OMG, it's the 35, I used to take that!"

"OMG it's Tower Bridge"

During the immersive experience, **[TKG2G]** was occupied, calm, and clearly fascinated with the *Number 12* Bus. **[TKG2G]** was very concerned when the music and video stopped and asked
"How do you restart the Video?"

Phobia: Banging – [TKG2G] was distressed when he heard the noise.

"Argh, OMG, I don't want to do this, I just want to go around"

At this point, [TKG2G] turned his attention to another area of the VR.

"Why is it night outside?"

[SIG2G] has social interaction and does not like change ***"Yeah, feels good, looks good!"***

[TKG2G] was asked to leave the group (Meltdown)

Week 6. Notes

Wednesday 8th December 2021

Group 1 – The Violins

Head Teacher: I.M.

Today's session was the final session of the six-part SPiME series. The objectives for this session were to complete the individual trials for the children who forewent the opportunity to complete their virtual reality session the previous week following a somewhat chaotic technical glitch.

This week, the children from this group were all present; therefore, this was an optimal opportunity to revisit sounds and phobias the children were sensitive to.

[TKG2G] was very excited to be selected first. When asked about her phobias, **[TKG2G]** stressed the sound of Thunder was something she disliked and was very frightened of. During her trial, a sample of Thunder was loaded into the software interface and output via the trial room's large interactive displays audio system. Whilst **[TKG2G]** was interacting with the virtual reality, the sample sound [Thunder] was played repeatedly at random intervals to test her physiological and psychological responses. Initially, the first response made **[TKG2G]** jump somewhat, but remarkably after six to seven repetitions of the same sound being presented at greater (slightly more intense) volumes each time— **[TKG2G]** had become accustomed to the sound. The observation was that **[TKG2G]** phobia was being masked by the 'personalised' virtual reality preferences causing a distraction during the immersion.

"It makes me feel a little bit nervous", **[TKG2G]**

Over five weeks, **[FBG1V]** grasped his final section more confidently. **[FBG1V]** was clearly observed interacting and navigating using the motion controllers with little instruction or fear within the virtual environment.

During each session, having the children's musical preferences [i.e. their favourite music] incorporated into the virtual environments encouraged them to display physical interactions such as body movement and dance moves.

[ESG1V] stated her preference to sit down during this week's session as she felt more comfortable navigating her virtual world. **[ESG1V]**, like the other children before her, displayed much more confident physical body language (when compared to previous weeks). Notably, the volume level of the HMD was not causing any adverse reactions to hypersensitivity (or hyperacusis, a trait common in people with ASD). **[ESG1V]** stressed her fear of Thunder and lightning and was administered sound samples repeatedly during her session. As observed previously, **[ESG1V]**, total immersion rechannelled her distraction whilst using the VR into not being startled by the sounds.

When asked how **[ESG1V]** felt the noise of the Thunder within the VR, her verbal response was

"Nothing really because I was indoors" **[ESG1V]**

"*I don't care about the lightning!*" [ESG1V]

When asked if she heard the same noise whilst outside (i.e. in-vivo), **"…would [you] possibly feel more frightened if she heard the noise outside?" [ESG1V]** responded with:

"A little bit, I would just run and scream like a banshee…." **[ESG1V]**

To conclude the virtual reality session, both **[CFG1V]** and **[NCG1V]** were each content with minimal interaction. It was evident from non-verbal cues and body language that both preferred not to engage during the session, nor were they absorbed in the technology. As an alternative option, both **[CFG1V]** and **[NCG1V]** used a numeric keypad interface

At the end of the trial session, all the groups gathered and were given a certificate of achievement and a token Christmas gift to thank them for participating during the trials. Headteacher IM, kindly signed the children's certificates on behalf of the school.

As a further test, a sample sound of a dentist drill was played back, and the children responded without any concerns or discomfort after completing their VR trial session.

Group 2 – The Guitars

Teaching Assistant: J.K.

[TKG2G] started the session by stating

"I've already seen this room…"

During the trial, a sample sound of loud knocking was played externally. **[TKG2G]** remarkably was not reacting to the sound (noted as his unpleasant sounds).

"I've found some blocks; I know what to do…" **[TKG2G]**

This week **[THG2G]** sustained an injury to his toe. It was advised that he should sit down in the centre of the room. During his exploration, **[THG2G]** was administered audio samples of a hand dryer at varying sound levels through the large interactive display within the room. During his immersion, **[THG2G]** distraction empowered him to continue the investigation of his personalised virtual world without any awareness of the hand dryer noises.

Throughout the past five weeks, **[THG2G]** has presented himself as a very apprehensive yet knowledgeable individual displaying restricted body movements—characteristic of autistic individuals. It was very encouraging to observe at the end of the group sessions **[THG2G]s** confidence had flourished by exhibiting more significant physical interactions.

[SIG2G] expert knowledge of Augmented Reality (AR) surprised the entire group:

"If I am correct…I think Augmented Reality is like using something like a phone or a tablet… Say you have an AR app… you use that up to see something in the area that is actually not there." **[SIG2G]**

This prompted a conversation between the group, who engaged in a shared discussion about their common interest in technology.

Group 3 – The Saxes

Teaching Assistant: J.K

During the session, a conversation was initiated regarding the James Webb telescope.
Once again, the children were engaged in conversation regarding technology. It was observed that Samuel was very interested in the project's development and how the virtual environment was constructed during a demonstration of the Epic Games Unreal Engine.

Similarly, **[MMG3S]** participated in a series of tests **(********* nine presentations)**

"It just startled me!... it was fine!" [MMG3S]. A hand dryer audio sample was presented and the volume was increased halfway through the test. Intervals between each presentation were varied. When **[MMG3S]** was administered the authentic hand dryer, she responded with

***"It's even better now!"* [MMG3S]**

[LBL3S] emphasised his sound phobia was loud screams. A series of **(******)** six scream samples were presented during **[LBL3S]** session.

[JWG3S] was immersed in his VR world and asked about his phobias. A sample sound of a hand dryer was presented repeatedly **(***************)** fifteen times during his immersive VR session.

***"I don't react properly; it hurts my ears but sure!"* [JWG3S]**

At the end of the session, **[JWG3S]** was quickly escorted to use a natural hand dryer. When asked if the actual hand dryer was better than expected, **[JWG3S]** responded

"It hurt my ears a little bit, but it was better than normal"...

[RUG3S] was not present this week

Group 4 – The Pianos

[LHB4P] was quick to respond for selection first, which was a very encouraging sign of personal development over the six weeks. **[LHB4P]** worked out how to navigate

When asked if the TA could see a difference with **[LHB4P]**, she replied:

***"Yes.. absolutely"* SL.**

***"When he's over here, he's got that confidence"* SL.**

At the end of his session, **[LHB4P]** recommended the creation of a virtual bowling environment with ten pins!

***"When are you going to make the bowling?...where we can go to, and throw balls?"* [LHB4P]**

[RNG3S] used free improvisation during her session to compose a piece of creative music using entitled "Funeral song". **[RNG3S]** chose a set of modern samples to record and present to the group members, who were excited and fully engaged. After her composition, **[RNG3S]** interacted with her VR environment for several minutes to experience a sensory room and soothing sounds.

Similarly, **[LMG4P]** commenced his session by arranging a piece of music before applying himself to his personalised ViMRI session and repeating, once again, his dance routine to his favourite song. One of the most remarkable aspects of **[LMG4P] 's** observations has been the continuity of physical interaction (i.e. dancing to his song) on each occasion, particularly when he has been immersed within his personal VR. Besides the fact that this was demonstrated in the first trial, **[LMG4P] 's** interaction was repeated once more in the second trial — within the same environment.

[LMG4P] TA commented during his trial session when questioned if this would be a typical interaction:

"with others that would be doing it, he could join in…[but] not independently."

***"…or being so happy"* SL.**

Due to the restricted time, **[OSG4P]** and **[TBG4P]** sessions amounted to five minutes each. Each child was observed, and both were competent in navigating their virtual environments.

