Electronic Musical Instruments as Interactive Exhibits in Museums

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Academic Integrity

The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Whilst recent museum exhibitions have explored electronic musical instruments, the interpretational focus has been on materiality rather than sounds produced. Similarly, whilst authors have 'followed the instruments' to find the people who used and designed them, those who create and shape their sounds remain comparatively hidden. To address this problem, this thesis introduces sound genealogy – a methodology towards following the evolution of a sound through material networks and people - as an interpretational framework to support exhibition teams in explicitly connecting sounds to instrument interfaces using multi-sensory interactive exhibits. Adopting this methodology will improve visitors' experiences of music and sound content, helping them connect sounds from their lived experiences to the instruments associated with them: demonstrating how material networks can influence a sound's popularity and musical value over time, whilst drawing attention to the people involved in the design and use of both sounds and instruments.

Chapter one positions this research within contemporary exhibition practices and analyses the methodologies and literature that define the scope for upcoming discussions. The involvement of the UK's Science Museum Group institutions is also highlighted. Chapters two to four present three case-study insights based on observations of objects and their sounds, and the use of representative exhibits, in North American, European, and British museums. These case studies were chosen so as to represent a range of instrument categories (synthesizers, samplers, drum machines) and interpretational foci (interface, sound, function). Interview data obtained from exhibition team members highlights the strategies and challenges in co-creating positive exhibit experiences for diverse audiences. Evidence from these case studies also supports the analyses of theories and concepts from museum studies, science and technology studies, and sound studies in chapters five and six. This helps to position - and advocate for - the adoption of a sound genealogy methodology in demonstrating the value of sound through interactivity. Additionally, the anticipation and management of visitor behaviours is considered in the context of successfully attaining learning and entertainment goals. Finally, chapters seven and eight document the creation and evaluation of an original interactive exhibit by the author, supported by the sound genealogy methodology.

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Abbreviations

ANT. Actor-Network Theory

BME. British Music Experience, Liverpool

DAW. Digital Audio Workstation

CMI. Computer Musical Instrument, Fairlight

EDP. Electronic Dream Plant

EMP. Experience Music Project (now the Museum of Popular Culture, or MoPop), Seattle

FM. Frequency Modulation

GUI. Graphical User Interface

LFO. Low Frequency Oscillator

MC. Micro Composer, Roland

MIDI. Musical Instrument Digital Interface

MIM. Musical Instrument Museum, Scottsdale

MoMM. Museum of Making Music, Carlsbad

NIME. New Interfaces for Musical Expression conference.

NMC. National Music Centre, Calgary

NSMM. National Science and Media Museum, Bradford

RoHS. Restriction of Hazardous Substances

SCOT. Social Construction of Technology

SMG. Science Museum Group, UK

STS. Science and Technology Studies

TB. Transistor Bass, Roland

TR. Transistor Rhythm, Roland

USB. Universal Serial Bus

V&A. Victoria and Albert Museum

VST. Virtual Studio Technology

1 Introduction

1.1 Research Motivation

Electronic sounds are used in a wide variety of musical styles and continue to be consumed and enjoyed by millions. The electronic musical instruments responsible for such sounds – e.g., synthesizers, samplers, and drum machines - also continue to be collected, preserved, and exhibited in museums globally as objects. This is not only evident in music-focused institutions such as musical instrument museums and museums of popular music, but also within science-focused institutions such as science and technology museums which value the contributions made by these devices to wider technological and cultural interests.[1] As Boon and others argue,

> For a science and technology museum, few exhibition topics have more potential appeal then music. Music is a major enthusiasm for a significant proportion of museum visitors […] [and is] also overwhelmingly artefactual: with the exception of unaccompanied and unmediated vocal performance, all music uses instruments and devices, to the extent that it perfectly encapsulates the relationships of technology in culture.[2]

The challenge for exhibition teams has been to demonstrate the significance of these instruments and their sounds to visitors – for example, as intrinsic to their lived experiences of music and sound cultures.[3] However, when instruments enter museum collections as musealised objects (removed from their natural or cultural environment and used for museum practices) they lose their original function ('use value') and are often relied upon solely as soundless *representations* of music, musicians (users), designers, cultures, and sounds, for example ('symbolic value').[4] This 'widely practiced approach to conserving media technology objects' - kept out of visitors' reach, turned off, and *silenced* – has meant that visitors 'cannot directly interact with sounds made by such objects' and therefore cannot understand what made

[1] Judith Dehail, 'Musealising Change or Changing the Museum: The Case of the Musical Instrument Museum from the Visitor's Perspective', *Museological Review*, 2014, 54.
[2] Tim Boon and others, ''Organising Sound': How a Research Network Might Help Structure an Exhibition', *Science Museum Group Journal*, Autumn.8 (2017).
[3] Kate Bailey, Victoria Broackes, and Eric De Visscher, ''The Longer We Heard, the More We Looked': Music at the Victoria and Albert Museum', *Curator: The Museum Journal*, 62.3 (2019), 340–341.
[4] Dehail, 53-54.

these objects unique in terms of what they were specifically intended to do: generate, trigger and modify sounds electronically.[5] Furthermore, as objects their functionalities and sounds also often remain visually hidden, which is particularly true of instruments whose physical features present little visual clues that indicate their sounding potential.[6]

Whilst the digitisation of instrument objects as new interactive exhibits has produced new representative devices that are – instead – turned on, used, and heard, many exhibition teams still continue to struggle to communicate the importance of specific sounds associated with each instrument. Additionally, misalignments between the design of exhibit interfaces ('the contact surface of a thing') and visitor behaviours continue to lead to tactile engagements that produce negative consequences for both visitors and exhibition teams.[7] Davies describes such a scenario at the Gemeentemuseum in Den Haag:

> A synthesizer […] in a 'hands-on' room […] necessitates a perspex covering that is fixed over most of the controls […] [leaving] only a few important controls accessible. The more controls there are on an instrument, the easier it is for someone to make a few random adjustments that result in the sound disappearing, and to be unable to reverse the process. There is little point in providing an electronic instrument in a hands-on situation unless it will always produce a sound, even if many of its capabilities are thereby excluded.[8]

Therefore, in this thesis I aim to explore the digitisation of electronic musical instruments for museum interactivity: creating unique exhibits which demonstrate sounds that may – themselves – be considered significant, but also represent noteworthy instrument objects, functionalities, or themes within the same museum. This is realised through visitor-centred and sound-focused approaches towards, first, the analysis of recent exhibition practices - based on valuable insights from exhibition teams in addition to observations within museums – and second, the construction of a new multi-sensory interactive exhibit hosted within the temporary exhibition *Sonic: Adventures in Audio* at the National Science and Media Museum in Bradford (NSMM). The NSMM was the partner institution that commissioned this Collaborative Doctoral Partnership research, forming part of the Science Museum Group (SMG). Importantly, discussing the creation of the exhibit provides the opportunity to present and analyse qualitative data from visitors

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[5] James Mansell, Alexander De Little, and Annie Jamieson, 'Staging Listening: New Methods for Engaging Audiences with Sound in Museums', *Science Museum Group Journal*, Spring.17 (2022), 5.
[6] Dehail, 53.
[7] Brenda Laurel, 'Introduction', in *The Art of Human-Computer Interface Design*, ed. by Brenda Laurel (Boston: Addison-Wesley Publishing Company, 1990), XII.
[8] Hugh Davies, 'The Preservation of Electronic Musical Instruments', *Journal of New Music Research*, 30.4 (2003), 299.

(collected through observations and questionnaires) regarding their learning and entertainment experiences. Analysing the results of these methodological approaches helps to provide answers to the following questions:

- How have electronic musical instruments been framed as objects and demonstrated through interactivity in recent exhibitions, and how have these methods proved problematic for exploring instrument sounds?
- What sort of methodological framework should exhibition teams adopt to tackle existing problems in framing the sounding potential of electronic musical instruments using interactivity?
- What practical steps could be taken to ensure that visitors gain positive learning and entertainment outcomes, whilst exhibits remain resilient to various tactile behaviours?

As this thesis explores the sounds of electronic musical instrument technologies using examples from science, design, and music-focused exhibitions, much of the theoretical underpinning is formed through my synthesis of the fields of science and technology studies (STS), sound studies, and museology, which have already produced studies of electronic musical instruments and related exhibitions (more on this later). This demonstrates that there already exists significant academic interest in this area of research, which supports and highlights the need for practical and empirical research to be conducted. However, whilst significant authors in these fields such as Bijsterveld, Leonard and Pinch have examined music objects and museum sound, as well as electronic musical instrument innovations, there is yet to exist focused research on the demonstration and interpretation of these instruments and their sounds as multi-sensory exhibition content, which I address in this thesis.

Furthermore, the creation, interpretation and use of my exhibit tests a new methodology for studying and interpreting electronic musical instruments and their sounds called *sound genealogy*: following sounds back and forth in time to find the people and material networks (e.g., musical instruments and recorded media) responsible for creating, triggering, and shaping it. I argue that a sound genealogy methodology can be useful for museums as a possible solution to tackle the interpretation of instrument objects and interactive exhibits in exhibitions, in terms of their sounding potential as well as the sounds that visitors might consider relatable. However, whilst I also argue that interactivity is the best tool for conveying and connecting sounds and instrument interfaces, exhibition teams should consider using more than just a single exhibit to communicate a sound genealogy methodology. Ideally, exhibition teams should consider the inter-dependence of various multi-sensory content (vision, touch and hearing as objects, interactivity, and sound) towards enhancing visitor experiences of electronic musical instruments.

1.2 Thesis Structure

In chapters two, three and four I present three case study instruments installed as objects and/or interactive exhibits in exhibitions, globally. Case studies include the Electronic Sackbut in the Canada Science and Technology Museum, Ottawa (displayed in the *Sound by Design* gallery), the Mellotron M400 in the Musikinstrumenten-Museum, Berlin (previously displayed in the temporary exhibition *Good Vibrations: A History of Electronic Musical Instruments*, then the *Electronic Musical Instruments* gallery), and the Roland TR-808 (Transistor Rhythm) in the Design Museum, London (based on an exhibit that was due to be hosted in the temporary exhibition *Electronic: From Kraftwerk to The Chemical Brothers*). I specifically chose these three case studies not only to represent the three categories of instruments – synthesizers, samplers, and drum machines (respectively) – but also to highlight each museum's interpretational focus towards these devices - interface, sound, and function.

I have structured each case study chapter in the same way. First, the history of each object's design and use is explored in relation to the development of sounds which musicians have created, triggered, and modified using these instruments, before exploring how this history has been contextualised in exhibition settings. Interviews with both museum professionals and instrument/exhibit designers are then used in combination with observations of both the exhibitions and the case study instruments and interactive exhibits to discuss how recent museological practices have attempted to enhance multi-sensory visitor experiences.

In chapters five and six I use the case studies in the previous chapters to analyse contemporary exhibition practices in relation to theories and examples from literature. To begin with, I highlight the issues that a reliance on objects might present to exhibition teams in demonstrating their functionalities and sounds. Data collected through the case studies, as well as additional interview data and examples of exhibition practice, are used to highlight the urgency of these museological issues. I then introduce and use the sound genealogy methodology for framing the heritage of electronic instrument sounds in exhibitions to demonstrate ways of solving these problems. Then, in chapter six, I examine museum interactivity in relation to electronic musical instruments and sound, and how it is approached – from the perspectives of both exhibition teams and audiences – and how it can shape and enhance visitor experiences.

In chapters seven and eight, I apply the sound genealogy methodology towards a study of the Amen breakbeat, focusing on the impact of the Akai S950 digital sampler and its time-stretching function on the breakbeat's sonic identity, as well as its application towards forming and shaping musical styles. This study formed the basis for the design and framing of my exhibit *Drum and Bass - Time and Space*, installed in the *Sonic…* exhibition at the NSMM. I split the two chapters chronologically in order to, first, identify how the design of the exhibit was intended to meet specific requirements - as stated in the museum's call for applications – and second, utilise visitor observation and questionnaire data to examine the various interpretations, actions, and behaviours that actually occurred during the exhibit's exhibition lifetime, which helped visitors to realise different learning and entertainment outcomes. Finally, I use the concluding chapter to evaluate the scope and potential for adopting the sound genealogy methodology using the additional insights gained through creating and testing my exhibit at the NSMM and identify further avenues for research and exhibition practice.

1.3 Literature Review

1.3.1 Electronic Musical Instruments and Music-Focused Exhibitions

Before exploring the installation of interactive exhibits that represent instrument objects, exhibition teams can draw upon extensive academic literature in the design, use, functions, and sounds of electronic musical instrument artefacts.[9] For example, separate books have been written on the Theremin, Mellotron, and the Electronic Sackbut (all of which were featured in the exhibitions visited during this research project: the latter two being the focus of two of the three case study chapters in this thesis).[10] Additionally, numerous musicology and history of technology resources explore and compare a wide scope of instrument designs and uses, whilst additional encyclopaedic compendiums investigate a plethora of instruments and their functionalities.[11] For example, Bjooks Media have recently published several resources of this kind such as *Push Turn Move: Interface Design in Electronic Music* and *Patch & Tweak: Exploring Modular Synthesis*: both of which explore electronic musical instruments in detail – focusing on interface design – with

[9] Early examples include: Richard H. Dork, *Electronic Musical Instruments* (New York: Radio Magazines, 1954); F.C. Judd, *Electronics in Music* (London: Foruli Limited, 1972); Walter Sear, *The New World of Electronic Music* (Alfred Pub Co., 1972).

[10] Albert Glinsky, *Theremin: Ether Music and Espionage* (Illinois: University of Illinois Press, 2005); Nick Awde, *Mellotron: The Machine and the Musicians That Revolutionised Rock* (Desert Hearts, 2008); Gayle Young, *The Sackbut Blues: Hugh Le Caine, Pioneer in Electronic Music* (Ottawa: Ottawa National Museum of Science and Technology, 1991); Thomas Brett, 'Prince's Rhythm Programming: 1980s Music Production and the Esthetics of the LM-1 Drum Machine', *Popular Music and Society*, 43.3 (2020), 244–61; Sean Williams, 'The Transformation of the Stepped Filter into a Musical Instrument', in *Material Culture and Electronic Sound*, ed. by Frode Weium and Tim Boon (Smithsonian Institution Scholarly Press, 2013).

[11] Kim Bjorn, *Push Turn Move: Interface Design in Electronic Music* (Denmark: Bjooks Media, 2017); Mark Vail, *The Synthesizer* (Oxford: Oxford University Press, 2014); Peter Shapiro, *Modulations: A History of Electronic Music: Throbbing Words on Sound* (New York: D.A.P., 2000); Mark Cunningham, *Good Vibrations: A History of Record Production* (Surrey: Castle Communications PLC, 1996); Robert Santelli, *Soundbreaking: Stories from the Cutting Edge of Recording Music* (Milwaukee: Hal Leonard Corporation, 2019).

supporting interview data.[12] Additionally, Vail's book *The Synthesizer* provides a deeper exploration of both synthesizer designs and synthesis methods in the context of using electronic instruments for composition, sound design ('programming'), and performance.[13] In doing so, Vail briefly discusses several early and rare synthesizer instruments and their designers, such as Thaddeus Cahill's Telharmonium, Friedrich Trautwein's Trautonium, and a replica of Oskar Sala's Mixturtrautonium - all of which are displayed (in some form) in the *Electronic Musical Instruments* gallery at the Musikinstrumenten-Museum, Berlin (see Figure 1.1. below).[14]

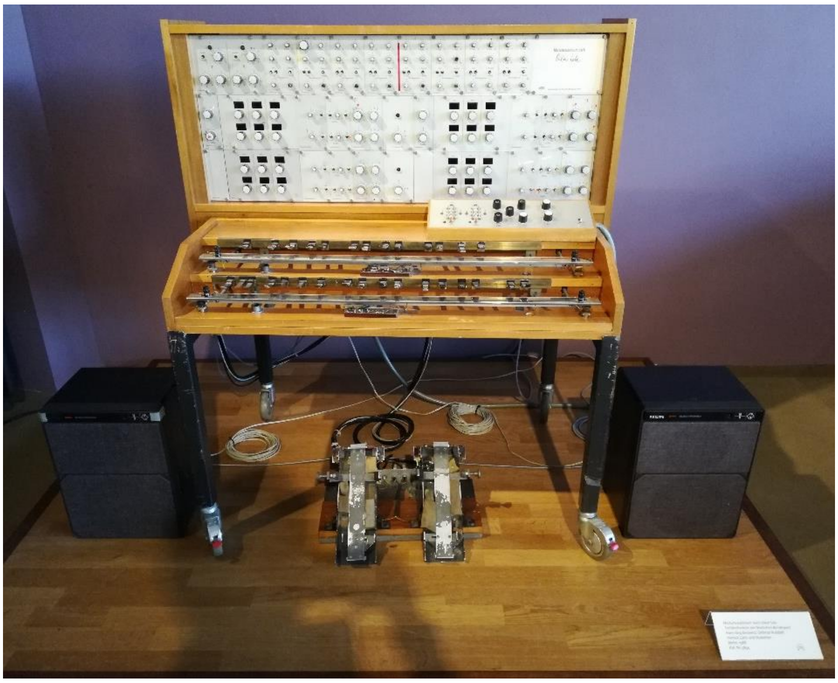

Figure 1.1. A replica of the Mixturtrautonium instrument, displayed in the *Electronic Musical Instruments* gallery in the Musikinstrumenten-Museum in Berlin.[15]

Resources such as these may have proved useful as research materials for exhibition teams to help frame and interpret instruments in exhibitions. However, certain members of exhibition teams have also been known to both curate and author electronic musical instrument research. For example, Bjorn – author and co-author of the previously mentioned *Push Turn Move…* and *Patch & Tweak…* books – also constructed a *Push Turn Move…* exhibition in Turin (2019), allowing visitors to interact with some of the modern

[12] Bjorn; Kim Bjorn and Chris Meyer, *Patch & Tweak: Exploring Modular Synthesis*, ed. by Paul Nagle (Denmark: Bjooks Media, 2018).
[13] Vail.
[14] Vail, 3, 8-9, 24-25, and 117-118.
[15] Katherine Wright, *New Worlds of Sound: Electronics and the Evolution of Music in Canada* (Ottawa: Canada Science and Technology Museums Corporation, 2013), 23-24.

instruments featured in his book.[16] Additionally, curators of exhibitions that feature electronic musical instruments and sounds – such as Benedikt Brilmayer (Musikinstrumenten-Museum, Berlin), Frode Weium (Norwegian Museum of Science and Technology, Oslo) and Tim Boon (Science Museum, UK) - have also written and edited books and articles on instruments from their museum's collections, and the themes that have framed them whilst exhibited.[17] Furthermore, my research follows a body of literature on music and sound in museums, conducted and commissioned by the SMG and published in their own journal.[18]

Nonetheless, little has been written on the collection, demonstration, interpretation, and management of such electronic musical instruments as objects and interactive exhibits in exhibitions. However, if we expand this area of literature, we can see there exists a larger – and often enlightening – number of articles written on music and sound objects, more generally, by employees of music-focused museums (past and present) and researchers. This demonstrates that museums – often in collaboration with others – are keen for their objects and exhibitions to be researched (which justifies the timeliness and significance of this doctoral research).

For example, at the turn of the millennium, Davies documented his experiences of working as an external consultant on electronic instruments at the Gemeentemuseum, Den Haag, between 1986 and 1993.[19] The author identified issues with managing electronic musical instrument objects in museums (whilst also highlighting various solutions) and discussed the challenges these modern objects presented to the working practices of the traditional museum. By doing so, he provided a valuable understanding of museological conflicts with electronic instruments representative of the time in which Davies was employed, which makes an interesting comparison to more contemporary exhibition practices.

Nonetheless, as Davies intended to discuss the *preservation* of electronic musical instruments (as the title of the article states), he only mentions interactivity in the museums 'hands-on' room in a small paragraph (as previously quoted) which, by default, also challenges the preservation of such objects. However, although his focus on interactivity is relatively small, Davies evidences an instance of the 'configured' approach to interactivity: covering parts of an instrument with clear Perspex as an attempt to direct visitors towards controls that the exhibition team believes to be more helpful for triggering and modifying

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[16] 'Push Turn Move', *FFLAG*, 2019 <http://www.fflag.it/push-turn-move/> [accessed 30 November 2020].
[17] Benedikt Brilmayer, 'Electronic Musical Instruments: How Electricity Came to Music', in *Good Vibrations: Eine Geschichte Der Elektronischen Musikinstrumente = a History of Electronic Musical Instruments*, ed. by Conny Restle, Benedikt Brilmayer, and Sarah-Indriyati Hardjowirogo (Berlin: Musikinstrumenten-Museum, 2017), pp. 23–27; Frode Weium, 'The Reception of the Hammond Organ in Norway', in *Material Culture and Electronic Sound*, ed. by Frode Weium and Tim Boon (Washington D.C.: Smithsonian Institution Scholarly Press, 2013); Boon and others.
[18] Boon and others; Mansell, De Little, and Jamieson; Tim Boon, Merel van der Vaart, and Katy Price, 'Oramics to Electronica: Investigating Lay Understandings of the History of Technology through a Participatory Project', *Science Museum Group Journal*, October (2014); Tom Everrett, 'Writing Sound with a Human Ear: Reconstructing Bell and Blake's 1874 Ear Phonautograph', *Science Museum Group Journal*, 2019.
[19] Davies, 'The Preservation of Electronic Musical Instruments'.

sounds.[20] This implies certain judgements regarding visitor's prior knowledge, skills, and problem-solving abilities in relation to the use of electronic musical instruments. Importantly, this an approach that is still used by museums globally: as evidenced with the interactive theremin in the Musical Instrument Museum, Scottsdale (see chapter six) and, more recently, for a mixing desk exhibit in the temporary *Use Hearing Protection: The Early Years of Factory Records* exhibition at the Science and Industry Museum, Manchester (2021).[21]

Since Davies was employed at the Gemeentemuseum, changing behaviours towards electronic musical instruments, interactivity, and sound from both museum professionals and visitors have been reflected in literature.[22] For example, although Davies frames interactivity as problematic, Bruce describes it more positively, based on his contributions towards the installation of (predominantly) interactive content in Seattle's more recently built Experience Music Project (EMP: now the Museum of Popular Culture, or MoPop). The exhibition spaces are described by Bruce – who was employed as the Director of Curatorial and Collections for the EMP - as 'the combined dialogue between artifacts and media/technology in an environment that is dynamic, multi-sensory, and interactive.'[23] He advocated that interactivity, in general, benefited visitors by helping them to know 'a great deal more about music' whilst feeling like they had had less of a learning experience, which he links to the democratization of exhibition experiences and the museum's success.[24] This book chapter is useful as it provides a justification towards studying music- and sound-focused interactivity as a method towards creating exhibitions that might provide suitable degrees of learning for an anticipated audience.

Whilst Bruce's chapter succeeds in framing contemporary interactive exhibitions as spectacles that often evade authenticity in the hope of providing a more beneficial democratic experience, Bruce refrains from highlighting which specific exhibits provide the best experiences for visitors and does not discuss best practices towards interactive design in relation to music- and sound-focused content.[25] Considering that certain institutions within the SMG are keen to explore music and sound heritage in similar ways (as was expressed in the quote at the beginning of this chapter from Boon and others), first-hand accounts of exhibition practice such as this may prove useful for the SMG's exhibition teams, going forward. However,

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[20] Edward Wilson-Stephens, 'A Taxonomy of Interactive Theremin Instruments in North American Museums', in *Electronic Musical Instruments in Collection Context*, ed. by Benedikt Brilmayer, Seven (Mainz: Schott Music, 2022), 131.

[21] Science and Industry Museum, 'New Exhibition, Use Hearing Protection: The Early Years of Factory Records, to Open at the Science and Industry Museum in Manchester from 19 June', *Science Museum Group*, 2021 <https://www.scienceandindustrymuseum.org.uk/about-us/press-office/new-exhibition-use-hearing-protection-early-years-factory-records-open> [accessed 4 December 2022].

[22] Chris Bruce, 'Spectacle and Democracy: Experience Music Project as a Post-Museum', in *New Museum Theory and Practice: An Introduction*, ed. by Janet Marstine (Oxford: Blackwell Publishing Ltd, 2006), pp. 129–51; Francesca Monti and Suzanne Keene, *Museums and Silent Objects: Designing Effective Exhibitions* (New York: Routledge, 2013); Bailey, Broackes, and Visscher.

[23] Bruce, 143 [Emphasis in the original].

[24] Bruce, 139-140.

[25] Bruce, 139-140.

not every institution has the budget to implement the 'technology-driven spectacle' that the EMP presents (as funded by billionaire Paul Allen), nor does every museum have the resources (such as technical staff) to build, install, and maintain expensive interactive content either in-house or externally.[26]

Alternatively, although they were not involved in the creation of the Horniman Museum and Gardens in London (whose history dates back to 1890), Monti and Keene document their observations of visitors in the institution's *Music Gallery* as one of three London-based case studies (alongside the Victoria and Albert Museum (V&A) and the British Museum) used to analyse exhibition design towards supporting different visitor's learning styles (as an audience development tool). They focus specifically on the Horniman's interactive *Sound Benches* which contextualise the exhibited instrument objects with additional visual, textual, and sound content (in addition to the printed labels which accompany each object). The authors describe the *Sound Benches* as 'exceptionally enjoyable' and 'immediately understood by every visitor.'[27] However, the book omits a documentation of the sounds that were chosen to represent each electronic musical instruments on display (see Figure 1.2. below), as well as a description of how individuals responded to such sounds and how they may have enhanced visitor learning (which was the focus of their study). Additionally, the authors do not indicate whether the *Sound Benches* acted solely as multimedia sound stations, or whether they provided visitors with the means to play virtual versions of the instruments in the museum's collection (or on-loan).

[26] Bruce, 129.
[27] Monti and Keene, 106.

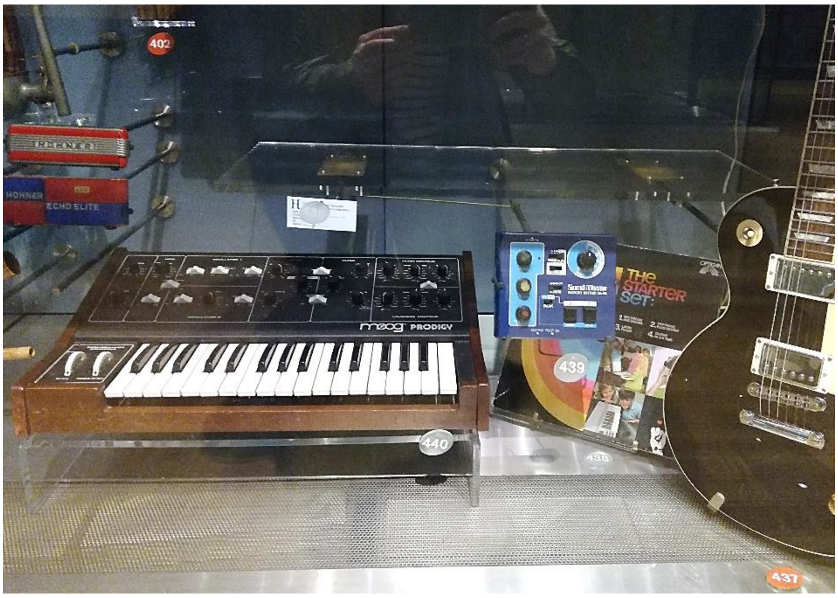

Figure 1.2. A display of musical instruments – including a Moog Prodigy synthesizer (left) and blue Soundmaster SR88 'Rhythm Synthesizer' drum machine (centre) – in the *Music Gallery* at the Horniman Museum, London.

Additionally, recent years have seen an emergence in the study of both popular music exhibitions and the management of sound in museums.[28] This reflects the increasing number of popular music exhibitions and museums (such as the Grammy Museum, Los Angeles, and the British Music Experience, Liverpool) and the increasing use - and management of - sound in exhibitions globally. Using popular music exhibitions as case studies, authors have discussed how the incorporation of interactivity and sound has helped to make artefacts and stories relating to popular music and culture more 'engaging and accessible'.[29] Additionally, Leonard frames interactivity at *The Beat Goes On* exhibition (hosted by National Museums Liverpool in 2008) as a tool to help attract 'teenagers and people in their early twenties who are under-represented in the visitor profile.'[30] In another paper – 'Constructing Histories through Material Culture: Popular Music, Museums and Collecting' - the author highlights the inter-relationship between material objects and immaterial sounds and the potential for one to evoke memories of the other from visitors, which might benefit their exhibition experience.[31] Simultaneously, research into the management of content within a broader range of exhibition 'soundscapes' (the changing qualities of the sonic environment) - beyond music-focused exhibitions - points towards the acknowledgement of sound as something that exhibition

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[28] Marion Leonard, 'Constructing Histories Through Material Culture: Popular Music, Museums and Collecting', *Popular Music History*, 2.2 (2007), 147–67; Andy Bennett and Ian Rogers, 'Popular Music and Materiality: Memorabilia and Memory Traces', *Popular Music and Society*, 39.1 (2016), 28–42; Sarah Baker, Lauren Istvandity, and Raphaël Nowak, *Curating Pop: Exhibiting Popular Music in the Museum* (New York: Bloomsbury Publishing Ltd, 2019).
[29] Marion Leonard, 'Exhibiting Popular Music: Museum Audiences, Inclusion and Social History', *Journal of New Music Research*, 39.2 (2010), 176.
[30] Leonard, 'Exhibiting Popular Music: Museum Audiences, Inclusion and Social History', 175.
[31] Leonard, 'Constructing Histories Through Material Culture: Popular Music, Museums and Collecting', 162-163.

teams need to consider in terms of its potential to positively enhance, or negatively affect, the quality of visitors' multi-sensory museum experience.[32] This also helps to justify the exploration of museum sound in this thesis – in relation to electronic musical instruments – as an original contribution to research that provides both academic *and* practical solutions.

Additionally, articles exist that frame both popular music exhibitions and the management of sounds together. Again, Leonard discusses the importance of managing sound content in the exhibition spaces of the British Music Experience (BME), Liverpool, where digital interactive technologies and other sound-producing multimedia support the use of objects in framing musical history and contributing to the production of meaning.[33] Furthermore, Bailey, Broackes, and Visscher examine the management of sound within a series of popular music exhibitions at the V&A, London. As well as discussing the spaces for communal listening that interrupted visitor's individual headphone experiences of sound in the *David Bowie is…* exhibition (2013), the authors briefly highlight the inclusion of interactive content that allowed visitors to modify the levels of different instruments and remix the song 'Money' within the exhibition *Pink Floyd: Their Mortal Remains* (2017).[34]

Whilst authors such as Leonard have made important contributions to the study of popular music exhibitions and sound, my research adds value to this area of interest through a deeper exploration of electronic musical instruments and their sounds in relation to interactivity. Exploring the importance of this content in popular music exhibitions could help to highlight the positive contributions that sounding exhibits and separate interactive spaces – such as the *Gibson Brands Interactive Studio* in the BME (see Figure 1.3. below) where tutorial videos help visitors learn how to play instruments - make to visitor learning and entertainment. Additionally, as is explored later, we should also consider the contribution that sound studies research has made to understanding and framing sound in exhibitions.

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[32] Trevor Pinch and Karin Bijsterveld, 'Sound Studies: New Technologies and Music', *Social Studies of Science*, 34.5 (2004), 642
Examples include: Salome Voegelin, 'Soundwalking the Museum: A Sonic Journey through the Visual Display', in *The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space*, ed. by Nina Levent and Alvaro Pascual-Leone (Plymouth: Rowman & Littlefield, 2014), 119–30; Tim Boon, 'Music for Spaces: Music for Space - An Argument for Sound as a Component of Museum Experience', *Journal of Sonic Studies*, 2014; James Mansell, ''A Chamber of Noise Horrors': Sound, Technology and the Museum', *Science Museum Group Journal*, 2017; Peter Janis, 'Optimizing Acoustics in Museums', *MUSE Magazine*, 2017; Michael Stocker, 'Exhibit Sound Design for Public Presentation Spaces', *Museum Management and Curatorship*, 13 (1994), 177–83.
[33] Leonard, 'Exhibiting Popular Music: Museum Audiences, Inclusion and Social History', 172.
[34] Bailey, Broackes, and Visscher.

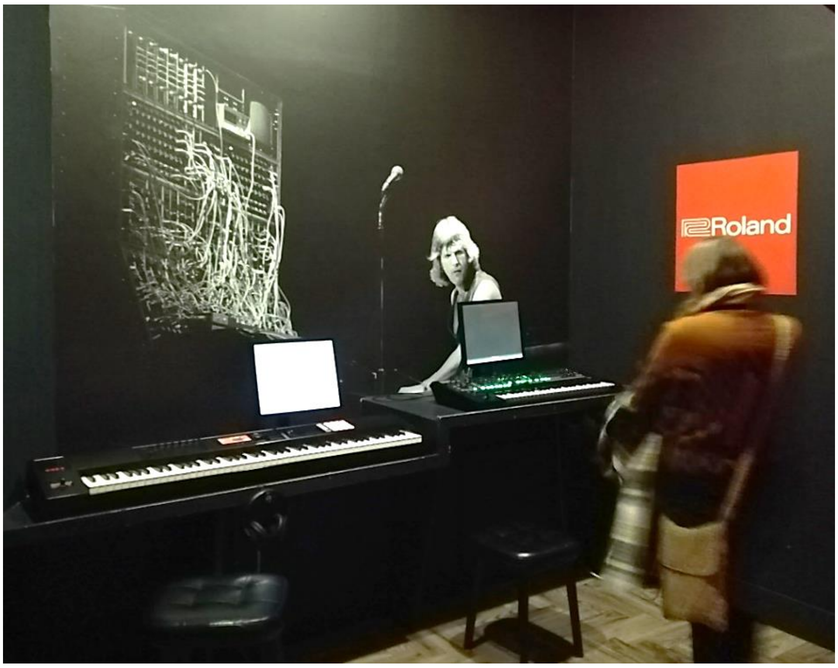

Figure 1.3. A Roland synthesizer station within the *Gibson Brands Interactive Studio* at the BME, Liverpool.

1.3.2 Interactivity and Science-Focused Institutions

Due to a vast majority of electronic musical instruments and interactive exhibits being dependent on some form of tactile engagement to produce sound (as opposed to instruments such as the Theremin, which were designed with the intention of being operated 'hands-free'), my research contributes to the interdisciplinary study of museology by engaging with theories and practices relating to the creation of multi-sensory content as a communication strategy for exhibitions.[35] The importance of doing so is reflected by Filippoupoliti who argues that investigations of communication strategies are 'a primary concern of museum professionals as well as a key subject in the literature of museum studies.'[36] However, as previously highlighted, little literature exists from the study of museology that documents the results of different strategies in terms of how they might help visitors to understand the sounding potential of instruments via interactivity. As is explained later in this chapter, several exhibition observations and interviews highlighted that exhibition teams of both music- and science- focused institutions do indeed take varying approaches to curating, installing, and managing interactivity as an attempt to create more valuable multi-sensory experiences for visitors.

[35] Wilson-Stephens, 126.
[36] Anastasia Filippoupoliti, 'Introduction', in *Science Exhibitions: Communication and Evaluation*, ed. by Anastasia Filippoupoliti (Edinburgh: Museums Etc Ltd, 2010), 11.

Much of the data collected for this research has centred on exploring the challenges in creating learning and entertainment opportunities that may help in planning to enhance *visitor exhibition experiences* in my partner organisation's permanent *Sound and Vision* galleries. However, the aim of this research is not only to assist the NSMM in producing high-quality, sound-focused exhibitions, but to assist any member of an exhibition team, globally, who is considering the exhibition of electronic musical instruments (i.e., not just for the institutions of the SMG and other science and technology institutions, as well as music-focused institutions). This has been the intention behind other instances of museology literature focused on exhibition practice. For example, Black's book *The Engaging Museum: Developing Museums for Visitor Involvemen*t intends to 'guide museums on how to create the highest quality experience possible for their visitors,' offering 'a set of principles that can be adapted to any museum in any location.'[37] Therefore, to expand upon the literature which explores music-focused institutions (as previously discussed), we also need to explore the research conducted through science and technology museums and science centres. [38]

However, compared to the quantity of literature exploring visitor experiences music and sound objects in music-focused exhibitions and museums, there exists comparatively little literature on similar objects and interactivity in science-focused exhibitions and museums. This presents a gap in academic study due to a considerable number of electronic instruments exhibited and/or demonstrated in science and technology museums and science centres (particularly in recent years). In addition to our first case study – the *Sound by Design* gallery in the Canada Science and Technology Museum –contemporary examples include the *Music Machines* gallery at the Norsk Teknisk Museum, Oslo, *Bechtel Gallery 3: Seeing & Reflections* at The Exploratorium, San Francisco, and *Use Hearing Protection: The Early Years of Factory Records* at the SMG's Science and Industry Museum, Manchester (2021).

Nonetheless, beyond music and sound-focused content, there exists several articles that incorporate collaborative approaches towards the *design* of interactive exhibits more generally: using these as a foundation for analysing visitor experiences of the resulting products.[39] These often conclude by providing future exhibition teams with solutions to the problems they observed and encountered once their exhibits were used by visitors. This exemplifies the desire for institutions of science to commission research (internally and externally) to help them to improve the quality of design and the visitor experience of interactive technologies and scientific phenomena. It also helps to justify my construction of an interactive

[37] Graham Black, *The Engaging Museum: Developing Museums for Visitor Involvement* (Oxon: Routledge, 2005), i.
[38] Whilst many institutions of science can be considered as 'science and technology' museums, I have extended this title to reflect additional museums whose titles suggest other contexts. For example, in the SMG alone, there is the 'Science' Museum, the National 'Science and Media' Museum, and the 'Science and Industry' Museum.
[39] Examples include: Joshua P Gutwill, 'Challenging a Common Assumption of Hands-on Exhibits: How Counterintuitive Phenomena Can Undermine Inquiry', *Journal of Museum Education*, 33.2 (2008), 187–98; Sue Allen and Joshua Gutwill, 'Designing With Multiple Interactives: Five Common Pitfalls', *Curator: The Museum Journal*, 47.2 (2004), 199–212; John H. Falk and others, 'Interactives and Visitor Learning', *Curator: The Museum Journal*, 47.2 (2004), 171–98; M. Fleck and others, 'From Informing to Remembering: Ubiquitous Systems in Interactive Museums', *Pervasive Computer*, 2002, 13–21; Michael Horn and others, 'Of BATs and APEs: An Interactive Tabletop Game for Natural History Museums', in *CHI* (Austin, 2012), pp. 2059–68.

exhibit for the NSMM as part of an exhibition team and test its use and interpretation in the hands of visitors, extending the examples in literature to include music technologies and the science of sound. The methodology for this practical research is explored later in this chapter, whilst chapters seven and eight describe the exhibit's construction, interpretation and use in full detail.

As an example of pre-existing literature, Allen and Gutwill – as employees of The Exploratorium and authors of interactive design papers – describe the pitfalls of an uncritical 'more is better' approach to interactivity for science learning and provide solutions which can be applied to any form of exhibit.[40] They also suggest that exhibition teams should invest in the formative and remedial evaluation of exhibits (in addition to summative evaluation) in order to create more positive interactive experiences for a museum's anticipated audience. Additionally, King and others describe the collaborative process between researchers, scientists and other staff - both internal and external to the Exploratorium – towards the development of interactive content which demonstrates research data on natural phenomena, helping to give scientists a voice on the museum floor.[41] Their paper concludes by highlighting the successes and pitfalls of such collaborations for members of future exhibition teams to acknowledge and follow prior to embarking on similar projects.[42] Therefore, whilst the literature based on music-focused institutions only briefly mentions that interactivity was offered, these examples of science-focused institutions suggest that, whilst interactive design can be problematic, collaborative research continues to be valuable towards finding solutions that go beyond covering up technologies with Perspex and actually enhance visitor satisfaction.

Nonetheless, as was the case with Bruce's depiction of interactivity at the EMP, authors such as those mentioned above have based their experiences on the quality of the resources which The Exploratorium and other science centres have for designing, building, and testing exhibits in-house: a luxury that many science (and other) museums do not have. However, constraints in resources can lead to more creative, collaborative interactive designs with external exhibit/instrument designers, which this thesis demonstrates through the three case studies (chapters two, three and four) and the construction of my exhibit for the NSMM (chapters seven and eight). Additionally, whilst studies of science centres are useful for understanding the pitfalls and solutions of interactive design, a focus on this type of institution is problematic for this research because the phenomenological experiences from interactive music and sound technologies often exist without the addition of object displays for visitors to make comparisons to (as opposed to science and technology museums, where the balance of objects and interactivity is less one-sided). Nevertheless, there remains a lack of literature which documents the demonstration of musical

[40] Allen and Gutwill, 199.
[41] King and others, 'Developing Interactive Exhibits with Scientists: Three Example Collaborations from the Life Sciences Collection at the Exploratorium', *Integrative and Comparative Biology*, 58.1 (2018), 94.
[42] King and others, 94.

instrument functionality in science centres (as well as in science centre-style museum exhibitions, such as the NSMM's *Wonderlab*).

1.3.3 Electronic Musical Instrument Replication

Whilst little literature exists regarding the representation of electronic musical instruments and sounds using museum interactivity, specific examples of redesigning electronic musical instruments as interactive exhibits for science museums and digitising vintage instruments for non-commercial applications (which may, otherwise, have had potential as exhibits in museums) have nonetheless been documented.[43] For example, Boon, van der Vaart and Price discuss the *Oramics to Electronica* project (2011) in which the exhibition team collected interpretations of Daphne Oram's Oramics Machine synthesizer from different groups of expert and lay participants (i.e., potential museum visitors) to use as formative research towards constructing the temporary exhibition *Oramics to Electronica: Revealing Histories of Electronic Music* at the Science Museum.[44] This article is not only useful as a case study for those who wish to adopt similar methodologies, but is also relevant to this research as it highlights that musical instrument objects (and the themes they represent) have the potential to be interpreted differently – especially in cases where participants have not knowingly seen or heard of instruments before – and therefore the use of interpretational tools to provide context could aid visitor learning.

However, due to the focus of the article, the discussion of the digital *Oramics Machine* app – designed by Parag Mital and Mick Grierson and installed in the same exhibition space as the original instrument - is minimal. It, therefore, shares much with the articles written by Davies as well as Bailey, Broackes, and Visscher, as previously discussed.[45] If the article had focused on the interactive elements of the exhibition instead, it may have usefully discussed the approach towards the replication of this unique instrument and its sound, as well as the ways in which the app added value to the exhibition experience. Nonetheless, an image at the end of the article (see Figure 1.4. below) clearly indicates how the interactive version of the instrument was installed (as a touchscreen interface embedded in a floor-standing kiosk) and how visitors

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[43] Examples include: Boon, van der Vaart, and Price; Robert Barry, 'Sound Artist Yuri Suzuki On Reconstructing Raymond Scott's Electronium', *The Wire*, 2019 <https://www.thewire.co.uk/in-writing/essays/sound-artist-yuri-suzuki-on-reconstructing-raymond-scott-electronium> [accessed 6 July 2021]; Anton Spice, 'Ghost in the Machine', *Electronic Sound* (Norwich, 2020), 52–55; Yana Boeva and others, 'Doing History by Reverse Engineering Electronic Devices', in *Making Things and Drawing Boundaries: Experiments in the Digital Humanities*, ed. by Jentery Sayers (Minnesota: University of Minnesota Press, 2018), 163–76.
[44] Boon, van der Vaart, and Price.
[45] Boon, van der Vaart, and Price, 8.

used it to create and shape the unique sounds of the instrument (using fingers to ‘draw on the filmstrips to change the sound’).[46]

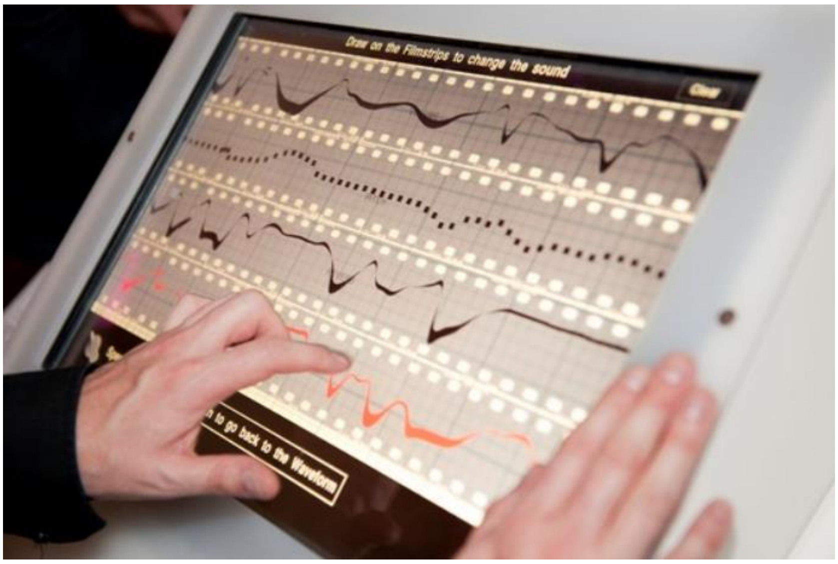

Figure 1.4. The Oramics Machine app installed in the *Oramics to Electronica…* exhibition at the Science Museum, London.

In comparison, Boeva and others focus their article on documenting their collaboration towards replicating Hugh le Caine’s analogue Sonde instrument as digital software through the processes of reverse engineering and, what the authors refer to as, ‘humanistic fabrication.’[47] Considering that the original Sonde was a complex and powerful instrument that could produce 200 sine waves simultaneously, the authors advocate for the use of Max (graphical programming software often deployed for bespoke sound applications) as a tool for digital replication and interface design (as opposed to building a new, physical device). As an experiment in the digital humanities – as the book title suggests - this method allowed the authors to realise some of the key differences between the original interface devised by Le Caine (late 1960s) and the later upgraded version designed by the University of Toronto Electronic Music Studio (early 1970s).[48] Similar replication activities as practice-informed research are explored throughout this thesis, including the replication of Le Caine’s Electronic Sackbut as an interactive exhibit for the Canada Science and Technology Museum (discussed in chapter two).

Additional authors have discussed their use of Max for music and sound installations in exhibitions. For example, Lane and Parry describe how they used Max as a tool for recording the oral reminiscences of

[46] Boon, van der Vaart, and Price, 31.
[47] Boeva and others, 163.
[48] Boeva and others, 167.

visitors and playing them back as layered, transformed audio elsewhere, as part of *The Memory Machine* sound installation in the British Museum.[49] These examples demonstrate the importance of documenting how music and sound experiences are realised using modern digital technologies – in particular, how Max was used to replicate the functionality and sound of the Sonde. They also provide a justification for my use of this tool to help build an exhibit that demonstrates the functionality and sound quality of the Akai S950's time-stretching effect (which is explained in more detail in chapter seven).

Additionally, other than exploring the replication of older instruments through interactive design, a significant number of papers have also explored contemporary design processes for new music and sound applications, published as the result of conferences such as the CHI Conference on Human Factors in Computing Systems and The International Conference on New Interfaces for Musical Expression (NIME).[50] One such paper, titled 'Towards a Dimension Space for Musical Devices', is perhaps the most significant. In this paper, Birnbaum and others apply dimension space analyses and visualisation to musical devices 'across performance, installation, and related contexts.'[51] The authors' produce a selection of criteria which they use to compare eight digital instruments and sound installations (i.e., potential interactive exhibits for museums).[52] The evaluation of each instrument results in points mapped along seven different axes (one per criterion) which, when connected together, produce a mapped shape within a dimension space which helps with 'exposing patterns across existing musical devices and aiding in the design of new ones .'[53] Criteria such as what the authors suggest (e.g., required expertise, musical control, and the role of sound) can present a useful framework (or at least a starting point) for exhibition teams to use when considering interactive content.[54] Additionally, articles such as this demonstrate a desire to create new interfaces and instruments beyond what is already manufactured and sold – which also applies to constructing new interactive exhibits for museums.

[49] Cathy Lane and Nye Parry, 'The Memory Machine: Sound and Memory at the British Museum', *Organised Sound*, 10.2 (2005), 141–48.
[50] Examples include: Jan O. Borchers, 'WorldBeat: Designing a Baton-Based Interface for an Interactive Music Exhibit', in *Conference on Human Factors in Computing Systems - Proceedings*, 1997, 131–38; Arvid Jense, 'Reimagining the Synthesizer for an Acoustic Setting; Design for a New Type of Electronic Musical Instrument' (University of Twente, 2013); Katsuhiko Onishi, Kazuaki Teramoto, and Atsushi Yamaji, 'Interactive Rhythm Making System for Musical Instruments in Museums', *2017 IEEE 6th Global Conference on Consumer Electronics*, 2017, 1–2; Bert Bongers, 'Physical Interfaces in the Electronic Arts: Interaction Theory and Interfacing Techniques for Real-Time Performance', *Trends in Gestural Control of Music*, 2000, 41–70; Michael Gurevich, Adnan Marquez-Borbon, and Paul Stapleton, 'Playing with Constraints: Stylistic Variation with a Simple Electronic Instrument', *Computer Music Journal*, 36.1 (2012), 23–41.
[51] David Birnbaum and others, 'Towards a Dimension Space for Musical Devices', in *Proceedings of the 2005 International Conference on New Interfaces for Musical Expression (NIME05)* (Vancouver, 2005), 192-193.
[52] Birnbaum and others, 193-194.
[53] Birnbaum and others, 192-194.
[54] Birnbaum and others, 193-194.

1.3.4 Expanding Contexts through STS and Sound Studies

Literature from the field of STS and sound studies demonstrates that both electronic musical instrument artefacts and their sounds are useful as case studies that evidence theoretical analyses of the interplay between designers, users and other stakeholders, and their impact on technological invention and innovation. Furthermore, these technical and social histories of technology can be important for exhibition teams when they attempt to frame these objects using researched stories. The fields of STS and sound studies are also useful for this research because they frame such inventions and innovations within larger social, cultural, political, and economic entanglements, which can be transferred towards understanding the effectiveness of interactive exhibits in the hands of social and cultural groups in museums (i.e., visitors and audiences). Additionally, authors within these fields have aimed these interdisciplinary studies towards sociology, science, and technology themed publications (for example), which has helped to extend the research of electronic musical instruments into other non-music focused areas.

With this in mind, this research would not be possible without the extensive and ground-breaking contributions that Pinch (and his collaborators) have made to studying inventions and innovations of electronic instruments and sounds, and the wider contexts in which they are entangled. In his early career, Pinch studied the interpretation of various technological artefacts by different social groups within what was known as the field of Science Studies, which formed part of the 'turn to technology' in research: a predominantly visual paradigm.[55] Continuing to focus on materiality, his studies on musical instruments as technological artefacts within the field of STS included the article 'The Social Construction of the Early Electronic Music Synthesizer' which compared the designs of the commercially-viable Moog Modular and Minimoog with the more psychedelic Buchla synthesizers of the 1960s in relation to different musician groups with whom the instruments appealed to.[56] He and Bijker argued that this helped determine the degrees of commercial or underground success which designers Robert Moog and Don Buchla achieved.[57] Pinch later referenced and developed this research in several articles based on the same (and similar) electronic musical instruments, as a way of discussing developments in – and the introduction of - the fields of STS and sound studies.[58]

[55] Trevor J. Pinch and Wiebe E. Bijker, 'The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other', *Social Studies of Science*, 14 (1984), 412-413; Owen Marshall, 'Synesthetizing Sound Studies and the Sociology of Technology', *Sociology Compass*, 8.7 (2014), 949.
[56] Trevor Pinch and Frank Trocco, 'The Social Construction of the Early Electronic Music Synthesizer', *Icon*, 4 (1998), 9–31.
[57] Pinch and Trocco, 9.
[58]Trevor Pinch, 'Emulating Sound. What Synthesizers Can and Can't Do: Explorations in the Social Construction of Sound', in *Wissen Und Soziale Konstruktion*, ed. by C. Zittel (Berlin: Akademie Verlag, 2003), p. 109–127; Trevor Pinch, 'From Technology Studies to Sound Studies: How Materiality Matters', *Epistemology and Philosophy of Science*, 56.3 (2019), 123–37; Trevor J. Pinch and Karin Bijsterveld, ''Should One Applaud?': Breaches and Boundaries in the

In 2004, Pinch and Bijsterveld introduced the field of sound studies to the STS community which has since signalled a 'turn to sound.'[59] Much of his more recent work concentrated on the interrelationship between electronic instruments and their sounds. For example, Pinch explored , 1) the challenges in using digital synthesizers to emulate older analogue synthesizers which, in turn, emulated older acoustic instruments; 2) the reasons to why musicians preferred to use older analogue gear, newer digital tools, or replications of older instruments, to create new music; and, 3) the stabilisation of early electronic synthesized sounds.[60] In this research, I have compared multiple theories and concepts - introduced to, and developed within, the field of STS and sound studies by Pinch and his collaborators – to those which exist in the interdisciplinary field of museology where, as previously mentioned, similar technological artefacts and sounds exist in exhibitions.

Bijsterveld's work is also pertinent to this research.[61] In addition to collaborating with Pinch on introducing the field of sound studies and co-editing books (which also featured articles written by both authors), she has analysed the design of classical musical instruments and their sounds through STS and sound studies perspectives, in order to address how instrument makers 'innovate and sell in a tradition-bound field.'[62] This demonstrates an important comparison to modern electronic musical instrument developments: many of which are bound to the ideals of progression and continual innovation, and therefore may need to be framed differently. She also documented sound installation practices in museums and public spaces, as a way of addressing the role of sounds as soundscapes that represent the acoustic heritage of sites (for example, the simulation of the sound of the Dam Square in Amsterdam between 1895 and 1935, and the re-enactment of the acoustic environment of the medieval town of Arboa Vetus for the *Sound Ways* exhibition at the Aboa Vetus & Ars Nova Museum, Finland).[63] This research also extended to the consideration of methods towards transmitting soundscapes through private audio guides and public speakers. Both this and the previously mentioned articles on sound in popular music museums have demonstrated that sound should be treated as a crucial part of the multi-sensory museum experience. As

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Reception of New Technology in Music', *Technology and Culture*, 44.3 (2003), 536–59; Trevor Pinch, 'Technology and Institutions: Living in a Material World', *Theory and Society*, 37.5 (2008), 461–83.

[59] Pinch and Bijsterveld, 'Sound Studies: New Technologies and Music', 635–48; Marshall, 948.

[60] Pinch, 'Emulating Sound. What Synthesizers Can and Can't Do: Explorations in the Social Construction of Sound'; Trevor Pinch and David Reinecke, 'Technostalgia: How Old Gear Lives On in New Music', in *Sound Souvenirs: Audio Technologies, Memory and Cultural Practices* (Amsterdam: Amsterdam University Press, 2009), pp. 152–66; Pinch, 'From Technology Studies to Sound Studies: How Materiality Matters'; Trevor Pinch, 'The Art of a New Technology: Early Synthesizer Sounds', in *The Routledge Companion to Sounding Art*, ed. by Marcel Cobussen, Vincent Meelberg, and Barry Truax, 1st Edition (Abingdon: Routledge, 2020), pp. 451–61.

[61] Karin Bijsterveld and Marten Schulp, 'Breaking into a World of Perfection: Innovation in Today's Classical Musical Instruments', *Social Studies of Science*, 34.5 (2004), 649–74; Karin Bijsterveld and Jose van Dijck, 'Introduction', in *Sound Souvenirs: Audio Technologies. Memory and Cultural Practices*, ed. by Karin Bijsterveld and Jose van Dijck (Amsterdam: Amsterdam University Press, 2009), pp. 11–21; K. Bijsterveld, 'Ears-on Exhibitions: Sound in the History Museum', *The Public Historian*, 37.4 (2015), 73–90; Karin Bijsterveld and others, 'Shifting Sounds: Textualization and Dramatization of Urban Soundscapes', in *Soundscapes of the Urban Past: Staged Sound as Mediated Cultural Heritage*, ed. by H Schulze, Vol 5 (Bielefeld: Transcript, 2013), pp. 31–66.

[62] Bijsterveld and Schulp, 649.

[63] Bijsterveld; Bijsterveld and others.

an addition to this research, my thesis explores sounds in connection to the instruments that originally triggered or modified them: focusing on the use of museum interactivity for demonstrating the significance of these instruments as sound-emitting devices for music and sound applications.

Additionally, both Bijsterveld and Peters advocate for the application of STS concepts towards organology ('the science of musical instruments and their classification'), which, in turn, has been applied to the classification and management of musical instrument developments in traditional musical instrument museums and art galleries.[64] Their justifications are based on the benefits of studying musical instruments in settings beyond the scope of organology, and analyses of modern performances of early music that utilise, and potentially transform, the original instruments.[65] This demonstrates that there is already some acknowledgement that both musical instruments and their sounds should be studied not just *by* museums, but also *in* museums, where they may take on new meanings as their temporal and spatial settings extend beyond that which they were designed for.

Beyond the work of Pinch and Bijsterveld and their collaborators, only a small number of specific electronic musical instruments have been studied within the fields of STS and sound studies.[66] For example, Harkins applies Pinch and Bijker's social construction of technology (SCOT) approach from STS to a study of the Fairlight Computer Musical Instrument (CMI) digital sampling instrument (see Figure 1.5. below), arguing that although the instrument was intended to reproduce acoustic instruments through digital synthesis, musicians used it instead to build libraries of their own, unique sounds.[67] Additionally, Tjora uses the Roland MC-303 (Micro Composer) Groovebox technological artefact as a case study to demonstrate the discrepancies between how the use of an instrument was marketed by the designers and interpreted by musicians, which he frames using Akrich's script theory from the sociology of science (more on this in chapter six).[68] In doing so, Tjora also explores the digital replication of sounds, functions and interfaces from older 'vintage' Roland instruments (such as the TR-808: the case study in chapter four) to create a repackaged, all-in-one manufactured 'groovebox' machine which benefitted musicians by offering things like better programming stability at a more affordable price.[69] When released in 1996, it therefore became a more accessible option for creating strands of electronic music for 'a growing market of would-be music composers/producers 'with little or no musical training'' (as opposed to acquiring the original instruments separately).[70] Broader socio-economic stories such as these may also help us understand how objects and

[64] Karin Bijsterveld and Peter Frank Peters, 'Composing Claims on Musical Instrument Development: A Science and Technology Studies' Contribution', *Interdisciplinary Science Reviews*, 35.2 (2010), 106–21.
[65] Bijsterveld and Peters, 114-115.
[66] Aksel H. Tjora, 'The Groove in the Box: A Technologically Mediated Inspiration in Electronic Dance Music', *Popular Music*, 28.2 (2009), 161–77; Paul Harkins, 'Following the Instruments, Designers, and Users: The Case of the Fairlight CMI', *Journal of the Art of Record Production*, 2015, 1–14.
[67] Harkins, 6.
[68] Tjora.
[69] Tjora, 165.
[70] Tjora, 165.

interactive exhibits may be framed and interpreted differently depending on the type of institution they are installed in and the type of audience it intends to attract.

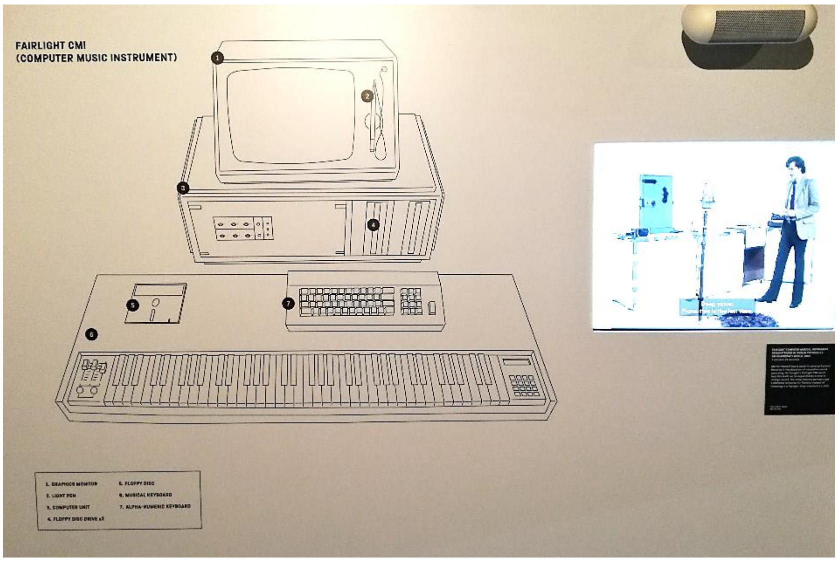

Figure 1.5. A diagrammatic representation of the Fairlight CMI in the *Use Hearing Protection: The Early Years of Factory Records* exhibition at the Science and Industry Museum, Manchester.

1.4 Methodology

1.4.1 An Interventional Methodology

In this thesis, exhibitions of electronic musical instruments are considered from a visitor-centred approach – an approach often preferred by authors of museology – in order to develop a better understanding of what user-based definitions of exhibition quality might be.[71] According to Black, exhibition quality is realised during a museum visit when 'visitors are satisfied that both their needs and expectations have been met or exceeded,' although the author acknowledges that the concepts of 'quality' and 'satisfaction' are likely to vary between individual visitors and will arise from a combination of interpretations.[72] This

[71] Black, 102-103.
[72] Black, 102-103.

demonstrates that user-based definitions of quality are complex and difficult to understand or advocate for, unless a broad range of methodologies are followed to help develop this understanding.

An intervention methodology has been adopted as the rationale for conducting this research and tackling the research problems: namely, the quality of interactivity that helps visitors explore and understand electronic musical instruments and their sounds. Vermillion claims that an intervention methodology is comprised of four universal processes: identifying the suboptimal outcome (observe), researching solutions (research), implementing a behaviour change (intervention), and measuring the outcome (evaluation).[73] In this thesis, I discovered suboptimal outcomes through visiting museums and using exhibits, which lead to the construction of a new exhibit as practice-informed research, which I then installed as an intervention and evaluated through conducting visitor observations and questionnaires (more on the intervention and evaluation stages later). Furthermore, it is intended that the interventional solutions advocated for in the conclusion will be implemented as behaviour changes towards the construction of the museum's permanent *Sound and Vision* galleries.

Additionally, this methodology contextualises the mixed methods chosen for data collection. The outcomes from these methods helped to develop a depth of knowledge regarding the problems that necessitated an intervention, whilst also helping to inform the quality of the proposed interventional solutions. However, although exhibits and exhibitions at the NSMM were observed prior to the launch of *Sonic…* and *Boom…*, the factors which the interventional solutions intend to address had not explicitly presented themselves until these two exhibitions had taken place. Additionally, although an understanding of the problems in exhibiting and demonstrating instruments had already been developed through visiting many other museums, the launch of the NSMMs temporary exhibitions on sound identified whether the same problems (or others) were evidenced in this institution. Nonetheless, my exhibit was intended as a proof-of-concept towards advocating for specific interventionalist methods, which were tested in the NSMMs temporary exhibition setting.[74] The mixed methods adopted in this thesis are explored in more detail in the following sections.

[73] Mark Vermillion, 'Research Methods & Intervention', *YouTube*, 2017 <https://youtu.be/xfVM5uhksS8> [accessed 7 December 2021].
[74] Audrey Begun, *Social Work 3402 Coursebook* (Columbus: The Ohio State University) <https://ohiostate.pressbooks.pub/swk3402/chapter/module-3-chapter-1/>.

1.4.2 Observing Exhibitions and Using Exhibits

As previously highlighted, each of the museum case studies focus on a unique synthesizer, sampler, and drum machine instrument in order to help demonstrate the challenges that each object and its sounds – as well as their representative interactive exhibits - may place on exhibition teams. Similarly, each case study was based on a different museum and exhibition context in which each instrument and/or exhibit was interpreted differently – with a focus on interface, sounds, or functions – which helps to demonstrate the potential complexity in framing and managing objects, sounds, and interactive content for visitors. This follows the investigative approach employed by Monti and Keene (as described in their book *Museums and Silent Objects: Designing Effective Exhibitions*), in which different museums were selected to allow 'investigation with a range of contexts and audiences,' so that 'site- and context-specific variables could be compared.'[75] The authors claim that this resulted in a deeper level of understanding towards the design of 'effective exhibitions' (as their book title states) in which displays of 'silent' objects can be transformed into 'an exciting and interesting encounter for the visitor.'[76] Similar to Black, the authors' visitor-centred approach also helped identify several commonalities in display approaches, which helped them to draw conclusions which they believed to be widely applicable.[77] Within this thesis, similarities and differences between the display and use of objects and interactive exhibits are also evaluated as a means of constructing interventional solutions for exhibition teams to follow.

Interestingly, the authors' range of museums considered for data collection may seem relatively restricted as they have only explored three 'traditional', pre-twentieth century London-based museums: the British Museum, the V&A, and the Horniman Museum. In comparison to the broad range of institutional contexts in existence, the collection remits and exhibition contexts of their chosen museums, as well as their methods of display, seem in relatively close relation. Initially, this suggested that the drawing of comparisons between their institutions of study was likely, if not predictable. However, in reality, each institution now has a broader and more diverse collecting and exhibiting remit which can help them offer unique exhibition experiences to visitors (often in their temporary exhibition spaces). Therefore, for my research, it was important to consider museums for data collection at an exhibition level – rather than considering each museum as a whole – in order to find displays of instruments relative to this research in both likely and unlikely places.

With this in mind, the uniqueness of exhibitions within museums is explicitly stated and analysed in this thesis, demonstrating the flexibility in displaying electronic musical instruments within music and non-

[75] Monti and Keene, 18.
[76] Monti and Keene, 4.
[77] Monti and Keene, 18.

music contexts. However, at the beginning of this project, a lack of opportunities to explore the breadth of exhibition practices relating to instruments, sounds, and interactivity in UK-based institutions was identified. Therefore, I visited several music- and science-focused museums in North America, which generated a more informed view of the range of contemporary exhibition practices in relation to this research. Additionally, opportunities to present papers at conferences hosted by European institutions (such as the previously mentioned *Electronic Instruments: Perspectives on History and Museum Collections* symposium at the Musikinstrumenten-Museum, Berlin) provided the means to explore additional euro-centric exhibitions of electronic musical instruments. This provided the opportunity to develop the research methodology adopted by Monti and Keene and explore a broader range of museum and exhibition contexts on a global scale, which is reflected by the case studies based in a Canadian science and technology museums, a traditional European musical instrument museum, and a contemporary British design museum. The visited museums relevant to this research are listed below in Table 1.1. (each year of visit is highlighted because certain exhibitions have since finished, whilst institutions such as the Museum of Making Music have since been renovated).

NAME OF INSTITUTION	SPECIFIC EXHIBITIONS AND GALLERIES	LOCATION	YEAR
Case Study Institutions			
Canada Science and Technology Museum	Sound by Design.	Ottawa	2019
Musikinstrumenten-Museum	Electronic Musical Instruments (previously Good Vibrations: A History of Electronic Musical Instruments)	Berlin	2019
Design Museum	Electronic: From Kraftwerk to The Chemical Brothers.	London	2020
Other Institutions			
The Horniman Museum and Gardens	The Music Gallery	London	2019
Montreal Science Centre		Montreal	2019
Grammy Museum		Los Angeles	2019
Musical Instrument Museum (MIM)		Scottsdale	2019
Museum of Making Music (MoMM)		Carlsbad	2019
The Exploratorium	Bechtel Gallery 3: Seeing & Reflections	San Francisco	2019
The Metropolitan Museum of Art	The André Mertens Galleries for Musical Instruments	New York	2019
Rose Museum		New York	2019
New York Hall of Science		New York	2019
Bate Collection of Musical Instruments		Oxford	2019
British Music Experience (BME)	Souvenir: 40 Years of OMD.	Liverpool	2019
Barbican Centre	Tangerine Dream: Zeitraffer, a Barbican Music Library Exhibition.	London	2020
Museum of London	Dub London: Bassline of a City	London	2020

Table 1.1. A list of relevant institutions visited during this research project (in addition to those that comprise the SMG), in order of attendance.

Additionally, considering that a large percentage of electronic musical instruments have been designed, sold, and used within countries that constitute what some consider the 'developed world,' this provides a justification for the collection and exhibition of such objects by museums in these countries, as representations of local and national histories. This, in-turn, provides a rationale for the international reach of this research, which has provided a deeper understanding of the challenges relating to electronic musical instruments in museums (than if I had focused exclusively on UK institutions), as well as the opportunity to explore additional factors such as provenance (which are explored later in the thesis). Furthermore, whilst museums such as the EMP, the BME, and The Exploratorium are often used as case study institutions in literature (as previously discussed), the opportunity to find and visit many other museums – especially in North America - provided the means to address the lack of representation in literature of several other music- and science-focused institutions which warrant inclusion. This is because of their substantial and significant collections of electronic musical instruments, as well as the broad evidence of good curatorial practices (also highlighted in this thesis).

Whilst visiting museums, I took the opportunity to familiarise myself with music- and science-focused exhibitions as a form of experiential learning, collecting data on all forms of museology practice, including the ordering and framing of object displays, the installation and use of multi-sensory content, and other factors. This provided the impetus for constructing interview questions for members of exhibition teams (more on this later), following a similar approach to Prax, Eklund and Sjöblom who also constructed questions for similar participants based on collecting ethnographic observations of the exhibitions first-hand prior to conducting interviews.[78] The method adopted towards finding and using interactive exhibits is defined by Jordan as a *cognitive walkthrough*: a usability approach taken from design theory whereby an expert investigator 'approaches the evaluation from the point of view of a typical user trying to perform a particular task,' in order to 'predict whether or not a user would have any difficulties at the various stages of trying to complete the task.'[79] Through following this method, not only did I take the opportunity to use interactive exhibits and evaluate their effectiveness and value as demonstrative tools (from a visitor's perspective), I also observed other visitors whilst they used these exhibits to try and determine whether they considered their engagement with an exhibit as 'successful' or not.[80] Observations and interactions were recorded as videos, photos, and written notes, whilst anecdotal information gained through more casual conversations with museum employees (some of whom were also participants in the interviews, discussed later) was also transcribed in note form afterwards.

However, following the cognitive walkthrough approach as an expert investigator requires one to make assumptions about each visitor's cognitive abilities, prior knowledge, and expectations in relation to how

[78] Patrick Prax, Lina Eklund, and Bjorn Sjöblom, ''More like an Arcade' - The Limitations of Playable Games in Museum Exhibitions', *Museum & Society*, 17.3 (2019), 440.
[79] Patrick W Jordan, *An Introduction to Usability* (London: Taylor & Francis, 1998), 79.
[80] Jordan, 63.

easy the exhibits were to use and understand, and whether specific learning and entertainment outcomes (whatever they might be) might be reached.[81] Considering that each museum and exhibition is likely to frame objects and exhibits within differing contexts and attract audiences specific to each exhibition, the concept of embodying the same 'typical' visitor (whoever that might be) every time I followed the cognitive walkthrough approach was, therefore, problematic. Furthermore, although my prior knowledge and experience of working with electronic musical instruments may have produced an advantage towards understanding them within each museum, this (along with a growing expertise in understanding interactive design for museums) may have conversely hindered my understanding of what a 'typical' visitor would be able to achieve and understand if the exhibition was not intended to attract expert users like myself. Therefore, it was also necessary to collect data directly from visitors in order to evaluate a more authentic and wider scope of interpretations relating to this content, as was the case with observing and interviewing visitors in relation to my exhibit (more on this later).

1.4.3 Synthesising Museology and STS Methodologies

> If we are interested in technical objects […] we cannot be satisfied methodologically with the designer's or user's point of view alone […] we have to go back and forth continually between the designer and the user, between the designer's projected user and the real user, between the world inscribed in the object and the world described by its displacement. For it is in this incessant variation that we obtain access to the crucial relationships: the user's reaction that give body to the designer's project, and the way in which the user's real environment is in part specified by the introduction of a new piece of equipment.[82]

The displacement Akrich refers to is from a designer's setting (e.g., the work bench) to a user's setting (e.g., a studio space). By following the author's claim above, the methodological approach for this thesis requires analyses – developed from the points of view of both exhibition teams and visitors – of technological artifacts *displaced further* into exhibition settings as objects or as replicated interactive exhibits. This, as previously mentioned, helps us to gain insights into how exhibition quality and visitor satisfaction can be defined. Additionally, the data collected from both members of exhibition teams and visitors may provide

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[81] Jordan, 79.

[82] Madeleine Akrich, 'The De-Scription of Technical Objects', in *Shaping Technology / Building Society: Studies in Sociotechnical Change*, ed. by Wiebe E. Bijker and John Law (Cambrid: The MIT Press, 1992), 208-209.

insights into how interactive technologies are used in ways that might *meet or contrast* the imagined or intended uses of such technologies by those who designed them. Considering that the aim of this thesis is to add to the knowledge of how real visitors-as-users engage with multi-sensory exhibition content, visitors are theorised and consulted not only through the lens of traditional museology and audience development theories and methodologies but also through STS methodologies (the field in which much of Akrich's work belongs). The synthesis of these two areas of literature offers museum exhibition teams additional insights into how and why visitors matter, in order to better design and manage sound-focused interactive exhibits that improve the experiences of electronic musical instruments.

In considering the synthesis of STS and museology, authors have used interview data to collect and interpret stories from both users and designers, and visitors and exhibition teams, respectively. However, when authors of STS have restricted their data collection to either users *or* designers using these methods, we do not gain the opportunity to compare stories regarding the same, or similar, artifacts from both sides, as Akrich advocated. For example, Tjora provides an analysis of how a specific technology is used and interpreted based on data collected exclusively from users, whilst Woolgar relies on insights provided by those who work for a company that designs computers.[83] Similarly, in museology literature, Prax, Eklund, and Sjöblom rely exclusively on the 'expert opinions' of museum staff as an account of visitor behaviours in exhibitions (as collected through interviews).[84] Therefore, in reference to the quote above – we did not get to go back and forth between the designer and the user – exhibition team and audience - of a technology.[85]

As a solution, various methods have been employed in this research to gain perspectives from both visitors and members of exhibition teams in relation to instruments, interactive exhibits, and sounds. This reflects the research of Dehail who conducted qualitative research with both visitors at the end of their visit, and with museum professionals, in two different museums: the Musée de la Musique, Paris, and the GRASSI Museum für Musikinstrumente, Leipzig.[86] If we consider exhibitions using Lord's perspectives on Foucault's writings on museums – that they consist of interpretations of the ways in which objects are explicated – we can further justify the adoption of a qualitative research paradigm for the collection of interpretations of such content from multiple viewpoints. However, the study of one particular object and its accompanying interactive exhibit from multiple viewpoints was problematic. First, many of the original instrument designers have now passed on (such as Hugh le Caine in 1977). Second, either the opportunity for exhibition teams to complete formative evaluations of exhibits and exhibitions had not presented itself, or the exhibitions had already finished, which made it difficult to find past visitors who were happy to participate in questionnaires or interviews (the quality of which would depend on visitors being able to

[83] Tjora; Steve Woolgar, 'Configuring the User: The Case of Usability Trials', *The Sociological Review*, 38.S1 (1990), 58–99.
[84] Prax, Eklund, and Sjöblom, 440.
[85] Akrich, 208-209.
[86] Dehail.

recall their experiences clearly). This is beneficial for museums because, as Caulton argues, 'it is cheaper to rectify mistakes identified at the research and development stage than it is after the exhibit is built to exhibition standards.'[87]

Nonetheless, perspectives from exhibition teams and visitors on the *same* interactive exhibit were gained through constructing an exhibit for the NSMM. The opportunity to create my own exhibit produced a situation in which I was positioned as both the researcher and the designer of the exhibit-as-technological-artefact. This placed me in a better position to understand how similarities and differences arise between what is envisaged of visitors by members of exhibition teams prior to, and during, the creation of an exhibition (what they imagined would happen), and the range of behaviours and responses visitors exhibit once the exhibition is launched (what actually happened – in the setting of displacement). By following Akrich's methodological approach, I was able to collect data from visitors as well as other members of the exhibition team I was in (the results, of which, are explored in detail in chapters seven and eight). This consideration of multiple voices to help analyse a specific artifact of sound is akin to Pinch and Trocco's enquiry into the Minimoog synthesizer, in which evidence was collected as qualitative responses from the designer himself (Robert Moog), famous users of the synthesizer, and those who helped sell and market the technology.[88] Additionally, although mediators of technologies such as sellers and repairers have been represented in STS literature (as with Pinch and Trocco, mentioned previously), the addition of insights from various members of exhibition teams who mediate the design, use and interpretation of technologies in exhibition settings is new to this academic field. Furthermore, this research also adds to the knowledge produced by authors of STS by evidencing perspectives on the ways in which technologies are used in museums (i.e., 'unreal' settings), in comparison to those socio-technical settings in which 'real-world' use of technologies occur.

Whilst we have identified ways in which data is collected from users and/or designers (and others) in the field of STS, authors have also often focused on the interpretations of just *one specific instrument* for their study. This was the case with Pinch and Trocco and the Minimoog, Tjora and the Roland MC-303 Groovebox and Harkins and the Fairlight Computer Musical Instrument (although Harkins later explored multiple instruments in his book *Digital Sampling: The Design and Use of Music Technologies*).[89] By doing so, we cannot gain an insight into how interpretations may differ when exploring multiple (and similar) technological artifacts through the same lens and methods. Therefore, the use of multiple case studies and examples in this thesis presents the opportunity to compare and contrast various curatorial practices relating to different electronic musical instruments and accompanying interactive exhibits.

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[87] Tim Caulton, *Hands-on Exhibitions: Managing Interactive Museums and Science Centres* (Oxon: Routledge, 1998), 47.
[88] Trevor Pinch and Frank Trocco, *Analog Days: The Invention and Impact of the Moog Synthesizer*, New Editio (Massachusetts: Harvard University Press, 2002).
[89] Pinch and Trocco, *Analog Days: The Invention and Impact of the Moog Synthesizer*; Tjora; Harkins.

1.4.4 Interviewing Members of Exhibition Teams

The first formal means of applying a qualitative research paradigm to the method of collecting data from others was in the design of interview questions for members of exhibition teams, delivered in a semi-structured format. The results provided behind-the-scenes accounts of the construction of exhibitions and exhibits – past and present - beyond what I was able to observe when visiting their museums of employment. Music and sound practitioners were also interviewed in the hope of gaining additional, unique insights regarding their use of historically significant electronic musical instruments. In total, seventeen individuals and groups were interviewed specifically for this research. The names, job titles, and previous/additional roles of each of these interviewees (listed in Table 1.2. below) confirm that a range of professionals were consulted in order to increase the chances of gaining a broad range of perspectives into the challenges and best practices associated with exhibiting the multi-sensory features of instruments. However, whilst this range was diversified through consulting an equal balance between female and male members of exhibition teams in managerial, curatorial, and research positions, the same is not evidenced in the range of interviewees employed in more technical roles, which was clearly male-dominated. Furthermore, whilst the latter might indicate a potential gender imbalance in technical roles within the global museum sector, a bigger issue stems from a noticeably lack of BAME (black, Asian and minority ethnic) employees - an issue recently acknowledged by Charr in European and American museums - as nearly all who were interviewed were white.[90]

Members of exhibition teams provided anecdotal stories relating to visitor behaviours and levels of satisfaction – some of which demonstrated outcomes which were intended by exhibition teams, whilst others identified outcomes which were unexpected or even unfavourable. Obtaining qualitative stories from those who constituted exhibition teams – various museum staff, as well as external exhibit designers and instrument makers - also provided the opportunity to develop a better understanding of how those internal and external to the museum collaborated during various processes to produce interactive solutions which intended to meet the needs of the museum and its audience.

The interview data obtained from the participants listed below was subject to the thematic analysis qualitative analytic method.[91] Through following this method, the identification of patterns within the data set helped to identify the challenges that were more typically experienced across institutions globally, which helped to guide the focus of this research.[92] However, this did not overshadow the opportunity to

[90] Manuel Charr, 'Museums and Employee Diversity', *MuseumNext*, 2022 <https://www.museumnext.com/article/museums-and-employee-diversity/> [accessed 26 November 2023].
[91] Virginia Braun and Victoria Clarke, 'Using Thematic Analysis in Psychology', *Qualitative Research in Psychology*, 3.2 (2006), 77 and 79.
[92] Braun and Clarke, 79.

identify and use more atypical, unique insights that were pertinent to this research – which also applied to the visitor data discussed below – in order to avoid a confirmation bias.[93] Both typical and atypical data have been incorporated into this thesis in the form of quotations from interviewees Benedikt Brilmayer, Tom Everrett, Thorsten Feuerherdt, and Moritz Simon Geist. These are used as evidence for reporting on contemporary curatorial and interactive design practices in the case study chapters.[94] The complete interviews from which quotes were taken can also be read in appendices A to E.

[93] Science Museum Group, *Expanding Our Horizons: Annual Review 2017-2018, 33*.
[94] George E. Hein, *Learning in the Museum* (London: Routledge, 1998), 69.

NAME	JOB TITLE(S)	PREVIOUS/ADDITIONAL ROLES
Exhibition Team Members		
Benedikt Brilmayer (BB)	Research Associate, Musikinstrumenten-Museum, Berlin.	
Tom Everrett (TE)	Curator of Communications, Canada Science and Technology Museum, Ottawa.	
Thorsten Feuerherdt (TF)	Instrument Designer, Manikin Electronic, Berlin.	
Reek Havok (RH)	Interactive Exhibit Creator, Sounds Amazing, Los Angeles.	Musician.
Jeanine Head Miller (JHM)	Curator of Domestic Life, The Henry Ford Museum of American Innovation, Michigan.	
Jonathan Piper (JP)	Manager of Museum Collections and Exhibitions, Museum of Making Music, Carlsbad.	Musician.
Moritz Simon Geist (MSG)	Interactive Exhibit Creator, Sonic Robots, Dresden.	Performer, Musicologist, and Robotics Engineer.
Bradley Strauchen-Scherer (BSS)	Curator or Musical Instruments, The Metropolitan Museum of Art, New York.	Musician.
Mimi Waitzman (MW)	Deputy Keeper of Musical Instruments, The Horniman Museum and Gardens, London.	
Reckless Night Music LLC - Stan Warnow, Deborah Scott Studebaker, and Sheri Timmons (RNM)	Members of the team behind Scottworks: The Raymond Scott Festival, California.	
David Wegehaupt (DW)	Associate Curator for USA/Canada and Europe, Musical Instrument Museum, Scottsdale.	Musician.
Frode Weium (FW)	Head of the Department of Exhibitions and Collections, Norwegian Museum of Science and Technology, Oslo.	

Music and Sound Practitioners		
Jon Burton (JB)	Senior Lecturer In Sound, Lights and Live Event Technology, University of Derby.	Sound Engineer, Front of House Engineer, and Monitor Engineer on tour and in the Laundry Rooms Studios, Sheffield.
Dave Howes a.k.a. Synthesizer Dave (DH)	Musical Instrument Repairer, Norfolk.	Musician.
Keith Tenniswood (KT)	Vinyl Cutting and Mastering Engineer, Curvepusher, Hastings.	Musician (as Radioactive Man and, previously, as one half of Two Lone Swordsmen).
Drew Schlesinger (DS)	Sound Designer, USA.	Musician.
Daniel Wheeldon (DWh)	PhD Candidate, University of Edinburgh.	Chair of the Banjos, Mandolins, and Guitars Working Group for the American Musical Instrument Society. Musical Instrument Repairer, 'Tin Pan Alley', London.

Table 1.2. A list of interviewees (arranged by surname in alphabetical order) whose insights are – or could have been – used in this thesis.

1.4.5 Practice-Informed Research

The quality of intervention documented in this thesis is strengthened further by the practice-informed part of this research, which constitutes the final two stages of the interventional methodology previously identified. Being successful in applying to - and creating something towards – the NSMM's micro-commissions programme involved a navigation of different roles as an outsider, which helped strengthen the potential to action an informed intervention. Working as both a researcher (i.e., a PhD student appointed by both the University of Leeds and the SMG) and exhibit builder as part of the micro-commissions programme (i.e., a professional, self-employed designer commissioned by the NSMM) provided me with the opportunity to be part of the museum's exhibition planning and management work as an external agent (i.e., not as an employee of the NSMM).[95] Burns argues that this can assist with finding and exploring systemic patterning which those internal to the organisation (or, as Burns puts it, those 'within a local problem context') might not be aware of.[96] Therefore, this practice-informed research not only provided the means to test the sound genealogy methodology, but also gain a better understanding of how collaborative work within the NSMM (and other museums) might be navigated.

Through interactivity, my exhibit-as-intervention addressed the underrepresentation of the hidden sounds and technological functions of electronic musical instruments in museums – in particular, those often associated with the sonic identity and history of drum and bass music. This was realised through following a *research-creation* methodology (the Canadian term for practice-informed research), which – as Chapman and Sawchuk argue – allows the researcher to investigate a topic of study 'that could not be addressed without engaging in some form of creative practice,' in tandem with other theoretical and practical aspects of research.[97] In this case: in order to better understand the design of interactive exhibits for museums, as well as the social contexts in which exhibits are experienced, it was necessary to build my own.[98] Chapman and Sawchuk identify four sub-categories of a research-creation methodology: two, of which, are described below. These also share commonalities with the plan and act, and observe and reflect, stages of action research, which Burns describes as follows:

> By planning, I mean a process of thinking through and developing our intention to act. By acting, I mean intervening in complex social processes. By observing, I mean seeing or finding out what happened as a result of our actions. By reflecting, I mean cognitive, sensual and emotional sense making.[99]

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[95] Burns, 24.
[96] Burns, 25.
[97] Owen Chapman and Kim Sawchuk, 'Research-Creation: Intervention, Analysis and 'Family Resemblances'', *Canadian Journal of Communication*, April (2012), 5–6.
[98] Chapman and Sawchuk, 11–12.
[99] Danny Burns, *Systemic Action Research: A Strategy for Whole System Change* (Bristol: The Policy Press, 2007), 12-13.

1.4.6 Research-for-creation (Plan and Act)

Research-for-creation evaluates the 'initial gathering together of materials, ideas, concepts, collaborators, technologies, et cetera' towards building various prototypes, leading towards the final product.[100] Chapman and Sawchuk compare this to the methods of consulting literature and conducting interviews, 'producing various academic contributions to knowledge.'[101] For this thesis, many ideas and concepts were gained through observing exhibits and exhibitions of electronic musical instruments – such as those discussed in chapters two, three, and four. This helped me realise that there has been little representation of the sounds associated with electronic instruments, the functions that help create, trigger, and modify sounds, and the people responsible for the performance and design of sounds (both electronically generated or triggered ones, and those that are sampled) in museums. With this in mind, I acted by submitting a proposal to build an exhibit which would demonstrate the impact of digital time-stretching technology on the formation and shaping of drum and bass music – with a particular focus on the sounds associated with the genre (as described in the previous chapter). Once successfully commissioned, the gathering of resources and construction of prototypes assisted the planning and building of the exhibit. In particular, various types of interfaces and controls were discriminated over in order to provide the intended exhibition audience with the most accessible means to engage with the underlying time-stretching function, as well as trigger and modify the *Drum* and *Bass* sounds.

1.4.7 Research-from-creation (Observe and Reflect)

Following research-for-creation, *research-from-creation* applies to the use, or performance, of the exhibit to 'generate user-responses to help build the project in question, as well as future initiatives.'[102] In this instance, the collection of data occurred in the exhibit's naturalistic setting via a cross-sectional study of visitors (i.e., as part of their museum and exhibition experience, rather than in a 'test' space).[103] Through conducting observations and questionnaires, the collection of qualitative data from visitors that used and interpreted it (which Black advocates will 'always be the most effective way of evaluating the complexities of individual satisfaction levels and of defining shared elements') provided the means to effectively evaluate the exhibit's potential to generate visitor satisfaction (as discussed in the results and discussion

[100] Chapman and Sawchuk, 15–16.
[101] Chapman and Sawchuk, 15–16.
[102] Chapman and Sawchuk, 16–17.
[103] Begun; Hein, 69.

sections of this chapter).[104] The conclusion of this thesis will serve as a space for reflecting on the findings specific to creating an exhibit, in terms of how far this research has come since the initial research questions were proposed, and how the research methods have contributed to this.

1.4.8 Visitor Observations and Questionnaires

Visitor data was collected through observations of behaviours whilst the exhibit was used, and responses to questionnaires afterwards. These methods of collecting visitor data aimed to provide additional insights that couldn't be obtained from observing and using exhibits built by others. One of the main aims of this data collection was to ascertain whether *using* the exhibit was effective in helping visitors to better understand it's context and learning goals - as highlighted in the accompanying interpretational text - and determined by each visitor's prior knowledge and skills. This would help determine the validity of interactivity in applying the sound genealogy methodology towards interpreting electronic musical instruments in exhibitions. Additionally, the data collection aimed to determine whether the exhibit had been successfully built to withstand a 'lively' audience - as requested in the call for applications to the micro-commissions programme – and whether the sequence of actions that visitors needed to follow was easy enough for them to recognise, enabling the exhibit to be used as intended and avoiding the possibility of negative consequences for future visitors.

To facilitate the observational data collection, I listed a series of prompts to refer to which Hein refers to as 'guides to enable (me) to come to some understanding of the meaning of what (was) observed.'[105] The quality of the prompts aimed to encourage consistent recordings of the types of behaviours exhibited by each group of participants, in qualitative form. Additionally, I designed questionnaires that intended to persuade visitors to provide qualitative answers immediately following their use of the exhibit: the timing, of which, increased the likelihood that visitor responses would correspond better to the behaviours they recently demonstrated.[106] Furthermore, being prepared to collect data through both methods provided some flexibility over how to engage with different visitor groups during times in which many visitors were using, or waiting to use, the exhibit at once (for example, conducting several observations in the time it would have taken to conduct one questionnaire). Whilst examples from these observations and questionnaires are used in chapter eight, the entirety of the data collected is presented in appendices F, G and H.

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[104] Black, 109.
[105] Hein, 73.
[106] Hein, 123-124; University of Liverpool Online Centre for Student Success, 'Introduction to Research Methods and Methodologies', *YouTube*, 2018 <https://youtu.be/nv7MOoHMM2k> [accessed 7 December 2021].

Finally, the difficulties in authentically re-creating a similar test environment elsewhere in the museum, as well as the restrictions on museum opening times imposed by the coronavirus guidelines, meant it was too problematic to arrange prior, formative user-testing for the exhibit and adjust it accordingly (as was also the case with *Play the Electronic Sackbut* in chapter two). Therefore, this evaluation of my exhibit is purely based on its installation as a final product in a 'live' exhibition and its use by visitors *a posteriori* (as well as the iterative alterations made by the technicians during its exhibition lifetime).[107]

[107] Hein, 59-60.

2 Electronic Sackbut: Canada Science And Technology Museum

2.1 Introduction

Before we begin to explore recent offers of interactivity in support of an instrument object, we must first consider a scenario in which little is known of how the object in question works, whilst the rarity and fragility of the object compromises the hands-on efforts of an exhibition team towards gaining a better understanding of the object's design. Furthermore, the scenario is made more challenging by the object's rarity in relation to exploring and understanding the full sounding potential of the instrument: the range, of which, was poorly captured when the instrument was still in use.

The following case study is focused on the Electronic Sackbut synthesizer and the unique challenges faced by the exhibition team at the Canada Science and Technology Museum, Ottawa, in collaboration with staff at the National Music Centre (NMC), Calgary, and external interactive designers. In displaying the older, fragile prototype of the instrument (which forms part of the museum's collection) next to the modern 'finished' interactive version, contrasting approaches towards managing visual authenticity and visitor behaviour in the permanent gallery *Sound by Design* are evidenced (as is explained later). Additionally, both the existence of very few recordings of the instrument being performed by its designer – Canadian inventor Hugh le Caine – as well as the continuing efforts to understand how the controls on the prototype affected the sound, challenge the creation of an authentic experience of the instrument's sound when visitors engage with the interactive version.