Verdict:

The observations relating to each child's musical preferences and repetition within the VR. were clearly evident. It was clear that using similar exposure therapy methodologies, systematically presenting each child's personal preferences (albeit music and virtual) repeatedly.
The immersive nature of virtual reality (*in-vivo*) causes a distraction whilst de-sensitising the individual on the next encounter.

It would be strongly encouraged for additional sessions and investigations (after 3 months) and continue at greater length to test the hypothesis that ViMRI has positive cognitive and physiological effects (longer term) for children to improve their social and emotional wellbeing.

All groups were presented with a completion certificate.

Appendix I.

Interviews and Responses

Music Therapist A. Interview Notes

Music Therapist B. Interview Responses

Interview (Correspondence) with SR - NHS DTP.

From: SR (DEVON PARTNERSHIP NHS TRUST) <********@nhs.net>

Sent: 09 April 2020 14:07

To: Ioannou, Chris (c.ioannou54@canterbury.ac.uk) <c.ioannou54@canterbury.ac.uk>

Subject: Re: NIHR Introductions: Chris Ioannou: Devon Partnership Trust

Hi Chris

Really lovely to chat through your ideas and share some of mine this morning! Very happy if you want to talk again. I'd certainly be very keen to involve the NHS wards where I work when you get to that stage. Just let me know. It is an incredible instrument. Worthy of Dragons' Den for professional business assistance??

The Project Manager of the UK Clinical Research Facilities Network, tel *** *****. He sent the original email to the ********** requesting collaborators to support/offer academic and clinical input to your questions. 'Join us at the UKCRF Network Annual Conference 2020. You could look that up!

For my final year of training, I wrote what I thought was a pilot study (but they said it was more like a research project), and attach a copy in case you can pick up some ideas from the format.

Musical instruments you might like to consider:

Ocean drum
Gathering drum
Djembe
Bongo drums
Tambourine
Maracas
Rainstick (I had a Rainbomaker)
Windchimes
Reverie harp
Guitar (there are guitar apps where chords can be put in and played)
Harp
Violin
Metallaphone
Slit drums
Glockenspiel
Piano (as most people have encountered, and many have played, piano)
Handbells (hand/desk bells) can be put on table and you press the top down to sound it. Should have shown you this one!
Birdsong.

SR

End.

Interview (Correspondence) with EK.

From: Ioannou, Chris (c.ioannou54@canterbury.ac.uk) <christosioannou123@gmail.com>

Sent: 25 March 2020 16:50

To: ek@********.co.uk

Subject: Hello from Christos

Hi Emma,

Thank you so much for taking the time to talk about your work and open up some important areas for me to research further.I will look into Virgina Axline and SPD further

Please see attached a visual of the device I have produced, I am just in the middle of developing the Virtual Reality side but this could be tested/trialled in a play therapy setting also.

Thanks and stay safe.

Christos

End.

Discussion Video Meeting with Sarah Brand 10th June 2020 14:00

mobile: +44 (0)**** *** ***

Sarah is a Music Therapist and has studied at CCCU – her PhD is based on free improvisation.

During our discussion, the following points were noted:

- Music Therapy has been around for approx 50 years
- Music Therapy is a specialist clinical form of medicine that can only be practised by professionally accredited and fully trained music professionals. MTs generally must be accredited by a body of specialists NIMT and must hold accreditation. Not anyone can practise as an MT
- Sarah stressed the importance of an individual (client) being able to relate their feelings to a MT – the most essential attribute is one-one interaction.
  An emotional and social psychological connection made during a session must occur in a physical environment.
- A Virtual session is possible – however, the client would need to interact and be able to see or have an interaction with the MP present.
- One idea was to have the MT play out a part using a virtual story and the client respond to the virtual part within the same scene (This would need to be tested).
- Unreal Networking Online Games Option to research further.
- A proper event (trials) would need to be set up outlining the:
    - Goals of the trial
    - Clients sessions recorded
    - Analysis Before / During / After
- The Book 'Music Therapy An Art upon Words – Leslie Bunt' was recommend to read
- Sarah definitely sees the device as a valuable addition to MT but was sceptical (at this stage) about MTs using the device wholly. This is more of a supplemental device.
- The device would have to adhere to the practices of Music Therapy and be regulated.
- It is a Device that has the potential to support vulnerable individuals with special educational needs, sensory impairments and social and emotional communications".
- Some ASDs struggle with tactile touch and lights etc. note: wearing gloves or pressure gloves may be challenging to get them to put them on!
- Without the device being physically built and Sarah being able to play with the device, it is not easy to get an idea of the benefits initially.
- Be careful not to make a claim that it can help ASD or PWD as an intervention as this needs testing. State "It has the Potential".

Interview with Claire the Music Therapist

1. **What types of instruments do you use during a therapy session?**

String:

Percussion

Woodwind

A standard session would involve:

Harmonic instrument – to provide musical grounding and harmonic support – piano and or guitar

Untuned percussion:

Drums (standing, djembes) small drums, tambourines, cymbal

wooden instruments - slit drum, wood blocks, shakers, cabassas

Tuned percussion:

xylophone, glockenspiel, chime bars

Harmonic wind instruments:

melodica, harmonica, single note horns

Then depending on the client, any other kind of instrument that they are interested in and able to use.

Claire and I have found that a wireless microphone is really helpful for teenagers. Although we are not sure about using any blowing instruments or instruments which come in contact with the mouth in light of CV19.

2. **What instruments provide the most benefit and nurture positive results?**

Music therapy tends to be a client led intervention – which means that where possible and appropriate you encourage the clients to choose their preferred instruments. This is not always the case – if someone struggles with this, cannot make choices, or if someone only chooses one instrument each week and the aim is to help them be more flexible, then I would work on expanding this.

Having said that, for able bodied children I find that a standing drum with beaters is often very helpful, as is a hand held drum/tambour.

The piano is great because its so easy to access and can be shared easily.

The guitar can be held by the therapist and then offered to the client whilst the therapist is still holding it.

If I had to only work with 2 instruments, I would choose a piano and a hand drum.

3. **Do you use any other non-musical instruments as intervention?** (Bears)

I find having a scarf/cloth or blanket to be very useful and also sometimes have toys, puppets and art materials available. But this would not be considered an essential or even necessary part of music therapy kit.

4.What instruments are needed in a room as a pre-requisite to carry out a session?

Piano/Good quality keyboard and some untuned percussion.

(Having said that, there are times when I only use my voice)

5.Does the location of instruments and room layout change with each session?

I will set up the room differently for each client, depending on what instruments they like. I will try and recreate a similar layout each week – this forms part of the therapeutic process of providing familiarity and helps clients to feel secure.

6. **Can smell effect an individual's session?**

This is not something I usually consider – I don't try to change this in any way, but am aware that a lot my clients will have be acutely aware of sensory elements, including smell!

7. How much improvisation would a typical high functioning autistic individual demonstrate in a session? (i.e. 60/40%)

It really depends on the client and how they respond within therapy. If they are really 'into' music then I would expect most of the session to be music based. But its also possible that someone who would make music in other contexts (a music lesson for example) may use the session completely differently and be reluctant to play.

I'm aware that a lot of my answers are very open ended – this reflects the nature of music therapy, that it is also very open ended and really depends on the individual's needs and then on their specific journey within therapy.

8 What types of instruments do you use during a therapy session?

I tend to use instruments that are easy for the clients to access without prior knowledge. Hence percussion, tuned and untuned, easily accessible woodwind (harmonica, melodica, horn, swanee whistle), piano and guitar.

Some therapists do bring in their own instruments – e.g., Violin, cello, clarinet – if they think this will add to the client's experience.

9.What instruments provide the most benefit and nurture positive results?

Really depends on the client and their preferences and needs. Can really change from session to session.

10. Do you use group therapy?

Yes – can tell you more about this if necessary

11. How is a client referred to you for music therapy?

I work in 3 different settings, 2 special schools and 1 charity where parents apply for children to attend.

Special school: any professional who works with the children in school can refer including senior management team, teachers, speech and language therapists, physiotherapists and teaching assistants.

Charity: parents apply for an assessment and then children are seen when a space is available

12. To what degree of musicality does an autistic client have?

This completely varies. There is no need to demonstrate a particular musical skill to access music therapy and benefit from it.

Music therapy is about supporting anyone, regardless of musical ability, to access interactive music making.

13. Does the client prefer a therapist in session?

An essential part of the therapy is building a trusting relationship with the client so that they feel they can express themselves freely with support and without judgement.

14. Does the response of the therapist during a session encourage the client?

I hope so! This is very important to the music therapy process.

15. Does this help them with the recovery process?

The clients I work with are not necessarily referred with 'recovery' in mind.

They are usually referred to offer support in the following areas:

- emotional needs, including working with trauma – this in turn can address behavioural issues
- communication
- social interaction
- developmental milestones
- making and maintaining positive relationships
- wellbeing and confidence

Hopefully, through the trusting relationship and the use of music as a means of interaction, the clients are able to make and experience some positive change, a sense of being heard and of having communicated something important.

16. **What are the perceptions of an individual prior to having therapy?**

At school I tend to get the perspective of the teaching staff and therapy team. I work with such a wide range of children that each perspective is different.

At the charity were parents refer, I know the childrens' stories via their parents.

17. **Would a musical device attract an individual during a session?**

I'm sure it would! I can't think of a child who would not be interested.

Some of the children I work with would be able to manage using a device alongside other instruments.

Other children (who spend a lot of time on tablets) might become easily obsessed, so I would have to think about how best to use it.

18.What are the outcomes of their perceptions after therapy?

Do you mean how they are perceived by others? If so, this really varies.

Sometimes the changes are really obvious – i.e. decreases in challenging behaviour, more vocal sounds/speech, greater ability to self regulate, more sociable.

Other times music therapy is something that offers an enjoyable and helpful experience but may not demonstrate any major external changes, but is valuable nevertheless. (About quality of life and experience.)

19. Inattention?

Music therapy can really support client's who struggle to focus, it is often a key aim of the work.

20. **Would you consider using a technologically mediated musical device in a session with no therapist being physically present but available online to offer support?**

Yes! Definitely post C19. Prior to the pandemic it wouldn't have featured in my work, but it is much more likely to now.

21. **What preference do individuals have to types of musical instruments?**

The same as anyone else. Sometimes autistic clients who are very sensory can be very attracted to metal instruments which have a long vibration, such as cymbals, wind chimes and chime bars. I might not always encourage this, as they can get so distracted by the sensory element that they don't engage with me.

22. **What are your personal experiences when working with individuals with ASD, do they have a common factor compared to say a patient recovering from trauma?**

The most common experiences are of individuals struggling to connect with others, struggling to be flexible and often struggling to manage their emotions.

I have and do also work with children on the autisic spectrum who have experienced trauma. This tends to enhance their difficulties with connection, flexibility and self regulation.

23. **Do you use an iPad during a session?**

I don't own one, but would like to start using one. I have used garage band on a laptop and find that some clients, particularly those who are more cognitively able find it helpful to be able to listen back to themselves.

As you know, I also wanted a device that would enable some of my physically disabled clients to have more of an active role in composing and mixing their own music.

Appendix J.