2.2 Hugh Le Caine

Hugh Le Caine (born 1914, died 1977) was a Canadian inventor who began experimenting with instruments of electronic sound when he was child (under his father's guidance), developing 'such futuristic, if rather impractical, devices as an electronic ukulele, a paper-roll-driven autoharp, and a guitar with foot pedals for tuning like those of a harp.'[108] Like other inventors of electronic musical instruments such as Leon Theremin and Robert Moog, he later married his early musical interests and talents to his scientific research in order

[108] David Keane, 'Gayle Young. The Sackbut Blues: Hugh Le Caine, Pioneer in Electronic Music.', *Canadian University Music Review* (Ottawa, 1991), 128; Lowell Cross, 'Gayle Young. The Sackbut Blues: Hugh Le Caine, Pioneer in Electronic Music.', 6.

to experiment with instrumentalising electronic sound in new ways. For example, he developed a free reed organ whilst studying at Queen's University, which resulted 'in a new kind of galvanometer that the department's atomic physicists found very useful' and encouraged ongoing support from his professors and co-workers to continue building musical instruments.[109]

Public demonstrations of the Electronic Sackbut prototype convinced Canada's National Research Council (NRC) to allow Le Caine to work full time on electronic instruments, beginning in 1954.[110] In the same year, he established the electronic music laboratory within the NRC and worked there until his retirement in 1974, creating such notable works as his composition 'Dripsody', which Cross refers to as 'a classic of experimental music.'[111] The experimental nature of his music reflects the mid-twentieth century era of experimentation with electronic sound and early synthesizer design, which is also evidenced by the inventions and music of Raymond Scott and Daphne Oram (for example).

Due to Le Caine's shyness and his inability to produce a 'finished' instrument ready for manufacture, believing that his instruments were never perfect enough, his inventions received little praise whilst he was still alive.[112] However, although the commercial success of Hugh Le Caine's inventions were hampered by his personal shortcomings, Wright also states that 'a lack of Canadian manufacturing experience, probably in combination with a pervasive academic naïveté at the university music studios and the NRC, meant that the instrument never made it to market.'[113] As Cross states: **'**both Le Caine and the NRC administration had hoped that his equipment designs would enjoy commercial success, from patent or other licensing agreements with musical instrument manufacturers, but these prospects were never realized.'[114]

Similarly, Keane notes that even though Le Caine published in both technical and musical journals, 'the world was not quite ready at that time to make use of such information.'[115] Additionally, although he composed experimental music with his inventions, he didn't consider himself a real composer and 'maintained that he was only trying out his instruments to see them from the composer's point of view.'[116] Furthermore, as Wright states: 'Le Caine was not inclined to pursue recognition or commercial success, and as a result his influence is often overlooked.'[117] Although many understand the Electronic Sackbut to be significant as the world's first synthesizer of its kind, it is difficult to know whether Le Caine's invention had

[109] Wright, 45; Cross, 6.
[110] Wright, 45.
[111] Cross, 7.
[112] 'Hugh Le Caine, Electronic Music Pioneer - Waveshaper TV Ep.8 - IDOW Archive Series - YouTube', *Waveshaper Media*, 2019 <https://youtu.be/OiZP-aQ70ZI> [accessed 15 April 2019]; Keane, 128.
[113] Wright, 46.
[114] Cross, 7.
[115] Keane, 128-129.
[116] Keane, 128.
[117] Wright, 44-45.

a direct influence on synthesizer design, even though, as Wright explains, 'many of the features of the Electronic Sackbut became popular decades later.'[118]

2.3 The History of the Electronic Sackbut

Le Caine developed the original monophonic, voltage-controlled Electronic Sackbut in his home studio between 1945 and 1948 and continued to redesign and improve the instrument until 1973, building three prototype versions.[119] Although the instrument is significant as the first synthesizer instrument in the world to be designed in this way, little is known regarding how the instrument works. This is due to various reasons. For example, there exists little in the way of recordings of the synthesizer being performed solo. Second, although the operation of the controls of the interface may seem relatively straight-forward, there is a lack of documentation regarding the instrument's underlying electronic circuitry. Third, there exists ethical and safety concerns over whether the instrument should, or even could, be readily plugged in and turned on: especially considering the age of the instrument and its electronic components. This point is a key concern for the Canada Science and Technology Museum in Ottawa which has, since 1975, retained custody of the only known surviving iteration of the prototyped instrument, as part of its collection of Hugh le Caine inventions (see Figure 2.1. below). Finally, since author Gayle Young's book *The Sackbut Blues: Hugh Le Caine, Pioneer in Electronic Music* was first published in 1989, little research has been conducted into the history of Hugh le Caine and his inventions: which is something that Tom Everrett (TE) - the Curator of Communications at the Canada Science and Technology Museum – has been keen to address.[120]

[118] Wright, 44-45.
[119] Vail, 11; Wright, 45; Cross, 6.
[120] Young.

Figure 2.1. The floor-standing Electronic Sackbut instrument prototype displayed in the *Sound by Design* exhibition at the Canada Science and Technology Museum, Ottawa.

In order to better understand the instrument, attempts have been made to map out the first complete circuit diagram via a pilot collaboration between the Canada Science and Technology Museum and the NMC since 2015.[121] John Leimseider (who passed away in 2018), technical lead on the project at the NMC, utilised his expert knowledge in performing an appropriate, non-destructive takedown of the instrument, and making the instrument 'work' with varying degrees of success. This is demonstrated in a video excerpt of the conservation project which evidences several problems in attempting to better understand the instrument, such as not being able to safely separate the keyboard from the instrument.[122] Prior to his death, Leimseider also produced circuit diagrams of the instrument, although he was unable to finish them. Nonetheless, there remain concerns with the Canada Science and Technology Museum over how often a teardown of the instrument should be performed, as each successive teardown project has the potential to damage the only prototype in known existence. In situations where very little material evidence exists in the world and a museum is able to perform this kind of practical research, this represents a paradox whereby new evidence cannot be added without what Mann refers to as the 'cumulative degradation' of the original evidence.[123]

Although the form of the instrument shared a lot with other keyboard instruments, Vail notes that the Electronic Sackbut's wooden horizontally spring-loaded keys set the instrument apart from others by

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[121] Canada Science and Technology Museum, 'Sackbut Conservation Project (Excerpt)', 2018 <https://youtu.be/LqVE7I3mWNA> [accessed 11 November 2020].
[122] Canada Science and Technology Museum.
[123] Peter Robert Mann, 'Working Exhibits and the Destruction of Evidence in the Science Museum', *The International Journal of Museum Management and Curatorship*, 8.4 (1989), 378.

allowing for lateral movements that altered the pitch up or down to varying degrees (as set by the user): producing either subtle vibrato or pitch adjustments across an entire octave (which is why Le Caine decided to name the instrument after the Sackbut: the ancestor of the trombone).[124] The keys were also designed to allow musicians to vary the attack of the instrument's sound: pressing a key softly resulted in a note that came in gradually whilst hitting it harder made the note sound more immediately.[125] Additionally, Vail notes that continued pressure sensing whilst a key was held down allowed for real-time variation in note volume which produced crescendos and diminuendos after a note was initially pressed down.[126]

Bongers has described Hugh Le Caine as one of several early designers who saw the potential for electricity in designing new instruments which placed human beings first, as part of a user-centred design approach.[127] In an attempt to create an electronic instrument that was as expressive as an acoustic instrument (but with the 'extended timbral opportunities afforded by electronics'), Le Caine implemented additional controls that accompanied the unique keyboard interface (see Figure 2.2. below).[128] For example, a touch-sensitive ribbon was provided as a secondary control for adjusting pitch.[129] Additionally, Vail describes several other ways for musicians to control the sound of the instrument:

> To address timbre, Le Caine equipped the Electronic Sackbut with a lefthand control section for precise parameter manipulation using fingertip pressure. The performer's left index finger varied among basic waveforms, some of which were evocative replications of clarinet, flute, oboe, trumpet, and organ. Other waveforms stressed the fundamental or certain harmonic intervals. As a note sounded, the player could morph through different timbres. In addition, the left thumb and remaining fingers shaped the Electronic Sackbut's tone: while the performer used his or her thumb to control filter resonance and the formant, or peak in the frequency spectrum, he or she could modulate amplitude and frequency and add noise or periodic voltages using other fingers.[130]

[124] Vail, 11.
[125] Vail, 11.
[126] Vail, 11.
[127] Bongers, 42.
[128] Vail, 12-13.
[129] Vail, 11.
[130] Vail, 12.

Figure 2.2. The Electronic Sackbut prototype from above.

Other controls that exist on the original prototype (as demonstrated in John Leimseider's video excerpt) include an octave switch, a master tune control, and controls for glide (portamento) and attack (determining how quickly the pitch builds upwards) which are both twelve-position rotary switches.[131]

2.4 The Exhibition: *Sound by Design*

As previously mentioned, the only known surviving prototype of the Electronic Sackbut is in the custody of the Canada Science and Technology Museum and currently on display in their gallery *Sound by Design*.[132] This permanent gallery, located at the back of the museum, demonstrates the strengths of the museum's *communications* object collection, focusing specifically on the electronic musical instruments and sound technologies within this collection (as well as those loaned from other museums) which were designed for both expert users and everyday use. The exhibition was curated by TE who, at the time, was newly appointed (and continues to be employed) as the Curator of Communications at the museum (and was the subject of the interview data in this chapter). TE's research interests in sound and music – evidenced in his publications on exhibition sound management, the history and culture of multichannel sound, and Bell and Blake's ear phonautograph – positioned him as an ideal curator for developing this exhibition.[133]

[131] Canada Science and Technology Museum.
[132] A second prototype might also still exist, but the exhibition team are not aware of its location.
[133] Tom Everrett, 'A Curatorial Guide to Museum Sound Design', *Curator: The Museum Journal*, 62.3 (2019), 313–25; Paul Theberge, Kyle Devine, and Tom Everrett, *Living Stereo: Histories and Cultures of Multichannel Sound* (New York: Bloomsbury Publishing Ltd, 2015); Everrett.

The objects are accompanied by bilingual interpretation text (English, followed by French), colourful visual apparatus, and several interactive exhibits whose sounds radiated into the exhibition space through various speakers. The need for both English and French text throughout the museum imposed constraints on how much text was written, which was evident in the delivery of short, concise statements that accompany each object.

Many of the exhibition's themes are focused on Canadian invention and innovation. For example, within the theme *Making Silence* the *Quiet Cube* exhibit exists to tell the story of one of Canada's first anechoic chambers (built by Bell Northern Research, later Nortel) whose purpose is explained as thus: 'researchers create silence to improve sound'. This was accompanied by a glass-cased display of test equipment (designed by Brüel and Kjaer and used by Nortel) which helped to measure sound levels (see Figure 2.3. below). Other Canadian innovations include the Berliner GT Gramophone and several 'Mantel' radios (designed for the fireplace), which were displayed in the *Design Icons* theme. As the Electronic Sackbut was invented in Ontario by Hugh Le Caine, a Canadian inventor, the provenance of this object, as part of the museum's wider collection of Le Caine's musical inventions, is strong.

Figure 2.3. Test equipment displayed in the *Making Silence* theme of *Sound by Design* at the Canada Science and Technology Museum.

The objects chosen for exhibition were influenced by the collecting activity of previous curators prior to TE's arrival at the museum, as well as the short amount of time available for creating Sound by Design, alongside another exhibition, prior to the museum's reopening in 2017:

> We've always had this electronic instrument collection, but it hasn't been developed in a very careful, thorough way. It has just been collected as part of this general history of the development of sound technology […] When it came to developing the exhibit, I had to select from objects we did have and I couldn't do much collecting to supplement what we already had in the collections […] We are a National Canadian museum, so typically we're not out to have the best collection of the history of electronic instruments. What we're trying to do is […] have the best collection of electronic instruments that speaks to the Canadian experience and the involvement of Canadians in that history. If we did start branching out […] to look at what Canadian musicians have done over the last, say, seventy-five years, then we could start to talk to musicians, reach out, and make those acquisitions and I'm sure that a lot of that electronic gear will be Japanese or American. (TE)

The context of the museum and the collecting remits of other museums also imposed constraints on the type of music and sound objects collected exhibited at the Canada Science and Technology Museum:

> There's also the challenge too […] we're a Science and Technology museum. There are museums like the National Music Centre in Calgary that really deals a lot more with music production, so because we're one institution and I'm just one curator and we have to represent so much, I can't just all of a sudden develop one of the world's best, most comprehensive electronic instruments and music production collections because it might overlap with collections that are already existing in Canada […] it might be easiest to just loan stuff from the National Music Centre and bring in some of those pieces to do displays, or if people are looking to research that area we could loan that material over here to do hands-on research seminars. (TE)

2.5 Electronic Sackbut: The Prototype Object

The Electronic Sackbut is displayed within the theme *Electronic Instruments*, alongside an RCA theremin, a Minimoog, and other Hugh Le Caine inventions from the museum's collection (see Figure 2.4. below): the Serial Sound Structure Generator analogue sequencer (complete with new bespoke panels created by artist Ann Law Thompson Daniels) and the Polyphone (considered the world's first polyphonic synthesizer).[134]

[134] 'Hugh Le Caine, Electronic Music Pioneer - Waveshaper TV Ep.8 - IDOW Archive Series - YouTube'.

The instruments are separated from each other and displayed in their own individual cases as 'hero objects', installed on stage structures unique to each instrument. Four of these instruments are large, floor-standing exhibits: two of which (the RCA theremin and the Electronic Sackbut) are accompanied by smaller interactive versions installed on plinths so that visitors can use them as table-top instruments in a standing position. The fifth instrument, the Minimoog, is the only table-top 'portable' object on display.

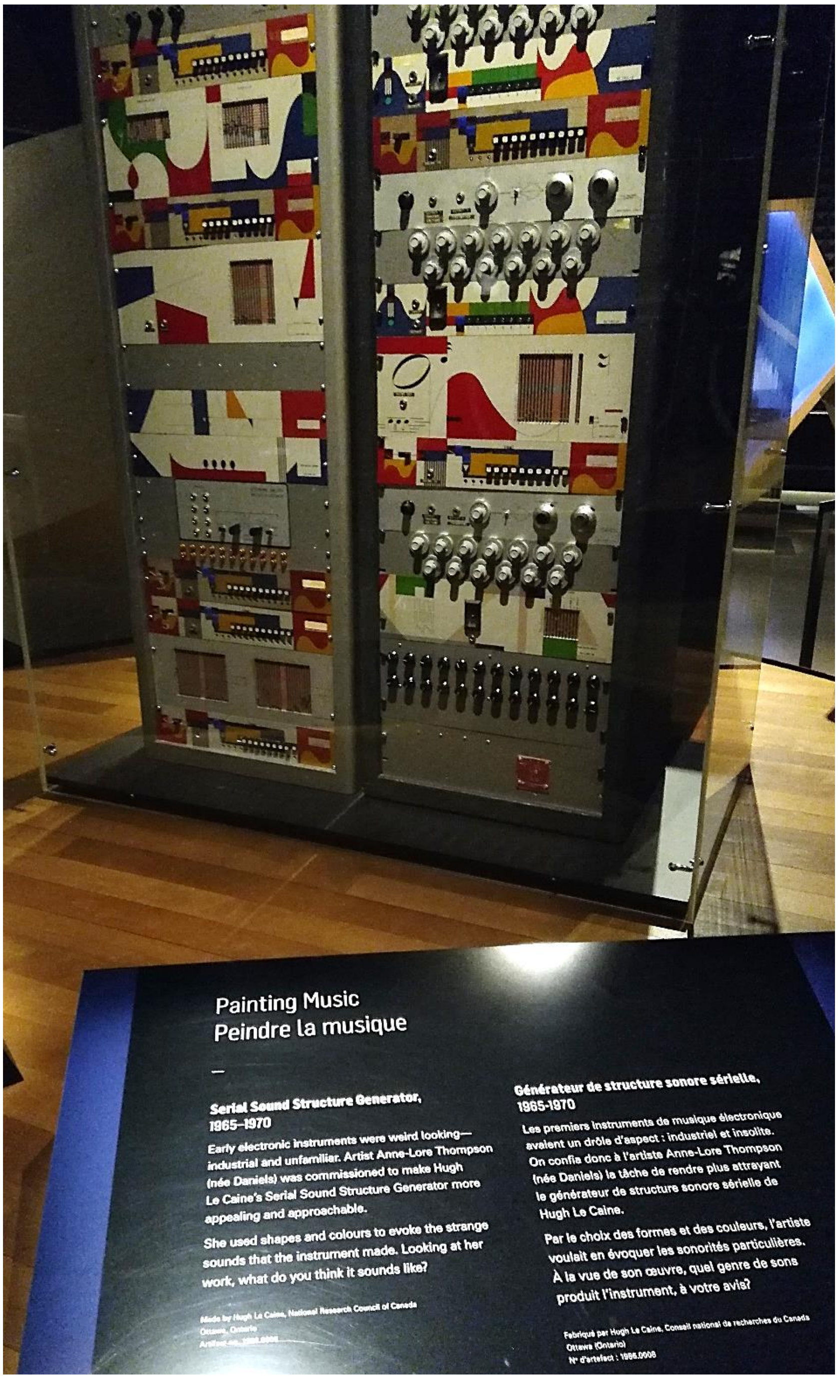

Figure 2.4. Hugh le Caine's large Serial Sound Structure Generator displayed in the *Electronic Instruments* theme of the exhibition.

As TE explained, adopting the hero objects approach to help create space between the instruments allowed visitors to walk around each object and observe them from several angles, in order to better understand their intended uses:

> The important thing for us was to not have these black boxes on display, so that you see a bunch of knobs on the front and nothing on the inside. The idea was to put them on wooden stages to give visitors the sense that these are performance objects and they are designed for making music […] We also wanted to make it so you could get behind the scenes, see inside the black boxes and get a sense of the circuitry and how complex these instruments were, so you can draw a relationship between the innards and the front-facing knobs. Get a sense through the interactives of how this all comes together to create different kinds of sounds […] Right from our very earliest design drawings, we had to make it so you could see the back [of each instrument]. (TE)

In terms of visitors making the connection between an instrument's visible interface and the electronic components often hidden inside the case, the Electronic Sackbut makes an interesting case study in comparison to the other instruments on display (and most electronic musical instruments that people are likely to encounter) because it is a prototype that was not ready for manufacture. The museum's decision to case the prototype in glass allowed visitors to observe its wooden build and electronic circuitry, left exposed by its designer. Visitors could see how complex the instrument was from the array of wires and old electronic components affixed to rough blocks of wood and small boxes of metal which, unlike manufactured instruments, do not form a complete enclosure that would otherwise hide these electronic parts.

However, as the Virtual Museum of Canada states: 'the rudimentary appearance of the synthesizer - its three legs made of crossed pieces of scrap wood and with instructions pencilled onto its surface - camouflages the brilliant concept behind this invention.'[135] The paradox of this aesthetic is that although it may underplay its significance as the instrument considered to be the world's first synthesizer of its kind, it conversely helps to demonstrate the instrument's authenticity as an early electronic musical instrument, whilst also demonstrating that technologies such as these are the result of a design process, prior to becoming finished, or manufactured, devices. Nonetheless, whilst 'framed' publicly in this exhibition, the

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[135] MvcVmc, 'Electronic Sackbut Synthesizer - Canada Museum of Science and Technology', 2013 <https://youtu.be/LHtseplPqO4> [accessed 11 November 2020].

museum context helps to infuse the instrument with a sense of importance. Hypothetically, if the instrument were to be displayed or found elsewhere, supported by little contextual information, it may be perceived as just a hobby project or, worse still, a pile of old junk. Additionally, the construction of a believable narrative for the development of electronic musical instruments in another museum focused on objects may be hindered by the Canada Science and Technology Museum's reservations in loaning such a vulnerable, one-off prototype elsewhere.[136]

2.6 Play the Electronic Sackbut: The Interactive Exhibit

The interactive version of the instrument was displayed next to the original prototype. The exhibit, *Play the Electronic Sackbut*, was described in the text that accompanied the exhibit as a way for visitors to 'experiment with some of the functions of the world's first synthesizer' (see Figure 2.5. below). By doing so, although the authenticity of the experience is debateable (as is discussed below), visitors are nonetheless offered the opportunity to perform with a materialisation of the Electronic Sackbut concept, which is likely to be the only opportunity to do so in the world considering that the instrument does not exist in any other form (physical or virtual).

Figure 2.5. The interactive exhibit *Play the Electronic Sackbut* displayed next to Hugh le Caine's prototype object.

[136] This is not to say the museum has not considered loaning an invention from the Hugh le Caine collection before. For example, Le Caine's Special Purpose Tape Recorder was loaned to the Musikinstrumenten-Museum in Berlin to form part of the *Record Play* theme of their exhibition *Good Vibrations: A History of Electronic Musical Instruments* (more on this later).

Considering the instructional text and labels which accompany the exhibit – as well as the fact that the word *Play* was included in the exhibit's title - it seems likely that the interpretational focus for the exhibit was aligned to the original instrument's *interface*. One of the difficulties that TE experienced in presenting this complex synthesizer as an interactive exhibit was navigating the balance between demonstrating how the original instrument worked and creating a simplified exhibit that was more likely to be usable by many visitors. As with most synthesizers throughout history, visitors new to the technology may struggle to understand how it works due to difficulties in deciphering the nomenclature that labels the functionality associated with each control. There may also be difficulties in understanding the relationship between the controls and the keyboard, and how both affect the sound (originally generated by a single oscillator).[137] TE discussed how these issues affected the interpretation of the original prototype object:

> As much as the Electronic Instruments section was about the machines themselves and looking under the hood, we found it really difficult to convey information about that and talk about the historical context of the pieces […] getting into the nuts and bolts [with the original prototype] about how voltage control works […] and how all those components work: the next thing you know we're talking about modulators and envelopes and filters and touch sensitivity and it just gets really technical really quickly. Instead, we simplified it to 'it was created at this time before anyone else did it', 'this is why it was so innovative', and 'this was what [Hugh le Caine] was trying to accomplish' […] That's as deep as we could go. (TE)

In terms of demonstrating what the instrument sounded like, TE advocated for the inclusion of a playable version of the instrument (the interactive exhibit), rather than relying on additional apparatus such as listening stations for playing pre-recorded audio examples:

> I thought that instead of having a button that you click and you listen to the Sackbut being played, or you can listen to Hugh Le Caine talking about the Sackbut, we will give you a Sackbut to play and that's how you hear the sounds. So 'here [is the prototype], do you want to hear what it sounds like? Step two feet over and play it yourself' and that's the way you can hear what it sounds like. (TE)

137 Arvid Tomayko-Peters, 'Hugh Le Caine', 2003 <https://www.arvidtomayko.com/writing/Hugh_Le_Caine.php?msclkid=8507685fbdbd11ec82939b5d4cd61f96> [accessed 16 April 2022].

However, TE continued to discuss how these challenges transferred to the design of the interactive version of the instrument:

> When we developed the Electronic Sackbut interactive we didn't use that as an opportunity to delve deeper into what was happening under the hood. It was complicated enough for people to figure out that they play the keys and then adjust the sound with these different features. We labelled things, so you have your modulator, you've got your filter, your envelope, octave switch, glide […] The main names are there and we do have a little description of what each of those features do […] It was just all about the playability and the control of these different features, without worrying about what's going on under the hood […] If we actually displayed all the wires, we didn't think they would add too much because we weren't talking about how those wires interfaced and what they were actually doing, so the whole design was black-boxed […] We were even going to update the information on the panel to show people, maybe with a video screen, that you're supposed to be doing it simultaneously. So that's the challenge when you're dealing with multi-generational audiences: people may have never come across this stuff before, so you've really got to limit the information and then limit the complexity. Certainly, if we had added that layer of showing all the wires […] it might have gone against what we were trying to do because it might have made it excessively intimidating or seem excessively technological, whereas in its current state it's a lot more inviting for visitors to go in and play with. (TE)

The exhibition team's approach to interactive design, as described above, demonstrates that the authentic replication of the instrument's functionality under-the-hood (or through-the-hood) was sacrificed for the sake of producing a more universally-accessible exhibit. Similarly, whilst the interfaces of the exhibit and the prototype share much in common, the overall forms of both were very different. Furthermore, TE explained that additional parts of the exhibit's design rendered the potential for authentic replication inappropriate.

> Another thing is, with all of those interactives in the space, they are not analogue. We have not made analogue reproductions: and that's why we do not call them reproductions, we call them interactives. Anything we showed under the hood would have been a lie because it's not vacuum tube based, it's all just computerised. (TE)

The user-testing approach for the interactive exhibits in this exhibition were adopted *a posteriori* as a result of needing to create two exhibitions within a limited amount of time. Some of TE's observations highlighted contradictions in terms of different people's expectations within the exhibition team:

> We couldn't do the kind of user-testing that we would have loved to have done […] Because of all the exhibitions happening simultaneously, things were just too hectic […] What we did do is visitor observations, and what you could see was that people didn't know what to do with the centre bed (of the exhibit's interface). They did not know that you could put your fingers on there or how that moves: you could tell they were confused. A lot of people, rather than using the pinky and the thumb controls as you would be expected to if you played the Electronic Sackbut, a lot of people were putting their fingers on and sliding up, because they thought that it was a slide-up action as opposed to a pressing action […] So what they would do is they would play [the keyboard] with [one] hand and they would touch with the same hand. So you would hear the sounds of the keyboard and it would go quiet when you removed your hand, and then touch and nothing would happen because that's changing the sound and you need to do both things simultaneously […] We also noticed some wonderful things too, where one person would play the keyboard and other people […] would be adjusting the timbre controls: fun stuff like that. But in terms of the goal of trying to give people a real sense of the playability of the original, I think we missed the mark on some of that. But the way the people who built it rationalised it to us, it was about durability. If they did do something more mechanical, it would be getting destroyed all the time, so I think that's why they made a lot of the decisions to use what they used and do what they did. But of course, the irony is that it does break down, and kids are always breaking those keys off anyway. (TE)

This demonstrates that, although the potential for users to break things (whether consciously or by mistake) was designed into the exhibit through the choice of robust controls, exhibition teams could not stop certain visitors from attempting to break parts of an exhibit (as demonstrated by the missing keys in Figure 2.5. above). Nonetheless, TE experienced many positive reactions from visitor's who used, or at least experienced, the interactive version:

> People are engaging with it and having a lot of fun […] so the fun factor is high. The interactive factor is high. As a teaching tool its wonderful for me when I do tours or I do classes in [the exhibition space], by being able to actually play an instrument and have people listen to it, with the original Sackbut beside, it really increases the engagement and helps with the teaching. It's imperfect, but its miles ahead of what the exhibition would have been without it. (TE)

Although durability was a key issue for the designers of the interactive version, some of the imperfections that TE referred to above arose from transferring a lack of knowledge as to how the original prototype worked, or how the interface affected the sound, from the museum to the interactive designers. However, TE believes that some of these problems may have been resolved if the interactive designers had regularly communicated their progress prior to delivering the final product:

> It was a sub-contract, so we were dealing with the big design firm for the exhibition and they had sub-contractors that were developing the interactives […] the museum had no contact with the sub-contractors who were designing [the interactive Electronic Sackbut] […] I prepared some briefs that I made in consult with John [Leimseider] as well as my father-in-law who used to teach electronic music production at Carlton [University]: Jack […] [The design firm] took it to their sub-contractor and said 'deliver this product' […] We actually travelled to meet the team in Montreal and we went and met with the subcontractors and we got to see some of the prototypes as they were being developed […] It wasn't what I had asked for, or what I expected, but at that point it was clear that we couldn't turn the ship around. It was going to be delivered that way, or else we'd have nothing […] it was disappointing for me because it was lacking the mechanical qualities that I felt were important. I wanted something that had proper keys: the original keys were made out of wood, so I thought it would be nice to have that wood feel […] I was hoping for hinged actual mechanical components: I wanted it to be as similar as possible […] So we went and saw it and the timbre plate: there was nothing that moved on the interactive, it was just flat. So that was really disappointing as there was nothing to clue in the visitor as to, like, 'how do you use this thing?' It was just a flat circle […] The pinky and the thumb control, also, were very flush with the surface, they did not have much movement, they were nothing like the original…the whole thing, to me, was not very intuitive […] in that it didn't have any of the feel of the original. (TE)

Additionally, the sound incorporated with the instrument was not the sound that TE was expecting to hear.

> In terms of the sound, when I started playing it […] I was quite amazed by how much it sounded like a modern synthesizer. Whether or not that is accurate to the original is impossible to say for now because it is missing a lot of the controls that we would need to begin mimicking some of Le Caine's steps […] but there are a lot of controls such as the attacks and decays, all of that that are in the original, that aren't on the interactive, so it's hard to say how close it is to the original. (TE)

Whilst the exhibition continues to exist (and whilst the original prototype remains at the museum), TE began a new restoration project in 2020 (marking seventy-five years since Hugh le Caine started work on the original prototype) towards a better understanding of how the original prototype worked using John Leimseider's incomplete circuit diagrams, which in turn will lead to an upgrade, or redesign, of the interactive exhibit. TE is, first, aiming to have a new fully-functioning interface built by the end of 2021, which he intends to connect to the original prototype in 2022. If this connection proves impossible, the build of a new accurate facsimile of the original prototype will be commissioned, and the new interface will connect to this. TE aims to complete this project by 2023, although the final machine will not be made accessible to the public. However, future visitors to the museum will, instead, eventually be provided with a better interactive version of the instrument:

> Things have been delayed due to COVID, but we were talking about how to make the interactive a little bit more intuitive. So we were looking at having a video that shows you where to put your hands and all of this, but my opinion on the matter was […] 'what if we prototyped a new design?' where we actually have it looking and feeling a little bit more like something that people might recognise. Will they more intuitively be able to grasp it? [...] But that'll be further down the road once we've completed the reconstruction of the [Electronic] Sackbut that we're working on now to form a professional model. What I would like to do is take what we learn from that and apply it to the interactive. So we might learn that all we need to do is introduce these two additional knobs that allow you to control the attack or the decay, for example. By introducing those all of a sudden we might be able to get close to demonstrating 'oh, if I move the timbre plate over here, it sounds more like a flute' 'if I move it here it sounds more like an oboe' […] or we might learn that it's too complicated to actually achieve any

> of that: the simple version was better, so let's keep it simple and just allow people to play with just the main controls […] what we might learn from developing the professional version is that, actually, under the hood it's all wrong and that's not how it would have sounded or how it would have worked […] Things that I can say with some confidence is that sometime within the next five years, that interactive will be eventually changed. (TE)

2.7 The Science Museum Group and Elsewhere

Due to the aforementioned issues with the instrument's fragility and uniqueness, the likelihood of the SMG loaning-in the original Electronic Sackbut prototype for an exhibition might be rather slim. Nonetheless, most of the synthesizers in the SMGs collection were designed for manufacture by recognisable industry names such as Moog (System 900), ARP (QUADRA), Casio (Casiotone MT-30) EMS (V.C.S. 3) and EDP (Wasp).[138] There already exists much documentation and sound recordings relating to these synthesizers in the public domain, which could prove useful if one of these instruments were to be re-designed as an interactive version. Considering these instruments were made for manufacture, it may also be easier and safer to plug them in, turn them on, and discover how they work, first-hand, especially considering that their internal electronic components and external controls may, also, be more easily replaceable.

The SMG has also acquired a selection of one-off instruments from British electronic music composers. For example, the SMG is the custodian of British electronic musician Daphne Oram's Oramics Machine, complete with Sound Generator, Programmer, several waveform slides, speakers, amplifier, reverberation line, and a prototype four track tape recorder designed for the instrument.[139] Prior to the instrument's inclusion in the *Boom: Experiments with Sound* exhibition at the NSMM, several projects had already been undertaken to help understand how the Oramics machine worked. For example, various staff from the SMG played a pivotal role in creating the *Oramics to Electronica: Revealing Histories of Electronic Music* temporary exhibition and museum programme in 2011.[140] These activities also involved the creation of a touchscreen iOS app version of the Oramics machine, which visitors could use in the exhibition. Additionally, a selection of Hugh Davies' instruments have also been acquired by the SMG, which include the aforementioned manufactured EDP Wasp synthesizer, as well as his own home-made music and sound

[138] Science Museum Group Collection, 'Search Our Collection (Acoustics)' <https://collection.sciencemuseumgroup.org.uk/search/categories/acoustics> [accessed 13 November 2020].
[139] Science Museum Group Collection, 'Search Our Collection (Daphne Oram)' <https://collection.sciencemuseumgroup.org.uk/search/objects/makers/Daphne Oram> [accessed 13 November 2020].
[140] Boon, van der Vaart, and Price, 2.

technologies which include a mixing board and the 'Sho-Zyg' electro-acoustic instrument (built into a volume of an encyclopaedia).[141]

There are also examples which demonstrate that the re-design of electronic musical instruments as interactive exhibits does not have to be exclusively tied to one public institution or outdoor space. One of the most novel re-interpretations of a vintage synthesizer comes in the form of the *Giant '303*, designed by the Edinburgh-based collective Ray Interactive (see Figure 2.6. below).[142] Although this has not been exhibited in a museum, this larger interactive version of the Roland TB-303 (Transistor Bass) has been installed at festivals such as Pukkelpop (2017), Kelburn Garden Party (2017) and Bangface Weekender (2016).[143] Both the sound and interface of the original instrument have been reproduced at a much larger scale, offering real-time knob control of the sound-shaping parameters and note-input per sequencing step via buttons. Unfortunately there exists no documentation on the company's website regarding how this interactive exhibit was designed although, from viewing videos uploaded by the designers to YouTube, it seems that some of the buttons now offer additional sounds which accompany the analogue waveforms from the original instrument.[144] Ray Interactive have also completed a similar re-interpretation of Roland's TR-909 drum machine whose enlarged interface is physically connected to another replication of Roland's classic drum machines: the TR-8 (manufactured by the Roland Corporation).[145]

[141] Science Museum Group Collection, 'Search Our Collection (Hugh Davies)' <https://collection.sciencemuseumgroup.org.uk/search/objects?q=%22Hugh Davies%22> [accessed 13 November 2020].
[142] 'Giant 303', *Ray_Interactive_V2* <https://www.rayinteractive.org/giant-303> [accessed 2 December 2020].
[143] 'Giant 303'.
[144] ray interactive, 'Giant 303's First Outing - Bangface 2016', *YouTube*, 2017 <https://youtu.be/zgD1g9jusW0> [accessed 2 December 2020].
[145] ray interactive, '9ft 909 / Bestival / Main Ingredient', *YouTube*, 2017 <https://youtu.be/ZMQGs8O6dmU> [accessed 2 December 2020].

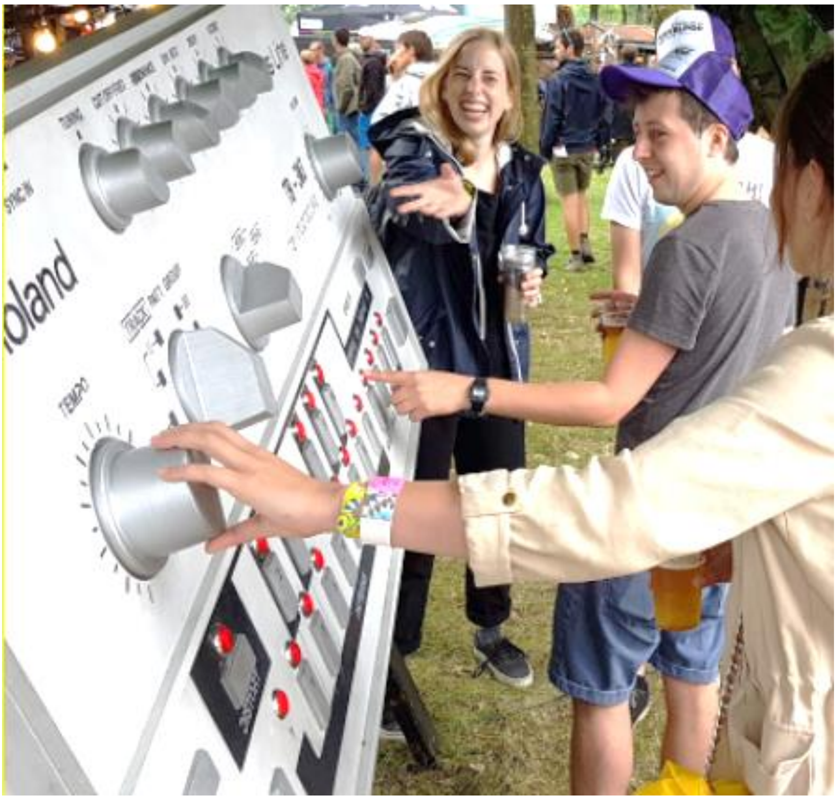

Figure 2.6. The Giant '303, created by Ray Interactive.

2.8 Conclusion

The *Play the Electronic Sackbut* exhibit was a unique case study in the digitisation of electronic musical instruments for museum interactivity due to the little (albeit evolving) knowledge of the original instrument's design and the sounds it was capable of producing. Whilst the visitor experience of the instrument was compromised by miscommunications surrounding how the various parts of the interface should be designed and operated, visitors enjoyed using the exhibit nonetheless (as was observed by TE and colleagues): perhaps too much (or too little) in those cases where visitors had managed to break off the keys from the interface. Furthermore, TE was able to use the exhibit as a tool for teaching visitors about the importance of Hugh le Caine as a Canadian inventor.

However, whilst national visitors may develop an attachment to the instrument as an important Canadian contribution to global electronic musical instrument history, a lack of recorded music in which the Electronic Sackbut featured (in comparison to the instruments in the forthcoming case study chapters) might have created a challenge in helping visitors to understand the importance of the instrument's sounds in relation to their lived experiences of music. Furthermore, as it is difficult to ascertain which sounds the instrument was capable of producing (or how to recreate them) within what little recorded music exists involving the instrument, it may be a challenge to make sound the interpretational focus within a future exhibition involving the Electronic Sackbut: particularly as it would be difficult to isolate certain sounds from within that recorded music or replay them on the instrument. Nonetheless, both the original prototype and the exhibit (as well as the ongoing, extensively documented research conducted at the museum) represent important leaps forward in the development of knowledge and interest in Hugh le Caine and electronic musical instrument heritage.

3 Mellotron: Musikinstrumenten-Museum

3.1 Introduction

Whilst the uncertainty around the Electronic Sackbut's functionality and sounding potential may compromise the opportunity for others to reproduce or reinvent the instrument as a commercial, manufactured instrument, many other historically significant electronic musical instruments have since been reintroduced to the music technology marketplace or redesigned for personal use. These efforts have resulted in new physical devices and virtual instruments: many of which have solved problems inherent in the original designs (as experienced by musicians) or have improved - or added to - the design, functionality, and sounding potential of the original instruments.

In this case study, a recently manufactured replication of the Mellotron instrument – the Memotron M2K – was obtained by the Musikinstrumenten-Museum, Berlin, as a playable interactive exhibit in support of the visitor experience of the Mellotron M400 object. Whilst the instruments were installed and framed within the *Record Play* theme of the temporary exhibition *Good Vibrations: A History of Electronic Musical Instruments,* they now reside in the permanent *Electronic Musical Instruments* gallery with no thematic framing. Whilst individuals may already know more about the Mellotron than the Electronic Sackbut – partially due to its sounds appearing in various popular songs – there still exists the potential for visitors to struggle to connect the Memotron M2K to the Mellotron M400 object, or to connect either to the musicians, sounds, and recorded music associated with various Mellotron designs. Furthermore, whilst the cases of most manufactured instruments are designed to remain closed (in contrast to the bare wires and wood of the older Electronic Sackbut prototype), the museum's decision to keep this instrument's lid down whilst exhibited hides the evidence of the more unusual electro-mechanical playback of sampled sounds. Additionally, the museum's ability to disseminate knowledge of the various qualities and related stories of each object is constrained by their limited use of interpretational materials in their permanent galleries.

3.2 Harry Chamberlin, Streetly Electronics, and the Mellotron

In his paper 'A History of Sampling', Davies provides several examples of inventions that pre-dated the Mellotron, where the sound recording techniques available at the time were utilised for instrumentation.[146] Examples include patents for 'instruments in which electromagnetic wires, discs or cylinders were the recording media' as well as a British patent for Estell Scott who proposed the use of an 'electrostatic disc containing sampled waveforms photo-etched from oscillograms.'[147] Likewise, before the invention of the Mellotron, Harry Chamberlin designed the Model 100 Rhythmate drum machine in 1952 (considered by many as the world's first drum machine) which was also based on keyboard-activated sounds (in this case, a series of drum patterns) recorded onto lengths of tape.[148]

Around the same time, Harry Chamberlin also designed the pre-cursor to the Mellotron: the Chamberlin. This instrument worked in a similar way to the Mellotron, using lengths of tape for each key to playback eight seconds of sounds performed by the Lawrence Welk Orchestra (recorded by Chamberlin).[149] Bill Fransen, a salesman at Chamberlin's manufacturing shop in California, took two of the Chamberlin instruments to Britain and introduced them to the Bradley family, who ran the company Bradmatic (later Streetly Electronics, formed in 1991), to 'see if they could improve the reliability of the tape heads'.[150] The Bradley family were impressed with Harry Chamberlin's instrument. Once Chamberlin had sold the rights to them, the Bradley family formed another company, Mellotronics (which handled 'the recordings, distribution and sales), and produced the first Mellotron in the 1960s, followed by a later version called the Novatron.[151] Harry Chamberlin continued to develop commercial versions of the Chamberlin; which many claimed had a better sound, suggesting it was 'clear and more direct…which is strange because the Mellotron was (allegedly) better engineered than the Chamberlin.'[152]

Cella claims that the Mellotron M400 was 'the most famous and the most widespread of the Mellotrons.' As with other versions of the instrument, the M400 looked much like an upright piano or organ but could playback various sounds pre-recorded onto lengths of tape (as opposed to generating its own electronic sound).[153] These sounds included acoustic instruments such as flutes, brass, tenor sax, string sections, as well as sound effects which Vail describes as canned laughter, cuckoo clocks, frogs and toads, ship horns,

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[146] Davies, 5-6.
[147] Davies, 5-6.
[148] Wright, 47; Davies, 7..
[149] 'The 'Chamberlin', Harry Chamberlin, USA, 1951', *120 Years of Electronic Music* <http://120years.net/the-chamberlin-harry-chamberlin-usa-1951/> [accessed 19 November 2020].
[150] Wright, 47; David Etheridge, 'The Mellotron - Analog Technology in a Digital World: History, Applications and Technology', *Royal Birmingham Conservatoire*, 2017, 18-19.
[151] Wright, 47; Davies, 7; Etheridge, 3.
[152] Wright, 47.
[153] Wright, 19.

and a thunderstorm.[154] Although users were not able to record their own sounds onto tape using the Mellotron, Davis notes that many consider the instrument as an early analogue sampler (although Vail's definition of the Mellotron as a 'sample player' is probably more fitting).[155] Additionally, since the tape frames feature recordings of older acoustic instruments, the Mellotron could be framed as a tool for preserving the sounds of instruments beyond their materiality.

When a musician pressed down on one of the M400's keys, the length of tape below that key would commence playback.[156] Each length of tape has three sounds recorded onto it lasting eight seconds each, all running parallel to each other, so that when a musician moved the sound selector switch on the interface between points A,B or C, a play-head frame shifts left or right to choose either of the three sounds across the instrument's 35 keys.[157] Lengths of tape were used instead of tape loops as this enabled the playback of individualised attack transients within each sound.[158] Additionally, musicians formed ways of working around the limited sustain of eight seconds of sound through 'two musical approaches, either slowly arpeggiating a held chord to allow individual notes to reset on long chords, or composing music with many chord changes.'[159]

Unfortunately, it is reported that both the Chamberlin and the Mellotron were temperamental. As Howell explains:

> Mechanically, the Mellotron was a nightmare — 35 tape heads to keep aligned, 35 pinch rollers to keep clean, and 35 pressure pads to adjust so that the tape made proper contact with the heads (not too much pressure, not too little). It was necessary to keep an eye on those return springs, too (all 35 of them!), because if they malfunctioned, the tape wouldn't be returned to the actual start and subsequent playback would start some way into the sound, resulting in the characteristic 'clicky' Mellotron effect heard on so many records. However, this had another side effect; if the tape didn't return to the start, you wouldn't even have eight seconds to play with![160]

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[154] Vail, 68-69.
[155] Hugh Davies, 'A History of Sampling', *Organised Sound*, 1.1 (1996), 5-6; Vail, 68-69.
[156] Steve Howell, 'Q. Did Mellotrons Use Tape Loops or Not?', *Sound on Sound*, 2005 <https://www.soundonsound.com/sound-advice/q-did-mellotrons-use-tape-loops-or-not> [accessed 18 November 2020].
[157] Bell Tone Synth Works, 'Inside a Mellotron M400: How the Mellotron Works', 2017 <https://youtu.be/ByD8gH7kYxs> [accessed 18 November 2020]; Howell.
[158] Vail, 69.
[159] Etheridge, 6-8; Howell.
[160] Howell.