Qualitative and Quantitative Data

Critical Values t-Distribution Table: Two-Tailed *t*-test

Parents and Caregivers' Response Data

Two-tailed t-test: alpha $\alpha = .05$

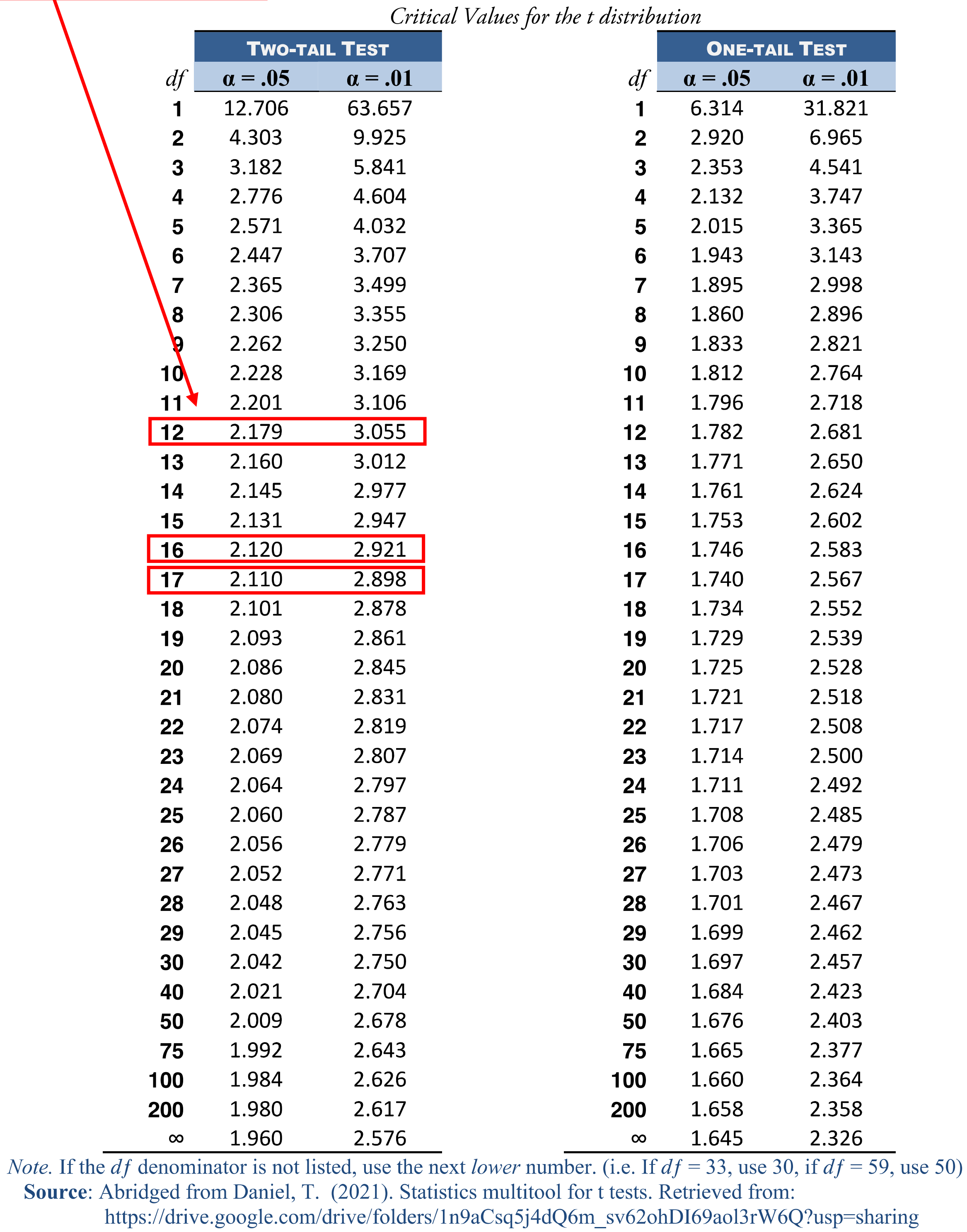
12 degrees of freedom t-value 2.179

16 degrees of freedom t-value 2.120

17 degrees of freedom t-value 2.110

STUDENT'S *t* DISTRIBUTION TABLE

Critical Values for the t distribution



	TWO-TAIL TEST			**ONE-TAIL TEST**	
df	**α = .05**	**α = .01**	*df*	**α = .05**	**α = .01**
1	12.706	63.657	**1**	6.314	31.821
2	4.303	9.925	**2**	2.920	6.965
3	3.182	5.841	**3**	2.353	4.541
4	2.776	4.604	**4**	2.132	3.747
5	2.571	4.032	**5**	2.015	3.365
6	2.447	3.707	**6**	1.943	3.143
7	2.365	3.499	**7**	1.895	2.998
8	2.306	3.355	**8**	1.860	2.896
9	2.262	3.250	**9**	1.833	2.821
10	2.228	3.169	**10**	1.812	2.764
11	2.201	3.106	**11**	1.796	2.718
12	2.179	3.055	**12**	1.782	2.681
13	2.160	3.012	**13**	1.771	2.650
14	2.145	2.977	**14**	1.761	2.624
15	2.131	2.947	**15**	1.753	2.602
16	2.120	2.921	**16**	1.746	2.583
17	2.110	2.898	**17**	1.740	2.567
18	2.101	2.878	**18**	1.734	2.552
19	2.093	2.861	**19**	1.729	2.539
20	2.086	2.845	**20**	1.725	2.528
21	2.080	2.831	**21**	1.721	2.518
22	2.074	2.819	**22**	1.717	2.508
23	2.069	2.807	**23**	1.714	2.500
24	2.064	2.797	**24**	1.711	2.492
25	2.060	2.787	**25**	1.708	2.485
26	2.056	2.779	**26**	1.706	2.479
27	2.052	2.771	**27**	1.703	2.473
28	2.048	2.763	**28**	1.701	2.467
29	2.045	2.756	**29**	1.699	2.462
30	2.042	2.750	**30**	1.697	2.457
40	2.021	2.704	**40**	1.684	2.423
50	2.009	2.678	**50**	1.676	2.403
75	1.992	2.643	**75**	1.665	2.377
100	1.984	2.626	**100**	1.660	2.364
200	1.980	2.617	**200**	1.658	2.358
∞	1.960	2.576	∞	1.645	2.326

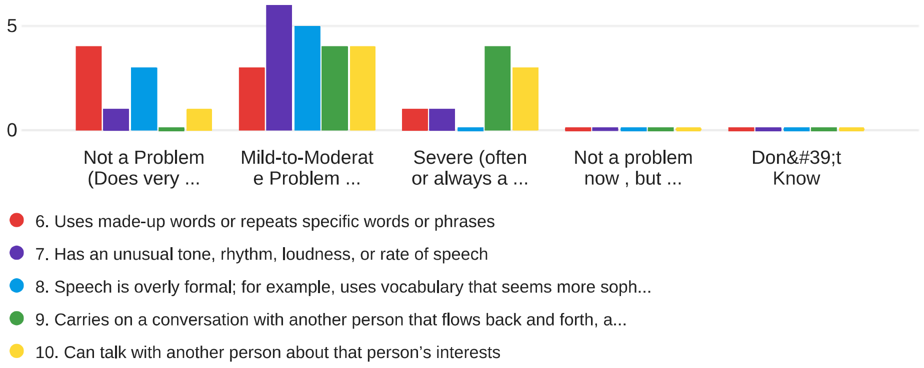
Note. If the *df* denominator is not listed, use the next *lower* number. (i.e. If *df* = 33, use 30, if *df* = 59, use 50)

Source: Abridged from Daniel, T. (2021). Statistics multitool for t tests. Retrieved from: https://drive.google.com/drive/folders/1n9aCsq5j4dQ6m_sv62ohDI69aol3rW6Q?usp=sharing

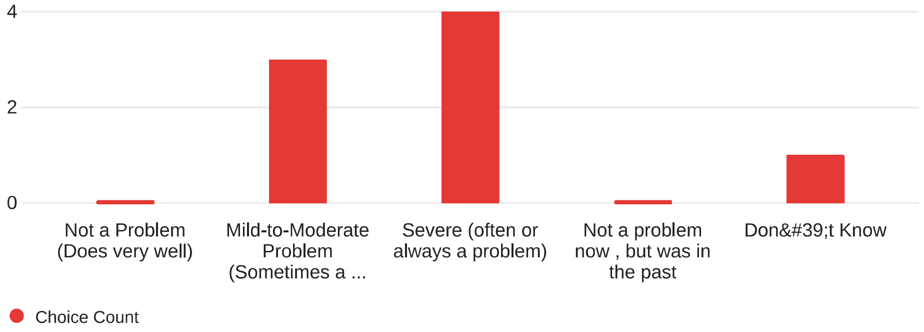
Link to source

Q6 - How does the person you are rating communicate?

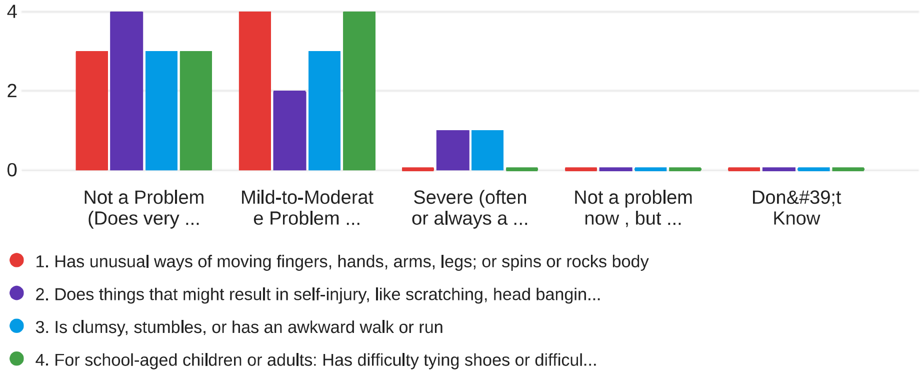
Q7 - Does the person you are rating do any of the following?



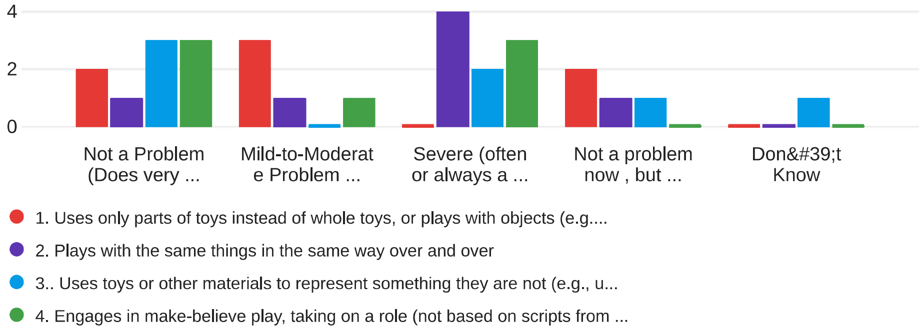
Q8_1 - 1. Makes eye contact when speaking with or listening to another person



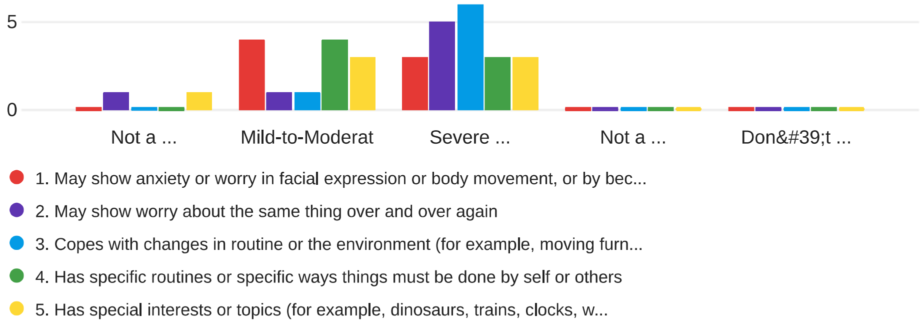
Section 3 - How does the person you are rating move his or her body?



Q9 - How does the person you are rating play? (For an older person, how did he o...



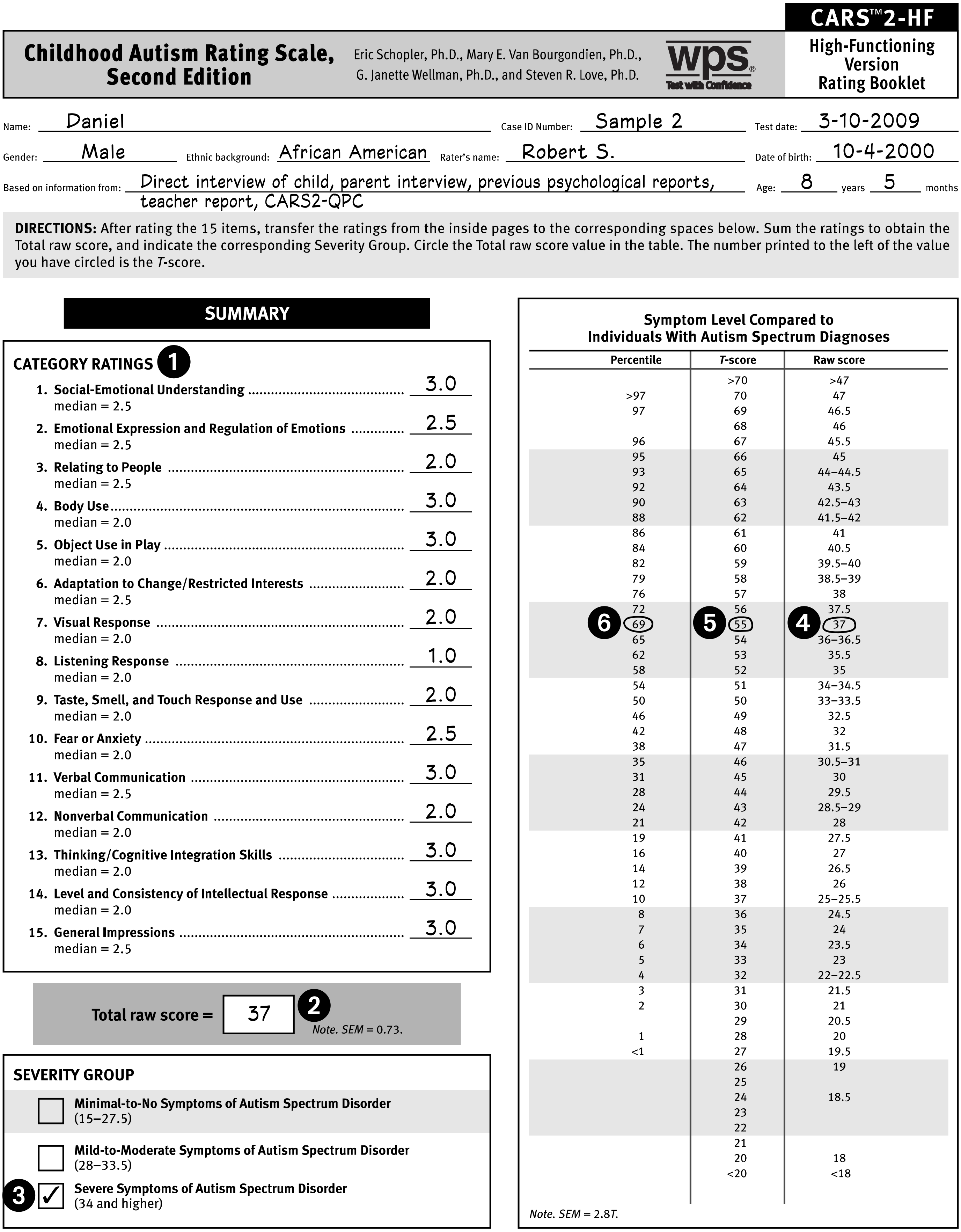
Q10 - How does the person you are rating react to new experiences and changes i...



Appendix K.

Childhood Autism Rating Scale, Second Edition (CARS-2)

Example *CARS-2-HF* Score Report



CARS™2-HF

High-Functioning Version Rating Booklet

Childhood Autism Rating Scale, Second Edition

Eric Schopler, Ph.D., Mary E. Van Bourgondien, Ph.D., G. Janette Wellman, Ph.D., and Steven R. Love, Ph.D.

wps® Test with Confidence

Name: Daniel

Case ID Number: Sample 2

Test date: 3-10-2009

Gender: Male

Ethnic background: African American

Rater's name: Robert S.

Date of birth: 10-4-2000

Based on information from: Direct interview of child, parent interview, previous psychological reports, teacher report, CARS2-QPC

Age: 8 years 5 months

DIRECTIONS: After rating the 15 items, transfer the ratings from the inside pages to the corresponding spaces below. Sum the ratings to obtain the Total raw score, and indicate the corresponding Severity Group. Circle the Total raw score value in the table. The number printed to the left of the value you have circled is the *T*-score.

SUMMARY

CATEGORY RATINGS ①

1. Social-Emotional Understanding median = 2.5	3.0
2. Emotional Expression and Regulation of Emotions median = 2.5	2.5
3. Relating to People median = 2.5	2.0
4. Body Use median = 2.0	3.0
5. Object Use in Play median = 2.0	3.0
6. Adaptation to Change/Restricted Interests median = 2.5	2.0
7. Visual Response median = 2.0	2.0
8. Listening Response median = 2.0	1.0
9. Taste, Smell, and Touch Response and Use median = 2.0	2.0
10. Fear or Anxiety median = 2.0	2.5
11. Verbal Communication median = 2.5	3.0
12. Nonverbal Communication median = 2.0	2.0
13. Thinking/Cognitive Integration Skills median = 2.0	3.0
14. Level and Consistency of Intellectual Response median = 2.0	3.0
15. General Impressions median = 2.5	3.0

Total raw score = 37 ②

Note. SEM = 0.73.

SEVERITY GROUP

☐ **Minimal-to-No Symptoms of Autism Spectrum Disorder** (15–27.5)

☐ **Mild-to-Moderate Symptoms of Autism Spectrum Disorder** (28–33.5)

③ ☑ **Severe Symptoms of Autism Spectrum Disorder** (34 and higher)

Symptom Level Compared to Individuals With Autism Spectrum Diagnoses

Percentile	*T*-score	Raw score
	>70	>47
>97	70	47
97	69	46.5
	68	46
96	67	45.5
95	66	45
93	65	44–44.5
92	64	43.5
90	63	42.5–43
88	62	41.5–42
86	61	41
84	60	40.5
82	59	39.5–40
79	58	38.5–39
76	57	38
72	56	37.5
⑥ [✓ 69]	⑤ [✓ 55]	④ [✓ 37]
65	54	36–36.5
62	53	35.5
58	52	35
54	51	34–34.5
50	50	33–33.5
46	49	32.5
42	48	32
38	47	31.5
35	46	30.5–31
31	45	30
28	44	29.5
24	43	28.5–29
21	42	28
19	41	27.5
16	40	27
14	39	26.5
12	38	26
10	37	25–25.5
8	36	24.5
7	35	24
6	34	23.5
5	33	23
4	32	22–22.5
3	31	21.5
2	30	21
	29	20.5
1	28	20
<1	27	19.5
	26	19
	25	
	24	18.5
	23	
	22	
	21	
	20	18
	<20	<18

Note. SEM = 2.8*T*.

CARS-2-HF, p34. Credit - Schopler, E., Van Bourgondien, M. E., Wellman, G. J., & Love, S. R. (2010). Childhood Autism Rating Scale, Second Edition [Manual]. Torrance, CA: Western Psychological Services.

Appendix L.

Additional Texts

Broader Applications of Non-Musical Intervention

Auditory Integrated Training

Comparison Grid Links

Broader Applications of Non-Musical Intervention

Academics at the University of Kent have researched many forms of virtual and immersive technologies; these give rise to future collaborations for developing interventions in neurodegenerative and neurodevelopmental domains (Jian-Ang, 2021). One example of virtual chewing technology is currently in development.

Technicians from the School of Computing, Digital Forensics and Cyber Security at Canterbury Christ Church University (Werb, 2020) are evaluating the possibility of a virtual environment to coincide with digital forensic investigations through VR.
The Digital Forensics paradigm would benefit from virtual reality technologies through the prospect of continuously growing data. Forensic evidence could be logged within a virtual timeline and presented to investigators or a jury during a court case. Although not related directly to the ViMRI intervention nor its associated technologies, these applications would benefit from further investigation.