Furthermore, Howell explains that '[the Mellotron] literally had to be serviced every time I wanted to use it for recording and if I took it out live, it would have to undergo a thorough check before the gig.'[161]

Several iterations of the Mellotron have since been produced by different designers, with various alterations. For example, the Mellotron Mark II (weighing 350lb) incorporated 'twin 35 note keyboards […] the right-hand keyboard provided 'lead' sounds, while the left-hand one was split, giving 'rhythm' and 'fill' sections thus producing complete recorded backings and music phrases.'[162] A 52 note model, the Mellotron 300, was later introduced in 1966.[163] Additionally, Rick Wakeman created an alternative version with Dave Biro, called the Birotron, which used 'tape loops that rotated continuously,' producing sounds with indefinite sustain.[164] However, one of the most interesting stories of the instrument's development involves Moody Blues musician and chief tester for Streetly Electronics Ltd, Mike Pinder.[165] The improvements Pinder made to his instrument whilst on tour (such as 'replacing the rhythm tapes with a second set of lead tapes to allow for sustained chords over more than 7 seconds') were incorporated into future iterations of the instrument.[166] Furthermore, Pinder was instrumental in introducing bands such as The Beatles and The Rolling Stones to the Mellotron.[167] These stories help to demonstrate the influence of users not only towards customising instruments for their own use, but also on the future design and manufacture of instrument models: both of which demonstrate ways of solving problems that previous iterations presented.

Although both digital sampling and portable synthesizers made tape-based instruments obsolete, the original Mellotrons experienced a revival in the 1990s due to a preference towards the instrument's grainy sounds.[168] Since then, in 2007 Streetly Electronics developed a new model of the Mellotron, the M4000, which still used magnetic tape (with a view to imitating the original M400 model), whilst designer Marcus Resch created the digital Mellotron M4000D in 2010 which included '100 original Mellotron and Chamberlin lead sounds [...] taken from the original first-generation tape library.'[169]

Additionally, Davis reported a continued interest in the Mellotron through the dissemination of digital recordings of the sounds on certain sample CDs and CD-ROMs.[170] Today, the instrument's sounds and interface have also been digitised as virtual studio technology (VST) instruments. For example, sixty-five of the original sounds from various models of the Mellotron have been digitalised and repackaged as the

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[161] Wright, 47.
[162] Etheridge, 4-5.
[163] Etheridge, 13.
[164] Howell.
[165] Etheridge, 9.
[166] Etheridge, 9.
[167] Etheridge, 11.
[168] Wright, 48.
[169] 'The M4000 Mellotron', *Streetly Electronics*, 2014 <http://www.mellotronics.com/new instruments.htm> [accessed 19 November 2020]; 'The M4000D Digital Mellotron', *Mellotron* <https://www.mellotron.com/digital-mellotron.html> [accessed 19 November 2020].
[170] Davies, 9.

Mellotron V (created by the company Arturia) which also features new digital affordances such as envelope shaping and controls which imitate variations of the sonic aesthetics and imperfections of analogue tape.[171] The sounds from the various iterations of the Mellotron were originally performed by musicians such as cellist Reginald Kirby and trombonist George Chisholm, and were recorded in studios such as IBC studios in London.[172]

3.3 The Exhibitions: *Good Vibrations / Electronic Musical Instruments*

The Musikinstrumenten-Museum's collection dates back to 1888.[173] However, since 1984, the museum's organological practices and objects have been transferred to a modern glass-fronted building, which is connected via walkways to other musical institutions such as the Staatliches Institut für Musikforschung and Philharmonie, within the Kulturforum area of Berlin.[174] The guide to the museum explains that 'special attention is devoted to professional conservation, restoration and the replication of valuable historical musical instruments.'[175]

There are several features which make the museum comparable to other traditional art galleries and museums such as the permanent Music Gallery in the Horniman Museum, London, and the Metropolitan Museum of Art, New York. For example, there is a display of historic acoustic instruments which is accompanied by various pieces of portrait art and antique furniture (creating a scene of 'music in the home'), whilst the cases of several other instruments and mechanical playback devices are also decorated with art and illustration (such as a Cembalo, or Harpsichord, with built-in octave virginial, made by Joannes Ruckers).[176] Additionally, visitors can hear sound examples of certain instruments (taken from, what the museum considers to be, an 'extensive archive of audio documents') through headphones (supplied with the museum's personal audio guides), which helps to create a silent reverence of music, art and instrument design.[177] Therefore, the overall experience created in the museum is that of silently observing the form and craftmanship of instruments, whilst privately listening to audio examples in a way that does not interrupt the public silence.

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[171] Arturia, 'Overview (Mellotron V)' <https://www.arturia.com/products/analog-classics/mellotron-v/overview> [accessed 19 November 2020].
[172] Etheridge, 6; Claudia Schmidt, 'Sounds of the Psychedelic: The Tale of the Mellotron', *Happy Media 2022*, 2021 <https://happymag.tv/mellotron/> [accessed 18 December 2022].
[173] 'Guide Sheet No. 24 The Musikinstrumenten-Museum' (Berlin: Musikinstrumenten-Museum), 1.
[174] 'Guide Sheet No. 24 The Musikinstrumenten-Museum', 2.
[175] 'Guide Sheet No. 24 The Musikinstrumenten-Museum', 2.
[176] Dieter Krickeberg and Conny Restle, 'Guide Sheet No. 5 The Harpsichord: National Differences' (Berlin: Musikinstrumenten-Museum, 2015), 2.
[177] 'Guide Sheet No. 24 The Musikinstrumenten-Museum' (Berlin: Musikinstrumenten-Museum), 2.

Benedikt Brilmayer (BB), a research assistant at the Musikinstrumenten-Museum and electronic musical instrument enthusiast, was responsible for the recent exhibitions in which the museum's collection of electronic musical instruments have been displayed. To accompany this exhibition work, BB also helped organise the international symposium *Electronic Instruments: Perspectives on History and Museum-Collections* in 2019 (during which I delivered a paper on interactive theremin instruments). BB explained why the museum's architecture produced specific challenges in relation to planning for sound management in the *Good Vibrations: A History of Electronic Musical Instruments* exhibition:

> This is, for our museum, a very special problem: it is one huge exhibition hall. If you make just a small noise or sound in some corner of the museum, you will hear it throughout the whole museum. For this special exhibition, we decided that, for example, all the software was playable without headphones but all other interactive instruments were equipped with headphones. It was just to keep the noise level a little lower […] with the Memotron M2K we could have used loudspeakers but that would have been too powerful and also there is the problem of visitors fiddling around with the volume of the Memotron M2K which […] could have disturbed other visitors […] [however] if you turn the volume [of the tablets] up to maximum they are not so loud that they really disturb others too much. (BB)

Following the conclusion of the *Good Vibrations…* exhibition, roughly a third of the museum's collection of electronic musical instruments were moved into a permanent gallery titled *Electronic Musical Instruments*. This large gallery is installed in a corner of the first floor of the museum: finishing the chronological ordering of musical instruments across the museum. Unlike their temporary exhibition *Good Vibrations…* (which was installed in the museum's designated temporary exhibition space), the instruments in the permanent gallery are not explicitly ordered: thematically or chronologically. The labels that accompany the instruments only state the instrument's name, the inventor or company who designed it, where it was designed, the year of its release, and the museum's catalogue number. Visitors can also access additional information regarding the museum's collections using the computer stations and printed guide sheets. Although text was more prominent in the temporary exhibition, BB shared his reservations towards enhancing the interpretation of musical instruments by visitors at the Musikinstrumenten-Museum using written text:

> As we always have the problem that parts of written text are not read by our visitors when they are too long, we included a lot of that information in our audio guide for the special exhibition, as well as additional text presented through our digital museum guide. (BB)

There is also very little in the way of supporting visual content that could help demonstrate how the instruments were used. However, visitors are able to see the floor-standing, table-top and glass-cased instruments from many different angles, whilst some instruments such as the Volkstrautonium are displayed with the back of the case removed so that visitors can see the electronic circuitry responsible for generating and shaping sound. Additionally, special consideration was given to older, historically significant musical instruments (some of which were the only instruments of their kind still in existence) in terms of their position in the exhibition space, as BB explained:

> There was, for example, our Mixturtrautonium created by Oskar Sala, which actually is a copy of the original Mixturtrautonium. This is one of our most precious electronic instruments because this is an absolutely unique instrument: it only exists once in the world […] we have the Mixturtrautonium in a very special place so it can be seen as the first electronic instrument [in the gallery space allocated for electronic musical instruments] from quite a distance, to give some kind of an introduction to the complex world of electronic instruments. (BB)

The museum launched the temporary exhibition *Good Vibrations: A History of Electronic Musical Instruments* (curated by BB) on March 25 2017, which ran until June 25 (see Figure 3.1. below). The seven colour-coded themes were titled *New Sounds New Forms* (early electronic musical instruments), *Record Play* (samplers, recording and playback devices), *Sounds Out of Nowhere* (synthesizers), *Rhythm Maschines* (drum machines: analogue, digital and samplers), *Beyond the Keyboard* ('alternative' controllers), *Virtually Playful* (computer-based music production), and *Under Construction* (what the museum considered as a view to the future of electronic musical instrument design). Additionally, a published exhibition catalogue not only provides a guide to the objects and themes that constituted the exhibition, but also includes specially commissioned papers exploring the history of, and contemporary practice with, electronic musical instruments (co-edited by BB, who also contributed papers).[178]

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[178] *Good Vibrations: Eine Geschichte Der Elektronischen Musikinstrumente = a History of Electronic Musical Instruments*, ed. by Conny Restle, Benedikt Brilmayer, and Sarah-Indriyati Hardjowirogo (Berlin: Musikinstrumenten-Museum, 2017).

Figure 3.1. The temporary exhibition *Good Vibrations: A History of Electronic Musical Instruments* installed at the Musikinstrumenten-Museum, Berlin.

Within this exhibition, many more electronic musical instruments were exhibited to the public than what was available in the museum's collection (such as the aforementioned Special Purpose Tape Recorder designed by Hugh Le Caine). Interactive exhibits were also installed in almost every theme of the *Good Vibrations…* exhibition to accompany the object displays. For example, the Memotron M2K accompanied the Mellotron M400 in the *Record Play* theme (see Figure 3.2. below). BB explained how the instruments loaned to the museum helped to strengthen the exhibition's themes:

> For the list of objects we wanted to present for the special exhibition, we tried to fill the list as much as possible with our own instruments, but we sometimes had huge gaps with our electronic musical instruments. For example, with our computer part, everything from there was on-loan because we didn't have the platforms [computers or tablets] as well as the software itself […] So we tried to fill up the gaps with instruments on loan […] for the early history of electronic instruments, we had to have a theremin but we didn't have a theremin in our collection, so we borrowed it from Paris [Musée de la Musique], as well as the Ondes Martenot. (BB)

Figure 3.2. A visitor performing with the Memotron M2K instrument, installed in the *Record Play* theme of the *Good Vibrations…* exhibition.

BB decided not to provide interactivity in the synthesizer-focused theme *Sounds Out of Nowhere*, due to his perception of the audience's abilities:

> For the third section, based on synthesizers, we left [interactivity] out because we thought it would be too complicated for the average visitor […] Actually, after the exhibition I also discussed [the possibility of designing an interactive exhibit]with the guy who gave us the regular Moog system and he said well, with […] half a year for preparation, he could have built us a very simple system with just some modules where visitors probably would have managed to understand the technical things and produce some kinds of sounds. But in preparation for the exhibition, we really didn't have the time to discuss and to think about that. (BB)

3.4 Mellotron M400: The Manufactured Object

The museum originally borrowed a Mellotron instrument from the Musée de la Musique, Paris, in order to display it in their *Good Vibrations…* exhibition. Shortly after this exhibition finished, the museum acquired their own Mellotron M400 which continues to be displayed in the permanent *Electronic Musical Instruments* gallery (see Figure 3.3. below), sharing a small stage with two other instruments. Whilst the instrument is often demonstrated to visitors during exclusive guided tours, the decision to leave the instrument's lid down whilst exhibited removes the potential for visitors to understand how the instrument works as the tape mechanisms remain hidden inside. In fact, as it remains as a black-boxed (or indeed, white boxed) instrument, there is no way for visitors to know that this is a tape-operated instrument at all. In reference to Figure 9.3. below, visitors might even believe this instrument to be some form of piano or organ. Nonetheless, the markings on the object provide material evidence of its age and, potentially, the way in which it was used. For example, the missing sections of wood on the edges might indicate that this was a gigging instrument, rather than one that was installed permanently in a studio.

Figure 3.3. The heavy, floor-standing Mellotron M400 exhibited in the permanent *Electronic Musical Instruments* gallery.

3.5 Memotron M2K: The Interactive Exhibit

The Memotron M2K started life as a collaboration between Thorsten Feuerherdt (TF) and Markus Horn of Manikin Electronic (the instrument designers) and Klaus Hoffman-Hoock (the sound designer), who had been professionally refurbishing Mellotron M400s and had 'more than two hundred tape frames […] he knew exactly what a Mellotron should sound like' (TF). TF explained some of the key differences between the older, manufactured Mellotron M400 and their digital replica, the Memotron M2K manufactured instrument:

> Basically, it's a white keyboard playing Mellotron sounds. The main difference is, of course, the Mellotron is using tapes and we are using samples. It sounds nearly the same […] We tried to leave the character of the sounds, which is done using samples key-by-key of really old frames, so [the Memotron is] not dealing with the original master tapes, we are dealing with sampled vintage instruments […] We tried to leave the user-interface as close to the old M400. Of course, the Memotron is a digital instrument so it needs a digital screen to make it usable, to enter sounds, to go into setups. We added MIDI [Musical Instrument Digital Interface]: you know, a modern instrument needs to be controlled from the outside. Meanwhile, we added to the M2K two additional keys, because the original Mellotron has 35 keys and we have 37. It's easier to get keyboards of this size. We added an effects processor which deals with amplifier modules and phaser, chorus, delay and reverb stuff, which makes it easier to use the Memotron as a stand-alone instrument in a small setup. The main thing that is different is: if you want to change the sounds on the original M400, you have to change the whole tapes, the frame, and the frame always has six sounds on position A, B and C. With the Memotron you can do something similar: you can load sounds from the memory but you can say 'I want violins on position A, on position B sounds like strings, and something strange like a Harpsichord on position C', which is a combination that was never available on the original frame for the M400. The flexibility is much larger than it was on the M400 and it only takes a finger slide to change the sounds, not half-an-hour. Then we also decided to remove the complete body of the M400 because, as anyone who has an M400 knows, it is a large, very heavy instrument. Nowadays, a digital Mellotron should look like a keyboard and be light weight. The old one was […] maybe 60Kg, whilst the new one is 12Kg so much easier to handle. (TF)

The Memotron M2K is an interesting case study because, much like the aforementioned M4000D, it was originally designed to be manufactured as an instrument for professional gigging musicians (see Figure 3.4. below). On their website, the designers - Manikin Electronic - provide a list of well-known musicians who use the instrument (as well as the company's other Mellotron-related products), which includes Tangerine Dream, Noel Gallagher's High Flying Birds, Justice, and Rick Wakeman.[179] As TF explained, the benefit of a client list such as theirs was the professional feedback received from these users, in combination with feedback received from other musicians the company knew, which helped Manikin Electronic to improve on the instrument's design (which also encouraged them to consider designing other instruments):

> We have a lot of musicians around us who help us to make ideas better, to make our instruments better. We have a lot of contact with professional musicians worldwide who are giving feedback, and we are also getting ideas from them. They are saying 'this kind of controller is missing' or 'I want to do this…maybe this could be a product?' If we can figure out that this idea is good, and maybe the idea will have a market, we can ask our retailers worldwide what they think about this and then maybe we will make a decision to say 'okay, lets design an instrument or controller or something'. (TF)

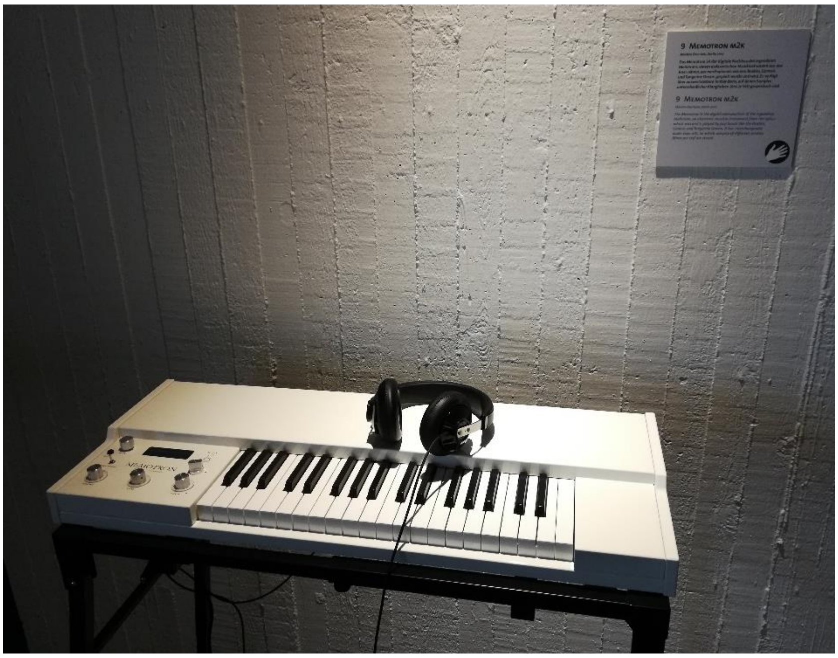

Figure 3.4. The Memotron M2K exhibited close to the Mellotron M400 in the *Electronic Musical Instruments* gallery.

[179] Manikin Electronic, 'Artists' <http://www.manikin-electronic.com/Artists/> [accessed 18 November 2020].

Although the company's audience of expert musicians may differ to what the museum attracts, this form of user testing may have proved vital for the instrument's suitability as both a musical tool for composition and performance, and as a demonstrative exhibit which members of the public can use.

Since the *Good Vibrations*… exhibition, this interactive exhibit has remained in the museum as one of two interactive exhibits installed in the permanent Electronic Musical Instruments gallery (the other being a Moog Theremini) and continues to accompany the Mellotron M400 from the museum's object collection (displayed close by). Here, this smaller, lighter interactive instrument was installed on a black keyboard stand with headphones and was accompanied by text which stated that the instrument was a digital reproduction of the 'legendary Mellotron' as played by 'pop bands like the Beatles, Genesis and Tangerine Dream.' TF believes that displaying the interactive, sounding Memotron M2K near to the original Mellotron M400 object should provide a means for visitors to hear the sounds that this and the original Mellotron could produce, helping them to understand the importance of the instrument in shaping the sonic culture of popular music:

> The Memotron M2K in the museum in Berlin gives visitors the chance to check out the sounds of a Mellotron. Due to the fact that the Memotron sounds very very close to an M400, based on the samples, the visitor is getting a real feeling, especially for the guys who grew up with The Beatles […] or Jean-Michele Jarre, they are loading sounds like the flutes that [you can hear] in Strawberry Fields Forever…so they know 'ah, this is the instrument from my youth' […] you can put [the M400] in this context to share with the next generation and say 'okay, this instrument isn't working anymore, but if you look back to the seventies you can hear it here in the musical context' (TF)

However, considering that the Memotron M2K is shipped with a 'basic collection' of one hundred sounds which users can also add to by importing their own, the probability of a visitor finding the exact sound that was used in a song familiar to them (such as the aforementioned flute from 'Strawberry Fields Forever') within their limited time in the exhibition might be slim.

Separately - as an observation of instrument preservation practices - TF advocated for the collection and preservation of documentation relating to how the instrument was designed, as well as the acquisition of spare components, in order to help both exhibition teams and the wider world of instrument designers to repair, or replicate, older instruments such as the Mellotron:

> In the end, I see that if you really want to have these instruments in a museum, maybe you'll have the instruments themselves but they won't be working anymore. Museums have to take care to collect everything around, like schematics, documentation of the housing, maybe ideas behind why it is designed in this way and not in another way. Maybe the sound: what can be recorded. Maybe also the musical usage. (TF)

TF provided another important comment: if exhibition teams (or anyone else concerned with preservation) are considering the acquisition of replacement electronic components for an electronic musical instrument in a collection, then they are too late! These replacement parts should, ideally, be collected with the object at the point of acquisition.

At Manikin Electronic, the consideration of each instrument's material durability also helps with addressing wider environmental issues which electronic products currently pose on the world. To this end, the company states (in the accompanying manual) that the Memotron M2K is 'RoHS [Restriction of Hazardous Substances] compliantly manufactured in accordance with the directive of the European Parliament and Council and is thus free of lead, mercury, cadmium and hexavalent chromium,' and requests that users do not dispose of the instrument in ordinary household waste as it is considered 'special waste.'[180] This is part of what TF believes sets Manikin Electronic apart from other electronic musical instrument designers:

> Instruments are mostly a piece of hardware, something like a computer, therefore you need a lot of knowledge about designing cases: production of housing and cases for instruments. You need knowledge of electronic design schematics. You need a lot of knowledge of laws if you want to sell electronic stuff. All governments worldwide are looking at instruments as a special kind of waste: electronic waste. This is a very strong discussion in our scene, that musical instruments are not built for the trash after a few years, they are built to help musicians for a long time, so they are completely different compared to a laptop or a smartphone […] In the end, if you are looking around in our market you will find that some instruments are designed to be cheap on the market. There are some companies that are producing masses of instruments for a low price, especially in Asia. We are designing and building everything here in Germany. We know that Manikin Electronic products are a little bit more expensive than others, we know it! But, if we know that some parts are a little bit more expensive than others but are more reliable, then we will use them and say that we need to raise the price, but we'll know

[180] Manikin Electronic, 'Memotron M2K OS v1.3 User Manual' (Berlin, 2016) <http://www.manikin-electronic.com/.cm4all/iproc.php/m2k/Dokumente/Memotron_m2k_Manual.pdf?cdp=a>, 24.

> that they'll work for a long long time […] we started in 2003 and we published our first Schrittmacher step sequencer in 2004. I know from a lot of customers that these units are still working: that's sixteen years! For electronics, that's a long long time. (TF)

The design of the Memotron M2K by TF and his colleagues at the Berlin-based company Manikin Electronic helped with representing local innovations in the museum. The close working relationship between the Musikinstrumenten-Museum and Manikin Electronic (as well as the geographical proximity between the two) means that the interactive Memotron M2K can be repaired more easily if a problem arises. Similarly, BB explained that some of the objects and interactive exhibits installed in the *Good Vibrations*… exhibition were chosen because, like the Memotron M2K, they also demonstrated local and regional innovations in music technology:

> It is part of our duty as a museum to put at least a part of our working focus on our regional developments. Of course, in Berlin you have a lot of sources for that, so that was the reason we reached out to the Ableton company and they were very happy to support us with the Ableton Push and the Ableton Live software for [*Good Vibrations…*]. They even supported us with the complete hardware, so we not only got the Push but also a working computer on which we were able to run the Ableton Live software. (BB)

Both BB and TF believe that interactivity, generally, can benefit a visitor's experience of electronic musical instruments in a museum, which is evidenced in the visitor feedback which BB has received:

> The feedback is mainly that visitors want to touch something […] My personal feeling is every time I am in a musical instrument museum, I want to touch something, but normally it is forbidden. With the Memotron, the feedback from visitors is its cool we can touch something [and] if something is not working, because we have built the instrument it is easy to repair. (TF)

However, even though both the Mellotron M400 and the Memotron M2K are displayed in close proximity to each other, some visitors have stated in their feedback that they were not able to make the connection between the original tape-operated instrument and the digital, interactive replica:

> It is a little sad that they don't really get the connection that the Memotron is the digital replica of the Mellotron, when both instruments are just five meters away from each other, and the instrument design is almost identical. It is quite interesting that the positive feedback is only 'we now have some interactive instruments' but not 'ah, you can play a modern replica of a Mellotron' (BB)

3.6 The Science Museum Group and Elsewhere

The SMG have acquired two Mellotrons from Streetly Electronics Ltd in Sutton Coldfield: the MK2 model, manufactured in 1965 (see Figure 3.5. below) and Model 300, manufactured between 1968-1971.[181] In the SMG's Collection Policy from 2016, the museum lists the Mellotron as one of the highlights of their existing collection of sound technologies, advocating for the object's significance and provenance as an instrument 'used by the BBC Radiophonic Workshop and on many progressive recordings in the 1960s and 1970s', which therefore 'could form the basis of important narratives in the history of sound technologies.'[182] Indeed, Pinch and Bijsterveld state that unique instruments such as the Mellotron and the theremin fascinated musicians of psychedelic music and influenced the design of early synthesizers made by inventors such as Don Buchla and Robert Moog, which made appearances in music festivals during the mid-sixties.[183] Mellotron instruments have also been collected and displayed in other museums. For example, the Museum of Making Music (MoMM) in Carlsbad displayed a Mellotron gifted by Los Angeles studio musician Michael Lloyd, which was originally owned by the band The Carpenters.[184]

[181] 'Search Our Collection (Mellotron)', *Science Museum Group Collection* <https://collection.sciencemuseumgroup.org.uk/search?q=mellotron> [accessed 19 November 2020].
[182] Science Museum Group, *Science Museum Group Collecting Policy Statements October 2016*, 2016.
[183] Pinch and Bijsterveld, ''Should One Applaud?': Breaches and Boundaries in the Reception of New Technology in Music', 551.
[184] I spotted this Mellotron whilst visiting the museum in 2019. The Museum of Making Music has since been renovated and therefore it is hard to say whether this instrument is still on display or not.

Figure 3.5. The right-hand side of the Mellotron Mark 2, currently in storage at the NSMM, originally acquired from Streetly Electronics Ltd between 1992 and 1993 by the Science Museum.

Although there are benefits to the digitisation of sounds in an instrument such as the Memotron M2K such as eliminating the need to arrange for the repair or replacement of vulnerable analogue tape, this is not to say that the institutions within the SMG have been adverse to providing visitors with interactive experiences relating to tape-operated sound technologies. For example, in the exhibition *Above the Noise: 15 Stories from Bradford*, the NSMM provided a wall-mounted Bush personal cassette recorder as a means for visitors to hear 'snippets from the life stories of Bradford's textile workers and the unique sounds of Bradford mills' (see Figure 3.6. below). Visitors had to wear the headphones supplied and operate the cassette player using its original push-button interface in order to listen to the content.

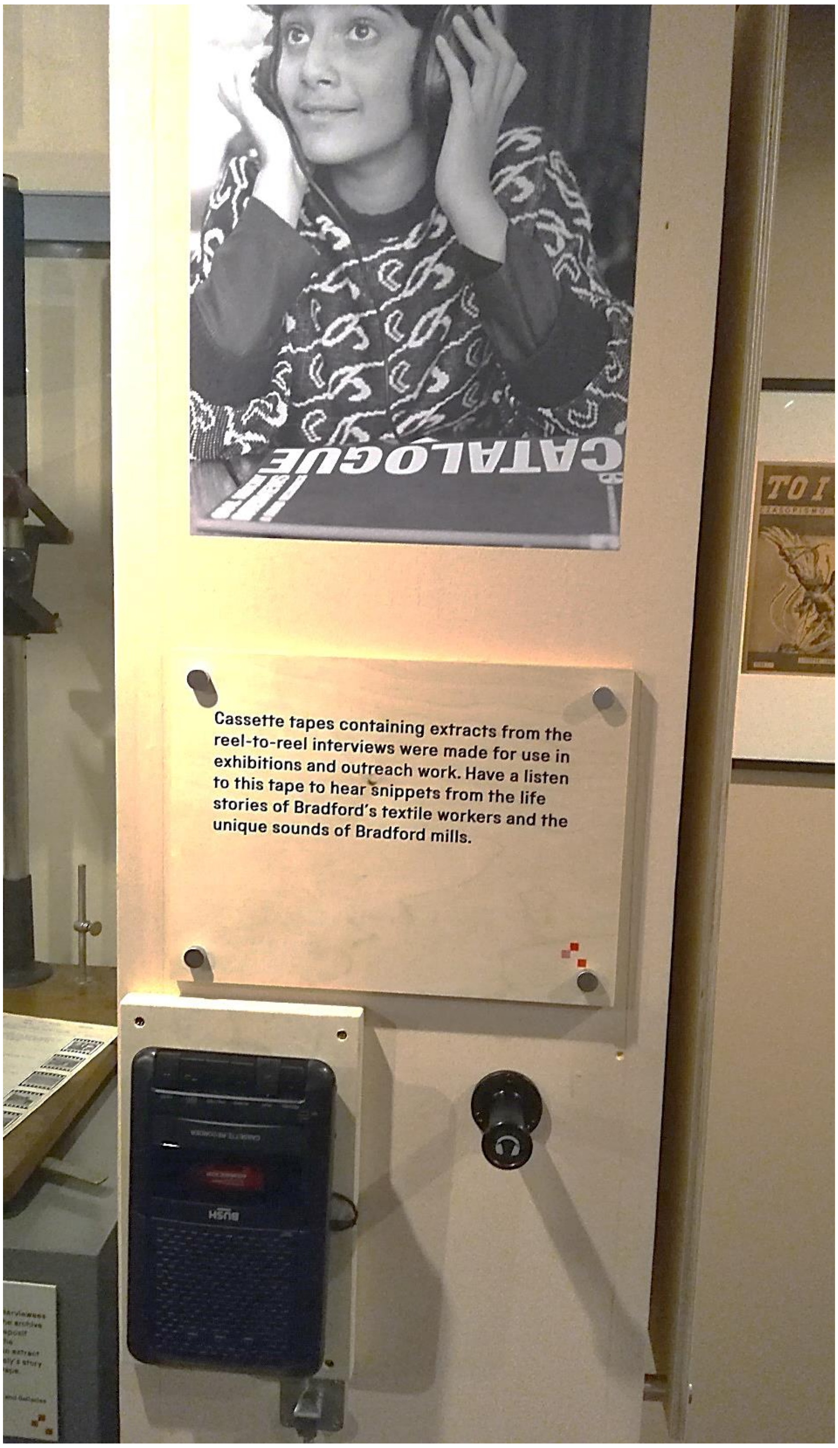

Figure 3.6. A Bush personal cassette recorder, provided in the *Above the Noise: 15 Stories from Bradford* exhibition at the NSMM.

In fact, the Science Museum exhibited an interactive tape recorder in the 1950s, which was designed to record a visitor's voice and automatically play it back to them shortly afterwards. This exhibit was documented in a television broadcast by the BBC in 1959, where a school boy can be seen using the tape recorder to record himself saying 'Hello, my darling'.[185]

The SMG also acquired another of Chamberlin's tape-operated inventions: the Rhythmate Model 40 drum machine.[186] This plays recorded acoustic percussion patterns via forty-two different tape loops, split into fourteen banks.[187] Musicians select one of the fourteen banks using a lever that slides along the top of the instrument, whilst a sub lever below is used to select one of three sub tape loops: a similar design to the Mellotron.[188] Other notable tape-operated electronic musical instruments and sound technologies include the Varispeed Revox A77 tape recorder (used by electro-acoustic musician Hugh Davies) and the Maestro Sireko Echo Delay Unit.[189]

Outside of the SMG, tape has been utilised creatively in a variety of ways in different museum and art gallery exhibitions. For example, Bruce Nauman created an installation involving a Sony stereo tapecorder (placed on one side of an exhibition space) and a long loop of tape spun around the leg of a wooden chair (installed on the opposite side of the space), as part of his exhibition *Disappearing Acts* in the Museum of Modern Art, New York (see Figure 3.7. below). The vulnerable tape loop created a barrier that coerced visitors to walk around the tape, so as not to interrupt the sounding media in motion. Nauman's installation represents a history of experimentation with tape for musical composition, in which a number of composers and artists have produced pieces 'derived from the properties of tape loops and tape delays.'[190] These include Pauline Oliveros, Steve Reich and Nam June Paik: the work of which has been exhibited in museums and art galleries globally (such as in the exhibition *When All is Quiet: Kaiser Chiefs in Conversation with York Art Gallery* which examined the work of Pauline Oliveros).[191]

[185] BBC Archive, 'BBC Archive - 1959: News: Science Museum |', *Facebook*, 2020 <https://fb.watch/24Md2InVCs/> [accessed 30 November 2020].
[186] 'Rythmate Rhythm Generator', *Science Museum Group Collection* <https://collection.sciencemuseumgroup.org.uk/objects/co408659/rythmate-rhythm-generator-magnetic-tape-musical-instrument> [accessed 30 November 2020].
[187] Cordell; P.W. Elverum & Sun, 'Chamberlin Rhythmate 40, Tape Loop Drum Machine, First Drum Machine Ever Made', *YouTube*, 2018 <https://youtu.be/dHO_EbGqIUc> [accessed 30 November 2020].
[188] Cordell; P.W. Elverum & Sun.
[189] 'Varispeed Revox A77 Tape Recorder Used by Electro-', *Science Museum Group Collection* <https://collection.sciencemuseumgroup.org.uk/objects/co8088553/varispeed-revox-a77-tape-recorder-used-by-electro> [accessed 30 November 2020]; 'Echo Delay Unit, Maestro Sireko Model', *Science Museum Group Collection* <https://collection.sciencemuseumgroup.org.uk/objects/co117518/echo-delay-unit-maestro-sireko-model-echo-delay-unit> [accessed 30 November 2020].
[190] Nicolas Collins, *Handmade Electronic Music: The Art of Hardware Hacking*, Third Edition (New York: Routledge, 2020), 68-69.
[191] Collins, 68-69; 'When All Is Quiet: Kaiser Chiefs in Conversation with York Art Gallery', *York Museums and Gallery Trust* <https://www.yorkartgallery.org.uk/exhibition/when-all-is-quiet/> [accessed 15 April 2022].

Figure 3.7. A tape loop extends beyond the reels of a Sony tape recorder in the exhibition *Disappearing Acts* at the Museum of Modern Art, New York.

3.7 Conclusion

The Mellotron represents an important part of Anglo-American electronic musical instrument heritage. The construction, distribution, and marketing of the instrument pre-dates the commercial availability of synthesizers such as the Minimoog, which may have influenced its adoption by popular music bands of the sixties as an alternative device for musical expression. Whilst the sounds of the Mellotron were therefore popularised in various forms of music from the 1960s, they have since been digitised and incorporated as presets within subsequent hardware and software instruments, such as the Memotron M2K. This situation is evidently beneficial to exhibition teams as it provides multiple ways in which visitors could hear and interact with the Mellotron's sounds via different devices, rather than relying on the original instrument and its tapes. Although the digitisation of sounds and playback mechanism in the Memotron M2K may be considered inauthentic to working the tapes of the Mellotron, the use of tapes for interactive sound triggering (performance) could create a challenge for future exhibition teams in maintaining or repairing their working condition, as opposed to how visitors might engage with tape when used as part of an artistic installation (observation) such as within Nauman's *Disappearing Acts* exhibition. Nonetheless, whilst the Memotron M2K instrument was not built with museum interactivity in mind, the care and attention that TF and Manikin Electronic applied to the choice of robust, high-quality components and materials helped to ensure its longevity in the hands of museum visitors.

However, whilst the Musikinstrumenten-Museum used the Memotron M2K to discuss and demonstrate the *use* of the Mellotron's sounds in popular music, the initial *performance and recording* of the instruments behind those sounds was left unidentified. Nonetheless, the work involved in performing, recording, distributing, and digitising these sounds – whether they remain hidden inside an instrument or piece of recorded music, or as separate audio tapes and files - has been extensive. Therefore, the opportunity exists for future exhibition teams to explore the more hidden communities of sound associated with the instrument (perhaps in collaboration with someone like TF at Manikin Electronic) and display the Mellotron object with its case open to highlight the original, unique storage and triggering of sounds via tape.

4 Roland TR-808: Design Museum

4.1 Introduction

Although manufacturing is intended to place products into the hands of more users, it does not guarantee that those users will ascribe legendary status to such products over time. In fact, several electronic musical instruments have only later become popular once manufacturing has ceased: often for reasons that differ to what the original designers had imagined and marketed. Additionally, some may argue that the increased popularity or desire for an instrument - in relation to the scarcity of surviving models and the prices that owners demand through the second-hand market – may lead to the greater possibility of that instrument being, later, replicated as a new manufactured model.

Considering the huge popularity of the Roland TR-808 drum machine and the global dissemination and modification of its percussion sounds across many other instruments and thousands of recorded songs, it is more likely that people have already heard of the instrument's name and have heard it's sounds. However, the likelihood of museum visitors to have already *connected* the instrument to its sounds (as with the Mellotron in the previous case study), or to already know what the TR-808 looks like, is still a consideration that exhibition teams need to face when exhibiting the instrument. What makes this case study unique is the installation of an interactive version of the instrument - the MR-808 drum robot - and the omission of the instrument itself as an object in the same exhibition. With this in mind, the opportunity exists to frame the MR-808 as a representation of other things in the exhibition. For example: as representative of functionalities that other exhibited objects provided (such as step sequencing); representative of objects in their entirety (such as other popular Roland instruments: designed around the same time and often used to create similar strands of music); or, by widening the scope further, representative of the thematic display that hosts electronic musical instruments as well as stories of music, musicians, and cultures (*Man & Woman Machine*). However, although the designers intended for the means of generating sounds to be more visually appealing for visitors (compared to the electronic circuitry hidden inside the original TR-808), the exhibit's ability to authentically represent the timbres of the instrument's original sounds is questionable. Nonetheless, as each of the sounds within the original instrument have evolved significantly since its release, the potential for authentic replication is not a straight-forward proposition.

4.2 Roland and the TR-808

The Roland Corporation (previously ACE Electronic Industries) was founded in 1972 in Japan by Ikutaro Kakehashi (born in 1930, died 2017).[192] Their TR-808 (Transistor Rhythm) drum machine was invented in 1980 by Tadao Kikumoto (in collaboration with musician Don Lewis) and is considered by many to be the most famous drum machine of all time.[193] Before the invention of the TR-808, Roland had already developed a number of analogue and digital drum machines and sequencers, beginning with the R-1 Rhythm Ace in 1964 which also generated transistorised versions of drum sounds.[194] Prior to this, other electronic percussion instruments had been invented, dating back to the world's first drum machine, the Rhythmicon (invented in the early 1930s as a collaboration between Leon Theremin and composer Henry Cowell) which relied on 'optoelectronic sound generation and rotating perforated discs' to produce 'complex pulse patterns.'[195]

Like Roland's previous CR-78 (CompuRhythm) which was designed as 'a rhythm accompaniment device for organs', the TR-808 was designed to be used as a cheaper alternative to hiring a session drummer for creating backing tracks.[196] Roland utilised unique components and analogue synthesis methods for generating percussive sounds inside the TR-808 using cheap transistors (as opposed to digitally producing sounds using more expensive memory chips). Whilst this practice was not new, the Roland Corporation had sourced a batch of transistors which were deemed 'out of specification.'[197] This, according to Kakehashi, gave many of the instrument's sounds their unique 'sizzling' timbral qualities.[198] However, the company would probably not have advertised that the components were 'out of specification' as the reason behind

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[192] Roland Corporation, 'Roland - Company - Company Overview - Corporate Information' <https://www.roland.com/global/company/overview/> [accessed 23 November 2020]; 'Ikutaro Kakehashi, the Driving Force behind MIDI', *MIDI Association* <https://www.midi.org/midi/midi-articles/ikutaro-kakehashi-the-driving-force-behind-midi> [accessed 19 November 2023].
[193] 'Three Minute Epiphany - Don Lewis: The TR-808 Drum Machine', *BBC Sounds*, 2020 <https://www.bbc.co.uk/sounds/play/p090xgs0> [accessed 8 May 2022]; Roland Corporation, 'Roland - The TR-808 Story', 2020 <https://www.roland.com/uk/promos/roland_tr-808/> [accessed 23 November 2020]; Oz Owen and Roland UK Team, 'TR-808 Drum Machine Flashback - Roland Resource Centre', *Roland Australia* <https://rolandcorp.com.au/blog/tr-808-drum-machine-flashback> [accessed 19 November 2023].
[194] Gordon Reid, 'The History Of Roland: Part 1', *Sound on Sound*, 2004 <https://www.soundonsound.com/music-business/history-roland-part-1> [accessed 12 June 2022].
[195] Malte Pelleter, 'Beating Time: Futuristic Histories and Past Futures of the Drum Machine', in *Good Vibrations: Eine Geschichte Der Elektronischen Musikinstrumente = a History of Electronic Musical Instruments*, ed. by Conny Restle, Benedikt Brilmayer, and Sarah-Indriyati Hardjowirogo (Berlin: Musikinstrumenten-Museum, 2017), 41-42; Hanif Abdurraqib, 'The History of the TR-808 Drum Machine | Arts & Culture', *Smithsonian Magazine*, 2020 <https://www.smithsonianmag.com/arts-culture/history-tr-808-drum-machine-180975205/> [accessed 19 November 2023].
[196] Alexander Dunn, *808* (UK: Apple Music, 2015); Roland Corporation, 'Roland - The TR-808 Story'.
[197] Dunn; Roland Corporation, 'Roland - The TR-808 Story'.
[198] Dunn; Roland Corporation, 'Roland - The TR-808 Story'.

the unique sound aesthetics when the instrument was being manufactured: especially considering the price tag ($1,200) and the fact that it was intended to be used as a professional instrument.[199]

Nonetheless, although it was designed to be used as a realistic replacement for a session drummer, many users were keen to use the instrument's sounds because they sounded anything but realistic. As musician David Noller (a.k.a. Dynamix II) explains: 'The TR-808 drum machine had a very distinctive sound and it didn't sound like a real acoustic drummer. It sounded very electronic and robotic.'[200] Additionally, the implementation of rotary controls on the instrument's interface allowed musicians to continually alter the timbre of the sounds, which was key to the instrument's success and its sonic identity. Whilst collaborating with Tadao Kikumoto, Don Lewis suggested that they move these controls from the inside of the machine to the outside, so that the timbre of the percussion sounds could be adjusted not just by those who worked at the factory - within the hidden circuitry - but also by musicians.[201] Lewis advocated for this because he wanted to be able to adjust the sounds depending on the type of music he was playing.[202] One of the benefits to musicians in adjusting the sounds was the ability to extend the decay for the kick drum sound for a long time, which the analogue technology was able to produce.[203] This sound has since been re-interpreted in different ways: for example, some musicians have set a long decay, sampled the sound, and then re-using it melodically as a bassline.[204]

Although the instrument produced its five analogue percussion sounds using analogue transistors, the TR-808 could be considered a hybrid instrument. A digital microprocessor (hence the instrument's tagline 'computer controlled') enabled the sequencing (or programming) of drum patterns within a bar of music that was split into sixteen steps (marked as red, orange, yellow and white buttons), which musicians could then save and recall (see Figure 4.1. below).[205] Additionally, the instrument incorporated Roland's own DCB communications protocol which was the immediate precursor to the Musical Instrument Digital Interface (MIDI) protocol (which Kakehashi helped develop).[206]

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[199] Abdurraqib.
[200] Mike Sparks, 'Dynamix II: On Miami Bass, the TR-808, and Finding the Perfect Tempo', *Roland Articles* <https://articles.roland.com/dynamix-ii-on-miami-bass-the-tr-808-and-finding-the-perfect-tempo/> [accessed 23 November 2020].
[201] 'Three Minute Epiphany - Don Lewis: The TR-808 Drum Machine'.
[202] 'Three Minute Epiphany - Don Lewis: The TR-808 Drum Machine'.
[203] Paul McCabe, 'Tadao Kikumoto: An Exclusive Conversation -', *Roland Articles* <https://articles.roland.com/tadao-kikumoto-exclusive-conversation/?_ga=2.32098743.80228520.1603737113-1204902582.1601477084> [accessed 23 November 2020].
[204] Dunn.
[205] Vail, 82-84; Roland Corporation, 'Roland - The TR-808 Story'.
[206] Vail, 82-84.

Figure 4.1. The Roland TR-808 drum machine.

Even though the instrument has been used in, and has helped create, various genres of electronic music and countless songs, and is, thus, now considered as iconic, production of the instrument ended after just a couple of years due to low sales.[207] This was partly due to the launch of the more popular Linn LM-1 drum machine (designed by Roger Linn) around the same time, which allowed musicians to program drum patterns as backing tracks using more realistic-sounding sampled percussion sounds (instead of transistorised percussion).[208] The short production run was also influenced by the inability of the Roland Corporation to continue sourcing the same transistors and, therefore, continue to produce the same unique sounds in each new instrument manufactured.[209] This led to the TR-808 being sold in second-hand shops at a vastly reduced price after production had ceased, attracting a different set of users who were searching for a more affordable drum machine compared to those users which the instrument was designed for.[210] Because of this, the analogue TR-808 'proliferated through an era of predominantly digital commercial music production' during the 1980s and 1990s, whilst its sounds became part of what Bennett describes as the 'sonic identity' of 'hip-hop and dance musics […] much the same way as electric guitars are traditionally aligned to rock music.'[211] Don Lewis even suggests that the boom of the kick drum sound also reflected the cultural identity of hip hop, which is part of the reason to why that instrument was heavily used within that genre.[212]

The continuing popularity of the Roland TR-808 drum machine is partly due to the replication of its sequencing and sound editing interface across other drum machines, sequencers and grooveboxes made by the Roland Corporation, as well as other instrument designers. Also, the instrument's percussion sounds have since re-appeared as preset sounds inside new digital electronic musical instruments. For example,

[207] Roland Corporation, 'Roland - The TR-808 Story'.
[208] Vail; Dunn.
[209] Dunn.
[210] Tjora, 164-165.
[211] Samantha Bennett, *Modern Records, Maverick Methods* (New York: Bloomsbury Publishing Ltd, 2019), 47 and 73.
[212] 'Three Minute Epiphany - Don Lewis: The TR-808 Drum Machine'.