Large-scale cloud-based testing

Through the development stages of this research, pixel streaming and dedicated high-performance computing platforms demonstrated restrictive factors whilst developing an immersive virtual environment and testing the conceptualisation locally. [205] Two reasons became apparent; firstly, professional tools exist for testing and deploying applications and streaming protocols. Educational tier subscriptions provide 'taster credits' — limited to their monetary value for early testing and developing proof of concepts requiring high-end virtual graphics and CPU-intensive virtual machines. These are prerequisites for developing cloud applications in virtual and immersive realms. Secondly, the IT processes required to configure and deploy a fully accessible virtual environment from any device on an internet browser (using cloud services) demonstrate complexities and require prior knowledge of secure password validation, encryption, and certification.

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[205] Development stages refer to the events summarised in [E6] and [E7] of the 3S-TDP **(see page 65).** High-performance computing platforms refer to Amazon AWS and Microsoft AZURE.

On the positive side, investigations and discussions with cloud-computing services steered the author's direction of this research into suitable application solutions utilising the NICE engine remote application streaming (NICE SRL, 2020). A host of intensive, interactive environments using a virtual desktop within a virtual machine. Additionally, discussions with solution specialists (AWS educational support) explained a potential for up-scaling complex models and further financial support via enterprise schemes. [206]

Intellectual property (IP) and commercialisation considerations

Intellectual Property (IP) and procedures for obtaining the Freedom to Operate (FTO) searches require further research. During early stage development, no third-party rights would be infringed. Subsequently, Intellectual Property (IP) to develop the intervention currently resides exclusively with the author, with all other development rights held via Canterbury Christ-Church University (CCCU) following their postgraduate IP policy. From a developer and academic perspective, technology companies offer support with licensing, interaction design, and priority access to new hardware and software products for varying levels of bespoke design and integration support. [207]

3D printing

There are caveats to traditional 3D printers; the process behaves similarly to an inkjet printer. Tiny print heads release thermoplastic filaments without (physical) supervision and necessitate unnecessary blockages leading to structural defects during the printing process. Moreover, final products can periodically feature unsightly stepped surfaces that require finishing or sanding and smoothing out manually afterwards. A future prototype is proposed using various materials and acrylic coatings fabricated using additive and generative manufacturing techniques to form a physical proof of concept. The physical equipment uses innovative mixed immersive technologies that will facilitate musical interventions for children with an autism spectrum condition (ASC).

---

[206] $3000 compared with $150: requires a small business registration to obtain complete advantage of a more respectable starter credit and professional IT support

[207] Third-party hardware or technologies incorporated into the proposal of ARTIMIS and its respective devices have been researched and these do adopt 'Partnering Program Developer licenses. Such programs ensure that a commercial license is obtained before any external commercial rollout

Auditory Integration Training (AIT)

The following text account has been taken from Neurodevelopmentalist Pauleen Allen at the Sound Learning Centre, London: AIT is a non-invasive therapy that balances the auditory system by using modulated music to surprise the brain, stimulating it naturally. Randomly modulated music of a specially approved music programme is presented to a patient using an original AIT device: the Audiokinetron and the Earducator. The music should cover a broad frequency response of around 30Hz to 15kHz. Music is transmitted optimally to the inner ear via a set of (closed-back) studio-quality headphones.

Removing and re-introducing modulated music in a random output way stimulates bone conduction and provides the listener with random music changes at varying intensities. This process prevents the listener from anticipating changes in volume levels and sound frequencies — therefore re-training and conditioning them — to shift their attention more efficiently and rapidly (Bérard and Brocket, 2011).
As a result, this stimulates the auditory cortex.

AIT is recommended for individuals aged three years and cannot be administered if a patient has undergone any auditory surgery. [208] The Bérard AIT protocol (Bérard and Brocket, 2011) recommends ten hours of treatment over ten to twelve (consecutive) days, with two half-hour sessions a day. A rest of no longer than three hours between sessions is advised. The Sound Learning Centre confirmed that individuals with an ASC who experience hypersensitivity to sound typically have difficulty processing auditory information— impacting behaviour and learning development. Therefore, if an autistic child can process auditory information more effectively, this can help improve and comprehend their social environment. Taking an audiogram makes it possible to determine where peak hypersensitive hearing of an autistic child occurs in the normal hearing range. [209]

---

[208] Headphones fit more comfortably from age 3 years+; Glue ear, where a grommet may be inserted.

[209] The human speech (sound frequency range) varies by an individual (taking into account different spoken languages) typically between 100Hz to 10,000Hz

Comparison Grid Links

Virtual studio technologies (VSTs)

A selection of 'pre-shipped' Virtual Studio Technologies (VSTs) incorporating digital effects processors is available for procurement (*Native Instruments GmbH*, 2021) Virtual instruments and sound samples are available as advanced third-party plugins. Composer Cloud (*Sounds Online*, 2019) is one example offering access to an online subscription service and a virtual sound library of over 40,000 premium-quality sampled virtual instruments. [210] The Composer Cloud has established itself as an indispensable sound and percussion palette for many professional music creators and remains the first choice for many award-winning Hollywood film composers. [211] [212]

DAWs feature multi-track sequencers that capture real-time audio and MIDI data — sequentially on a linear timeline. Live 11 (Ableton, 2019a) is an alternative DAW utilised amongst live performers, disc jockeys (DJs) and the free-improvisation community. The Live 11 interface differs from traditional DAWs by offering a unique session view, comprising vertically arranged tracks for live performers to 'lay down' audio or MIDI clips with ease. Sampled clips (live recordings) can effortlessly be arranged and launched within a scene and triggered to a quantized master track — during real-time performance. [213] [214] MIDI controllers and hardware interfaces incorporate programmable recording features to manipulate audio and MIDI data into a DAW. Many MIDI-compatible controllers can be used as solo devices (individually) or combined with a DAW during a performance **(see The Comparison Grid, Page 54).**

---

[210] EastWest Communications Link to source.

[211] VST virtual software instruments and effects processors offer a wide variety of synthesizers and drum presets. Many VST plugins are available on a subscription and offer libraries of sampled sounds that integrate seamlessly into the DAW environment.

[212] EastWest is used by many award winning film composers e.g., Danny Elfman, J.J Abrams, John Powell, and Zedd.

[213] Quantization is the shifting of imprecise recorded MIDI notes and data onto a locked (quantized) grid to a chosen tempo note resolution. Groove Quantize and Swing refer to preset parameters that a DAW predetermines.

[214] A flexible 'grid interface' approach offers immediate real-time music creation and personalisation during a live performance. Ableton also offers the benefit of an integrated 'Max for Live' programming environment (Cycling 74', 2022).

Vintage studio hardware

DAWs are synonymous with modern-day music studios, superseding dedicated processor units, multi-track tape recorders, physical musical instruments, and other studio peripherals. Analogue equipment and audio devices comprised a continuum of valves, pre-amplifiers, and resistors. Many audio preset configurations via external connections require audio cables and output via open-reel recording. [215] Vintage digital music studio equipment (during the 1980s) consisted predominantly of expensive hardware — plagued by reliability issues during long music sessions. Copious levels of heat dissipation cooled down the equipment's internal components to counteract overheating. [216]

Studio levels of audio clarity required trained engineers to adjust external rotary controls and sliders. By comparison, vintage studio hardware counterparts of the 80s shared a commonality with today's music technology — electromotive force.
Electrical voltage remains constant and is still the most fundamental principle of modern computing — albeit in a binary format.

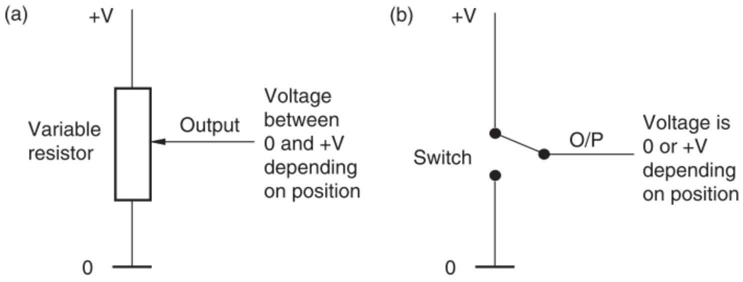

Figure 53. Analogous and digital voltage. Credit Rumsey (2004, p. 6).

Audio interfaces

Supporting the modern music production workflow requires connecting a computer via external equipment to a DAW workstation to allow audio and MIDI recording capability (Marks, 2017). Digital audio interfaces operate as the central hub for

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[215] Open-reel recording (also referred to as reel-to-reel audio) utilises a magneto tape format of widths of 6.35mm, 12.7mm, 25mm, 40mm, or 50.8mm spooled through the reels of a hub. An example device includes the Sony TC-630 (Sony, 1970)

[216] Externally mounted face-plates permitted the equipment to be secured directly into a studio cabinet.

internal and external connections to convert analogue signals of musical instruments or microphones into digital signals. Basic audio interfaces comprise volume control, dual balanced inputs, a stereo headphone jack, and individual lefthand and righthand monitoring outputs. At the professional level, audio interfaces incorporate premium-quality digital circuitry using a variety of inputs. [217]

For example, the RedNet™ Interface (*Focusrite Audio Engineering Ltd.*, 2019) is a professional studio-grade interface incorporating high dynamic frequency range response and audio sampling capabilities (equivalent to 192kHz). The audio hardware features a 24-bit sample rate resolution with high-quality optical connections and digital heat monitoring as standard. More recently, audio interfaces have incorporated *over-the-air-audio IP* (Internet protocol) capabilities adhering to the Dante ™ (*Audinate*, 2019) AV protocol — the standard of digital audio networking. [218]

Dedicated MIDI controllers

One example of a dedicated MIDI controller used by live performers to capture musical ideas, edit clips and perform expressively within a real-time environment is *Push* (*Ableton*, 2019b). This dedicated controller interface houses 64 silicone touch pads with high-resolution precision encoding and rotary knobs to adjust MIDI parameters in real-time (pitch, bend, velocity, aftertouch and polyphony). When connected to its native software (i.e., Live 11), the Push interfaces integral screen, pads, and surfaces synchronise to illuminate — coexisting with the DAW — whilst offering complete control over a real-time performance.

NOTE: This technology influenced the author to develop a reduced technology physical interface; without the performer's need to view different computer displays during a live performance.

---

[217] Inputs include FireWire (IEEE 1394), Thunderbolt (Intel and Apple Inc, 2011), USB-3 connectivity, and MIDI-compatible connectivity.

[218] *Dante* is an expandable audio-visual protocol replacing the traditional audio connections with ethernet cables offering a high-fidelity, robust and faster-routed connectivity. Dante-compatible devices can share a dedicated network, and the signals are transported between devices in any location on-site—reducing wiring.

Table 62.

Example MIDI Controllers

Controller	Manufacturer	Key Features
Push	Ableton	Realtime recording, multi-track, non-linear live composition
Sensel Morph	Sensel	Touch-sensitive programmable MIDI MPE pressure pad
Seaboard Rise 2	Roli	MIDI expressive keyboard
BLOCKS	Roli	5D Touch drum pad
Launchkey	Novation Music	Integrated MIDI controller keyboard

Musical Instrument Digital Interface

The *Musical Instrument Digital Interface* (MIDI) (The MIDI Association, 2020) is a universal musical communications specification protocol that defines the sounds and messages to inform behaviours relating to any General MIDI compliant (GM) device (Midi.org, 2022). [219] [220] The MIDI protocol supports communication between digital audio hardware and music software to ensure reliable compatibility. [221] The stability and robustness of the GM specification (i.e., SMPTE MIDI time code), its synchronisation and connectivity between devices have established MIDI as the gold standard communications protocol within the music industry. [222] Much to the versatility of the protocol, a revised MIDI 2.0 specification supporting MIDI polyphonic expression (MPE) appeared in 2020 (Beggs and Thede, 2001).

MIDI Controllers

Besides many technical networking enhancements, the second revision (i.e., MIDI 2.0) provides support for multidimensional hardware controllers and instruments. The Seaboard Rise 2 (Luminary ROLI, 2022) is one recent music controller,

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[219] MIDI messages consist of: notes, expression controllers, programme changes and timecode,

[220] The MIDI 1.0 specification was introduced in 1982; first appearing in its entirety in 1983. (Smith and Wood, 1982).

[221] Transmitting (TX) and receiving (RX) original data that adheres to the GM specification between sounds and file formats ensure consistency of playback and transferability between audio-video applications.

[222] SMPTE, devised by the Sound of Motion picture and Television Engineers, refers to the MIDI timecode specification that synchronises soundtracks to films and motion pictures.

incorporating 5-dimensional surface capability to control multiple MIDI MPE parameters (i.e., strike, glide, slide, press, and lift) simultaneously with low latency. [223]

Software Digital Audio Workstations (DAWs)

Logic Pro (*Apple Inc*. 2020a), Cubase Pro (*Steinberg Media Technologies GmbH*, 2021), and Pro Tools (*Avid Technologies Inc.*, 2020) are the benchmarks of music production software. These three high-end software applications support the *Musical Instrument Digital Interface* (MIDI) communications protocol and accelerated Digital Signal Processing (DSP) interfacing. Many advanced editing capabilities of these DAWs appeal to producers and studio engineers. The above applications surpass 2048-tracks of audio data and support a minimum of 1024 MIDI tracks, respectively. [224]

Free, Open-Source Software for the Recording Industry

Alternative *freemium* (i.e., free) music software is accessible through online browser-based software applications and appeals to musicians who seek basic functionality and accessibility for editing audio. In addition, many open-source sequencers provide full MIDI integration and compatibility with mobile and tablet devices. [225]

…

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[223] MPE allows sounds can be controlled in one direction or as multidimensional controllers such as the Sensel Morph (Sensel, 2022) and Roli Seaboard Rise 2 (Roli, 2022) demonstrate; offer five or more dimensions of instantaneous touch sensitivity to control MIDI parameters.

[224] Advanced editing capabilities are available on the professional versions of each software variant, including score editing, time stretch, and step editing.

[225] Soundtrap. Typeatone. Audiotool. AudioSauna. PatternSketch. Soundation. Looplabs. Available from the App Store (Apple) or Google Play Store (Google).

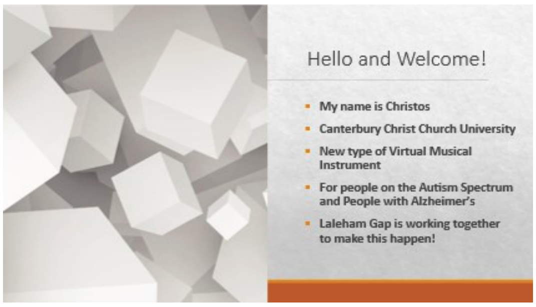
Appendix M.

Presentation Material

Presentations made to groups during the SPiME programme

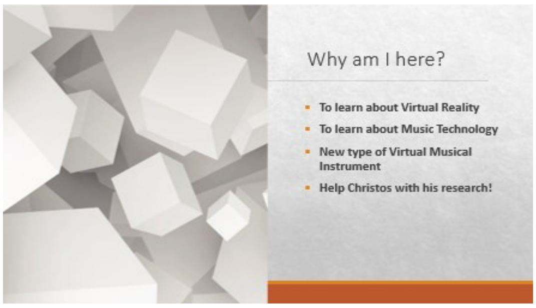
Virtual Reality Music

AT LALEHAM GAP



Hello and Welcome!

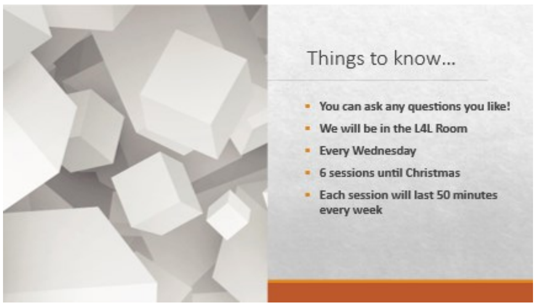
- My name is Christos
- Canterbury Christ Church University
- New type of Virtual Musical Instrument
- For people on the Autism Spectrum and People with Alzheimer's
- Laleham Gap is working together to make this happen!