Roland's MC-303 Groovebox instrument (introduced in the mid-nineties) was marketed as 'an upgraded composing machine, with a similar way of working (to the TR-808 and TR-909 drum machines) and with copies of the original sounds, but with digital sound generation, hence better programming stability.'[213] The sounds continued to reappear in Roland's later Groovebox instruments (such as the MC-505 and MC-909) and drum machines (such as the TR-8 and TR-8S, which both utilised Roland's 'Analog Circuit Behaviour' technology as an improved method of replicating the original analogue sounds).[214] For example, some of the sounds on the preset list of the Roland TR-8S 'Rhythm Performer' are named as '808 Bass1', '808 Noise Tom L' (Low), and 'DistSustnd808Bs1' (presumed to mean distorted-sustained-808-bass-1).[215] Furthermore, in celebration of its 40th anniversary in 2020, Roland introduced a TR-808 software synthesizer which allowed users to enhance the instrument's original sounding potential by additionally providing 'tuning and decay on each instrument and the ability to overdrive the internal circuitry', whilst the step sequencer was expanded to include sequencing lanes for each sound, enabling faster programming.[216]

The sounds of the TR-808 continue to be used in recorded music as patterns composed across the boundaries of different genres by a variety of artists. The instrument is also referenced in the lyrics and titles of many songs and albums. For example, the instrument is explicitly referenced in Kanye West's album *808s and Heartbreak*, Riccardo Villalobos' '808 The Bassqueen', and Tobias Von Hofsten's 'I Love my 808', and in the lyrics of Outkast's 'The Way You Move' ('But I know y'all wanted that 808') and The Beastie Boys' 'Super Disco Breakin' ('Nothing sounds quite like an 8...0...8').[217]

4.3 The Exhibition: *Electronic: From Kraftwerk to The Chemical Brothers*

Electronic: From Kraftwerk to The Chemical Brothers was originally scheduled to launch in April 2020 at London's Design Museum but due to COVID-19 the exhibition was postponed and later relaunched on July

[213] Tjora, 165.
[214] Roland Corporation, 'Roland - TR-8 | Rhythm Performer' <https://www.roland.com/global/products/tr-8/> [accessed 25 November 2020].
[215] 'TR-8S Ver.2.00 Preset INST Tone List' (Roland Corporation) <https://www.roland.com/uk/support/by_product/tr-8s/owners_manuals/>.
[216] Roland Corporation, 'Roland - TR-808 | Software Rhythm Composer' <https://www.roland.com/uk/products/rc_tr-808/> [accessed 25 November 2020].
[217] 'Kanye West - 808s & Heartbreak | Releases', *Discogs* <https://www.discogs.com/Kanye-West-808s-Heartbreak/master/8489> [accessed 25 November 2020]; 'Ricardo Villalobos - 808 The Bassqueen (1999, Vinyl)', *Discogs* <https://www.discogs.com/Ricardo-Villalobos-808-The-Bassqueen/release/34091> [accessed 25 November 2020]; 'Cynthia Stern / Tobias Von Hofsten - I Love My 808 (2000, Vinyl)', *Discogs* <https://www.discogs.com/Cynthia-Stern-Tobias-Von-Hofsten-I-Love-My-808/release/30476> [accessed 25 November 2020]; AlvaroHoyosD, 'OutKast – The Way You Move Lyrics', *Genius Lyrics*, 2014 <https://genius.com/Outkast-the-way-you-move-lyrics> [accessed 25 November 2020]; MattWalby1, 'Beastie Boys – Super Disco Breakin' Lyrics', *Genius Lyrics*, 2012 <https://genius.com/Beastie-boys-super-disco-breakin-lyrics> [accessed 25 November 2020].

31 2020, with an expected end date of February 14 2021. I attended the exhibition in October 2020 before the UK experienced a second lockdown, forcing the museum to temporarily close early (a virtual version of the exhibition took place online on December 17 2020 for those visitors which the museum may have failed to attract).[218] Before moving to London, the exhibition was originally titled *Electro: From Kraftwerk to Daft Punk* and was hosted at the Musée de la Musique in Paris between April 6 and August 11 2019 (Daft Punk being two French musicians, as opposed to The Chemical Brothers who are both English). Jean-Yves Leloup curated both iterations of the exhibition, whilst Gemma Curtin co-curated the exhibition at the Design Museum with Jean-Yves (both of whom also co-edited the exhibition catalogue for the Design Museum, along with assistant curator Maria McLintock). Additionally, the content within the *Electro…* exhibition is likely to have been influenced by the research disseminated during the *Electronic Instrument-Making* international conference of 2018, organised by the Cité de la Musique (which the Musée de la Musique exists within).[219]

Both versions of the exhibition were explicitly focused on the history of electronic music and electronic musical instruments. However, not only did the version at the Design Museum focus more on the history of electronic music in the UK (with exhibits relating to Daphne Oram and the BBC Radiophonic Workshop, the UK's criminal justice act, and nightclubs such as Fabric in London), the museum also used its curatorial focus to 'bolster the exhibition with a layer of design history that has only ever been patchily explored.'[220]

Much like the aforementioned Musikinstrumenten-Museum within Berlin's Kulturforum, the Musée de la Musique is situated in the Cité de la Musique (opened in 1997) which is comprised of several buildings which host museum galleries, concerts, conferences and other activity. The permanent galleries of the museum represent a traditional musical instrument museum, exhibiting a global ethnographic collection of mostly acoustic instruments, often accompanied by works of art indigenous to the instruments' origins. However, the museum's temporary exhibition spaces have been used as a way of breaking-out of the traditional structures of the permanent galleries, combining artworks, musical instruments, costumes, and interactive elements, in order to offer visitors 'an immersive journey into the world of music.'[221] Nonetheless, photographs of the exhibition spaces hosted online provide evidence that *Electro: From Kraftwerk to Daft Punk* also featured what may have been objects from the Musée de la Musique's

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[218] Design Museum, 'Electronic: From Kraftwerk to The Chemical Brothers -The Virtual Tour', 2020 <https://designmuseum.org/exhibitions/electronic-from-kraftwerk-to-the-chemical-brothers/electronic-from-kraftwerk-to-the-chemical-brothers-the-virtual-tour> [accessed 26 November 2020].
[219] 'Call for Proposals', in *Electronic Instrument-Making International Conference* (Paris: Cité de la Musique, 2018).
[220] Tim Marlow, 'Foreword', in *Electronic: From Kraftwerk to The Chemical Brothers*, ed. by Jean-Yves Leloup, Gemma Curtin, and Maria McLintock (London: Design Museum Publishing, 2020), p. 7.
[221] 'Exhibitions', *Philharmonie de Paris* <https://philharmoniedeparis.fr/en/musee-de-la-musique/exhibitions> [accessed 26 November 2020].

permanent collection (such as sculptural objects) which were not transferred over to the exhibition in London.[222]

The Design Museum started life in the Docklands area of East London in 1989 before moving into the larger, former Commonwealth Institute building in Kensington, West London, opening to the public in 2016.[223] A focus on design creates a wide remit for the museum to collect and exhibit works of art and technology designed for the home and professional settings. According to the museum, 'the Design Museum collects objects that help to explain what design is to a non-specialist audience. In addition to looking after key examples of design from the past, the museum acquires objects relating to the process of design, from tools, drawings and prototypes, speculative designs and finished production models.'[224] Additionally, the Design Museum has a history of hosting exhibitions in which music and sound-related objects and art were (and continue to be) displayed, such as *The Peter Saville Show* (2003) which featured the artist's work for Factory Records, and *Amy: Beyond the Stage* (2021) in which Amy Winehouse's blue Daphne Fender Stratocaster guitar was displayed.

The *Electronic…* exhibition was comprised of four themes (*Man & Woman Machine, Dancefloor, Mix & Remix,* and *Utopian Dreams & Ideals*) arranged in a linear order, connected through the use of darkened corridors with additional smaller cage-like break-out rooms. As evidenced in photos of *Electro…*online, the overall space designated to temporary exhibitions at the Design Museum seems noticeably smaller than what was offered at the Musée de la Musique, which may have created unique challenges in safely exhibiting content and managing visitor numbers during the COVID-19 pandemic.[225] Within the four themes exist smaller displays dedicated to sonic cultures and their geographical origins, such as Detroit and Techno, Chicago and Acid House, and New York and Disco. A wide range of design-focused material existed throughout. Examples include instrument objects and re-created studio spaces, costumes, enlarged photographs of crowds in club and festival spaces, graphic design for flyers and record sleeves, documentary footage and music videos, and audio-visual installations. Notably, a lack of both interactive exhibits (more on this later) and acknowledgments of how different designed objects were built, or how they were intended to function, suggested that this was an exhibition of design as *form*, rather than *function*.

The Design Museum may have chosen the title for the exhibition as …*From Kraftwerk to The Chemical Brothers* as a way of providing an entry point to electronic music culture for those who are not familiar with

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[222] Niall Patrick Walsh, '1024 Architecture Design Immersive Installations for Techno Exhibition in Paris', *ArchDaily*, 2019 <https://www.archdaily.com/916304/1024-architecture-design-immersive-installations-for-techno-exhibition-in-paris> [accessed 30 November 2020].
[223] 'Made in 1989', *Design Museum* <https://designmuseum.org/made-in-1989> [accessed 26 November 2020]; 'The Story', *Design Museum* <https://designmuseum.org/new-design-museum/the-story> [accessed 26 November 2020].
[224] 'Design Museum Collection', *Design Museum* <https://designmuseum.org/about-the-museum/design-museum-collection> [accessed 26 November 2020].
[225] Walsh.

it (considering that these two bands have headlined several internationally recognised British festivals such as Glastonbury and All Points East, having had several number one singles between them in the UK charts). However, once inside the exhibition there exists little reference to popular electronic music composition and culture. Instead, much of the content is focused on underground dance music and culture which began to rise in popularity during the late 1980s. Examples include artwork that represented the visual identity of record labels such as Underground Resistance, Suburban Base and Djax-Up-Beats, as well as photographs of clubs and outdoor raves taken during, and since, the period known as the second summer of love. In many ways, it seems as though the exhibition was co-produced by a generation X cohort for a similar generation X audience, who may have developed similar meaningful connections to the music and culture depicted in the exhibition prior to their visit. Jean-Yves Leloup, for example, is described by Walsh as 'a journalist, DJ, sound artist, and curator who has been at the front line of the emergence of the techno movement across France for the past thirty years.'

Nonetheless, the memories invoked by the focus on club culture, through visual and aural content, and the design of the darkened exhibition spaces (described as 'a raw, deliberately urban design [...] freed from the classic codes of presentation') offered visitors the (unexpected) chance to reflect on the value of the night time economy, globally, and hope for a swift return to normality following the on-going COVID-19 pandemic, so that they could part in the real thing (again).[226]

4.4 Roland TR-808: The Manufactured Object

Within the theme *Man & Woman Machine,* several table-top 'machines' were displayed on a table positioned against a wall which hosted a timeline of innovation from 1901 to 2020, comprising text, photographs of musicians, album artwork, marketing materials for instruments, and video clips of musicians using their instruments (see Figure 4.2. below). The timeline is split according to rough periods of history in which instruments and recordings of music were first introduced. The interfaces of these instruments range from the simple (such as the Croix Sonore) to the complex (modular and semi-modular synthesizers); from the cheap and toy-like (the Dato-Duo two-player synthesizer) to the expensive and professional (the Fairlight CMI, displayed in an advertisement); and from the popular (the Japanese inventions from Roland, Korg and Akai) to the rare (early instruments such as the Trautonium ELA T42).

[226] Walsh.

Figure 4.2. The main display for the *Man and Woman Machine* theme of the exhibition *Electronic: From Kraftwerk to The Chemical Brothers* at the Design Museum, London.

Although the accompanying text for the period *1977-86 - Postpunk, Synth Pop and Disco* states that 'the arrival of cheaper and more portable synthesizers from Japan widens their appeal,' unfortunately the TR-808 'machine' is missing from the timeline.[227] However, other Roland objects were displayed within this theme: the TR-909, TR-707, and Roland TB-303 from the Arnaud Rebotini collection (see Figure 4.3. below). Additionally, the following text is used to describe innovation in the year 1977 (accompanying an advertisement for the Roland SH-101 synthesizer):

> Japanese companies such as Korg, Roland and Yamaha undermine UK electronic producers by offering a new range of instruments at accessible prices, which are increasingly adopted by young musicians.[228]

[227] Quote taken from the exhibition text accompanying the period *1977-86 - Postpunk, Synth Pop and Disco*.
[228] Quote taken from the exhibition text accompanying the Roland SH-101 instrument.

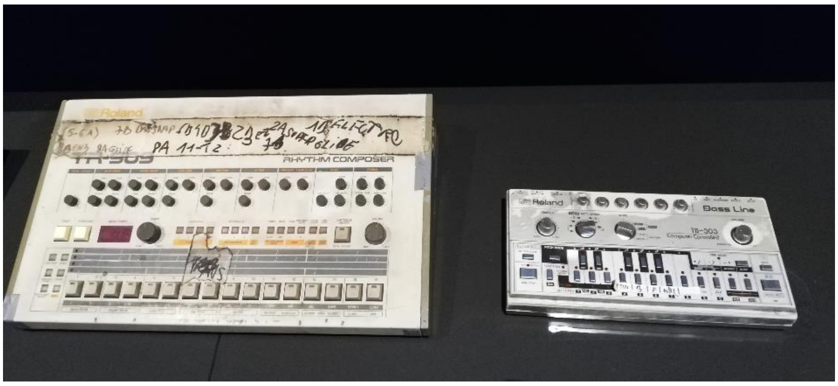

Figure 4.3. The Roland TR-909 drum machine (left) and TB-303 synthesizer (right) from the Arnaud Rebotini collection.

Considering the lasting impact of these drum machines and synthesizers, much of the recorded music represented in the period that follows (*1986-2001 - The Golden Age of House and Techno)* and elsewhere in the exhibition includes sounds from the TR-808 and other Roland instruments introduced between *1977-86*, such as Cybotron's album *Enter* and the song 'Acid Trax' by Phuture. This is explained in the text which accompanies the TB-303 object:

> From 1980 onwards, the Japanese firm Roland launched a series of instruments controlled by microprocessors. The drum machines TR 707, 808 and 909 were designed to replace the drummer, and the bass generator synthesizer TB 303 was launched to replace the bass guitar. Although not commercially successful, these affordable and easy-to-use instruments enabled amateur and low-income musicians, particularly from the Chicago, Detroit and New York scenes, to produce the first house and techno tracks.[229]

However, although sounds from many of these instruments may be known to have featured in the songs that soundtracked both exhibitions (several themed mixes were recorded by French DJ Laurent Garnier and played to visitors through speakers, accompanied by screened track listings), there was no sure way for visitors to know which (if any) of the exhibited instruments, including Roland's, were responsible for helping to create the songs that could be heard.[230]

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[229] Quote taken from the exhibition text accompanying the object.

[230] Other researchers, musicians and members of exhibition teams have attempted to highlight which sounds within a song an instrument is responsible for using the continuous DJ mix method. For example, prior to the installation of the NSMM's sound-focused exhibitions in 2021, I performed what I referred to as an 'object-based DJ set' which featured a PowerPoint presentation that I manually synchronised to my live DJ performance. The presentation consisted of images of different instruments in the SMG's collection, accompanied by the title of the track each instrument

Evidence of heavy use and user configuration is demonstrated on the black-boxed, manufactured TR-707, TR-909 and TB-303 objects. As well as the various scratches and scuffs, and the fact that some of the knob and fader caps are missing, the instruments also feature pen markings on the cases and on sections of masking tape, whilst gaffer tape has been fixed to some of the corners and sides (as shown in Figure 4.3. above). The TB-303 also evidences heavy use of the realtime knobs, which were designed for musicians to alter the timbre of the analogue waveforms whilst performing sequenced patterns of musical notes (a similar amount of wear can be seen around the machine's larger volume knob). Therefore, Rebotini's personalisation and repair of the materiality of these instruments helps to turn them into one-off objects unique to him, as an agent of technological change.

To accompany the timeline area in the *Man & Woman Machine* theme, two caged 'breakout' studio spaces are displayed opposite. The first features large, unique floor-standing machines such as Daphne Oram's Oramics Machine (1957), Christian Clozier's Gmebaphone 2 (1975), and Peter Keene's Forbidden Planet analogue synthesizer (2014). The second space is Jean-Michel Jarre's 'Imaginary' studio, featuring several of his own instruments. Unlike the timeline opposite where instruments are separated from each other and ordered to demonstrate technological and cultural innovations, Jarre's studio, like many studios, features an eco-system of old and new instruments working together. These instruments include the Geiss Matrisequencer 250 (custom built for Jarre in 1977) which features '100 notes that can synchronise and be played on several octaves', and a modern Eurorack modular synthesizer which features modules designed by Erica Synths (2016).[231]

featured in. This is available to view here: https://blog.scienceandmediamuseum.org.uk/sound-travels-an-object-based-dj-set/

[231] Quote taken from the exhibition text accompanying Jean-Michel Jarre's 'Imaginary' studio.

4.5 MR-808 Drum Robot: The Interactive Exhibit

The MR-808 drum robot was designed in 2012 and, in 2016, upgraded for interactivity by project director Moritz Simon Geist (MSG) in collaboration with *Sonic Robots* (who MSG describes as 'a loose group of friends, hackers, technicians and artists.')[232] The exhibit had already appeared at festivals, clubs and various other events prior to its installation at the Musée de la Musique.[233] However, whilst *Electro…* and *Electronic…* featured many audio/visual installations and listening/viewing stations, interactivity featured very little in either exhibition (the MR-808 was the only interactive exhibit installed in *Electro…*).[234] Furthermore, the exhibit was not transferred to the Design Museum due to safety concerns surrounding the impact of COVID-19 on visitor interactivity.[235] However, the interpretation of the exhibit in the *Electro…* exhibition might still have been influenced by visitor's abilities (or desires) to connect the exhibit to other drum machine instruments (or instruments with sequencing functionalities) displayed in the *Man & Woman Machine* section, which might have been compromised by the physical distance between the exhibit and those objects.

Nonetheless, whilst I was not able to experience the MR-808 first-hand at the *Electronic…* exhibition, the design process and visitor experience of the MR-808 at the Musée de la Musique is well documented on the designer's website, as well as on the *Sonic Robots* GitHub page and in various YouTube videos. As well as providing multiple, in-depth articles that describe the technical build of the different components of the larger machine (such as the lighting, the instrumentation, and the electronics), the design process is also summarised on a separate web page. In comparison to the other case studies: whilst owners of the Memotron M2K would be able to consult the user manual that comes with the instrument (a luxury the visitors of the Musikinstrumenten-Museum would not have the pleasure of), resources that describe how the instrument was built do not exist. Furthermore, the designers of the Electronic Sackbut offer nothing in the way of similar resources online. Not only could this make it difficult in the future for researchers to understand how the interactive versions were constructed (especially beyond the life of each exhibition, when the interactive exhibits are less likely to be available to use elsewhere), it creates a barrier for others who wish to build similar instruments but rely on instructional support.

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[232] Moritz Simon Geist, 'MR 808 Technique – Sonic Robots – Learning', *Sonic Robots* <http://learning.sonicrobots.com/mr-808-technique/> [accessed 30 November 2020]; 'MR-808 Interactive', *Sonic Robots* <http://sonicrobots.com/Project/mr-808-interactive/> [accessed 30 November 2020].
[233] 'MR-808 Interactive'.
[234] The Design Museum requested that visitors bring their own headphones in order to safely use the viewing stations and avoid the need for staff to regularly clean them. However, for the Kraftwerk concert experience installed in a separate room, special 3-D glasses were handed out to visitors, which they later had to return in order for the museum staff to clean and re-distribute.
[235] This was confirmed by Geist via email.

The means of generating and interfacing with sound are noticeably separated from each other (see Figure 4.4. and Figure 4.5. below). A large floor-standing replication of the original instrument utilises a unique, alternative means of generating sounds to the original TR-808. Instead of generating electronic signals to be used as sounds – a method that cannot be seen, actioned by components that would usually be hidden from view inside a case – each sound is generated by an electro-mechanical robot displayed in its own cabinet which lights up whenever each sound has been programmed to play. In the designer's own words, 'eleven sounds of the 80s drum computer TR-808 are replaced by mechanical actuators and physical tone-makers […] visualizing the ongoing bond of mobile digital interfaces and physical actions.'[236] These sound generation materials point outwards (rather than upwards, as with the table-top original) which make them viewable to a larger audience, creating a unique experience. Additionally, microphones are installed in each of the cabinets to help project each robot's sound through speakers. MSG provided an explanation towards this design approach:

> When I developed the MR-808 in 2012 I had in mind to create a visualisation of music with the help of mechanics. My background is in classical music, playing clarinet and piano, and when I switched to making electronic music with a computer, I felt that something was not right […] so, for me, the obvious connection was to combine physical computers with electronic music to make the sound creation more visible and understandable […] I wanted a general audience to understand how electronic music and its rhythmic structures could be visualised. A computer or synthesiser is a black box to most of the general public and it's much more educational to see the sounds evolving in front of your eyes. (MSG)

Therefore, although the sounds are actuated in a different way, this exhibit effectively unboxes the electronic sounds of the original instrument. This was also achieved through the curation of materials and actuators to help re-create the timbres of the TR-808's percussion sounds as closely as possible:

> I carried out a lot of experiments to match the sound of each of the instruments from the original 808, comparing the original sounds to those of the robots. With some instruments that worked well (the Bass drum, for example) but for others it was a challenge: the original 808 clap sound, for example, is a very iconic instrument,

[236] 'MR-808 Interactive'.

consisting of a series of white noises spiked with an envelope. This is very hard to replicate as a physical instrument. (MSG)

Figure 4.4. The large floor-standing part of the MR-808 drum robot exhibit, designed by Moritz Simon Geist in collaboration with *Sonic Robots*

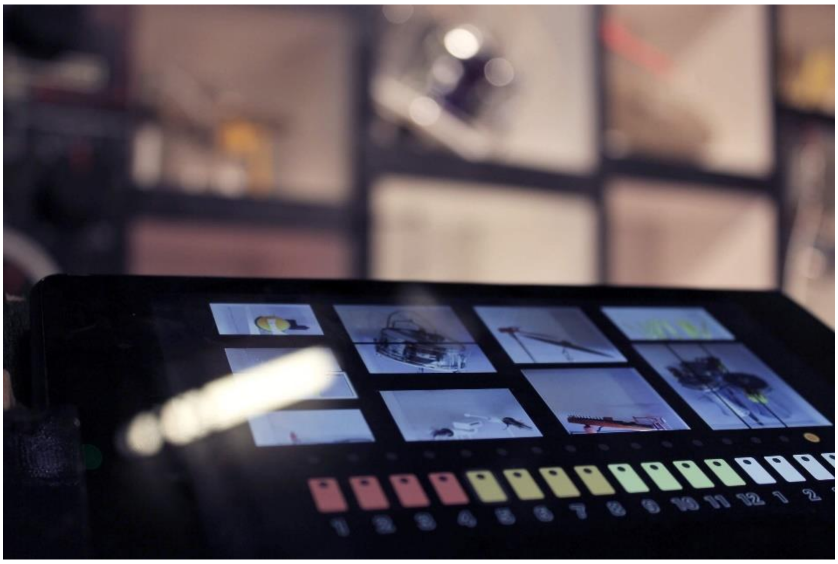

Figure 4.5. One of two digital touchscreen interfaces positioned in-front of the floor-standing part of the exhibit (shown behind).

Additionally, visitors can engage with the sound-generating materials by programming them to trigger at certain times (potentially all at once) using two small Nexus 7 tablets. These offer identical touchscreen step sequencing interfaces whose graphical user interfaces (GUIs) visually replicate the sound generating apparatus and sequencing of the floor-standing machine. Furthermore, the inclusion of more than one interface allows for this interactive exhibit to be performed as a collaboration between different visitors. With the affordances of the original instrument in mind, MSG attempted to constrain the degree of control over the sounds through the selection of controls offered on the interfaces:

> Creating interactive artworks for an audience with varying knowledge of how music works can be challenging. On the one hand one wants to give the audience a big control and impact of what is happening and what they can control. On the other hand, people with limited knowledge of music (‘uneducated players'') often create structures which sound ‘chaotic’, which is unsatisfying for the other attendees as well as for the player. With a fixed grid like a step sequencer, the rhythm possibilities are limited, but the outcome is always of certain quality, quickly giving the player a feeling of achievement. (MSG)

After experimenting with different sound-producing apparatus, some of the electo-mechanical robots were comprised of pre-existing acoustic percussion instruments being struck, whilst others were built from scratch.[237] The MIDI and lighting information was handled by Arduino microcontrollers, whilst additional software and instrumental fixes which used to adjust the latency (delay) between triggering a note on the sequencer and hearing and seeing the result.[238] Many of the plastic parts of the replicated interface such as the sixteen multi-coloured sequencing buttons were constructed via a process called thermoformed polystyrol.[239] Additionally, the case for the instrument was built as five separate parts, which enabled the instrument to be disassembled and more easily transported.[240]

The touchscreen GUI was designed as a web page using the CSS programming language, which communicated with a sequencer (designed using SuperCollider software) hosted on a separate server, which the tablets constantly communicated with.[241] This formed part of an ecosystem, connecting the Nexus 7 tablets with the floor-standing machine, through the following combination of elements: ‘a RaspberryPi Server running a MIDI sequencer, outputing the MIDI over a MIDI-USB card and a WiFi Hotspot so the clients (the Nexus 7 tablets) can connect.’[242] A wireless local area network (WLAN) was used to

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[237] Geist.
[238] Geist.
[239] Geist; ‘No Rocket Science: Vacuum Molding – Sonic Robots – Learning’, *Sonic Robots*, 2014 <http://learning.sonicrobots.com/2014/05/20/no-rocket-science-vacuum-molding/> [accessed 30 November 2020].
[240] Geist.
[241] ‘MR-808 Interactive Technique – Sonic Robots – Learning’, *Sonic Robots* <http://learning.sonicrobots.com/mr-808-interactive-technique/> [accessed 30 November 2020].
[242] ‘MR-808 Interactive Technique – Sonic Robots – Learning’.

privately connect the Nexus 7 tablets to the WiFi hotspot, so that visitors were denied access to the connection and to reduce further latency from being introduced.[243] The use of the GUI and tablet was configured in order to remove the possibility of visitors accessing both other applications and the 'back', 'home' and 'app' buttons synonymous with touchscreen devices.[244] Power management and screen time-out options were also set accordingly.[245]

Although, as previously discussed, the original TR-808 has been replicated as several manufactured digital hardware and software instruments, the MR-808 demonstrates how the instrument and its sounds continue to be reinterpreted through unique design approaches, forty years since the original was introduced. Additionally, MSG's contemporary approach to repair may enable further audiences to interact with, and experience, his exhibit in working order:

> That is the nice part of working with robotics: there is always something that breaks. In the beginning I even took a 3D printer to my shows so I could replace broken plastic parts on the fly! Now that the installation has run for over ten years already, all the parts that could break have already been fixed numerus times and the installation continues to amaze people.

Nonetheless, because the sounds are generated from acoustic materials (rather than via the transduction of electronic signals), and because visitors cannot engage with the sound modification parameters of the original TR-808 instrument, not only are visitors still unable to make the connection between the instrument and the songs its sounds have featured in, they may also struggle to understand how musicians have used the controls to modify each of its percussion sounds and create new timbres for new musical uses (as previously explored). If the designers had, instead, intended to reproduce and demonstrate the original electronic sounds in an authentic way, they could have used the data from the touchscreen interfaces to additionally trigger electronically-generated percussion – representative of the TR-808's sound palette – in synchronisation with the visual striking of acoustic materials.

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[243] 'MR-808 Interactive Technique – Sonic Robots – Learning'.

[244] 'Kiosk Mode for Nexus 7 Tablets for an Interactive Installation – Sonic Robots – Learning', *Sonic Robots*, 2016 <http://learning.sonicrobots.com/2016/05/20/kiosk-mode-for-nexus-7-tablets-for-an-interactive-installation/> [accessed 30 November 2020].

[245] 'Kiosk Mode for Nexus 7 Tablets for an Interactive Installation – Sonic Robots – Learning'.

4.6 The Science Museum Group and Elsewhere

Although the Roland TR-808 drum machine does not form part of the SMG's collections, other electronic drum machines and sequencers have been collected. As previously mentioned, the SMG acquired a Chamberlin Rhythmate Model 40 drum machine, which plays pre-recorded and pre-composed patterns via tape loops (as opposed to the TR-808 which generated electronic sounds that could be individually sequenced together by users). Other hardware sequencing tools have also been acquired by the SMG. For example, the Triadex Muse algorithmic music generator (see Figure 4.6. below) offered musicians a selection of sliders for altering notes produced by the instrument's deterministic event generation - allowing for the possibility of 14 trillion musical note combinations - whilst the Electronic Dream Plant (EDP) Spider sequencer (another instrument from the museum's Hugh Davies collection) could sequence electronic sounds generated elsewhere via CV and gate connectivity.[246] Virtual sequencing tools such as digital audio workstations (DAW) and MIDI sequencing software have also been collected by the SMG (such as FL Studio Producer Edition Version 10).[247] Additionally, the Science Museum built and installed an interactive step sequencer inside their exhibition *Digitopolis*: an exhibition launched in 2000 comprised of unique see-through structures which housed 'objects, information and games from robots to artificial intelligence, to digital sound interactives.'[248]

[246] Chris Carter, 'EDP Wasp', *Sound on Sound*, 1995 <https://www.soundonsound.com/reviews/edp-wasp> [accessed 19 November 2023].
[247] 'FL Studio V.10, Music Making Computer Software.', *Science Museum Group Collection* <https://collection.sciencemuseumgroup.org.uk/objects/co8238730/fl-studio-v-10-music-making-computer-software-software> [accessed 30 November 2020].
[248] 'Digitopolis, Science Museum', *Atelier One* <http://www.atelierone.com/digitopolis/> [accessed 30 November 2020]; both Dave Patten and Tim Boon (Head Of Research & Public History) at the Science Museum Group confirmed via email the inclusion of an interactive sequencer in this exhibition.

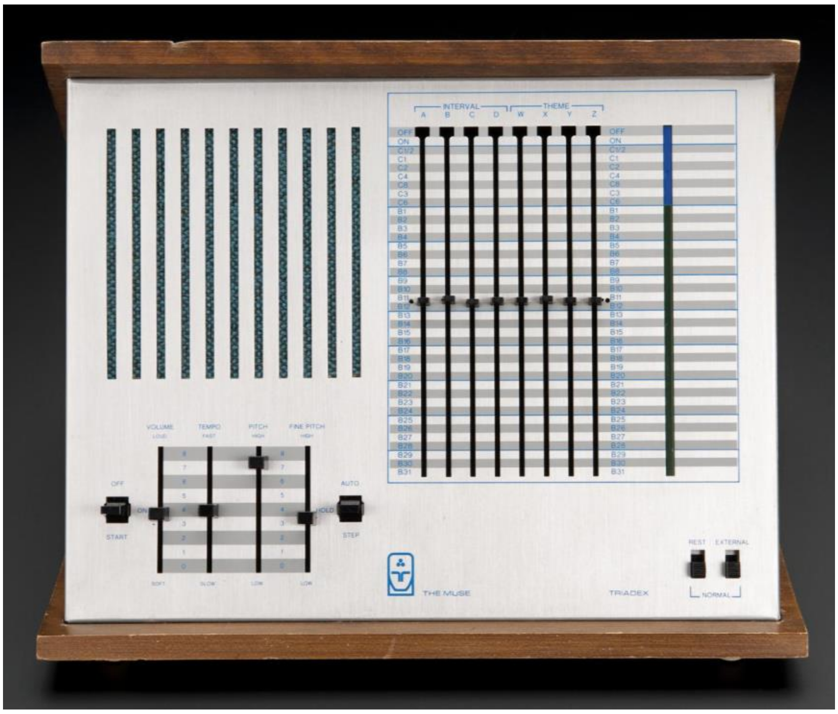

Figure 4.6. The Triadex Muse algorithmic generator.

In contrast, the temporary exhibition *Push Turn Move: Interface Design in Electronic Music* in Turin, 2019, a design-focused exhibition (a reflection of the book it was based on), focused on how electronic musical instruments were designed and 'how people interact with electronic musical instruments,' offering visitors a considerable number of manufactured interactives to play with.[249] Because of this, the exhibition reflected design from the perspective of *function*, rather than *form* (as was the case with the *Electronic…* exhibition at the Design Museum).

Elsewhere, the TR-808 (and the Roland Corporation) features heavily in the collections and exhibitions of various music-focused museums along the west coast of the USA. The proliferation of Roland content in these museums is due not only to the impact which the TR-808 and other Roland inventions have had on American music composed by American artists, but may also have been influenced by the close proximity of the Roland Corporation's USA headquarters in Lose Angeles (and, in the case of the Grammy Museum, the awarding of a technical Grammy to Ikutaro Kakehashi in 2013 for his involvement in the development of the MIDI protocol).

Both the MoMM, Carlsbad, and the Grammy Museum, Los Angeles, featured exhibitions sponsored by, or dedicated to, the Roland Corporation and Ikutaro Kakehashi. An original Roland TR-808 (a gift from the Roland Corporation USA) was displayed in the MoMM's *Ikutaro Kakehashi/Roland Corporation Gallery* amongst many other electronic musical instruments invented during the time period *1970-1989* (which this

[249] 'Push Turn Move'.

gallery represents). This and other instruments displayed in the gallery are accompanied by recordings of the instrument's sounds, which visitors can listen to through speakers using the gallery's sound station.

In comparison, although the Roland TR-808 was not exhibited in the Grammy Museum, the hands-on exhibition *Roland LIVE* provides visitors with the chance to use a Roland TR-8 (labelled 'drums') as part of an ecosystem featuring other, more recently invented, Roland 'AIRA' replications of their vintage products (see Figure 4.7. below). The TR-8 and other instruments were installed as configured interactives, where clear Perspex was used to cover the majority of the controls: leaving, in the case of the TR-8, just the sixteen-step sequencer exposed. Unfortunately, as visitors are not able to select individual drum sounds, they can only ever sequence one percussion sound over one repeating bar of music.

Figure 4.7. The contemporary AIRA range of Roland instruments, displayed as interactive exhibits in the *Roland LIVE* exhibition of the Grammy Museum, Los Angeles.

Finally, the unique musical sequencing interactive exhibit, *Rhythms of Life* (see Figure 4.8. below) installed in the Museum of Mathematics, New York, is another interactive exhibit comparable to the MR-808. As a form of science centre which focuses on interactivity as a tool for teaching mathematics, the museum does not hold a collection of objects and, therefore, exhibition content consists entirely of mathematics-focused interactive exhibits. Although at first glance the materialisation of this exhibit shares many similarities with the MR-808, the individual cabinets of this floor-standing installation host static objects which visually represent the sounds that can be heard (as opposed to actually generating those sounds) whilst the material sequencing interface is physically attached (rather than being separated as two duplicate touchscreen devices).

Figure 4.8. The *Rhythms of Life* exhibit at the Museum of Mathematics.

The sequencing interface may be considered as the most interesting part of this exhibit. Instead of allocating buttons for each of the sequencer's sixteen steps, grouped in a horizontal linear format where the bar of music starts on the left and finishes on the right (as with both the TR-808 and the MR-808), a bar of music is represented by three metallic platters where visitors are invited to place different sized curved metallic shapes (representing different note durations) onto each platter to complete three full circles. In this way, the contextual framework of sequencing is used to teach visitors how to calculate fractions by dividing a bar of music into sixteen 'steps' and adding fractions together until a whole number (one bar) is reached. Small see-through blocks can be placed behind each platter interface. Each of these blocks has a different image affixed to it: each, of which, visually represents a different static object in the cabinets, and indicates which sound will be heard when the platters are turning clockwise and each curved metallic shape spins passed. Therefore, in comparison to the MR-808, each visitor only gets to sequence one sound at a time per interface (as opposed to being able to sequence all the sounds using each touchscreen interface), although three visitors are able to use the exhibit at once (as opposed to just two). However, we must bear in mind that as this is a mathematics museum which does not collect or display objects, the comparison to the MR-808 here is only made possible through my knowledge of step sequencing, whereas visitors in the museum may not be aware of a connection between this exhibit and the programming of electronic sound through step-sequencing.

4.7 Conclusion

As previously identified, the sounds of the Roland TR-808 were initially created via a collaboration between instrument designer Tadao Kikumoto and musician Don Lewis. They have since appeared within a vast quantity of songs spanning multiple decades and musical styles and are still likely to be heard within music playback and performance spaces associated with electronic dance music and hip hop. However, whilst the method of electrically generating and shaping sounds using transistors and synthesis techniques has been sufficiently documented, this knowledge could remain hidden to museum visitors due to a lack of visual identification on the instrument, itself (in comparison to the visible ‘guts’ of the Electronic Sackbut prototype and the tape mechanisms under the lid of the Mellotron).

To help solve this problem, the interactive MR-808 displayed in the *Electro: From Kraftwerk to Daft Punk* exhibition represented a unique way for visitors to visualise the *types* of sounds the instrument could produce using various innovative sound-triggering methods. However, because the exhibit’s sounds did not closely represent the transistorised originals, visitors may have experienced difficulties in connecting the exhibit to songs they’ve previously experienced in which the original instrument featured. Additionally, a lack of contextual information in support of the songs chosen for the DJ mixes may have further hindered visitors’ abilities to connect the instruments displayed to the sounds that could be heard in the exhibition. Nonetheless, considering the vast amount of sound design work towards replicating the TR-808’s sounds in subsequent instruments, as well as the work of musicians in re-purposing those sounds in new forms of music, a great deal of knowledge could be explained and demonstrated to visitors regarding the evolution of these sounds, as well as their distribution in both instrument and recorded media networks. Displayed objects from these networks could help to represent a diverse range of musicians and musical styles associated with these sounds, highlighting an evolution of transistorised and digitised percussion sound over forty years.

5 Towards a Focus on Sound

5.1 Introduction

Much contemporary music is constructed from a plethora of electronic sounds and samples: some of which have become more recognisable than others.[250] This may be due to the popularity of a particular song in which a sound appears (for example, the iconic riff used in Van Halen’s ‘Jump’, created using the Oberheim OB-Xa synthesizer), or the repeated use of a sound across various styles of music (such as the Amen breakbeat, as is discussed in chapter seven).[251] However, whilst many are aware of the songs in which sounds appear, less attention is paid towards the instruments originally responsible for creating and shaping those sounds: in particular, being able to differentiate which instrument is responsible for each sound that can be heard in a song. Furthermore, less is known of how each instrument stimulates a specific aesthetic quality from the sounds it creates: as a result of electrical signals produced through the integration of electronic components and computing technologies unique to that instrument. Therefore, when a musician engages with an instrument’s functionality through its interface, they are engaging with the electronics hidden inside, which help to produce a distinct sonic quality from the instrument’s sounds: some, of which, may have become key to that instrument’s historical significance.

In this chapter, I evaluate the effectiveness of electronic musical instruments in visually demonstrating their sounds and the functionalities that help to create and shape those sounds, as well as the people involved in establishing the sounds unique to each instrument. In particular, I develop an understanding of how the musical value of instrument sounds can be demonstrated in museum exhibitions using objects. First, the framing and interpretations of value in relation to instruments and sounds – both in museums and more generally – are explored. Second, I examine the ways in which sounds are disseminated globally through material vessels such as instruments, in a similar way to how finished compositions – combinations of sounds over time, interpreted as music – feature on physical and digital media, consumed as music, film, television, etc. This helps us to understand how multiple material networks have been responsible for distributing sounds across time and space, helping to make certain sounds better known, or more significant, than others. Lastly, I argue that – in the majority of cases – material readings of instruments

[250] Musikinstrumenten-Museum, ‘What’s That Sound? The Classic Synthesizers Behind 10 Iconic Tracks’, *Google Arts & Culture* <https://artsandculture.google.com/story/what-s-that-sound-the-classic-synthesizers-behind-10-iconic-tracks/RQLik5CyN9w2KA> [accessed 19 November 2023]; James Mooney and Trevor Pinch, ‘Sonic Imaginaries: How Hugh Davies and David Van Koevering Performed Electronic Music’s Future’, in *Rethinking Music through Science and Technology Studies*, ed. by Antoine Hennion and Christophe Levaux (Abingdon: Routledge, 2021), pp. 113–49.

[251] Stefania Zardini Lacedelli, ‘The Oberheim Synthesizer: A Playlist’, *National Science and Media Museum Blog*, 2020 <https://blog.scienceandmediamuseum.org.uk/the-oberheim-synthesizer-a-playlist/> [accessed 23 August 2021].

displayed as objects cannot, alone, help visitors to understand which sounds the instrument is most known for creating, let alone its full sounding potential. In other words – it is difficult for exhibition teams to demonstrate the sounds of instruments to visitors when they are not able to hear them. This helps to support my claim that methodologies such as sound genealogy (explored later) can be adopted to help frame electronic musical instruments using additional interpretative tools. Importantly, this sets up the next chapter, where I frame interactivity as a tool to help exhibition teams follow a sound genealogy methodology, providing the means for visitors to associate sounds with instruments by combining tactility with electronic sound within multi-sensory exhibition environments. This can help to uncover hidden functionalities of instrument objects through new exhibit interfaces.

5.2 The Value of Instruments in Museums

For many years the collection and preservation of objects was, traditionally, the most important role of the museum. As Marstine states, 'the museum protects its treasures...objects are prioritized over ideas...collections are thought to be reborn in the museum, where they are better guarded and more appreciated.'[252] Alberti describes three phases in the life of museum objects:[253]

1. 'The mechanics of the movement of objects from their manufacture or growth through collecting and exchange to the museums.
2. The use of the item once it joined a collection, whether classificatory, analytical, or in display.
3. The role of the object in the experience of visitors to the museum and the nature of the relationship between the object and its viewers.'[254]

It is the third phase of a museum object's life that this thesis is primarily concerned with, as this is the point in which visitors can experience and interpret (or, better still – in reference to Marstine – 'more appreciate') technological artifacts such as electronic musical instruments in exhibitions.

Technological artifacts such as electronic musical instruments are said to have 'use' value (what Hannan and Longair refer to as an object's 'ability to meet specific human wants or needs') and are often

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[252] Janet Marstine, 'Introduction', in *New Museum Theory and Practice: An Introduction*, ed. by Janet Marstine (Oxford: Blackwell Publishing Ltd, 2006), 10.
[253] Prior to Alberti's three phases, there commonly lies a deeper history of design and use. Less commonly, a future of 'use' beyond a particular museum may be in-store as a result of deaccessioning and/or object exit.
[254] Samuel J. M. M. Alberti, 'Objects and the Museum', *Isis*, 96.4 (2006), 561.

exchanged for a counterpart (usually some form of currency) before becoming a form of private property.[255] When musicians use instruments, sound is generated, triggered, or modified for a music or sound application. Therefore, we can theorise the 'use' value of an electronic musical instrument based on its ability to produce sounds that are *useful* to a musician (and pleasing to a listener). However, once exhibited as objects, the instruments themselves can be framed with the intention of *demonstrating* their use value, aesthetic (or artistic) value, social value (in terms of authenticity, for example), sign value ('how people actively and creatively engaged with items, appropriating them for their own purposes'), or cultural value.[256] The various ways of demonstrating an object's value helps to demonstrate that instruments are polysemic and open to multiple interpretations when exhibited to an audience.[257]

Regardless of how instruments might be interpreted by visitors, exhibition teams can still attempt to frame them as objects with the intention of encouraging visitors to explore various musical cultures and technological developments through a certain narrative. As Duncan argues – to 'control a museum means precisely to control the representation of a community and its highest values and truths.'[258] For example – in reference to Clifford's art-culture system (see Figure 5.1. below) – the potential might exist for mass-manufactured commodities, for example, to travel from the domain of the inauthentic into the domain of the authentic through exhibition framing and contextualisation.[259] Additionally, exhibition teams might frame seemingly disparate instrument objects together as an attempt to change the ways in which visitors assign value to particular instruments and their sounds, as a result of them being grouped with others that are likely to be perceived as more or less valuable. For example, an instrument may be framed in close proximity to others in order to enhance visitor's perceptions of its relative value in the greater context of its contribution towards the cultural, musical, and technological development of electronic sound. As with the Electronic Sackbut discussed in chapter two, the values that visitors assign to it might be influenced by its close proximity to more commonly-known instruments such as the RCA theremin and the Minimoog, helping to elevate the contribution that Canadian Hugh le Caine made to electronic instrument design and electronic sound creation.

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[255] Igor Kopytoff, 'The Cultural Biographies of Things: Commoditization as Process', in *The Social Life of Things* (Cambridge: Cambridge University Press, 1986), 68; Leonie Hannan and Sarah Longair, *History through Material Culture* (Manchester: Manchester University Press, 2017), 17; Jonathan Sterne, *The Audible Past: Cultural Origins of Sound Reproduction* (Durham: Duke University Press, 2003), 162-163.
[256] Marstine, 11; Hannan and Longair, 7 and 9; David Grazian, 'Demystifying Authenticity in the Sociology of Culture', in *Handbook of Cultural Sociology*, ed. by John R. Hall, Laura Grindstaff, and Ming-Cheng Lo (Oxon: Routledge, 2012), 191-192; Anne Cranny-Francis, *Technology and Touch: The Biopolitics of Emerging Technologies* (Basingstoke: Palgrave Macmilan, 2013), 53-54; Alan Warde, 'Consumption and Critique', in *Handbook of Cultural Sociology*, ed. by J Hall, L Grindstaff, and M Lo (Oxon: Routledge, 2012), 409-410.
[257] Alberti, 567.
[258] Carol Duncan, 'The Art Museum as Ritual', in *The Art of Art History: A Critical Anthology*, ed. by Donald Preziosi, Second Edi (Oxford: Oxford University Press, 2009), 425.
[259] James Clifford, *The Predicament of Culture: Twentieth-Century Ethnography, Literature, and Art* (Harvard University Press, 1988), 223-225.

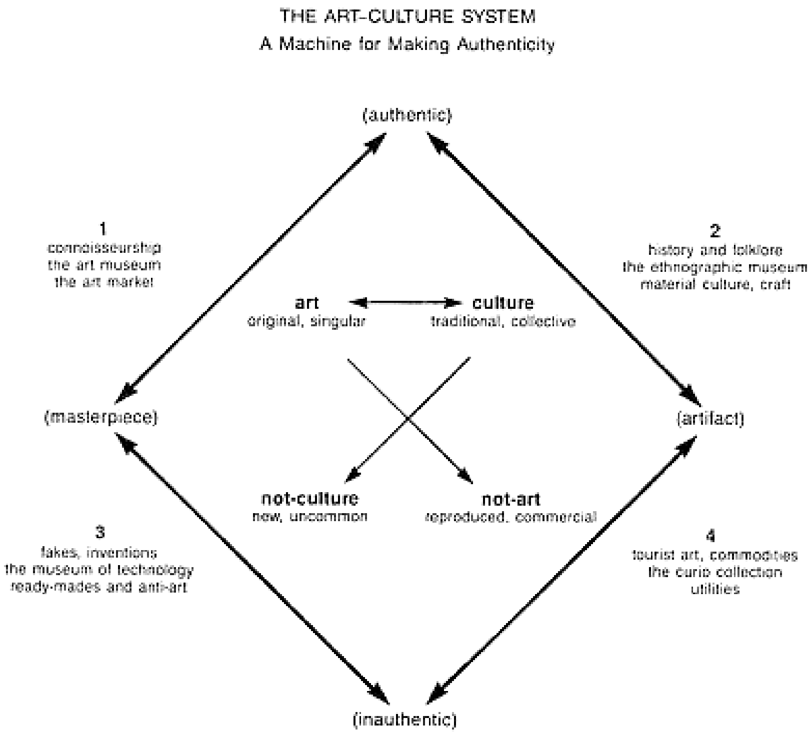

Figure 5.1.: A diagram of Clifford's Art-Culture System.

However, regardless of whether an object is accessioned into a museum collection or not, the perception of its value is likely to have changed over the course of its life and, additionally, its value is likely to continue to change both inside and outside the museum, beyond a date of accession (both for that particular iteration and collectively if the object was born from the result of manufacturing processes). These changes in value have been analysed through the interdisciplinary field of *object biography*, which Alberti describes as 'a valuable way of tracing the changes in classificatory schema, theoretical frameworks, and debates surrounding the objects.'[260] For museums, framing an electronic musical instrument based on a way in which it may have been valued prior to its displacement in an exhibition can become problematic if a static (or single) representation of use value (for example) is relied upon. This is because a static representation may not help visitors to engage with debates such as who used it, why was it used, how has its use changed over time, and how often was its use popularised since its manufacture. For example, as we saw with the Roland TR-808 drum machine in chapter four, certain instruments were initially considered a flop before various socio-economic factors helped to resurrect their popularity in the hands of new users. Nonetheless, regardless of what type of value an exhibition teams uses to frame an object, visitors still have the agency to interpret each object's value in ways that challenge or contrast the exhibition team's intentions.

[260] Alberti, 567.

5.3 The Value of Sounds in Material Networks

When considering the ways in which the use value of an electronic musical instrument may be interpreted in an exhibition, a shift in focus towards *sound* (as opposed to *materiality*) is important and timely for two reasons. First, as Pinch argues, 'sound has increasingly become embedded in material artefacts' (as is discussed further below), which can make it easier for museums to 'collect sound' through the acquisition of objects.[261] Second, electronic sound has followed the trajectory imagined by British composer and museum advisor Hugh Davies: extending its reach beyond the creation of electronic music to, later, infiltrate many genres of music that were previously considered 'nonelectronic,' creating a 'postelectronic sound world.'[262] Third – as identified by Marshall – authors have highlighted a recent 'turn to sound' in the study of technologies.[263] For example, the field of sound studies is used in this thesis to examine electronic sound in museums in relation to how it is listened to, produced, and interpreted in socio-technical environments (more on this later). Reasons such as these may incentivise exhibition teams to focus on sound when contextualising electronic musical instrument displays.

However, before we can focus-in on instruments and demonstrate what Pinch refers to as the 'musical value' of their sounds – in the context of museum exhibitions or more generally - we first have to acknowledge what electronic sound is, as a thing that we *hear.*[264] First, an electrical signal is communicated towards a technology such as a loudspeaker or headphones which transduces the signal into vibrations, which are then 'transmitted through a medium (such as air or water) as a series of changes in pressure,' which we perceive through our ears.[265] Therefore, sound perception – as defined by Arnott and Alain – is 'the registration in our brain of disturbances in surrounding air pressure.'[266] Additionally, as everyone's hearing is different, the perception of the same sound will differ from one human to the next.

With this in mind, it is problematic to apply an object biography approach towards understanding the value of sound as vibrational matter. Whilst an object biography approach could be used to analyse how and why values are assigned to a particular instrument as it moves between various social groups (for example, as it is displaced from a use setting to a demonstrative setting such as an exhibition) - the 'biography' of a sound

[261] Trevor Pinch, 'Moments in the Valuation of Sound: The Early History of Synthesizers', in *Moments of Valuation: Exploring Sites of Dissonance*, ed. by Ariane Berthoin Antal, Michael Hutter, and David Stark (Oxford: Oxford University Press, 2015), 17.
[262] Mooney and Pinch, 132.
[263] Marshall, 948.
[264] Pinch, 'Moments in the Valuation of Sound: The Early History of Synthesizers', 22-23.
[265] David Benyon, Phil Turner, and Susan Turner, *Designing Interactive Systems: People, Activities, Contexts, Technologies* (Harlow: Pearson Education Limited, 2005), 394.
[266] Stephen R. Arnott and Claude Alain, 'A Brain Guide to Sound Galleries', in *The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space*, ed. by Nina Levent and Alvaro Pascual-Leone (Plymouth: Rowman & Littlefield, 2014), 88.

that we hear is constrained to the perception of its transient existence once transmitted through a medium. However, when we consider sounds not as a transient phenomenon but as something physically encoded as data, etched into a vinyl record, or produced by an instrument's electronic circuitry (for example), we can associate them with the biographies of instruments and other music and sound materialities, such as recorded media. As Piekut explains:

> Musical sound makes many differences in the world […] Whatever music might be, it clearly relies on many things that are not music, and therefore we should conceive of it as a set of relations among distinct materials and events that have been translated to work together.[267]

The material networks in which sounds are embedded are described by Pinch as 'the media to give sonic objects a degree of permanence such that they can be subject to valuation techniques, categories, and procedures.'[268] Such networks can influence the popularity of sounds over time, leading to some becoming more ubiquitous or popular than others. For example, the more ways of hearing and using a sound – or in other words, the more exposure that a listener or musician might have to a sound – the more likely it might be that the sound becomes popular. However - as is the case with the Herbie Hancock collection discussed in chapter six - some instruments and sounds may, over time, become less musically valuable to musicians, and their use is therefore discontinued in favour of new sounds and technologies that are perceived to encourage innovation in their musical practice. We therefore need to understand what these networks consist of and how sounds are disseminated across them. This involves an understanding of how and why things are distributed, the social, cultural, and economic factors which influence the acquisition of instruments and consumption of sounds, and how aesthetics may influence the desirability of sounds for use in different musical contexts.

One way of doing this is through a consideration of how sounds help to construct finished compositions, and how those compositions are then disseminated as physical media (what Leonard and Knifton refer to as 'sound carriers') and digital files – singles, albums, films, recorded performances, broadcasts, etc. – which can then be sampled and re-interpreted by musicians through sampling technologies (see Figure 5.2. below).[269] Pinch attributes the origins of this media dissemination to 'the rise of the phonograph in 1877'

[267] Benjamin Piekut, 'Actor-Networks in Music History: Clarifications and Critiques', *Twentieth-Century Music*, 11.2 (2014), 191–192.
[268] Pinch, 'Moments in the Valuation of Sound: The Early History of Synthesizers', 17.
[269] Marion Leonard and Robert Knifton, 'A Critical Survey of Museum Collections of Popular Music in the United Kingdom', *Popular Music History*, 10.2 (2017), 178.

which 'enabled sound to be reproduced and hence travel in a way hereto impossible.'[270] Furthermore, as long as a sound's timbre is not altered so far as to completely disconnect it from its original state, each musician's use of sampling techniques (in combination with effects and dynamic processors) can result in a new and unique version of a sound being created: helping to widen the scope of variation for what that sound could be. These new versions may be used in new songs and therefore subject to dissemination in other media. Additionally, as sounds are sampled, recontextualised, and disseminated within new styles of music, they are subject to what Weium and Boon describe as a 'new kinds of discernment,' meaning that those who hear the sound in different contexts can assign different values to it over time.[271] Therefore, we can understand the ascription of values to sounds as a *process* that varies depending on the contexts in which sounds are heard, and who is listening to them. This is explored further in chapters seven and eight with the digitised Amen breakbeat, whose roots lie in the performance of an acoustic drum kit which has since been sampled and recontextualised, helping to insure its continuing popularity through further dissemination.

[270] Pinch, 'Moments in the Valuation of Sound: The Early History of Synthesizers', 17.
[271] Frode Weium and Tim Boon, 'Introduction', in *Material Culture and Electronic Sound*, ed. by Frode Weium and Tim Boon (Washington D.C.: Smithsonian Institution Scholarly Press, 2013), XII - XIII.

Figure 5.2. The front cover for the vinyl album 'Dub Me Crazy Part 7: The Adventures of a Dub Sampler' by Mad Professor, depicting electronic musical instruments that may have created the sounds recorded within.

Additionally, we can study a) the use of electricity in generating new sounds and replicating pre-existing ones; b) the further replication of sounds as presets in new digital instruments (partially to cater for musicians' nostalgia); and c) the production and availability of sample CDs and digital sample libraries (created by musicians and third-party companies); as methods for disseminating sounds through time and space (see Figure 5.3. below).[272] For example, many digital instruments offer multiple presets that replicate the sounds from vintage analogue instruments, which have since, according to Pinch and Reinecke, 'acquired such a legendary status that they are unaffordable to most working musicians.'[273] This was the case with the Roland TR-808 in chapter four and the replication of its analogue percussion sounds in new digital instruments, based on the continued desire for musicians to use those sounds in new styles of music – to 'mediate between past and present to achieve a particular sound and feel' – without having to purchase the original instrument at a higher price.[274] Additionally, we have to consider the use of electronic instruments in replicating pre-existing acoustic sounds. For example, Pinch highlights the ease of which

[272] Davies, 'A History of Sampling', 4.
[273] Pinch and Reinecke, 152.
[274] Pinch and Reinecke, 153.

musicians like Bernie Krause and Paul Beaver were able to reproduce the sounds of woodwind instruments because 'the standard waveforms produced had these sorts of sounds.'[275] This demonstrates how the dissemination of certain sounds can be traced back to the use of acoustic instruments, or even to sounds that exist in nature.[276] In contrast, we also have to consider the desire to use electronic instruments to create new and unique sounds – rather than using presets or synthesis to mimic what already exists.[277] Some of these have also become popular or even ubiquitous due to communities of users making their own sounds available for others to download or import into the user memory areas of similar instruments.

Figure 5.3. A front cover of a sample CD manufactured by Best Service, featuring sounds recorded from different synthesizer instruments.

When considering the musical value of sounds disseminated within instruments, we have to account for an instrument's unique sonic identity, which may also reflect certain musical styles or periods of history. For example, the presets in the Yamaha DX-7 digital synthesizer (see Figure 5.4. below) could be considered as 'soundmarks' (unique sounds that possess qualities that make them special to a community) of FM

[275] Trevor Pinch, 'Emulating Sound. What Synthesizers Can and Can't Do: Explorations in the Social Construction of Sound', 122.
[276] Weium and Boon, XIII; Pinch, 'From Technology Studies to Sound Studies: How Materiality Matters', 132.
[277] Weium and Boon, XIII.

synthesis, as popularised in 1980s popular culture.[278] Similarly, whilst most analogue synthesizers generate the same basic oscillator waveforms (sine, triangle, saw tooth, and square) as the starting point for sound design – each waveform delivering 'different over tones and musical properties' – the integration and design of electronic circuitry and corresponding controls within each instrument will help to define its sonic identity.[279] Pinch demonstrates this by comparing the Moog and Buchla analogue synthesizers from the 1960s in terms of how and why they managed to produce different sounds, which he attributes to the technologies within each instrument, the quality of each instrument's waveforms, and the types of interface controls.[280] This is also the case when comparing the sounds of analogue oscillators to digitally-replicated ones, as evidenced with the digitized *Play the Electronic Sackbut* exhibit in the Canada Science and Technology Museum (chapter two). Therefore, as with the impact of sampling practices on the timbral qualities of a sound (as previously discussed), each material instrument's circuitry and coding can vary a sound's aesthetic qualities, helping to differentiate one instrument from another.

Figure 5.4. The Yamaha DX-7 digital synthesizer (bottom) displayed in the *Sonic: Adventures in Audio* exhibition at the NSMM.

However, not every instrument is able to generate or represent a unique sonic, musical, or cultural identity over time. For example, many electronic instruments designed prior to the invention of compact instruments such as the Minimoog (which 'signalled the dawn of a mass-market for synthesizers sold through retail music stores') were only manufactured in short runs (or not manufactured at all) and were often only used in academic and research settings or expensive recording studios (the theremin being an

[278] R. Murry Schafer, *A Sound Education: 100 Exercises in Listening and Sound Making* (Ontario: Arcana Editions, 1992), 123; Gordon Reid, 'Yamaha GS1 & DX1: The Birth, Rise & Further Rise Of FM Synthesis [Retrozone]', *Sound on Sound*, 2001 <https://www.soundonsound.com/reviews/yamaha-gs1-dx1-birth-rise-further-rise-fm-synthesis-retrozone> [accessed 19 November 2023].
[279] Pinch, 'Moments in the Valuation of Sound: The Early History of Synthesizers', 21-22.
[280] Pinch, 'From Technology Studies to Sound Studies: How Materiality Matters', 132.

exception to this rule).[281] This is likely to have affected the exposure that people had to these instrument's sounds: especially when they were first designed and used. As Pinch argues, 'before the mid-1960s most people had not been exposed to electronic sound […] in popular culture the only electronic sounds likely to be heard were those emanating from marginal electronic instruments such as the Theremin, the Trautonium, or the Ondes Martenot.'[282] Because only a small number of composers had access to them, recordings of such instruments are also often rare and, therefore, without supporting documentation, it may be difficult to ascertain which sounds the instrument was capable of producing within each recording. This was the case with the Electronic Sackbut instrument in the Canada Science and Technology Museum, as explored in chapter two.

Nonetheless, we must also acknowledge the role of museums in both the organisation of research towards the repair or replication of rare instruments (as was the case with the Electronic Sackbut in chapter two) and the commissioning of musicians to perform with instruments in their collection so that the sounds can be recorded and preserved. Not only may these recordings act as additional evidence of each instrument's significance – the audio, of which, might even out-live the materiality of the instrument - these recordings may become the sounds that visitors hear when they engage with listening stations and private audio guides in exhibitions, or when they look at these instruments within a museum's online collection. The same can be said of archival projects such as *Save Our Sounds* at the British Library, where sounds (within finished musical compositions) are preserved through the collection of recorded media (and the mediums that play the media) which are in danger of becoming obsolete.[283] This digitisation project could ensure that future listeners are (re) introduced to instrument sounds that may have otherwise been lost, producing another avenue for the dissemination of sounds through material networks.

5.4 Sound Studies and the Sound Genealogy Methodology

The interdisciplinary field of sound studies acknowledges the 'material production and consumption of music, sound, noise, and silence, and how these have changed throughout history and within different societies,' taking sound as the 'analytical point of departure or arrival.'[284] As authors such as Pinch have

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281 Kim Feser, 'Semi-Modular, Non-Modular: Voltage-Controlled Synthesizers Between Complexity and Playability', in *Good Vibrations: Eine Geschichte Der Elektronischen Musikinstrumente = a History of Electronic Musical Instruments*, ed. by Conny Restle, Benedikt Brilmayer, and Sarah-Indriyati Hardjowirogo (Berlin: Musikinstrumenten-Museum, 2017), 30; Pinch, 'Technology and Institutions: Living in a Material World', 476.

282 Pinch, 'Moments in the Valuation of Sound: The Early History of Synthesizers', 16.

283 The British Library, 'Save Our Sounds | Projects', 2019 <https://www.bl.uk/projects/save-our-sounds#> [accessed 27 May 2021].

284 Jonathan Sterne, 'Introduction', in *The Sound Studies Reader*, ed. by Jonathan Sterne (Oxon: Routledge, 2012), 2; Pinch and Bijsterveld, 'Sound Studies: New Technologies and Music', 636.

expressed: whilst sounds and instruments are subject to stabilisation, subsequent instruments continue to generate variations of sounds, which are used in new musical genres and are heard differently depending on the listener and the listening setting.[285] Furthermore, in acknowledging that sound is a process, Marshall argues that authors of sound studies 'should be careful not to take sound as a stable topic for empirical work but rather as […] an icon for sensory contingency and multiplicity.'[286]

However, the literature within this field usually focuses on a single material network, which cannot provide a detailed and full account of how multiple dissemination networks influence the values that different humans and social groups assign to sounds. Therefore, considering the limitations of pre-existing sound studies literature and the wider material networks which influence the popularity of sounds (as described in the previous sub-section), I am therefore advocating for a more holistic approach towards the study of how musical sounds are disseminated across time and space through material networks. I refer to this methodology as *sound genealogy*. This includes the study of human actors involved in the production, re-production, and modification of sounds (sound designers, musicians, archivists, etc.). In this way, we are not just 'following the instruments': we are also following all of 'the technical devices used for making, transmitting, and storing sound.' By doing so, we might *find* the people who create and influence the material networks of dissemination.[287] Furthermore, we can *follow the sounds* in order to *find* the instruments, as well as those responsible for creating and shaping what we hear. Additionally, although we are focusing on things that exist in material networks, sound genealogy nonetheless acknowledges the transient phenomenological dimension of sound, as the *result* of its dissemination, use and consumption through those networks.

Exhibition teams can apply the sound genealogy methodology as an interpretational framework for instruments to help visitors become more aware of the significance of instruments based on their sounds. If we understand the purpose of using electronic musical instruments to be for the generation, triggering, and modification of sounds, it seems fair to suggest that the popularity of sounds associated with an instrument could be the main reason to why the instrument is considered a true innovation.[288] Additionally, not only can exhibition teams draw attention to the people and things that created a sound in the first place, they can also frame instruments as material avenues that help sounds to shift in differing ways over time, helping to expose them to different musicians and audiences. Furthermore, exhibition teams can demonstrate the musical value that sounds have had on the lived experiences of musicians, audiences, and other social groups, by connecting the sounds to musical, social, and cultural networks, as an attempt to make them more relatable to visitors.

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[285] Pinch, 'From Technology Studies to Sound Studies: How Materiality Matters', 129.
[286] Marshall, 951.
[287] Pinch, 'From Technology Studies to Sound Studies: How Materiality Matters', 125-126.
[288] Pinch, 'From Technology Studies to Sound Studies: How Materiality Matters', 126.

The concept of *depunctualization* ('the process of blowing open the black box to reveal a complex actor network contained within') from actor-network theory (ANT) could help exhibition teams to apply a sound genealogy methodology towards the framing of electronic musical instruments as a way of highlighting those responsible for creating and shaping both material instruments and their sounds.[289] In other words, rather than framing instruments as 'intact entities,' these assemblages can instead be unpacked and deconstructed in order to better understand the work that various humans contributed towards the construction of the material technology, as well as the design of electronic circuitry and digital presets (for example) that constitute an instrument's sounding potential.[290] Redström demonstrates this using the personal computer as an example:

> The many layers of design and use are evident: the computer itself is built using circuits and components developed and produced in many places of the world and then assembled by the manufacturer; the software is perhaps developed in some object-oriented programming language where a range of already available libraries and other resources are (re)used; users subsequently install and modify software and hardware, customise appearance, and, over time, fill the computer with their own texts, images, music, etc. Now, who is the designer of this particular object (the *personal* computer), who is responsible for giving it its current form?[291]

Therefore, what may be considered a 'Roland' synthesizer (for example) is challenged when one considers that such technological artifacts are assemblages: the end-product of a 'long chain of people, products, tools, machines, money, and so forth.'[292] Furthermore, as we saw in chapter three, the model of Mellotron instrument exhibited in the Musikinstrumenten-Museum could be considered the result of various designers forming different companies globally over time, producing different material variations of the Mellotron concept leading up to the realisation of the exhibited M400. Additionally, another network of humans was responsible for performing the original sounds, recording them to tape, and reproducing them in new analogue and digital formats.

This is not to suggest that designers of instruments and designers of sounds work in isolation from each other. For example, musicians have also been known to collaborate with designers and assist with the choice and installation of electronic components, the recording and shaping of samples, or the integration

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[289] Eliot Bates, 'Actor-Network Theory and Organology', *Journal of the American Musical Instrument Society*, XLIV (2018), 46.
[290] Bates, 'Actor-Network Theory and Organology', 46.
[291] Johan Redström, 'RE:Definitions of Use', *Design Studies*, 29 (2008), 420.
[292] Akrich, 205.

and design of presets based on raw sound materials. As we saw in chapter four, musician Don Lewis' contribution to the sound-shaping potential of the Roland TR-808 drum machine was significant in helping the instrument to develop a sonic identity, which continues to evolve.[293] Similarly, Pinch describes how Robert Moog involved local musicians in the design of his synthesizer by either delivering it to them personally or inviting musicians to his factory studio.[294] Through watching musicians use the instrument, Moog discovered ways in which its design could be improved, such as the addition of portamento (gliding between notes) which was suggested by composer Wendy Carlos.[295] Stories such as these can be used by exhibition teams to demonstrate how sounds may be co-produced, and how each instrument's significance may be understood in the context of the sounds and people responsible for, or associated with, them.

Similarly, we can use the concept of depunctualization to open up the black-boxed instrument and discover a world of sounds that lie hidden within when such instruments are not in use, as well as the people responsible for creating and shaping them. Whilst electronic keyboard instruments such as synthesizers might visually resemble acoustic instruments such as pianos, there is often far more sounding potential within the former than what can be created with the keys, hammers, and strings of the latter. With this in mind, exhibition teams can frame specific electronic instruments as being responsible for creating specific sounds that are thought to be highly valuable and significant for different cultures and social groups, which visitors may also associate themselves with. Therefore, through the use of depunctualization, exhibition teams can uncover not only the sounds of these instruments, but also communities of preset programmers, sound designers, recording engineers, and musicians, as well as those involved with producing commercial recorded media and sample libraries (as previously discussed).

To help explain this concept further, we can turn to a number of electronic musical instrument sounds explored within the recently published *40 Years: Innovating the Hits, The Story of Casio Instruments*. Perhaps most notable: the Casio MT-40 synthesizer's 'rock' preset rhythm pattern (featuring an electronic rhythm section and melodic bass line composed as two bars of music) provided what later became known as the 'Sleng Teng' rhythm (named after the Wayne Smith song 'Under Mi Sleng Teng', based on this preset), which was responsible for helping to create and shape Jamaican digital reggae and dancehall music in the 1980s.[296] Whilst other Reggae artists subsequently incorporated the Sleng Teng rhythm in their music, the sound was distributed globally and was used (and sampled) in the British rave song 'Way in My Brain' by SL2, as well as the American hip-hop song 'Reggae Joint' by 2 Live Crew.[297] However, the rock preset – and others – were initially created by Casio employee Okuda Hiroko who worked in the musical

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[293] 'Three Minute Epiphany - Don Lewis: The TR-808 Drum Machine'.
[294] Pinch, 'From Technology Studies to Sound Studies: How Materiality Matters', 130.
[295] Pinch, 'From Technology Studies to Sound Studies: How Materiality Matters', 130.
[296] *40 Years: Innovating the Hits, The Story of Casio Instruments*, ed. by James Thornhill (Casio, 2020), 7 and 9; Hashino Yukinori, 'Okuda Hiroko: The Casio Employee Behind the "Sleng Teng" Riddim That Revolutionized Reggae', *Nippon.Com*, 2022 <https://www.nippon.com/en/japan-topics/g02027/> [accessed 18 December 2022].
[297] Thornhill, 7 and 9.

instrument department (headed by Kashio Toshio).[298] At the time, her preset programming was influenced by the amount of Reggae music she was listening to, which infiltrated the musical style of the rock preset on the Casio MT-40.[299] Stories such as this help to demonstrate both sound genealogy and depunctualization: the global distribution of Jamaican music as recorded media, the community of people responsible for designing both the instrument and its preset sounds and patterns, and the global distribution of the Sleng Teng rhythm inside the instrument, itself, and as a sound that featured in various iterations of commercially-released recorded music.

5.5 Demonstrating the Value of Sounds: Material Readings of Exhibited Objects

Unfortunately, for exhibition teams, electronic musical instruments present a paradox because although this material culture can be framed as an important means of distributing sounds and making them popular or musically valuable for different social groups, the sounds which they distribute often remain hidden – both visually and aurally - when these material vessels are displayed as objects: i.e., when they remain turned off and unused.[300] Similarly, certain important functionalities that affect the instrument's sounds may remain hidden if they had not been labelled on the interface.

Instruments that have the potential to visually demonstrate their immaterial sounds can be theorised as *epistemic representations* (objects that stands in for something else) of things that are otherwise hidden within them.[301] However, whilst Falk and Dierking argue that visitors often prefer to deal with objects due to their suitability in representing concrete, observable ideas, the reliance on instrument objects to portray their sounds may conversely produce a learning experience that is too abstract.[302] This is partly because both the musical (e.g., 'portamento', 'tempo') and technical (e.g., 'waveform', 'quantise') language of electronic sound may become a barrier to knowledge when visitors are not already familiar with electronic musical instruments. Whilst expert visitors may have already developed an understanding of both these languages through engaging with electronic sound, lay visitors might find it difficult to understand why the controls are labelled the way they are, and how these controls relate to the sounding potential of that

[298] Yukinori.
[299] Yukinori.
[300] There may, however, exist occasions in which professional musicians are commissioned to perform with instrument objects for public consumption in an exhibition, or to help create sound recordings for listening guides, for example.
[301] Graham, 80-81.
[302] John H. Falk and Lynn D. Dierking, *The Museum Experience Revisited* (Walnut Creek: Left Coast Press, Inc., 2013), 110-111.

instrument, or the way that certain sounds can be created. This problem is exacerbated by the complex potential for generating, triggering, and shaping electronic sound using various types of instruments.

To help clarify this point, we can briefly explore the most common method of generating sound in synthesizers – subtractive synthesis – where much of the language originates in electronics and computing technologies (see Figure 5.5. below). Vail defines this as a way of 'electrically generating sound using oscillators capable of generating complex waveforms with lots of harmonic content and routing their signals through voltage-controlled filters to attenuate specific harmonics and contour the resulting timbre.'[303] Vail and Sear define the basic components as follows. An oscillator generates 'cyclic and repeating signals at frequencies that can be varied'; the filter attenuates or boosts frequencies above, below or around an adjustable cut-off frequency point, an envelope is 'a shape that changes aperiodically as a function of time, controlled by a set of rate or time and level parameters', and a low-frequency oscillator (LFO) is 'a signal generator that produces waveforms at sub-audible rates for controlling parameters.'[304] Lastly, the electrical signal often passes through an amplifier which attenuates the level of the signal before it is sent out of the system, where it is either recorded electronically or transduced into sound vibrations using mechanical energy (through headphones or a loudspeaker).[305] These components affect what Sear refers to as the three basic characteristics of sound that we hear - Pitch, Quality and Loudness.[306]

Figure 5.5. A Minimoog analogue synthesizer displayed in the MoMM, Carlsbad. This instrument utilises subtractive synthesis for generating and shaping sound.

With the above features in mind: although synthesisers usually offer various controls to engage with each of the components described above – each one accompanied by a text label that signifies its function (e.g., 'oscillator 1', 'filter cut-off', 'LFO speed') – visitors might not understand, for example, what the acronym LFO means, let alone how a low-frequency oscillator can be used to modify sound. This may be less

[303] Vail, 54.
[304] Vail, 137, 138, 150 and 151 .
[305] Sear, 22.
[306] Sear, 20.

problematic with instruments that also use shapes and symbols to help signify electronic signals relating to sound generation and shaping (e.g., waveform, envelope and LFO shapes), which may assist with material readings in exhibitions (see Figure 5.6. below). However, the understanding of these symbols in an exhibition setting is still dependent upon whether visitors can connect them to the creation and shaping of sounds they might have already heard. Therefore, the visual observation of electronic musical instruments in exhibitions may still remain too abstracted or disassociated from any form of lived experience where electronic sounds were heard.

Figure 5.6. An Oberheim OB-1 displayed in the MoMM. Two waveforms are provided for each of its two oscillators, as symbolised by triangular and square shapes.

The likelihood that visitors might comprehend an instrument's sounding potential could be complicated further when we consider the display of digital instruments which conceal a vast variety of presets (raw sound materials – either singular or combined together – accompanied by the precise settings of various interface controls and hidden functions). Although instruments such as the Roland Jupiter 4 synthesizer (see Figure 5.7. below) included a small number of presets (otherwise known as 'stored sounds' or 'factory sounds') that could be selected via individual buttons, whilst others listed the categories of their presets on their cases, the amount of presets stored within other instruments was so large that the instrument's designers were not able to clearly label them on the case (let alone provide individual buttons for accessing them).[307] Instead, the instrument's designers resorted to providing a printed patch list to accompany the instrument's manual. For example, the owner's manual for the Korg N5 digital synthesizer (see Figure 5.8. below) states that the instrument includes 1169 preset sounds, which would be impossible to list clearly on

[307] Pinch, 'Emulating Sound. What Synthesizers Can and Can't Do: Explorations in the Social Construction of Sound', 111. Whilst the Roland Jupiter 4 synthesizer could be considered as an analogue instrument, it actually offers digital control over its analogue oscillators, as well as digital storage capabilities. This might reflect the reason to why the instrument was termed 'compuphonic'.

its interface.[308] Therefore, it was intended that musicians refer to both the patch list and the instrument's screen, using buttons to scroll through the presets and audition them using the instrument's keys (as was also the case with the Memotron M2K in chapter three). However, although owners of digital instruments might familiarise themselves with the full range of sounds over time (or at least those that are useful to them), when displayed as objects in exhibitions without accompanying patch lists, the number (and also type) of sounds that these instruments offer remain hidden to visitors.

Figure 5.7. A Roland Jupiter 4 'compuphonic' synthesizer.

Figure 5.8. A Korg N5 digital synthesizer, which includes a total of 1169 pre-installed sounds (not listed on the case).

[308] 'Korg N1/N5 Owner's Manual' (Japan: Korg Inc., 1997) <https://www.korg.com/us/support/download/manual/1/162/1715/>. I have used the Korg N5 synthesizer as an example because it was the first synthesizer I owned. In discriminating over which synthesizer to purchase, I asked a sales assistant whether this synthesizer could produce the same sounds as the Roland TB-303, because at that time (1998) I was composing music within the 'freeform' genre which heavily featured the 303's 'acid' sounds. The sales assistant assured me that it definitely could. Since purchasing it and taking it home, I soon realised that it didn't. Although the lack of a filter resonance control on the interface could have been my first clue to this problem, what is important here is that without being able to turn the instrument on (or without at least being able to refer to a printed patch list), it was difficult to ascertain how useful this synthesizer would be for producing any style of electronic dance music that relied on 'acid' sounds (styles of which must have fallen outside of the 'diverse array of musical genres' which the instrument's sounds were said to cater for in the manual). Similar experiences of sales assistants are also documented in Tjora's paper *The Groove in the Box: A Technologically Mediated Inspiration in Electronic Dance Music*.

However, although the addition of text to describe the instrument's controls, or a patch list to highlight the included preset sounds, might help to demonstrate what the instrument is capable of generating or triggering, the problem remains in highlighting particular sounds from that list that have helped to make that instrument musically valuable. This was evidenced with the Memotron M2K instrument installed as an interactive exhibit (chapter three), whose extensive patch list made it difficult for visitors to locate and connect its specific flute sound to the song 'Strawberry Fields Forever'.[309] Again, using words and symbols alone to confidently describe a particular sound can be challenging, especially when we consider that very few electronic sounds can be expressed through onomatopoeia (e.g., 'boom', 'zap', and 'squeal'). Similarly, whilst Pinch uses words and phrases such as 'weird shit' and 'baruuump' to describe sounds created using Robert Moog's inventions, terms such as these can be interpreted differently by different people: whether in an exhibition or in other settings.[310]

Additionally, visitors may also have to rely on reading the nomenclature on the interface (the 'contact surface of a thing') to try an understand what *functionalities* the instrument is capable of performing.[311] These functionalities may be linked to specific electronic components, computing technologies, and materials enclosed under-the-hood of the instrument, which may also have been valuable when used by different people (as was the case with the sounds recorded onto reels of tape and hosted inside the Mellotron in chapter three).[312] However, in the case of digital instruments, the labelled controls on the interface may not directly map to every function the instrument is capable of performing. In other words, whilst a function within a particular instrument might be partially, or wholly, responsible for embedding that instrument's sounds with a certain aesthetic quality, its designers may have chosen not to label this function on the instrument, let alone assign a control to it, at the point of manufacture. This is because musicians were expected to use push buttons to navigate through the various levels of digital menus in order to access functions unlabelled on the interface (as with the navigation of preset sounds, as previous described), using LEDs and LCD screens for feedback.[313] Additionally, an instrument's designers may not have envisioned that a particular function would later be heavily deployed and associated with their invention, and therefore may not have felt it necessary to visually label it on the case.

Furthermore, the provision of buttons and menus has not always been favoured by users of electronic musical instruments. As Pinch states: 'some musicians prefer the old interface of "knobs and wires" […] also they feel that modern synthesizers don't have such an interesting range of sounds. They miss the sounds

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[309] Joe, 'HIT THE TONE : STRAWBERRY FIELDS FOREVER – MELLOTRON', *T.Blog*, 2018 <https://www.thomann.de/blog/en/htt-sff-mellotron/> [accessed 12 June 2022].
[310] Pinch, 'Moments in the Valuation of Sound: The Early History of Synthesizers', 15 and 25.
[311] Laurel, XII.
[312] Eliot Bates, 'The Social Life of Musical Instruments', *Ethnomusicology*, 56.3 (2012), 379.
[313] Pinch, 'Emulating Sound. What Synthesizers Can and Can't Do: Explorations in the Social Construction of Sound', 113.

"between the knobs" as it were.'[314] Therefore, the interface of an instrument can influence the range and quality of sounds that a musician may try to conjure from it. To give a more specific example, musician Martyn Ware provides the following reason to why he prefers the more 'analogue' interface of the Roland Jupiter 4 synthesizer (Figure 5.7. above) over other digital instruments:[315]

> It sounds fantastic and the limitations that you have with those things are very stimulating. Each button doesn't have 15 functions and you don't have an infinite number of patches to go through […] what we really need are loads of knobs and switches, each with a separate function.[316]

Evidently, Ware is one of those musicians - as described by Pinch above - who prefers the 'one-knob-per-function' interfaces of analogue instruments to the provision of buttons for accessing functions within menus. Additionally, his statement implies a preference towards the sounding potential and timbral quality of analogue oscillators, compared to the inclusion of multiple preset sounds in digital instruments, which may or may not deliver usable sound materials to work with. In contrast, when we consider samplers and the ease of loading and saving digital audio files - compared to loading and using sounds on analogue tapes (as was the case with the Mellotron, as discussed in chapter three) - a musician's preference over analogue or digital sounds might be less important when considering the practicalities of using digital samplers to record, trigger, and modify sampled audio in a more immediate way: achieved through the use of multiple buttons and menus. Furthermore, in cases where analogue instruments have been digitised as software versions, musicians may lose the use of physical interfaces but benefit from new features that the original instruments did not, or could not, offer. This was the case with Korg's digitization of their older analogue synthesizers as software (known as the Legacy Collection), which allowed their instruments to trigger sounds polyphonically (being able to play more than one note at a time).[317]

Visitors' ability to interpret the uniqueness and significance of instruments may be challenged further when the forms of each instrument chosen for display are too alike. As Weium and Boon explain, exhibition teams may experience issues when exhibiting technologies that do not convey their functions directly, especially in circumstances where 'one black box looks much like another'.[318] This issue has also been explored by Sumner who described computers from the 1980s exhibited in the *Information Age* exhibition

[314] Pinch, 'Emulating Sound. What Synthesizers Can and Can't Do: Explorations in the Social Construction of Sound', 113.
[315] Reid, 'The History Of Roland: Part 1'.
[316] Cunningham, 323-324.
[317] Pinch and Reinecke, 157.
[318] Weium and Boon, XIV.

at the Science Museum as ‘computers of the beige era’: ‘small, increasingly interchangeable machines marketed by box-shifting retailers as software-player devices to increasingly nonexpert and nonenthusiast users.’[319] Additionally, Foti discusses the challenges with exhibiting computer-based technologies at the Smithsonian Institute, describing the computer as a technology which ‘does not overtly reveal its function to the viewer.’[320] By quoting Smithsonian curator David Allison, Foti reveals the difficulty in exhibiting an important period in PC history because, although there were plenty of differences between each artifact, they all looked the same.[321] Allison’s solution was to help people see ‘through looking at three-dimensional objects, its significance historically and socially and making it relevant to them.’[322] With this in mind, similar problems might arise with electronic musical instruments that are unable to act as epistemic representations of the functions and sounds concealed within, in a way that has the potential to create relevant, engaging experiences for exhibition visitors.

Beyond the functionalities and digitised sounds installed in an instrument during initial manufacturing processes, additional ones can also be loaded-in at a later date via a software *upgrade* (usually through a USB digital communication port or storage device). For example, multiple firmware updates (‘computer programs contained permanently in a hardware device such as a read-only memory’) can be released over time after an instrument is manufactured, dramatically changing, or adding to, the sounding potential of that instrument.[323] However, because firmware updates are a form of software, the visible hardware remains unchanged and therefore the interface shows no clues as to what the instrument is capable of, post-firmware update. This presents a further challenge for exhibition teams in knowing whether an upgrade of this kind has even taken place or not, let alone figuring out how to demonstrate what an upgrade has added to the sounding potential of an instrument on display when the upgrade, itself, is immaterial.

For example, the firmware ‘SYSTEM PROGRAM (VER.2.00)’ for the Roland TR-8S ‘Rhythm Performer’ drum machine (see Figure 5.9. below) provides additional frequency modulation (FM) synthesis, as well as new effects (‘SATURATOR, FREQ SHIFT, RING MOD, and SPREAD’) and new preset patterns and kits.[324] Whilst this instrument is sold on the basis of providing realistic replications of Roland’s classic drum machines – such as the TR-808 from chapter four – the addition of FM synthesis, effects, and new presets has the potential to further expand the timbral quality of the original percussion sounds. However, without turning

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[319] James Sumner, ‘Making Computers Boring: Thoughts on Historical Exhibition of Computing Technology from the Mass-Market Era’, *Information & Culture*, 51.1 (2016), 29 and 35.
[320] Petrina Foti, *Collecting and Exhibiting Computer-Based Technology: Expert Curation at the Museums of the Smithsonian Institution* (Oxon: Routledge, 2019), 99-100.
[321] Foti, 99-100.
[322] Foti, 99-100.
[323] ‘Firmware | Definition of Firmware’, *Merriam-Webster* <https://www.merriam-webster.com/dictionary/firmware> [accessed 11 May 2021].
[324] Roland Corporation, ‘Roland - Support - TR-8S - Updates & Drivers’, 2020 <https://www.roland.com/uk/support/by_product/tr-8s/updates_drivers/e93722f3-45ec-4c0b-80b0-71a11603f6ea/> [accessed 30 September 2020].

the instrument on, the upgraded sounding potential of this instrument would remain hidden from view in an exhibition. This has also been evidenced in the display of software for computers. Through quoting the experiences of Stacey Kluck (Curator of the Music Collection at the National Museum of American History), although Foti offers a solution to exhibiting older software through its collection and display as 'physical displayable objects' (i.e., 5 1/4" disks, CD-ROMs, etc.), consumers have since been required to obtain software upgrades exclusively as downloadable, intangible files.[325]

Figure 5.9. A Roland TR-8S 'rhythm performer' drum machine.

5.6 Evidence of an Instrument's Use and Additional Visual Interpretative Materials

There do, however, exist certain scenarios in which the display of instruments as objects can provide clues as to how musicians have been able to produce musically valuable sounds using instrument interfaces. For example, the resulting wear and tear in the hands of a specific user can provide clear material evidence of how they used the controls to create and shape sound, which may compare to, or even contrast, the ways in which other musicians used the same instrument. As we saw with Arnauld Rebotini's Roland TR-909 drum machine in chapter four, the more defined wear surrounding particular rotary controls on the interface may help to determine which controls were most useful to that musician in shaping and performing with the instrument's percussion sounds. Similarly, the markings surrounding the control

[325] Foti, 73-74.

labelled ‘Hi Pass Filter’ on King Tubby’s MCI mixing console – which has been displayed in the Museum of Pop Culture (MoPop) in Seattle – demonstrates how the musician repurposed this sound technology as a musical instrument.[326] Therefore, the potential for a particular well-used instrument to speak to visitors through material readings can prove beneficial in helping to tell a story of how it was used by a specific musician to create notable sounds, as Tom Everrett (TE) explained:

> If we can say ‘this particular person used that object for this purpose,’ that shows how the object’s use value is actioned in real life, in addition to some of the evidence in the instrument itself: if certain knobs are more worn than others, or there are different scratches or different features which could suggest different kinds of usage, for example. If we could actually talk to the person who used that object, we can learn a lot more about the materiality of the object as we acquire it. (TE)

Additionally, the customisation of an instrument by a particular user can also indicate the wider musical, social, and cultural networks that both the musician and their instrument’s sounds contributed to, helping to uncover the instrument’s unique object biography. For example, the decision of musician Neil Landstrumm to customise his drum machine using stickers (see Figure 5.10. below) could help to demonstrate the record labels he released his music through (such as Scandinavia) and the venues he performed at (such as Sativa in Edinburgh) in an exhibition setting. This example is evidence of the potential for musicians to act as ‘agents of technological change’: modifying instruments in ways the designers *did not intend*.[327] However, although this can help identify how particular musicians used instruments to create and shape sounds, this still does not help exhibition teams to uncover those sounds and functionalities hidden within the instrument.

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[326] Williams, 170; ‘MCI Mixing Console Formerly Owned and Operated by King Tubby’, *MoPOP* <https://mopop.emuseum.com/objects/95703/mci-mixing-console-formerly-owned-and-operated-by-king-tubby> [accessed 12 June 2022].

[327] Nelly Oudshoorn and Trevor Pinch, ‘Introduction’, in *How Users Matter: The Co-Construction of Users and Technologies*, ed. by Nelly Oudshoorn and Trevor Pinch (Massachusetts: The MIT Press, 2005), 3-4.

Figure 5.10. A Roland TR-909 drum machine once owned by musician Neil Landstrumm.

Nonetheless, objects are often accompanied by supporting interpretational materials such as text, diagrams, and photography in order to assist visitors in their reading of material objects. As Falk and Dierking argue, 'rarely are the ideas objects embody fully and sufficiently communicated in the absence of some supporting informational tools, particularly for the many visitors who may not have the depth of prior understanding or knowledge to easily make the cognitive leap to the intended 'big ideas''.[328] However, each museum may have its own guidelines towards what they consider to be 'effective' interpretation, which could mean that the word count for text is limited and, therefore, the complexities of synthesis – for example - cannot be fully explained. Conversely, if exhibition teams rely too heavily on the addition of interpretational text and images to describe in detail what the different labels on an instrument mean, this could be counter-productive as the complexity and depth of description might overwhelm visitors further.

Otherwise, the addition of musical examples displayed as physical media (records, CDs, etc) alongside an electronic musical instrument may help visitors to make a connection between a particular sound that the instrument is capable of producing, and where they may have heard that sound before as part of a recorded composition or a live performance (see Figure 5.11. below). This may also help to link that instrument to a particular social or cultural network which the visitor may associate themselves with (a rock concert, a record store, or a festival, for example). However, the challenge in visually highlighting a particular sound within a recorded composition – as represented by a physical media object – whilst also demonstrating how a specific instrument was used to create that sound, remains. As Leonard argues: 'The curation of popular music artefacts cannot stand in for, or be detached from, the sonic and bodily experience of music and the emotional and social ways in which it is experienced in time and space.'[329]

[328] Falk and Dierking, 119.
[329] Leonard, 'Constructing Histories Through Material Culture: Popular Music, Museums and Collecting', 148.

Similarly, whilst certain physical media artifacts might have displayed the instruments used to create the recorded compositions as photographs (or listed the instruments as text), the same issue exists in providing visitors with the means to associate the individual sounds within the compositions to the instruments highlighted (as evidenced in Figure 5.2. previously).

Figure 5.11. A display of Manchester-themed objects at the BME, Liverpool, including an E-mu Emulator II sampler (left) – as used by New Order – and a selection of vinyl records.

5.7 Conclusion

In conclusion it is evident that, whilst some instruments are more capable of visually demonstrating their sounds than others, material artifacts such as these nonetheless struggle to highlight the sounds associated with them. Additionally, whilst certain users have added more markings and customisations to their instruments than others – which could help an exhibition team to demonstrate how (or even where) an instrument object's sounds were created, shaped, and used – this does not help to demonstrate the results that have been heard (in other words: what the sounds sound like). This is problematic because visitors may have been exposed to an instrument's sounds more than the instrument itself, and therefore the sounds may be more relevant to their lived experiences than the materiality of the instrument responsible for creating and shaping them. Therefore, for exhibition teams who wish to focus on the sounds that instruments produce – rather than the design of the instruments themselves – the *demonstrative* value of these objects is low.

This helps to argue that, in order for exhibition teams to follow a sound genealogy methodology, they will need additional multi-sensory materials to help visitors to hear the sounds of instruments and connect what they hear to the means of creating and shaping sounds via some form of tactile experience. As museum objects are usually collected and displayed with the intention of being preserved (and, in the case of electronic technologies, turned off), they cannot alone help exhibition teams to provide this quality of experience to visitors. However, objects remain useful for exhibition teams as they can help to provide real-life historical context to multi-sensory experiences of sound, and help signpost visitors to wider cultural, musical, and technological developments associated with electronic sound.