Why am I here?

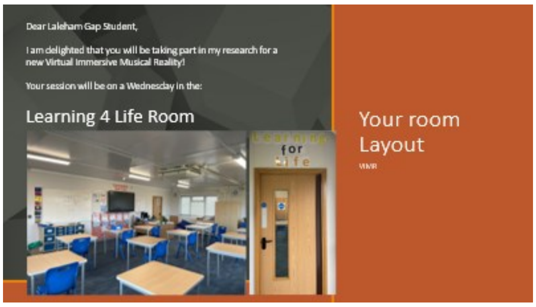
- To learn about Virtual Reality
- To learn about Music Technology
- New type of Virtual Musical Instrument
- Help Christos with his research!

The Device…



Things to know…

- You can ask any questions you like!
- We will be in the L4L Room
- Every Wednesday
- 6 sessions until Christmas
- Each session will last 50 minutes every week



Dear Laleham Gap Student,

I am delighted that you will be taking part in my research for a new Virtual Immersive Musical Reality!

Your session will be on a Wednesday in the:

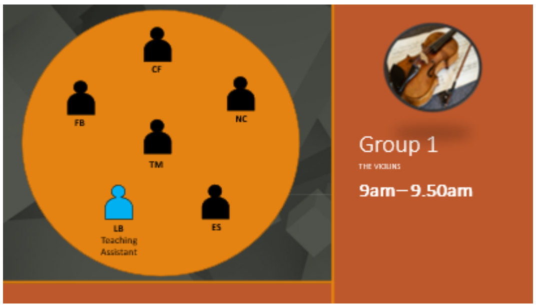
Learning 4 Life Room

Your room Layout

VIMR

Wednesday Nov 3rd	Session 1: Virtual Immersive Music- An introduction
Wednesday Nov 10th	Session 2: What do you like?
Wednesday Nov 17th	Session 3: First Exploration of VIMR
Wednesday Nov 24th	Session 4 : Virtual Play
Wednesday Dec 1st	Session 5: Virtual Immersive Music– A Customised Immersive Experience
Wednesday Dec 8th	Session 6: Virtual Immersive Music– Exit Interviews and questionnaires

1pm – 2pm :Notes & writeup



Group 1

THE VIOLINS

9am– 9.50am

Some musical instruments

- Traditional Instruments
- Electronic Instruments

Technology

https://www.youtube.com/watch?v=OCAuoCSWIOQ

- Sequencer / Loopers
- MIDI
- Electronic Music

Session 1: Virtual Immersive Music
An introduction

You will meet Christos for the first time in the *** Room
with your Teaching Assistant

In this session, we will introduce

- **A taster session of what is to come…**
- **Electronic music and traditional instruments**
- **Play with some musical instruments!**
- **This session will last for no longer than 50 minutes**

Session 1

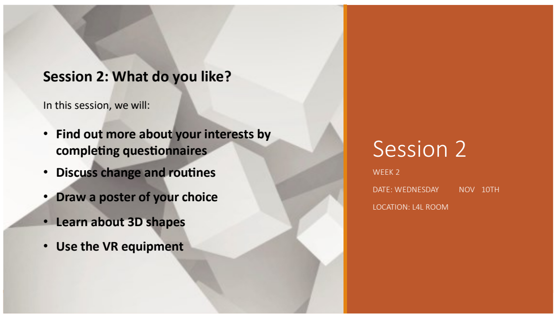
WEEK 1

DATE: WEDNESDAY NOV 3RD

LOCATION: L4L ROOM

Musical instruments

https://philharmonia.co.uk/resources/sound -samples/



Session 2: What do you like?

In this session, we will:

- **Find out more about your interests by completing questionnaires**
- **Discuss change and routines**
- **Draw a poster of your choice**
- **Learn about 3D shapes**
- **Use the VR equipment**

Session 2

WEEK 2

DATE: WEDNESDAY NOV 10TH

LOCATION: L4L ROOM

Session 3: First Exploration of VIMR

In this session, we will introduce

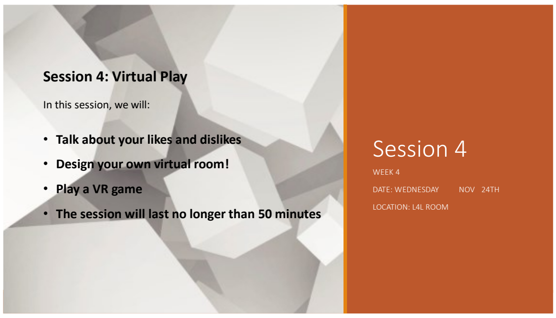
- **What is a VIMR?**
- **Exploring virtual worlds**
- **Listen to relaxing music**
- **Sensory Rooms**
- **The session will last no longer than 50 minutes**

Session 3

WEEK 3

DATE: WEDNESDAY NOV 17TH

LOCATION: L4L ROOM



Session 4: Virtual Play

In this session, we will:

- **Talk about your likes and dislikes**
- **Design your own virtual room!**
- **Play a VR game**
- **The session will last no longer than 50 minutes**

Session 4

WEEK 4

DATE: WEDNESDAY NOV 24TH

LOCATION: L4L ROOM

Session 5: Virtual Immersive Music –
A Customised Immersive Experience

In this session, we will

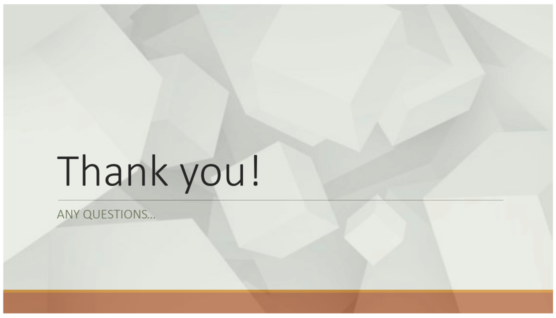
- **Immerse yourself in your own, customised immersive musical environment**
  (you designed from Session 4)
- **Introduce your familiar images and sounds**

Session 5

WEEK 5

DATE: WEDNESDAY DEC 1ST

LOCATION: L4L ROOM



Thank you!

ANY QUESTIONS…

Appendix N.

Audio-Visual Material

File Structure and Links to Video and Audio Materials

The author makes the following accompanying folders accessible online:

(Examiners receive a dedicated USB pen drive mirrored with the same file structure)

- 📁 IOA15122187_PhD XR Music and Neurodiversity
  - 📂 00. Appendices Link to folder
  - 📂 01. ARTIMIS (Desktop Application) Link to folder
  - 📂 02. CiiMS Software Sampler Link to folder

- 📁 00. Appendices
  - 📂 00. Appendix A. Research Consent
  - 📂 01. Appendix B. Data Collection Form
  - 📂 02. Appendix C. Participant Requirements
  - 📂 03. Appendix D. Transcripts
  - 📂 04. Appendix E. VIMARS
  - 📂 05. Appendix F. Development
  - 📂 06. Appendix G. Ethics and Guidance
  - 📂 07. Appendix H. Weekly Session Notes
  - 📂 08. Appendix I. Interviews and Responses
  - 📂 09. Appendix J. Qualitative and Quantitative Data
  - 📂 10. Appendix K. Childhood Autism Rating Scale - Second Edition (CARS-2)
  - 📂 11. Appendix L. Additional Texts
  - 📂 12. Appendix M. Presentation Material
  - 📂 13. Appendix N. Audio-Visual Material
    - 📂 Additional Audio
    - 📂 Additional Footage
    - 📂 Case Study 1
    - 📂 Case Study 2
    - 📂 Case Study 3
    - 📂 Case Study 4
    - 📂 Case Study 5
    - 📂 Case Study 6

- 📁 01. ARTIMIS [Desktop Application]

Please consult the READ ME ARTIMIS.txt file within this folder

- 📁 02. CiiMS Software Sampler

Please consult the READ ME CiiMS Software.txt file within this folder

Full file path:

https://drive.google.com/drive/folders/11EdbWESZTeJZPycKpP2bgIkV2qKHx515?usp=sharing