6 Interactivity and Sound: Actions, Learning, Entertainment

6.1 Introduction

As discussed in the previous chapter, when electronic instrument objects are exhibited in isolation, they struggle visually to demonstrate the sounds they produce, including those for which they are best known. Therefore, exhibition teams stand to benefit from incorporating additional sensory materials that allow visitors to not only hear the sounds of instruments, but also understand how each instrument's interface ('the contact surface of a thing') and materiality can influence a sound's development. Additionally, by following a sound genealogy methodology, exhibition teams can support these forms of sensory content with additional interpretational materials that help visitors understand who was responsible for constructing and shaping both the instruments and the sounds: both in terms of designers and users. By relating the instruments that can be seen, sounds that can be heard, and interfaces that can be touched, to wider musical and social developments, visitors might also be able to connect this content to their lived experiences of music, creating a more meaningful multi-sensory exhibition experience. As Leonard argues:

> It is crucial to understand and value the multiple and unpredictable ways in which objects, images and sounds within an exhibition can be used in the production of meaning […] Museum audiences […] bring a store of experience with them affecting how they relate to and interpret the content on display.[330]

In this chapter, I discuss the importance of sound and how interactivity can be used to make explicit connections between the things that generate, trigger, and shape sounds – interfaces and functions – and the sounds themselves. In other words, tactility can help visitors to understand sound through cause and effect: deploying physical actions and listening to the sonic results of those actions. Further to this, I conceptualise the visitor experience of electronic musical instruments in museums by comparing theories of actions and behaviours from STS and museology in relation to musical, learning, and entertainment applications and outcomes. Finally, in order to help improve the chances of a successful exhibition experience for visitors, I highlight and examine various solutions to the provision of sounding interactive exhibits in museums, gathered from various sources. The content explored within this chapter also helps to

[330] Leonard, 'Exhibiting Popular Music: Museum Audiences, Inclusion and Social History', 172.

setup and justify the approach towards the exhibit I created for the NSMM, which is explored in chapters seven and eight.

6.2 Sound in Exhibitions

Sound is an integral part of the multi-sensory museum experience. Baker, Istvandity and Nowak suggest that 'sound is often used to cohere the display of material objects by providing a sonic feature that contextualises the visual elements for visitors.'[331] Therefore, the demonstration of instrument sounds through audio content can provide context to the display of musical instruments in an exhibition and help to demonstrate the musical value of specific instruments for musical applications. More generally, Bijsterveld also argues that the communication of what was heard in the past, as well as the ways in which contemporaries *listened* (for the purpose of this thesis: the sounds of instruments, the settings in which they were heard, and the values that musicians and audiences have ascribed to particular sounds) can help to enhance visitors' understanding of the historical contexts in which sounds have been experienced.[332]

In museums, various types of exhibition content may be intentionally designed to trigger and shape sounds for public consumption – whether through some automated means or manually by visitors - in addition to sounds that people produce whilst occupying exhibition spaces. Depending on where a visitor is standing, they may not be able to ascertain the cause of the sounds they can hear as the things and events responsible for the production of sound may remain outside of their field of view.[333] As Schafer states: 'hearing gets to places where sight cannot.'[334] This suggests that the management of sound within exhibition spaces is paramount to ensuring that visitors encounter a high quality multi-sensory experience within exhibitions.

Nonetheless, as people move through these spaces and trigger sounds manually at random times (in addition to that which plays automatically), we can conceive of the exhibition soundscape as constantly changing. Additionally, whilst Arnott and Alain argue that research has helped determine the capacity of human beings to 'separate and identify the various sounds in the environment by allocating attention to auditory objects of interest,' this may nonetheless depend on factors such as the loudness and quantity of sounds present in an exhibition space – many of which may be competing for visitors' attention - and whether visitors are already aware of the things that might have been responsible for producing the sounds

[331] Baker, Istvandity, and Nowak, 142-143.
[332] Bijsterveld, 76-77.
[333] Arnott and Alain, 91.
[334] Murry Schafer, 44.

they hear.[335] Therefore, the placement of instrument objects, sound playback devices, an interactive exhibits can be crucial in helping visitors differentiate the sounds intended for consumption (i.e., those that support the exhibition team's learning outcomes) from other auditory content existing in the same space at the same time.

However, it can often be the case that sounds are incorporated into exhibitions without explicit associations to any material causes and are therefore viewed as distinct from their sources.[336] For example, based on his motivations towards curating and managing the resources that constitute the Museum of Portable Sound, Kannenberg uses the work of Pierre Schaeffer and other authors and composers to justify the use of 'museological sound objects' that exist for visitors to hear without the physical source being present.[337] Rather than relying on objects, recordings of sounds are 'accompanied by information about their sources in a printed gallery guidebook.'[338] Whilst there may be several occurrences in which this practice is justifiable – for example, in cases where it might be difficult, or even impossible, to install the sound source next to the sound playback device – this can be problematic when attempting to demonstrate the sounds that an electronic musical instrument has become most known for, or is capable of, producing.

The problem lies in trying to demonstrate to visitors *how* electronic sounds are generated, triggered, and shaped by such instruments - especially without an instrument's interface displayed in the same proximity as the sound that is heard. Better still: if a visitor was able to *use* an instrument as an interactive exhibit, they would be able to develop a first-hand understanding of the relationship between instrument interface and the production and modification of sound. Therefore, although personal audio guides and public kiosks can deliver sound examples from each instrument on display to visitors, these examples remain disassociated from the instruments themselves and, therefore, visitors may struggle to connect each sound to its source in lieu of some form of tactile triggering and modification of electronic sound using an interface.[339]

Nonetheless, the problem still remains over the *choice* of sounds that are used to represent a specific electronic musical instrument and whether these should be heard within the context of a song - in which other sounds exist at the same time - or whether they should be heard in isolation to help visitors make a much clearer connection between sound and instrument (amongst other things that could be connected, such as a musician, a musical genre, or a cultural movement). This *isolation* of sound is an important consideration - whether sounds are emitted from personal audio guides, public kiosks, or interactive exhibits – as this can help visitors to understand the value of a particular sound, as we explored in chapter

[335] Arnott and Alain, 103.
[336] John Kannenberg, 'Towards a More Sonically Inclusive Museum Practice: A New Definition of the "Sound Object"', *Science Museum Group Journal*, Autumn.8 (2017), 12-13.
[337] Kannenberg, 16.
[338] Kannenberg, 15.
[339] Kannenberg, 14.

five. For example - as argued by Pinch - when a sound becomes more recognizable and distinguishable to one's ear, it starts to acquire value 'as opposed to the vast array of sounds that are physically capable of being produced by the instrument.'[340] As we saw in chapter four: the songs that could be heard throughout the *Electronic…* exhibition may have consisted of sounds from different instruments on display, but because the exhibition team did not choose to isolate particular sounds from each song during playback and did not explicitly connect instrument objects to the sounds that could be heard, the potential for those songs to help connect sounds to instruments is arguably limited.

Nonetheless, when audio examples are used more effectively to help visitors understand what an instrument is capable of, and why it has become associated with different musical styles, this enables us to conceptualise sound as having *demonstrative value*. Additionally, in order to help exhibition teams to adopt a sound genealogy methodology, the choice of sound is important as it can help construct an interpretive framework in which visitors can 'follow the sound' and understand who was responsible for performing, recording, sampling, and modifying that sound since its creation, as well as which instruments have been used to generate, trigger, and modify that sound in different ways.

To illustrate the importance of isolating sound further, we can use an example of good exhibition practice from the BME. In 2020, the museum hosted the temporary exhibition *Souvenir- 40 Years of OMD* which featured a selection of instruments once owned and used by various members of the band Orchestral Manoeuvres in the Dark, displayed in a large floor-standing glass case alongside memorabilia such as posters, concert tickets, and recorded media (see Figure 6.1. below). Three touchscreen sound stations were installed in front of this display, each featuring identical content: nine of the instruments in the glass case. After selecting an instrument, visitors were provided with additional images and textual information regarding its history, the musicians' connection to it, and how it was used. Importantly, an audio example of the instrument's use within an O.M.D. song was also provided in isolation (displayed as a waveform), allowing visitors to acknowledge the recognisable sound that the instrument was capable of producing (see Figure 6.2. below).

Hearing each instrument's sound provided visitors with a unique experience in which they were able to connect sounds to songs: for example, the opening percussion loop in the song 'Enola Gay'.[341] Additionally, these audio examples helped to demonstrate the capacity of the instruments in helping O.M.D. realise their musical ideas, and therefore manifested demonstrative value within the exhibition. However - as previously stated - without visitors being able to get hands-on with one of the instrument's interfaces through some form of interactivity, the question remains as to how each instrument was used to create, trigger, or shape the sounds that could be heard. For example, whilst some may have the musical knowledge and listening

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[340] Pinch, 'Moments in the Valuation of Sound: The Early History of Synthesizers', 22-23.
[341] Mat Smith, ''Enola Gay'', *Electronic Sound*, 2020 <https://electronicsound.co.uk/the-regulars/landmarks/enola-gay/> [accessed 16 July 2022].

abilities to determine the combination of notes played on the synthesizer used in 'Enola Gay', the positioning of controls on the interface that helped form the sound's timbre may be harder to determine without being able to reconstruct the sound first-hand.

Figure 6.1. A display of electronic musical instruments once used by Orchestral Manoeuvres in the Dark, accompanied by touchscreen sound stations, at the BME, Liverpool.

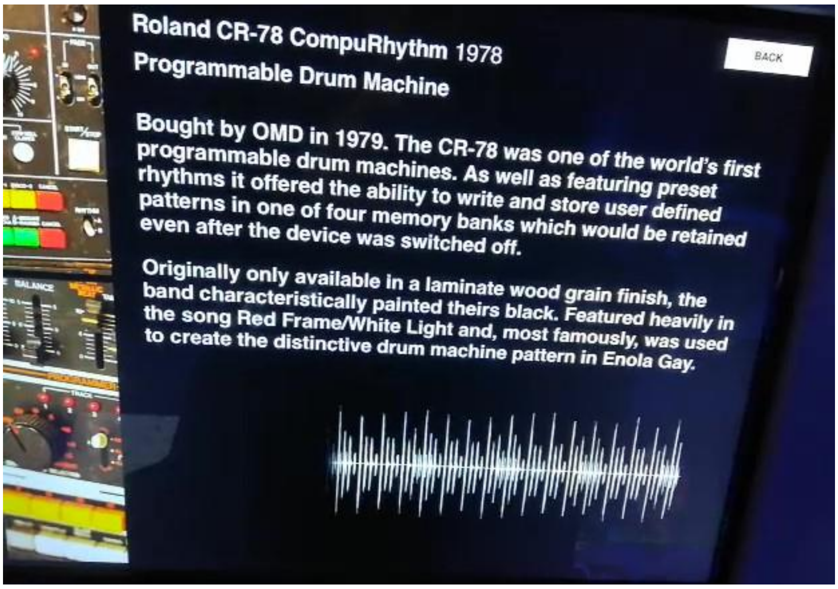

Figure 6.2. The touchscreen sound stations delivered images, text, and audio information in relation to instruments such as the Roland CR-78 drum machine, as used by O.M.D.

6.3 The Benefits of Interactivity

As we acknowledge that exhibition experiences often incorporate sound and touch modalities, as well as the visual, we can follow Allen and Lupo's conceptualisation of museum exhibitions as 'the interplay of the noumenal (real things) and the phenomenological (senses and meanings) within a dynamic network of interactions between people, objects, representations, and sites.'[342] As part of the broader growth in the 'experience economy,' interactivity has become increasingly popular and important for exhibition teams to consider in a variety of museum contexts: often with the aim of supporting visitor learning around museum objects.[343] As part of this growth, visitors continue to expect and desire playful multi-sensory interactive exhibits in exhibitions, often in the hope of gaining valuable educational outcomes whilst being entertained.[344] Similarly, Falk and Dierking argue that interactivity allows visitors to 'see, ideally even touch, taste, feel, and hear, real things from the real world in an appropriate setting': something that films, websites and school lessons are not able to achieve in the same way.[345] Furthermore, as Klingender claims, interactive exhibitions can benefit visitors through providing 'a more relaxed learning experience in

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[342] Jamie Allen and Eleanora Lupo, 'Introduction', in *Representing Museum Technologies*, ed. by Jamie Allen and Eleonora Lupo (Milan: Mela Books, 2012), 9-10.
[343] Bailey, Broackes, and De Visscher, 330.
[344] Eric De Visscher, 'Music in Museums – A Model For The Future?', in *Folkwang Studies: Music Exhibitions : Intention, Realization, Interpretation*, 2018, 20-21; Bailey, Broackes, and Visscher, 330 and 340-341.
[345] Falk and Dierking, 113.

combination with panels of text and cases of artifacts.'[346] Evidently, the statements above validate the importance of interactivity – when combined with objects and sound - in helping to shape the visitor experience in a positive way.

In the context of the sound genealogy methodology, interactivity can be a highly effective tool towards the examination of instruments and their sounds, helping to re-integrate interfaces with functions and sounds as tactile epistemic representations of electronic musical instruments. As Falk and Dierking argue, interactivity can help to 'juxtapose and visually and aurally connect ideas' as a 'vehicle for presenting abstractions or functionally invisible phenomenon.'[347] Importantly, interactivity is a useful tool because it enables the means of controlling sound to be linked to the sounds themselves. Visitors understand what the controls on the interface do through *hearing* the results as feedback from their *actions*, rather than through *reading* and *imagining*: as would be the case with objects, alone. Therefore, the value of interactivity in relation to musical instruments is developed through an exhibit's ability to *demonstrate* how sounds are generated, triggered, or modified. Furthermore, by redesigning electronic musical instruments specifically for interactivity – as was the case with the Electronic Sackbut and the MR-808 in chapters two and four – exhibition teams can follow the conceptual move - as advocated for in museology literature - 'from a commitment to the real object to that of the real experience.'[348] Additionally, through redesigning interfaces, exhibition teams can provide immediate access to sounds and functions that were otherwise hidden within (or unlabelled on) the original instrument (as is evidenced with the Akai S950's time-stretching function in chapters seven and eight).

However, there have existed instances where interactivity has not been utilised effectively to demonstrate the sounds that are most closely associated with an instrument. This was the case with the Roland LIVE gallery in the Grammy Museum in Los Angeles, which consisted entirely of interactive electronic musical instruments: one, of which, was the Roland AIRA TB-3 synthesizer (see Figure 6.3. below). Whilst this instrument was designed with the intention of continuing the Roland TB-303 synthesizer's heritage (as mentioned in chapters two and four), with additional features such as a touchscreen keyboard and multiple digital preset sounds (including 'the original TB-303 tones and new four-oscillator, effects-processed basses, leads, and sound effects'), this instrument was presented to visitors with a more generic electronic sound that shared very little resemblance to the original TB-303's infamous 'acid' oscillators.[349] Whilst it may not have been the intention of the exhibition team to link this instrument and its sound to various styles of acid music (e.g., acid house or acid techno), as well as the musicians responsible for creating and

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[346] Franz Klingender, 'Science and Technology Exhibits: The Use of Interactives', in *Science Exhibitions: Communication and Evaluation*, ed. by Anastasia Filippoupoliti (Edinburgh: Museums Etc Ltd, 2010), 272.
[347] Falk and Dierking, 119.
[348] Alcina Cortez, 'The Curatorial Practices of Exhibiting Popular Music in Portugal at the Beginning of the Twenty-First Century: An Overview', *Portuguese Journal of Musicology*, 2.2 (2015), 303-304.
[349] 'Roland - TB-3 | Touch Bassline', *Roland Corporation*, 2022 <https://www.roland.com/global/products/tb-3/> [accessed 10 July 2022].

shaping those styles, this nonetheless demonstrates that - unlike the Giant '303 discussed in chapter two - the interactive experience did not effectively link the instrument and its sound to wider musical and cultural developments. Therefore, this helps to demonstrate that the choice of sound(s) used to create an interactive experience of electronic musical instruments can be vital in helping exhibition teams to attempt to deliver various learning outcomes.

Figure 6.3. The Roland AIRA TB-3 touch bassline synthesizer at the Grammy Museum.

6.4 How Musicians Interact with Instruments for Musical Applications

Within the field of STS, technologies have been theorised using two semiotic approaches in the context of understanding user's actions, which Pinch summarises as follows: 'users of technology have to be 'scripted' as Akrich (1992) describes, or 'configured' as Woolgar (1991) suggests.'[350] Rooted in ANT, the 'script' metaphor describes a situation in which designers *inscribe* a script into their technology (an imagined use of their technology in a real-world setting) for users to then *describe* (i.e., follow) when using the technology.[351] This is based on the reading and writing of scripts for moving image, which would necessitate an actor or actress to agree to read it, and a role to follow in order to realise an experience within 'the space in which they are supposed to act.'[352] Similarly, an important part of Woolgar's configure metaphor is the *machine as text* concept, which is used to describe machines (in the author's case,

[350] Pinch, 474.
[351] Tjora, 162; Akrich, 207-208.
[352] Akrich, 208.

computers) as *mediators* between how the technology was built (written) and how users are configured to interpret (read) it, helping them determine 'what it is, what it is for, and what it can do.'[353]

As electronic musical instruments are also technologies, we may apply the reading and writing of real-world and imagined uses, respectively, from Akrich and Woolgar to the actions of musicians. For example, one could take on the role of composer - following a sequence of actions known as composing, towards the outcome of a composition in a studio; or the role of performer – following a sequence of actions known as performing, towards the outcome of a performance at a concert (for example). However, both theories have been critiqued as too deterministic in envisioning how users might behave with technological artifacts. For example, Woolgar's approach to users has since been critiqued by authors such as Oudshoorn and Pinch who identify configuration as 'a one-way process in which the power to shape technological development is attributed only to experts in design organizations.'[354] Additionally, the script metaphor, in particular, is problematic because it imagines one static use of a technology, which does not realistically reflect the ways in which musicians develop and alter their use of electronic sound over time, which Tjora defines as a user trajectory.[355] This is often influenced by the music in which musicians, instruments and sounds are entangled, which Dehail argues is also 'based on a practice that is multiple and changing.'[356] As we saw with the Roland TR-808 in chapter four, musicians used the various controls to modify the instrument's sounds, creating and shaping multiple genres of electronic music since the instrument was first introduced.

However, whilst a user trajectory relates to the changing use of one particular technology, musicians may also change the instruments they use as a way of supporting, or even encouraging, their developing musical interests, providing new sounds, functionalities, and interfaces to work with. This has been demonstrated in museums using instrument objects. For example, in discussing the accession of instruments from American jazz musician Herbie Hancock for the National Museum of American History, Washington D.C., Kluck describes how the musician changed the style of music in which he composed and, in doing so, took advantage of new tools to create this new music through experimenting with new sounds, rather than relying on his older instruments.[357] With this in mind, Hancock's technologies were exhibited as representations of the musician's musical innovations, meaning that the significance of the technologies were tied to the significance of Herbie Hancock as an American musician and the significance of his music as part of America's musical history. However, this also evidences Hancock's discontinued use of certain sounds for composition which suggests that, as new genres and styles emerge, certain electronic sounds may otherwise become unpopular which, therefore, suggests that the *musical value* ascribed to sounds can

[353] Woolgar, 60.
[354] Oudshoorn and Pinch, 8.
[355] Tjora, 163 and 172.
[356] Dehail, 53.
[357] Foti, 82-83.

also change over time. Nonetheless, as it is unclear whether sounds and interactivity were used to support this narrative or not, a lack of this sensory content may have made it difficult for visitors to ascertain what the most innovative or musically valuable sounds sounded like, or to understand how Herbie Hancock used his new tools to create those new sounds.

Similarly, instrument objects and their sounds can be used as epistemic representations of a musician's developing personal identity, which might also have been reflected in the ways in which their music changed over time. This was the case in the temporary exhibition *David Bowie Is…* at the V&A, London (2013). However, whilst Bailey, Broackes, and Visscher suggest that objects traditionally took priority in this museum, *David Bowie Is…* was used as an opportunity to experiment with sound by working with 'specialist live performance designers – in this case, 59 Productions – rather than museum exhibition designers, and to take design references […] from theatre, live events and Bowie's own performances.'[358] By doing so, the exhibition team combined film and sound with objects such as the musician's costumes to help focus on the themes of inspiration, process, and impact**.**[359] However, without the integration of interactivity, visitors may still have lacked a sense of how Bowie changed the ways in which he performed and composed with his instruments, and the impact that might have had on the evolution of sounds that reflected his developing identity.

6.5 Using Interactive Exhibits to Facilitate Learning and Entertainment Outcomes

Unlike electronic musical instruments, interactive exhibits have not been theorised within the literature of science and technology studies (STS). This may be due to their existence in 'unreal' settings - museum exhibitions – and their usefulness in demonstrating how pre-existing technologies (such as musical instruments) have been used in 'real-world' settings. However, as we saw with the Memotron M2K in chapter three, this is not always the case as museums often install pre-existing manufactured instruments as interactive exhibits, which highlights a displacement of technologies from real to unreal settings. Therefore, through adopting terminology from STS, we could also envision interactive exhibits as technological artifacts entangled within socio-technical settings - museum exhibitions - that may be of value to various users and social groups (i.e., visitors and audiences). Similarly, we could also conceptualise

[358] Bailey, Broackes, and Visscher, 331.
[359] Bailey, Broackes, and Visscher, 331.

visitors who use interactive exhibits as comparable to musicians who play with instruments, as Pearce suggests:

> Interactivity is the intimate relationship between this person – the user, the player, the interactor, what have you – and the software – the composition, the hardware – the instrument, and in the case of multi-use activities, other people – the jam session.[360]

However, whilst it may seem useful to adopt the previously discussed (and critiqued) theories from STS towards understanding how the design and installation of exhibits might affect the way that visitors engage and behave with them, we must first acknowledge an important distinction between musical instruments and interactive exhibits. Although interactive exhibits are also technologies, their use is usually not attributed to a music or sound application. For example, whilst many digital instruments allow musicians to save their sound and composition data for re-use at a later time, visitors are unlikely to want to save what they created using an interactive exhibit as they are not expected to use it on a specific musical project that would necessitate their return to the museum to complete. Therefore, the concept of a user trajectory is challenged as it assumes that users (e.g., museum visitors) will have the luxury of operating a technological artifact over a sustained period of time.[361] Whilst a musician might use an instrument over many years - referring to its operating manual for guidance – in an exhibition, visitors are not afforded similar lengths of time to become familiar with an exhibit's operation. Therefore, a one-time static view of a *visitor* may actually be more realistic.

Instead, exhibition teams envision learning and entertainment outcomes from the use of exhibits, which often relate to the broader agendas of the exhibition in which they are installed. Therefore, an exhibition visitor might take on the role of *learner* – following a sequence of actions known as learning, towards realising either the learning outcomes of the exhibition team or, in a less deterministic scenario, realising their own learning outcomes. As we have seen in all three case study chapters, it is not uncommon for members of exhibition teams to develop expectations (or even make assumptions) of certain abilities and preferences of their exhibition audiences and, therefore, create and install interactive content that embodies different degrees of complexity. This is often why it is important and valuable for exhibition teams to undertake formulative user testing with potential visitors (which is explored later) in order to develop a better understanding of how to design interactive products that have a better chance of meeting or exceeding visitor expectations.

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[360] Celia Pearce, *The Interactive Book: A Guide to the Interactive Revolution* (Indianapolis: Macmillan Technical Publishing, 1997), 493.
[361] Tjora, 172.

Nonetheless, it is the combination of multi-sensory content - objects, sounds, and interactivity – that help to construct the conditions that enable learning and entertainment to take place, which authors of museology argue to be at the heart of the visitor exhibition experience. For example, Ghose defines learning in the context of science museums as the opportunity to 'foster a spirit of inquiry, to kindle the fire of imagination, and to cultivate creative talent...'[362] To this end, specific learning outcomes are constructed for an exhibition through the integration of 'communication goals (what you want the visitor to learn) with behavioural goals (what you want the visitor to do), and even emotional goals (what you want the visitor to feel)': as described by McLean.[363] Therefore, as visitors engage with electronic musical instruments through interactivity, the potential exists for them to *learn how to* compose or how to perform (for example), whereby the process rather than the outcome (a composition or a performance, for example) is the focus.

In comparison to the previously critiqued theories from STS – script and configure – certain scholars of museology have conceptualised the realisation of learning outcomes in similarly deterministic ways. For example, Duncan sees 'ideal' visitor behaviours as being determined exclusively by the exhibition team and how well each visitor is 'educationally prepared' to perform the rituals as pre-determined by the museum.[364] She further argues that the museum is able to construct a '*dramatis personae*' (the characters of a play), which also suggests a deterministic view of the museum's staff as script writers (to adopt the terminology of Akrich).[365] Additionally, Duncan argues that, in reality, visitors often ''misread,' scramble or resist the museum's cues to some extent; or they actively invent, consciously or unconsciously, their own programs according to all the historical and psychological accidents of who they are.'[366] This shares much with Akrich and Latour's concept of antiprograms from the field of STS, which the authors define as 'all the programs of actions of actants that are in conflict with the programs chosen at the point of departure of the analysis.'[367] In the context of museums, whilst exhibition teams may attempt to program visitors to act in a certain way in order to realise specific learning outcomes, visitors may produce an antiprogram by acting in ways that were unexpected, enabling them to conflict with or overcome the program.[368]

As a way of enhancing the learning experienced through interactivity, Ghose proposes a move away from designing interactive exhibits to be merely 'hands-on' to creating exhibits which attempt to coerce visitors

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[362] Saroj Ghose, 'From Hands-on to Minds-on: Creativity in Science Museums', in *Museums of Modern Science*, ed. by Svante Lindqvist (Canton: Science History Publications, 2000), 125.
[363] K. McLean, *Planning for People in Museum Exhibitions* (Washington D.C.: Association of Science and Technology Centers, 1993), 95.
[364] Duncan, 428.
[365] Duncan, 428-429.
[366] Duncan, 428-429.
[367] Madeleine Akrich and Bruno Latour, 'A Summary of a Convenient Vocabulary for the Semiotics of Human and Nonhuman Assemblies', in *Shaping Technology/Building Society: Studies in Sociotechnical Change*, ed. by Wiebe E. Bijker and John Law (Massachusetts: The MIT Press, 1992), 261.
[368] Paula Jarzabkowski and Trevor Pinch, 'Sociomateriality Is 'The New Black': Accomplishing Repurposing , Reinscripting and Repairing in Context', *AIMS*, 16 (2013), 583.

to be 'minds-on'.[369] Visitors, therefore, learn through a discovery process, verifying the clues provided both alongside the exhibit, such as a set of instructions or contextual interpretative text, and via the interface of the exhibit itself through their own experimentation and realisation.[370] Additionally, Ghose states that 'it is not the answer that is so important, but the process of discovering the answer that leaves an everlasting impression on a visitor's mind […] it is the method of science and not science alone that characterises a truly minds-on exhibit.'[371] To help facilitate this, exhibition teams can move away from designing goal-orientated experiences and move towards designing electronic musical instruments as interactive exhibits that facilitate a *process of discovery* through the continual generating, triggering, and modifying of sound via an exhibit's interface, creating a more exploratory experience.

Furthermore, by facilitating the opportunity for a visitor to 'organise what he or she has discovered and construct new meanings as a result,' exhibition teams can create learning experiences that are less didactic and more constructivist, whereby visitors reflect on their experiences and 'construct their own understanding' of the world they live in.[372] As Black argues: this approach 'supports active engagement and fosters curiosity,' whilst enabling 'the development of intuitive and thinking skills, important for lifelong learning, and personalises the whole learning experience.'[373] However, as is discussed in chapter eight, this may also depend on whether visitors even read the text or other interpretational resources that accompany an exhibit, which may result in a more constructivist learning experience for visitors as they end up relying more on the knowledge and experiences previously accumulated. Scenarios such as this have also been acknowledged by authors such as Black, who states the following:

> [Visitors] create their own personal, exploratory routes, missing out elements, stopping at what interests them and moving on when they are ready, not necessarily after taking in all the material presented at that particular point. In other words, visitors go a long way toward creating their own constructivist layouts, no matter what approach is taken in the display itself.[374]

This also reflects the ways in which meaning-making in museums is, more generally, conceptualised in museology literature. For example, Leonard acknowledges that studies have shown that 'visitor interpretation draws on the existing experiences and knowledge base of visitors beyond the content of the

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[369] Ghose, 119.
[370] Ghose, 122.
[371] Ghose, 123-124.
[372] Black, 140.
[373] Black, 138-139.
[374] Black, 148.

exhibition thus contributing to the overall learning experience,' which, as Cortez argues, contradicts previous notions of visitors as remaining subordinate to the narrative delivered by the institutional voice of an exhibition, and its dictated meaning.'[375] Furthermore, Evans argues that 'the role of education within museums is now person centred, whereas previously it had been information centred, with knowledge transmitted to the visitor through the medium of sight.'[376]

Additionally, we can utilise Foucault's philosophies to re-interpret institutional power over social conditions.[377] By doing so, we can start to see that although museums may *attempt* to coerce certain behaviours from visitors and encourage specific learning outcomes, visitors still have the agency to enact their own power over such behavioural cues and generate their own meaning-making experiences unique to them. In this way, the 'misuse' of an exhibit – as interpreted by an exhibition team - could be a firm realisation of ones intended power over it. Therefore, instead of perceiving visitor antiprograms as misreadings or resistances of pre-determined courses of actions, we can understand this behaviour as productive, helping visitors to realise their individual expectations and goals.[378] Nonetheless, we also have to acknowledge that an exhibition teams' perception of visitor's behaviours is not singular and is – instead - constructed by various members of staff and stakeholders internal and external to the museum, all of which may conflict and challenge each other. Curators, technicians, interpreters, project managers, government bodies and private funders (for example) will not only understand the value of interactivity differently to each other, but they may also exercise power over the content of exhibitions in different ways: some of which may impact visitors' experiences more noticeably than others.

However, it remains difficult to analyse undesired or unexpected actions from the perspectives of exhibition teams when we are not aware of the intentionality or will of the visitors who act in these ways.[379] With this in mind, although we have now conceptualised *power* as belonging to, and enacted by, various stakeholders, it is those who work for, and with, the museum who maintain the overall *responsibility* towards the construction and maintenance of exhibition content and the behaviours acted upon it. In other words, as exhibition teams introduce touch through interactivity, the potential for wear and tear is also introduced to those things that can be touched. Nonetheless, museums may hope that members of the public will contribute an understanding of their own responsibility towards the ongoing working condition of interactive exhibits, based on their awareness of the *consequences* of their actions. To this end, it may be beneficial for museums to encourage a *community of responsibility* in which visitors are considered as equal members alongside those who work for, and with, the museum: especially in cases

[375] Leonard, 'Exhibiting Popular Music: Museum Audiences, Inclusion and Social History', 176; Cortez, 308.
[376] Steven Evans, 'Constructivist Theory and the Museum Sensescape: Exploring the Extent to Which Museums Engage the Non-Visual Senses and How This Occupies a Constructivist Learning Paradigm' (University of London) <https://birkbeck.academia.edu/StevenEvans>, 4.
[377] Sara Mills, *Michel Foucault* (Oxon: Routledge, 2006), 1-2 and 33-34.
[378] Mills, 33.
[379] Mills, 50.

where visitors were consulted in the creation of exhibition content through action research approaches (more on this in chapter seven).

6.6 Interactive Design Solutions – Some General Considerations

In order to help create 'successful' multi-sensory experiences of interactive exhibits and prolong their use – ideally for the lifetime of the exhibition in which they are installed – many authors of museology and interactive design have documented and critiqued good and bad practices across various institutions (as explored in chapter one). Whilst some of what has been suggested may seem specific to the museums, exhibitions, and audiences in question, several suggestions may be relevant and useful for future exhibition teams to adopt when considering the construction of new exhibitions that feature electronic musical instruments. Some of those suggestions that are relevant to this thesis are described below and are supported by my observation and use of interactive exhibits in contemporary exhibitions, as well as recommendations provided by those interviewed as part of this PhD project.

6.6.1 Interpretative Flexibility: The Theremin

As we saw in the previous case study chapters, both electronic musical instruments and interactive exhibits are often designed in different ways. Additionally, exhibition teams have taken different approaches to the redesign and installation of the same electronic musical instrument. This may be due to factors such as the museum's aesthetic approach to exhibit design in general, and the anticipation of visitor behaviours relating to the use of exhibits. With this in mind, we can adopt the term 'interpretative flexibility' - which Pinch and Bijker used to describe the differing interpretations of a technology by various social groups, and the different ways in which the same technology can be designed – to help us theorise the installation and design of interactive exhibits for exhibitions and their interpretation by various audiences.[380] In the following paragraphs, I use the theremin instrument as an example. Although the theremin was designed with the intention of being performed 'hands-free' – producing a unique sound timbre characterised by a continually rising and falling pitch, caused by hand movements near the instrument's antennae - it was nonetheless installed or redesigned to offer different tactile and non-tactile experiences within four North American museums.

[380] Pinch and Bijker, 421.

Prior to the museum's redevelopment, the MoMM, Carlsbad, adopted the *manufactured* approach towards the installation of a mass-produced (i.e., manufactured) Moog theremin in its entirety within the interactive *Innovation Studio* space.[381] This approach was also evidenced with the Memotron M2K in chapter three. However, in the Musical Instrument Museum, Scottsdale, a similar model of theremin was installed with a Perspex cover in their interactive *Experience Gallery*. Although the antennae were left exposed, the overall volume and pitch (as well as the waveform and brightness) of the sound could not be altered as the knobs that corresponded to these controls were covered by the Perspex (see Figure 6.4. below). This represented the *configured* (or *covered*) approach to interactivity, in which a recently manufactured instrument is installed so that 'the original form of the instrument is not compromised but certain parts of its interface are covered […] so although visitors could still see those parts, they could not touch them.'[382] This mirrored the approach which Davies encountered in the Gemeentemuseum in Den Haag, as quoted at the start of chapter one, and was also used by the Grammy Museum for installing the Roland AIRA TB-3 synthesizer (as shown in Figure 6.3. previously).

Figure 6.4. A Moog theremin instrument installed in the *Experience Gallery* of the Musical Instrument Museum, Scottsdale, following the configured approach to interactivity.

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[381] Wilson-Stephens, 129-131.
[382] Wilson-Stephens, 131.

In contrast, the exhibition team at the Canada Science and Technology Museum followed the *exclusive* approach to interactivity and, in collaboration with an external design company, redesigned the theremin exclusively for the museum's *Sound by Design* gallery, and named it *Play the Theremin* (see Figure 6.5. below).[383] Although the exclusive approach may result in an exhibit that closely resembles an instrument object, the redesigned interactive theremin bared little resemblance to the theremin object displayed opposite (the RCA theremin) – which was also the case with the *Play the Electronic Sackbut* exhibit installed nearby (as discussed in chapter two). Nonetheless, the use of diagrams and tagline 'What song can you pull out of thin air?' attempted to indicate that visitors did not need to touch the exhibit to play it. Lastly, following the *hybrid* approach results in an exhibit 'made from materials, electronic components and pre-existing 'black-boxed' instruments.'[384] This was demonstrated by the theremin exhibit installed in *Bechtel Gallery 3: Seeing & Hearing* (now referred to as *Bechtel Gallery 3: Seeing & Reflections*) in The Exploratorium science centre, San Francisco. As with the exclusive approach, the hybrid approach can produce an exhibit that bares much or little resemblance to a pre-existing instrument (as was the case with the MR-808 in chapter four, which shared much with the form of the original Roland TR-808 drum machine).

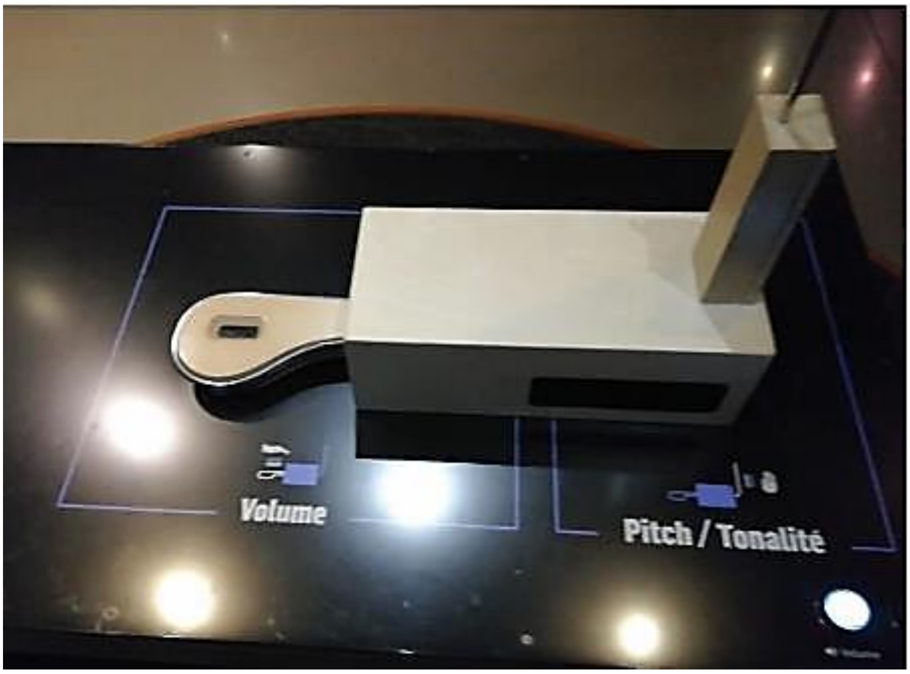

Figure 6.5. The 'Play the Theremin' exhibit designed for the *Sound by Design* gallery of the Canada Science and Technology Museum following the exclusive approach to interactivity.

[383] Wilson-Stephens, 135-137.
[384] Wilson-Stephens, 137.

The adoption of the exclusive or hybrid approaches to interactivity may be influenced by a museum's overall, or exhibition-specific, design aesthetic. For example, whilst Dr Frank Oppenheimer – founder of The Exploratorium – wanted to create exhibits that looked like 'they could be reproduced in a home workshop' in order to help visitors feel more comfortable, the exhibits were designed without 'the need for a uniform institutional style or consistent aesthetic.'[385] In contrast, other museums design their exhibits to look brand-new. For example, Caulton describes the design philosophy behind the Techniquest science centre, Cardiff, as an adoption of the 'Disney philosophy' in which the exhibits – which have 'a similar physical appearance to each other' - help to make the museum 'look as though it had opened yesterday.'[386] Therefore, we can see that electronic musical instruments are subject to interpretative flexibility – both as prototypes or manufactured technologies, and as interactive exhibits in museums – as the result of various factors which help to expand the scope of instrument designs. Nonetheless, we must acknowledge that many museums do not follow a set aesthetic for exhibit designs, and that multiple approaches to exhibit design may be evidenced across several different exhibitions in the same museum.

6.6.2 User Testing and Interpretative Flexibility

The practice of user-testing in the museum allows visitors to – often knowingly - influence the design of interactive exhibits. To help construct learning outcomes specific to an exhibit, and to help make the experience of using the exhibit more entertaining, exhibition teams may carry out user-testing (preferably before an exhibition opens) as a key component of a user-centred design approach that helps to anticipate eventual use 'by engaging people […] who are considered to be potential future users.'[387] Additionally, many exhibition teams rely on formative (and summative) user-testing to help determine whether an exhibit's interface needs to be adjusted further. In fact, the 'need to design interactive media that can be adapted as technology changes' was advocated for as a 'useful idea museums can implement to start working with interactive media' during the *New Directions in Interactive Media Symposium* of 2018.[388]

In many cases, exhibits are modified inside the museum – itself - so that exhibition teams can develop a closer relationship with the exhibits 'on the floor,' and with the visitors that use them. For example, Kullman describes the exhibits built and modified within The Exploratorium as *perennial prototypes*: multi-

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[385] Elaine Heumann Gurian, 'Noodling Around with Exhibition Opportunities', in *Exhibiting Cultures: The Poetics and Politics of Museum Display*, ed. by Ivan Karp and Steven D. Lavine (Washington D.C.: Smithsonian Institution, 1991), 179.
[386] Caulton, 7 and 41-42.
[387] Redström, 414.
[388] Alan Govenar, 'New Directions in Interactive Media for Museums', *American Alliance of Museums*, 2019 <https://www.aam-us.org/2019/01/11/interactive-media-for-museums/> [accessed 7 October 2020].

sensory devices whose temporary status on the exhibition floor is 'open to reconsideration.'[389] These prototypes are the result of a continual tinkering process which starts with the prototyping of ideas with colleagues and visitors, leading to the promotion of certain exhibits to the exhibition floor in a temporary state so that exhibit developers can carry out repairs and upgrades as a way of responding to 'shifting user requirements,' resulting in new insights about their exhibits which can be incorporated into future iterations. [390] This iterative process demonstrates a new perspective on interpretative flexibility in the context of continual exhibit development, suggesting that the approaches to interactivity discussed in the previous paragraphs may not result in 'finalised' or 'fixed' exhibits.

However, the three case study chapters demonstrated that not all museums and science centres have access to the same repair and upgrade facilities as the Exploratorium and may not design their exhibits in-house. This means that repair and upgrade work could be more challenging and less immediate, considering that the original designers (or exhibit developers) may be external to the institution. Furthermore, as an interactive exhibit may be reused in a different exhibition context, or even travel to another museum (as was the case with the MR-808 in chapter four), we can extend the concept of interpretative flexibility further. Not only can an exhibit take many forms during the stages of its development, but it may also be redesigned or reframed for new exhibition audiences in completely different museum spaces.

6.6.3 Creating Simpler Exhibits

With interactive design, the potential to offer multiple functionalities and controls is often discouraged. For example, Pearce stresses that 'more choice can be dangerous, especially if the choices appear to have no consequences,' and advocates for a *reductive technology* approach whereby interactive designers are asked to 'start with the person, develop the experience, and then ask yourself, What is the minimum technology I need to create this experience?'[391] Similarly, Clay argues that 'the most elegant solutions are those that use fewer materials, are unfussy and yet do a better job compared to their more complicated rivals,' quoting modernist architect Miles van der Rohe's phrase 'less is more' as a move towards 'simplicity, not in a crude sense but rather to beautifully get the maximum out of the minimum.'[392] With this in mind, the installation of a pre-existing manufactured instrument for interactivity might not be the best option if an exhibition is aimed towards a general audience: especially if the complexity of the interface may

[389] Kim Kullman, 'Perennial Prototypes: Designing Science Exhibits with John Dewey', in *Advancements in the Philosophy of Design*, ed. by P.E. Vermaas and S. Vial (London: Springer, 2018), 195.
[390] Kullman, 193-195.
[391] Pearce, 128 and 275.
[392] Robert Clay, *Beautiful Thing: An Introduction to Design* (New York: Berg Publishers, 2009), 4-5.

hinder the potential for visitors to confidently explore the sounding potential of an instrument, or to find and connect a specific sound to a piece of music (as we saw with the Memotron M2K in chapter three).

Nonetheless, the potential remains to design new interactive exhibits which are too complex for members of an exhibition audience to use. For example, Allen and Gutwill describe common pitfalls they encountered whilst designing and observing new interactive exhibits in The Exploratorium, which they summarise as follows:[393]

> There are many ways that interactive exhibits can fall short of creating a powerful, successful visitor experience. They include such things as poor accessibility (physical, sensory, or intellectual), confusing directions, controls that do not follow cultural conventions (such as turning a knob clockwise to decrease something), unclear feedback on whether the user has made a change to the exhibit, interaction that is so limited or mundane that it frustrates or bores visitors, fragility, lack of safety, and many more.[394]

The authors provide three possible solutions as a way of addressing these common pitfalls: 'limiting functionality', 'segmenting functionality', and 'creating a hierarchy of salience'.[395] However, they also argue that each exhibit will have 'its own optimal set of interactive features' which contribute to its unique design sweet spot: 'too few and the exhibit fails to engage visitors, but too many and the experience is confusing, disrupting or overwhelming.'[396] Nonetheless, as was evidenced with the Electronic Sackbut interactive exhibit in chapter two, there may exist scenarios where external designers might not understand the audience they are designing for – or even understand how the original instrument worked - leading to some of the common pitfalls described by Allen and Gutwill being encountered.

6.6.4 Accessibility and Multi-Sensory Exhibits

The term 'accessibility' can mean different things to different people. In the context of providing an interactive exhibit that many visitors will feel comfortable in using (or accessing), Pearce considers

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[393] Allen and Gutwill, 199 and 201.
[394] Allen and Gutwill, 200.
[395] Allen and Gutwill, 208-210.
[396] Allen and Gutwill, 210. This observation is based on a study by Allen and Feinstein which compared three iterations of a microscope-based exhibit.

accessibility as a way to make technologies seem 'friendly,' with the aim of creating a 'minimum intimidation factor.'[397] As Pearce argues, many people are 'natural technophobes' and 'reticent when encountering something new,' which may be especially true of museum exhibitions which feature many new and unique exhibits.[398] This may also be the case with specific types of visitor: particularly with exhibits that represent an inequality of access to 'real world' technologies and practices for certain communities. Therefore, exhibits should be designed to help eliminate fear, which Pearce argues is 'the greatest impediment to engagement, learning, and play'.[399] Similarly, authors such as Bjorn advocate for electronic musical instruments to also be made accessible, benefitting both novice and veteran users:

> Ideally, a beginner-friendly interface should make it easy to understand what everything does and how it all connects together. The novice who obtains good results from clearly-indicated actions is encouraged to explore more deeply. The more advanced user also benefits from the quick and easy results of such an interface design.[400]

The consideration of accessibility in the context of providing multi-sensory experiences can also help more visitors to attain the most knowledge and pleasure from their museum visit, and not be excluded as a non-user.[401] In terms of accommodating those who identify as having additional physical and learning needs, exhibition teams may have to consider multiple – or alternative – modalities when redesigning and installing electronic musical instruments for interactivity. Although it may be presumed that auditory modalities would be the focus: visual, haptic, and vibrational feedback can also augment the sensation of sound or, for deaf visitors and those who suffer from hearing-loss, provide essential feedback in relation to their actions. It is particularly important to consider this with electronic musical instruments because the controls on an interface often produce little visual or haptic feedback as to how the sound is being generated or modified (compared to the vibration of strings on a guitar, for example). Nonetheless – as previously highlighted - exhibition teams should consider how sound and other forms of multi-sensory content are managed in exhibition spaces so as not to negatively affect the experiences of other exhibits

[397] Pearce, 406.
[398] Pearce, 406.
[399] Pearce, 406.
[400] Bjorn, 24.
[401] Sally Wyatt, 'Non-Users Also Matter: The Construction of Users and Non-Users of the Internet', in *How Users Matter. The Co-Construction of Users and Technology*, ed. by Nelly Oudshoorn and Trevor Pinch (Massachusetts: The MIT Press, 2005), 76.

and objects displayed nearby.[402] This was the case with the installation of my exhibit within a 'Sound Circle', as discussed in chapters seven and eight.

6.7 Conclusion

In this chapter, we have considered sound and touch as additional modalities to the observation of electronic musical instrument objects, using sound playback devices and interactive exhibits. The latter is important as it allows visitors to better understand how sounds are generated, triggered, and shaped using an instrument's interface. However, the complexity of museums, audiences, and instruments means that the inclusion of instrument sounds and tactile interfaces is not straight-forward and, for many different reasons, it can be difficult to arrive at the best possible solution for interactivity.

Additionally, we have to consider the opinions and desires of multiple stakeholders – as much as the expectations and assumptions of visitor behaviours – towards the installation of content that visitors can touch and the consequences of wear and tear, or even misuse, caused by touching. Whilst many of the solutions offered above by authors and members of exhibition teams may attempt to help create more 'ideal' experiences of electronic musical instruments, unfortunately there is little one can do to completely remove the possibility of an exhibit being compromised or destroyed as the result of someone's intended or unintended actions. As is demonstrated in chapter eight: whilst members of exhibition teams may anticipate and prepare for the actions of a few that have negative consequences, there still remains the hope that these actions will not occur as the exhibition team are likely to retain and action the responsibility for repairs and upgrades.

We have also seen how important it is for sound to be heard, as part of a sound genealogy methodology. Whilst exhibition teams have traditionally focused on the designers and users of instruments, there remains a history of people responsible for creating and developing sounds, which can be brought to life through the inclusion of particular sounds in relation to instruments. Nonetheless, if exhibition teams are considering a sound genealogy methodology, they must ensure that both sounds and interfaces remain connected, to ensure that visitors are able to connect what they hear to lived experiences of musical and cultural developments (for example). It may even be the case that sounds can be used to not only represent a musician's personal or musical development - as with the *David Bowie Is…* exhibition – but may also trigger memories of a visitor's own developing personal or musical identities, which may align with the

[402] A discussion of approaches to sound management in exhibitions is beyond the scope of this thesis, but authors such as Everrett, Voegelin and Bijsterveld have advocated for various approaches based on exhibition case studies, which demonstrate that sound should be considered to be as important as visual stimuli in exhibitions.

musician in question. Therefore, exhibition teams should acknowledge the demonstrative value of sound and tactility for visitors as these forms of content can help bring to life, and unify, the histories of instruments, sounds, and people.

7 Creating a New Exhibit for an Exhibition on Sound

7.1 Introduction

Both digital time-stretching technology (enabling musicians to ‘lengthen or shorten a sample […] without any change in pitch’) and the Amen breakbeat (a drum solo excerpt taken from the song ‘Amen, Brother’, performed by The Winstons in 1969) have become synonymous with drum and bass music (also referred to as ‘drum ‘n’ bass’ or ‘jungle’ music) and other forms of electronic dance music since the early nineties.[403] However, although potential museum visitors may have heard the effect of time-stretching in many forms of recorded music, they may have remained unaware of the name of the effect, how the results were produced, or the significance of this technology in helping various musical genres to form their own sonic identities.[404] Similarly, although it is likely that people have heard the Amen breakbeat before, the name of the breakbeat, its origins, and its relationship to sampling technologies and instruments – such as the Akai S950 digital sampler – might not be known.

The aim of my exhibit, *Drum and Bass - Time and Space,* was to allow visitors at the NSMM to alter the speed (*Time*) of a pre-recorded (sampled) looping Amen breakbeat (*Drum*) using digital time-stretching technology to either make it fit within certain boundaries of musical genres or produce a special effect when using more extreme, slower settings (what Hockman describes as a ‘metallic sound’).[405] The time-stretching effect would be actioned in unison with an eight-channel sound diffusion within a 360° acoustic environment created by eight speakers positioned above the visitors (*Space*). After pressing play to commence the playback of the Amen breakbeat, both the time-stretching and sound diffusion could be controlled using a single joystick. Additionally, a selection of large arcade-style buttons allowed visitors to play a digitally-generated sawtooth waveform (*Bass*). This could be performed and heard either on its own or in unison with the Amen breakbeat, although the *Bass* sound could only be heard through the two front speakers of the eight-channel configuration and through an additional sub-woofer (re-producing loud bass frequencies that could be heard as well as felt: an affect synonymous with consuming drum and bass music in nightclubs). Additionally, the movement of the joystick affected both the timing of the drums as well as

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[403] Akai Professional, ‘Akai S950 Owners Manual’, 1988 <http://manuals.fdiskc.com> [accessed 18 May 2020], 6; Christian Dittmar and Meinard Muller, ‘Reverse Engineering the Amen Break: Score-Informed Separation and Restoration Applied to Drum Recordings’, *IEEE/ACM Transactions on Audio Speech and Language Processing*, 24.9 (2016), 1531.

[404] John Walden, ‘Time-Stretching’, *Sound on Sound*, 2007 <https://www.soundonsound.com/techniques/time-stretching> [accessed 15 May 2020].

[405] Jason A. Hockman, ‘An Ethnographic and Technological Study of Breakbeats in Hardcore, Jungle, and Drum & Bass’ (McGill University, 2013), 125.

the speed of a low frequency oscillator (LFO) applied to the filter frequency of the bass: helping to create an experience of synchronisation when either *Bass* button was held down. Digital MIDI communication and audio content was facilitated and hosted by Max software (installed on a desktop PC) and an Arduino micro-controller.

In this chapter, I explore the technologies, sounds, cultures, and practices associated with the above, in the contexts of meeting the needs of an exhibition and its anticipated audience. First, I explore the influence that the museum's list of pre-requisites (as stated in their call for submissions) had on the identification and – if successful – actioning of design qualities which would guide an exhibit towards meeting both the museums and its anticipated visitor's needs, with the least amount of ongoing invigilance from museum staff. Subsequently, after using sound genealogy to analyse the entanglements of drum and bass music, the Amen breakbeat, time-stretching functionality, and surround-sound technology, the construction and prototyping of the exhibit and its supporting interpretative tools are explored. The guidance provided by other exhibition team members, as well as the availability and suitability of technological resources, is also acknowledged.

7.2 Background

7.2.1 The Science Museum

According to Heumann Gurian, most science and technology museums were 'created […] to enlist the public's concurrence about the progress and future of industry,' offering a more permanent residence for science and technology object collections previously demonstrated at temporary events.[406] In America, science and technology institutions blossomed from the World Fair movement in the early twentieth century, as a means of demonstrating contemporary innovations in science and technology to the public.[407] In the UK, Bud traces the origins of the Science Museum back to the 'huge Loan Collection of Scientific Apparatus' exhibited in the South Kensington Museum in 1876 (the museum, of which, existed as a legacy of the Great Exhibition of 1851), which led to a permanent exhibition that was 'formally entitled the 'Science Museum'' in 1885.[408]

406 Heumann Gurian, 178.
407 Pearce, 314.
408 Robert Bud, 'Responding to Stories: The 1876 Loan Collection of Scientific Apparatus and the Science Museum', *Science Museum Group Journal*, Spring.1 (2014); Liba Taub, 'What Is a Scientific Instrument, Now?', *Journal of the History of Collections*, 31.3 (2019), 453–67.

There is a deep history to the provision of working objects and interactive exhibits at this museum. According to the Science Museum Group's (SMG's) website, the Science Museum 'has pioneered interactive science interpretation for more than eight decades.'[409] In fact, Mann argues that the Science Museum has 'probably been operating objects longer than any other museum in the world.'[410] Additionally, Caulton sites the Science Museum's *Children's Gallery*, which opened in 1931, as one of the first science centre experiences in the world.[411] Over the past forty years, interactivity at the Science Museum has often been attributed in literature to the *Launch Pad* exhibition which opened in 1986, following previous user-testing with exhibits in exhibitions such as the *Discovery Rooms* and *Test Bed* in the same decade.[412] In more recent years, as highlighted in previous chapters, the museum has also explored electronic musical instrument through objects, interactivity, and sound in exhibitions such as *Digitopolis* (2000 - 2006), and *Oramics to Electronica…* (opened in 2011).[413] The more recent exhibitions reflect the changes in the Science Museum's approach to exhibit design: whilst the museum initially produced its exhibits in-house (mirroring the approach of science centres such as The Exploratorium), it now contracts the development and construction of many exhibits to external firms.[414] Doing so may have potentially expanded the scope of interactive design practice towards multi-sensory exhibition content in the museum (evidence, of which, has been highlighted in previous chapters).

7.2.2 The National Science and Media Museum

Under various guises, the NSMM has aimed to blend the sometimes seemingly disparate worlds of art and science. When the building first opened as the National Museum of Photography, Film and Television in 1983 (in the same location as it currently stands), its collecting and exhibiting remit explored 'the art and science of the image.'[415] At the time of opening, the museum's multimedia and interactivity offer shared much in common with the boom in UK science centres, which included Techniquest in Cardiff, as well as the opening of The Exploratory in Bristol and Eureka! In Halifax in 1987.[416] Sound also played an important role

[409] 'About Us', *Science Museum Group* <https://www.sciencemuseumgroup.org.uk/about-us/> [accessed 29 April 2021].
[410] Mann, 382.
[411] Caulton, 3.
[412] Caulton, 4.
[413] 'Digitopolis, Science Museum'; Boon, van der Vaart, and Price.
[414] Caulton, 42.
[415] 'About Us', *National Science and Media Museum, Bradford* <https://www.scienceandmediamuseum.org.uk/about-us> [accessed 10 February 2021].
[416] Sharon MacDonald, *Behind the Scenes at the Science Museum* (Oxford: Berg Publishers, 2002), 39.

in the museum's formative years: as an essential part of the UKs first iMax cinema, installed in the museum in 1983, and integral to the first live broadcasting studio in a museum, launched in 1989.[417]

When it was later known as the National Media Museum (a title which reflected the institution's expanding collecting and exhibiting remit, which now featured web and digital technologies) it became part of the SMG, which also includes the Science Museum in London, the National Railway Museum in York, the Science and Industry Museum in Manchester, and Locomotion in Shildon. One major advantage of belonging to this group was the provision of access to a much larger collection resource, shared between all the museums. However, it also provided the museum the opportunity for new financial investment which could address the problems the institution faced in struggling to attract the number of visitors it once did (460,000 in 2016, compared to nearly one million in 2001).[418] However, the SMG's acquisition of this museum was also seen as controversial, as it led to the movement of a photo archive consisting of nearly 400,000 photographs to London's V&A Museum: an archive that formed an important part of the museum's collection when it was known as the National Museum of Photography, Film and Television.[419]

As the NSMM, the institution's exhibitions have continued to utilise the SMG's collection, placing various science and media objects together, often accompanied by physical and virtual interactive content.[420] However, the museum also hosts exhibitions that consist entirely of interactive exhibits: similar to that found in science centres. For example, the £1.8 million *Wonderlab* exhibition features bespoke multi-sensory, hands-on exhibits that allow visitors to 'explore light and sound and discover how they're the building blocks of the technology and media that surround us every day.'[421] In contrast, the *Games Lounge* (which was originally opened in 2010 whilst the museum was still named the National Media Museum) allows visitors of all ages to trace the evolution of digital gaming and experience it through the use of original games and gaming consoles, as well as original arcade machines.[422]

Where appropriate, the NSMM also attempts to involve members of the public (i.e., potential museum visitors) in the production of museum exhibition content, online content, and research through activities such as workshops with schools and communities, the documentation of oral histories, social media communication, and the user-testing of exhibition content. Recent examples of this work include the production of the exhibition *Above the Noise: 15 Stories from Bradford* (as part of *Bradford's National*

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[417] 'About Us', *National Science and Media Museum*. Examples of music and sound objects, as well as interactive experiences, can be seen in the museum's online *History in Pictures* gallery, which includes images of the museum's BBC tri-media studio (opened in 2003) and the Experience TV gallery (2006).
[418] 'Bradford's National Media Museum Changes Its Name', *BBC News*, 2017 <https://www.bbc.co.uk/news/uk-england-leeds-39209528> [accessed 10 February 2021].
[419] 'Bradford's National Media Museum Changes Its Name'.
[420] 'About Us', *National Science and Media Museum*.
[421] 'Bradford's National Media Museum Changes Its Name'; 'Wonderlab', *National Science and Media Museum, Bradford* <https://www.scienceandmediamuseum.org.uk/wonderlab> [accessed 10 February 2021]; 'Games Lounge', *National Science and Media Museum* <https://www.scienceandmediamuseum.org.uk/whats-on/games-lounge> [accessed 10 February 2021].
[422] 'Bradford's National Media Museum Changes Its Name'; 'Wonderlab'; 'Games Lounge'.

Museum project) which evidenced a dialogue between museum staff, people who live and work in Bradford, and researchers from the University of Leeds (all of whom comprised that specific exhibition team).[423] The fifteen stories demonstrate an example of the museum's approach to gaining new insights into its collections by following an action-research methodology - supporting 'participative solutions to entrenched problems,' in order to promote social inclusion.[424]

Additionally, the museum has recently moved towards an enhanced consideration of sound in exhibition spaces, supported by additional collecting and research into music and sound technologies. This is reflected on the museum's website, which now states: 'At the National Science and Media Museum […] we explore the science and culture of image and sound technologies and their impact on our lives.'[425] Several events and workshops (such as the museum's Lates events) have allowed members of the public, researchers, and sound practitioners to inform and better understand the role and value of the museum in terms of the preservation, display, and research of these technologies. Additionally, research projects such as *Sonic Futures* have aimed to 'identity new ways of engaging listening audiences with sound technology objects in museums' through the creation of digital and online 'interactive sounding exhibit prototypes,' experienced within particular listening scenarios.[426] This activity helped to guide the exhibition team at the NSMM in planning and realising their *Sound Season* of exhibitions, which were initially scheduled to open in April 2020 but were postponed until 23 July 2021 due to the impact of COVID-19 (more on this later). Both these exhibitions - which closed on 5 December 2021 – as well as the temporary exhibition *Use Hearing Protection: The Early Years of Factory Records* at Manchester's Science and Industry Museum (also part of the SMG) which opened around the same time, could be considered as a testing ground to inform the planning and provision of permanent *Sound and Vision* galleries at the NSMM (scheduled to open in 2024), which could assist the museum in becoming known as 'a site of audio as well as of visual experience.'[427]

[423] 'Part 1: Moments', *Bradford's National Museum* <https://bradfordsnationalmuseum.org/part-1-moments/> [accessed 9 February 2021].
[424] Burns, 1.
[425] 'About Us', *National Science and Media Museum*.
[426] Mansell, Little, and Jamieson, 1 and 9.
[427] Katie Canning, 'Press Release: Museum Secures National Lottery Support to Begin Development of Ambitious Sound and Vision Project', *National Science and Media Museum*, 2021 <https://www.scienceandmediamuseum.org.uk/about-us/press-office/museum-secures-national-lottery-support-begin-development-ambitious-sound-and> [accessed 13 October 2021]; Mansell, Little, and Jamieson, 2.

7.3 Call for Submissions

7.3.1 Theme

According to the original web page for the exhibition, the aim of the *Sound Season* was to explore 'how sound fills our world, how it's created, and how we can experiment and play with it,' and give visitors the opportunity to 'delve into the world of electronic sound with exciting new installations and interactive sound works from artists, scientists and makers.'[428] The overall exhibition team included staff at the museum and external designers Hadley Interiors and Field Dot Studio - in collaboration with Peter L Dixon design - who were commissioned to design the exhibition spaces and produce the main interactive content.[429] Additionally, the diverse community of successfully appointed global makers, artists, and researchers (myself included) were commissioned to design six individualised exhibits known as 'micro-commissions' (more on this later). These were introduced to the *Sonic…* exhibition on a rolling basis i.e., only two of the six were on-gallery for roughly nine weeks at a time. The first two commissions consisted of *Gramophony* by Jobina Tinnemans (displayed in the main exhibition area) and my exhibit, *Drum and Bass – Time and Space* (exhibited in the semi-enclosed *Sound Circle* space, opposite *Gramophony*).[430]

In the call for submissions, micro-commission applicants were asked to identify which of the following themes their interactive exhibit would speak to:

- 'Sound is created by vibration in a source which passes on to the air around it, forming a sound wave.
- Sound waves behave differently in different conditions (different media, reflections in different spaces etc.)
- Visualising sound in different ways can help us to understand it.
- How sounds are received and processed by both natural and artificial 'ears.'

[428] National Science and Media Museum, 'Sound Season', 2020 <https://www.scienceandmediamuseum.org.uk/whats-on/sound-season> [accessed 12 May 2020].
[429] fielddotstudio, 'Field.Studio (@fielddotstudio)', *Instagram*, 2021 <https://www.instagram.com/p/CRg9xu7hW1y/> [accessed 24 April 2022].
[430] 'Press Release: New Exhibitions to Uncover How Sound Shapes Our Lives', *National Science and Media Museum*, 2021 <https://www.scienceandmediamuseum.org.uk/about-us/press-office/new-exhibitions-uncover-how-sound-shapes-our-lives-0> [accessed 26 November 2023].

- When we understand how sound works we can synthesise, record and edit it, then put it to work in new ways.'[431]

Referring back to the museum's statement regarding the science and culture of sound on its website, the themes above suggest that the *Sound Season* is focused more on the impact that the *science* of sound has on our lives, rather than its *cultural* value. However, the agency for visitors to interpret the exhibition's objects, sounds, and interactive content based on their cultural values remains.

My exhibit explores the impact of time-stretching technology in helping new genres of electronic dance music to emerge, which has already demonstrated a technique for putting recorded audio to work in new ways. Therefore, in my proposal for the micro-commissions programme, I stated that my exhibit would speak to the theme 'when we understand how sound works we can synthesise, record and edit it, then put it to work in new ways.' Additionally, the focus on interfacing directly with time-stretching technology, augmented by sound diffusion across eight speakers, provides additional evidence for putting recorded audio to work in a way that is unique to the exhibition.

7.3.2 Meeting the Requirements

The call for submissions included various requirements for each applicant to consider in their application. These included:

- Being physically robust enough to remain on gallery for this length of time with minimal invigilation and with our lively, mixed-age audiences.
- The piece needs immediate and obvious visitor appeal for a mixed-age, non-specialist audience.
- The piece shouldn't be too subtle in the effects or phenomena being demonstrated. Visitors are not critical listeners and need an 'in your face' effect that can't be missed.
- Either individual or group experiences are welcome.
- The work must stand alone on gallery with minimal invigilation: not necessarily interactive (though that would be good) but it must have some visual and/or conceptual interest that can be represented in text or via on-screen interpretation.

[431] National Science and Media Museum.(the initial call for submissions was hosted at this link but has since been replaced by information directed at the general public regarding the upcoming Sound Season of exhibitions)

- Installation needs to be quick and simple because the majority of commissions will need an overnight install to minimise disruption to our visitors. Please consider how your work can be adapted to this turnaround schedule.
- A key concern is gallery accessibility for our audiences. Please consider accessibility requirements in your response e.g., children, wheelchair users.

Some of these requirements would also be shaped by whether applicants would prefer to install their exhibit in a semi-enclosed, acoustically treated space (the *Sound Circle*) or in an open, untreated space away from other sound-emitting content (both measuring approximately 3m x 3m). The aim of providing these options was to help manage the sound emitted by each exhibit within the overall exhibition space and avoid bleed, which could potentially confuse and frustrate visitors.

Some of these requirements assumed certain characteristics of the anticipated audience. Whilst all visitors have been described as 'lively,' 'mixed-age,' 'non-specialist,' and 'non-critical listeners,' some of these visitors may also be identified as having specific 'accessibility requirements.' Nonetheless, without being able to travel through *Time and Space*, myself, and witness who the audience would be first-hand, my priority was to demonstrate how the exhibit would meet the requirements in consideration of the anticipated audience in the hope of being successfully commissioned (and 'successfully' engaged with, if successful). The ways in which the final design was intended to meet the requirements are described below.

7.3.2.1 Physically Robust

Considering the anticipation of a 'lively' audience, the exhibit needed to be physically robust and withstand heavy use from potentially thousands of visitors: some of whom may engage with the exhibit in ways that members of the exhibition team did not intend or anticipate. Therefore, materials and electronic components were chosen for the exhibit to help ensure this. For example, the technical specification sheet for the chosen joystick stated that it was 'specifically designed for robustness, strength and performance' and should last for 5 million cycles: making it an ideal tactile control for this exhibition.[432] Additionally, there were no removable parts or sharp edges which could have been problematic, especially for younger visitors.

[432] APEM, 'BF240A01BK1200', *RS-Online* <https://uk-rs-online.com/mobile/p/joystick-switches/7275961> [accessed 18 May 2020].

7.3.2.2 Immediate and Obvious Appeal

Although this exhibition was focused on the science of sound as opposed to sound in culture and social history, the content was intended to be relatable and appealing to a mixed-age audience (as anticipated in the call for applications) as part of a wider celebration of the history of electronic sound – or, in other words, *Adventures in Audio* and *Experiments in Sound* (as the exhibition titles state). As the drum and bass genre is approaching a thirty-year history and is still a popular form of electronic dance music, the title for the exhibit *Drum and Bass - Time and Space* and the inclusion of the Amen breakbeat was intended to make the exhibit appeal to the exhibition's audience.

7.3.2.3 An 'In-Your-Face' Effect

Despite increasingly available and user-friendly tools for multi-channel sound diffusion, many musicians of electronic music compose and perform within a stereo configuration in order to produce work that can be consumed through conventional stereo (or mono) loudspeaker and headphone configurations (which reflects Smalley's argument: accepting what is commercially available and using it).[433] Therefore, the opportunity to engage with sound diffusion within the exhibit's 360° acoustic environment should present a unique and appealing experience for most visitors, regardless of prior musical knowledge or skill. Furthermore, in situations where people experience a *live* public performance (as is the case when visitors use my exhibit), Smalley argues that 'in order to create a rewarding experience, (one has) to provide something more than what is possible when listening at home.'[434] My exhibit attempts to create a 'rewarding experience' in the following way. When leaving the joystick in its centre position, an Amen breakbeat plays at one continuous tempo through just two speakers – the traditional method of listening to (and, in reference to DJ practice, mixing) electronic dance music. When the joystick is moved, visitors can continually modify the playback speed of the breakbeat to fit different tempos and shift the spatial position of playback in the acoustic space. The combination of multi-channel sound diffusion, a tactile interface, clear visual feedback from lights behind each button (actioned when the buttons are pressed), and vibrations produced by the sub-woofer, was intended to produce a multi-sensory, 'in-your-face' experience in the exhibition (as requested).[435] Additionally, not only would this exhibit allow visitors to actively engage

[433] Larry Austin and Denis Smalley, 'Sound Diffusion in Composition and Performance: An Interview with Denis Smalley', *Computer Music Journal*, 24.2 (2000), 13; Natasha Barrett and Alexander Refsum Jensenius, 'The 'Virtualmonium': An Instrument for Classical Sound Diffusion over a Virtual Loudspeaker Orchestra', in *NIME*, 2016, 55.
[434] Austin and Smalley, 11.
[435] Laurel, XII.

with sound hands-on: they could also take control and manage sound within the unique acoustic *Sound Circle* environment inside the exhibition.

7.3.2.4 Individual or Group Experiences

Although most visitors should be able to perform the *Drum* and *Bass* parts simultaneously, the exhibit was designed to allow more than one visitor to use it at any time. This provides the opportunity for visitors to perform a two-player scenario in which one visitor controls the drums on the left of the interface (the large 'play' button and joystick) and sets the master tempo, whilst another visitor plays the bass on the right (via six smaller buttons). There is therefore the potential for either collaborative musical performance or a 'versus' situation where the visitor with the joystick affects the timing of the LFO applied to the other visitor's bass, challenging the stability of the overall timing during their performance.

7.3.2.5 Text or On-Screen Interpretation

Text was produced in order to explain what the significance of time-stretching technology has been in relation to digital music technology heritage, and how this relates to the creation and shaping of musical genres. The interpretational and instructional text had to be constrained to a certain number of characters in order to avoid potentially overwhelming visitors. This copy was born from an iterative collaboration between me and the NSMM's Interpretation Developer, Sarah Rawlins: the aim, of which, was to discriminate over how best to explain what the exhibit represented, and how it worked, to the anticipated audience. Therefore, the voice of the text was that of both myself - as designer, researcher, musician and drum and bass enthusiast - and the skills and expertise of the interpretation team who represented the museum.

I also created two short videos in the hope that they could be used on the museum's social media channels, as well as on-gallery (hosted on a tablet device) to accompany the exhibit. The first video explained how time-stretching worked by, first, visually simulating a user adjusting the speed of a turntable's platter by moving its pitch control up and down (changing pitch and speed at the same time); second, the re-programming of individual drum sounds as MIDI data (how both the pitch and durations of MIDI notes also remain the same when the tempo changes); and, finally, the results of digital time-stretching (how note durations alter to reflect the tempo). The second video demonstrated how the exhibit was built at home, due to the restrictions imposed by COVID-19. An additional third video demonstrated the exhibit in action whilst installed in the Sound Circle, albeit without eight channels of audio.

7.3.2.6 Quick and Simple Installation

The interface was built as a separate entity to the cabinet that was built to fix it to. This made the installation much simpler as the doors of the cabinet could be opened in order to provide easy access to the interface's MIDI and power connections. It also meant that the cabinet could be fixed to a stand before attaching the interface, providing better physical stability. Additionally, the outputs of the multi-channel audio interface were clearly labelled and ordered (from left to right of the visitor as they stood in the centre of the space) so that the museum's speakers could be connected to the corresponding outputs straight away. Additionally, the BIOS settings of the computer were changed so that the computer (and, therefore, the exhibit) would automatically turn on every morning before the museum opened, which meant that minimal invigilance was required of the museum's technicians.

7.3.2.7 Accessibility

Most of what I identified was guided by Glasgow Museum's *Practical Guide for Exhibitions*, which included several recommended practices and measurements relating to accessibility.[436] For example, the choice of tactile controls on the interface were intended to provide a simple way of interfacing with sound that produces attention-grabbing results. In other words, every button push and joystick movement would have a direct, immediate impact on the visitors' multi-sensory experience. Although buttons can be pressed in any order and the speed of the Amen breakbeat can be adjusted to any tempo with a range of 160bpm to around 30bpm, the exhibit was designed so that visitors could not 'get it wrong.' Therefore, it was hoped that visitors would be able to understand how the exhibit works as they used it, whilst some might even be able to do so without needing to refer to the accompanying text instructions. Additionally, the exhibit had to be designed in order to allow wheelchair users to be able to move freely within the space between the exhibit and the circular walled enclosure it was installed in. The exhibit's cabinet also extended to a height that made the interface (which protruded from the cabinet) accessible for both wheelchair users (whose lower body could fit underneath the protruding interface) and small children.

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[436] *Glasgow Museums Display Guidelines - A Practical Guide for Exhibitions* (Glasgow) <https://www.britishcouncil.in/sites/default/files/guidelines_for_museum_display.pdf?msclkid=22b36cc9c32511ec90ccaea5df7e1979> [accessed 23 April 2022).

7.4 Applying the Sound Genealogy Methodology

7.4.1 Time-Stretching and the Akai S950

The Akai S950 MIDI Digital Sampler (see Figure 7.1. below) was, according to its manual, 'the first sampler in its price range to feature TIMESTRETCH,' enabling musicians to 'lengthen or shorten a sample by as much as 999% without any change in pitch'.[437] The sampler's 12-bit processing and 'cyclic' approach to time-stretching produced a unique aesthetic sound quality that has been described as a 'classic metallic-sounding effect.'[438] For *Drum and Bass - Time and Space*, the sound quality of the time-stretching function - produced using Max graphical programming software - was adjusted to 'low', which helped to achieve a more realistic replication of the Akai S950's time-stretching effect when applied to the sampled Amen breakbeat (also hosted in Max). As the time-stretching function of this sampler was often used to help create and shape early drum and bass music, a resulting time-stretched sound was representative of the music from that era. However, as Akkermann argues, the problem with attempting to create an exact authentic replication of sound is that 'the outcome is always reflected in comparison to the original which comes with all the constraints and imaginations of the past'.[439] Nonetheless, the 'low' setting in Max also helped to reduce the load on the computer so that the sound was less likely to stutter or drop out. The choice of Max seemed appropriate for this project because, as Boeva and others propose, it's programming language was 'originally developed by electronic musicians using the metaphor of a network of […] devices connected by physical patch cords.'[440] It also allows one to share the code on a website (such as GitHub) - along with electronic circuit diagrams and instructions for fabricating the exhibit - so that others can re-create, test and – importantly - *research* the experience later.[441]

[437] Akai Professional, 'Akai S950 Owners Manual', 1988 <http://manuals.fdiskc.com> [accessed 18 May 2020], 6.
[438] 'The AKAIZER Project', *The Akaizer Project* <http://the-akaizer-project.blogspot.com/?m=1> [accessed 18 May 2020].
[439] Miriam Akkermann, 'Archiving Music, Preserving Digital Instruments: Considerations on a Mutual Relationship', in *Electronic Musical Instruments in Collection Context*, ed. by Benedikt Brilmayer, Seven (Mainz: Schott Music, 2022), 96.
[440] Boeva and others, 167.
[441] Boeva and others, 171-172.

Figure 7.1. The Akai S950 MIDI Digital Sampler.

As the effect was often deployed in drum and bass music of the early nineties (when the genre first emerged) via the Akai S950 (and other models within the company's S-series of samplers), this aesthetic quality - as reproduced in my exhibit - links *Drum and Bass - Time and Space* to the genre as composed and heard in the nineties. However, time-stretching is still used as both a functional means of changing the playback speed of samples and as a special effect, although its deployment using contemporary technologies often creates a 'cleaner' aesthetic quality (using higher sampling bit-depths and better time-stretching algorithms) compared to that produced by the Akai S-series of samplers. Additionally, the upper limit to the time-stretching effect (160bpm) was chosen for this exhibit as a way of reflecting the average speed of drum and bass music in the early nineties, which has since increased to around 175bpm (see Figure 7.2. below).

Figure 7.2. The tempos of drum and bass tracks and other forms of hardcore music stated on the back cover of the CD 'Speed Limit 140 BPM Plus Three', released in 1993.

Aside from drum and bass music, time-stretching has also been used to both change the speed of audio playback to fit within different musical genre boundaries, and create a special effect, in popular music such as Fatboy Slim's 'The Rockefeller Skank' (in which Akai S950 hardware samplers were used to produce different time-stretching effects throughout the composition).[442] The aesthetic qualities have also been replicated in the freeware software application *Akaizer*, which was designed to offer users a similar quality to that produced by the original Akai S950 hardware without needing to purchase the sampler second-hand.[443] Beyond its time-stretching function, the S950 was still often used as the main sampling machine by musicians of early rave and techno music who needed a sampler to sample breakbeats, such as Bradford's Unique 3 who used two S950s in combination with a sequencer.[444] Additionally, other samplers from Akai's S-series which also provided the time-stretching function were equally desirable by musicians from the same era, such as the band Underworld who used both the Akai S3200XL and S6000 samplers.[445]

As stated in the introduction to this chapter, although the Akai time-stretching sound has been globally disseminated in recorded popular culture and in various musical tools that replicate the effect, potential visitors may not know what this effect was called, how it was produced, nor the various ways it has been used in composition and the impact this has had in generating and shaping genres of electronic music.[446] Therefore, the interpretational text accompanying the exhibit focused on summarizing these important points in the first paragraph:

> In the 1990s digital sampling technology such as time-stretching helped to create new music like drum and bass through the shaping of sounds to fit new tempos. Unlike changing the speed of a record on an analogue turntable, time-stretching changes the speed of playback whilst the pitch remains the same.

The comparison to how the rotational speed of analogue turntables affects the sound of records was intended to help make digital time-stretching more relatable by association to a more common, household technology.

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442 Tom Doyle, 'Classic Tracks: Fatboy Slim 'Praise You'', *Sound on Sound*, 2017 <https://www.soundonsound.com/techniques/classic-tracks-fatboy-slim-praise-you> [accessed 15 May 2020].
443 'The AKAIZER Project'.
444 Simon Trask, 'Dial 0274 For Bass (MT Feb 91)', *Music Technology (Mu:Zines Music Magazine Archive)*, 1991 <http://www.muzines.co.uk/articles/dial-0274-for-bass/778> [accessed 24 April 2022]; Hockman, 79.
445 Paul Tingen, 'UNDERWORLD: The Making Of Everything, Everything', *Sound on Sound*, 2000 <https://www.soundonsound.com/people/underworld-making-everything-everything> [accessed 19 November 2023].
446 Walden.

Nonetheless, whilst many would argue that the provision time-stretching technology at an affordable price has been the most significant innovation of the Akai S950, the sampler does not label this function anywhere on its front panel: not even in the written list of button-pressing combinations that serves to highlight how users can access various functions. In other words, you cannot *see* the time-stretching function on the instrument; you can only *hear* its effect. Therefore, if it were to be displayed as an object in a museum, exhibition teams would have to use additional interpretative resources to attempt to highlight and direct visitors towards the importance of including such an object, based on how this functionality was used. Similarly, although sounds on a floppy disk could be labelled and, therefore, displayed in material form next to the instrument, they nonetheless remain hidden inside if the instrument is displayed as an object that is turned off and silenced (albeit only epistemically, as imported sounds are lost once the machine is turned off). As was the case with the Roland TR-808 case study (chapter four), this helps to demonstrate why multi-sensory interactive exhibits can be vital as demonstrative tools that help to uncover hidden functionalities and sounds and bring them to life, whilst also widening the scope of electronic musical instrument interpretation beyond the display of objects in the same space. This also helps to demonstrate a paradox: whilst designers of digital instruments often hide offline functionalities within menus, digital interactive design can uncover those hidden functionalities (and sounds) through new, simpler interfaces and custom mapping, allowing visitors to engage with them as an online experience.

7.4.2 The Amen Breakbeat and Drum and Bass

Although the Amen breakbeat is synonymous with the (mostly sampled) percussion palette for drum and bass music – a genre of electronic dance music whose tempo usually exceeds 155bpm – the breakbeat's original performance can be traced back to the soul song 'Amen, Brother' performed by Gregory C. Coleman of The Winstons in 1969 (hence the name given to the breakbeat).[447] Breakbeats such as the Amen were usually performed using acoustic percussion instruments – part of the Hornbostel-Sachs classifications of membranophones and idiophones - such as those often found in drum kits (kick drums, snare drums, hi-hats, cymbals, etc.) and others such as woodblocks, shakers and tambourines.[448] During the original performance of the Amen breakbeat, these acoustic percussion instruments would have been recorded using a number of microphones and combined with other instruments and vocals to form the final, recorded song which was intended to be disseminated as consumable physical (and, later, digital) media.[449] The fact that breakbeats usually exist as percussion solos within recorded songs (i.e., moments in

[447] Dave Turner, 'The 20 Best Tracks That Sample the Amen Break', *Mixmag*, 2018 <https://mixmag.net/feature/the-20-best-tracks-that-sample-the-amen-break> [accessed 1 June 2020].
[448] Dittmar and Muller, 1531.
[449] Dittmar and Muller, 1532.

which other instruments are not heard) makes them easier to isolate, sample and use to form new compositions.[450] In the context of sound genealogy, the period of time in which the breakbeat is isolated from other instruments in 'Amen, Brother' has been crucial towards its re-design, re-use and re-interpretation as a sampled preset in new instruments, and within the palette of sounds that constitute new musical compositions.

Since the original performance was recorded, the Amen breakbeat has been sampled in isolation from this media and used as the rhythmic foundation for genres such as hip hop, rave, and drum and bass, as well as more recently formed sub-genres of electronic dance music (of which constitute what Reynolds refers to as the 'hardcore-continuum').[451] Popular examples include 'Straight Outta Compton' by N.W.A. (hip hop), 'I Want You (Forever)' by Carl Cox (rave), and 'Super Sharp Shooter' by DJ Zinc (drum and bass).[452] Elsewhere in popular culture, the Amen breakbeat has been used as the backbone to the theme tune for the animated series *Futurama*.[453] These examples demonstrate that sound can help to represent a 'cultural lineage', whilst the breakbeat's genealogy has evidenced a desire for musicians to redefine it through multiple subsequent interpretations.[454] Therefore, by following the Amen breakbeat sound, exhibition teams can exhibit content such as commercial recorded media to discuss the work of musicians such as The Winstons, DJ Zinc, N.W.A., and many contemporaries: both in association with the Akai S950, or any other form of digital sampling instrument.

The dissemination of the Amen breakbeat across various musical genres has been made possible through the use of time-stretching technology to speed up or slow down the breakbeat (originally performed at 142bpm by Coleman) to fit the tempo boundaries of each genre.[455] There have also existed alternative methods to changing the speed of a breakbeat such as sample chopping (where the percussion sounds within the breakbeat are sliced into individual samples and re-ordered as MIDI data using a MIDI sequencer) or changing the playback speed of the original Amen breakbeat on vinyl using the pitch control of a turntable (both techniques were demonstrated in the videos I created, as previously discussed). However, sample chopping does not allow for the note lengths of each percussion sound to expand or contract in parallel with the change of tempo (unless the pitch of each sound is also changed), whilst manipulating the turntable's pitch control does not allow for the speed to change without affecting the pitch. Therefore, the Amen breakbeat could be considered as audio evidence of the continuing creative use

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[450] Hockman, XI.
[451] Simon Reynolds, *Energy Flash: A Journey through Rave Music and Dance Culture*, Updated Edition (London: Picador, 2008), xviii; Goodman, 162; Dittmar and Muller, 1531.
[452] An extensive list of songs which have sampled the Amen breakbeat can be found in author Steve Goodman's book *Sonic Warfare: Sound, Affect and the Ecology of Fear*, Pg. 242-243
[453] Josh Jones, 'The "Amen Break": The Most Famous 6-Second Drum Loop & How It Spawned a Sampling Revolution', *Open Culture*, 2013 <https://www.openculture.com/2013/03/the_amen_break_the_most_famous_6-second_drum_loop_how_it_spawned_a_sampling_revolution.html> [accessed 19 November 2023].
[454] Ableton, 'Breakbeat Deconstruction: From Hip Hop to Drum & Bass and beyond | Loop', *YouTube*, 2017 <https://youtu.be/eJf9Jptq7VY> [accessed 26 October 2021].
[455] Rowan Anthony Oliver, 'Rebecoming Analogue: Groove, Breakbeats and Sampling' (University of Hull, 2015), 89.

of technology to re-appropriate sonic material in new cultures and contexts. It also has the potential to represent an additional avenue for collecting in museums, in which sounds are acquired not just as representations of instruments, but of the sonic aesthetic qualities produced when engaging each instrument's functionality. Furthermore, whilst it is difficult to collect time-stretching technology, specifically, in *material* form, the *aural results* of its deployment can be heard, recorded, and acquired as sound.

Additionally, the breakbeat not only takes on new aesthetic qualities through the deployment of technologies such as time-stretching, but it also takes on new meanings and sonic characteristics in each new context it is used in. As Katz explains:

> Sampling is most fundamentally an art of transformation. A sample changes the moment it is relocated. Any sound, placed into a new musical context, will take on some of the character of its new sonic environment […] Thus, the sound and sense of a two-second drum break may change radically from song to song, even if the patterns of 1s and 0s do not.[456]

As with the aesthetic quality of Akai's time-stretching technology, the role of the Amen breakbeat in generating and shaping the drum and bass genre has been identified by drum and bass producers, enthusiasts, and scholars as fundamental. Goodman considers the Amen breakbeat ('funk break') to have a significant impact on the formation of jungle (drum and bass) music as an example of 'riddim optimization' whereby a genre of music is defined by certain looped percussion sounds.[457] Furthermore, Oliver describes the Amen breakbeat's crash cymbal sound as a 'phrased textural rupture' where the 'progress of time seems briefly frozen and the listener's attention shifts to texture.'[458] This is comparable to the outcome produced by the deployment of time-stretching - as a contributing factor towards the breakbeat's popularity in the drum and bass genre.

However, compared to other sub genres of electronic dance music, drum and bass still suffers from a lack of technological identity. As we discovered in chapter four, some of the synthesizers and drum machines introduced by Roland in the late seventies and eighties continue to be closely associated with sub-genres of electronic dance music: the TR-808 and hip-hop, electro and trap; the TR-909 and house, techno and other forms of four-to-the-floor electronic dance music; and the TB-303 and acid house, acid techno and other

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[456] Mark Katz, *Capturing Sound: How Technology Has Changed Music*, Revised Edition (Berkeley: University of California Press, 2010), 174.
[457] Steve Goodman, *Sonic Warfare: Sound, Affect, and the Ecology of Fear* (Cambridge: The MIT Press, 2012), 161.
[458] Rowan Anthony Oliver, 'Rebecoming Analogue: Groove, Breakbeats and Sampling' (University of Hull, 2015), 89.

forms of music that rely heavily on the instrument's infamous 'acid' sound. Paradoxically, the heavy reliance on (and the easily recognisable use of) breakbeats such as the Amen as the grounding percussion for drum and bass production has also made it difficult to associate the genre with a particular electronic musical instrument that is capable of song (or at least pattern) creation using its own built-in sound generation (as is the case with the Roland instruments listed above). Although the Akai S950 helped create and shape drum and bass music in the nineties (which was also influenced by factors such as the popularity of rave music), the Amen is just one sound in existence that could be recorded and imported into it and is therefore not exclusively or intrinsically linked to this instrument, in the same way that the TB-303's waveforms and sound-modifying controls are hard-wired into that machine (for example).[459] Therefore, whilst the Akai S950 remains synonymous with early drum and bass music, and although some may argue that musicians of drum and bass music have demonstrated highly creative uses of electronic musical technologies, there does not exist a specific 'drum and bass machine' that museums and other collectors could preserve as the definitive material evidence of the genre's entire history.

7.4.3 Sound Diffusion

Sound diffusion is 'the projection and the spreading of sound in an acoustic space for a group of listeners,' involving 'real-time, usually manual, control of relative levels and spatial deployment during performance.'[460] This creates a multi-modal engagement with sound, encouraging listeners to track the sound with both ears and eyes, depending on which speakers are emitting sounds.[461] The means to practice sound diffusion would not be possible without preliminary research into stereo applications in order to produce more realistic representations of the movement of sounds as we naturally hear them (beyond what could be achieved with mono sound).[462] This research includes the work of Alan Blumlein and his exploration of binaural sound for applications such as stereo music and film in the 1930s.[463] Although the stereo format continues to be the most widely consumed form of recorded and live music, the need for multiple loudspeakers and sound diffusion practice later emerged from a need to project music across a large performance space.[464] This would allow all members of an audience to gain a better listening experience than a stereo loudspeaker configuration could offer, without losing intimacy or an accurate

[459] Hockman, 1.
[460] Austin and Smalley, 10; Jonty Harrison, 'Diffusion: Theories and Practices, with Particular Reference to the BEAST System', *EContact!*, 2.4 (1999) <https://econtact.ca/2_4/Beast.htm> [accessed 26 April 2021].
[461] Bongers, 46.
[462] Martin Shankleman, 'Celebrating a Stereo Pioneer: Alan Blumlein', *BBC News*, 2008 <http://news.bbc.co.uk/1/hi/technology/7538152.stm> [accessed 27 April 2021].
[463] Martin Shankleman, 'Early Stereo Recordings Restored', *BBC NEWS*, 2008 <http://news.bbc.co.uk/1/hi/technology/7537782.stm> [accessed 27 April 2021].
[464] Austin and Smalley, 12.

experience of the stereo field - as produced by the 'hole in the middle' effect, for example (which depends on the proximity between two loudspeakers in relation to where members of an audience are seated).[465] Experimental electronic music composed for multiple loudspeakers (often referred to as electroacoustic music) by musicians such as Karlheinz Stockhausen and John Cage later emerged in the 1950s.[466]

Contemporary electroacoustic music may be performed within a theatre space where multiple loudspeakers are installed to create an ideal listening environment for an audience (such as the Birmingham ElectroAcoustic Sound Theatre (BEAST) which can incorporate around one hundred loudspeakers for a performance).[467] This is often realised using specially-designed interfaces with faders that allow performers to alter the amplification of several audio elements (inputs) across multiple outputs (essentially, a mixer in reverse) connected to loudspeakers.[468] In comparison, my exhibit relies on just eight, equally-spaced loudspeakers around a circle for diffusing the Amen breakbeat (a configuration known as 'octophonic') with an additional sub-woofer deployed for reproducing bass frequencies (creating an overall 8.1 configuration).[469] These loudspeakers are merely installed as a way of reproducing a special 'space-stretching' effect that surrounds the visitor-as-performer as they diffuse the sound using a single joystick. In other words, instead of generating better clarity and a sense of depth as the intended outcomes for the *audience* of this multi-channel performance, the sound diffusion in my exhibit is intended for the visitor-as-*performer*'s benefit (as well as benefitting anyone else who happens to be in the space). Nonetheless, it was hoped that the movement of sound around the space would encourage evidence of 'attention-focusing behaviour' such as moving one's head so that the eyes follow the sound or pointing at speakers to indicate the aural results of the exhibit user's tactile actions.[470] This would help produce a situation in which 'authentic sounds, interpretation, movement, and interactivity (are) brought together.'[471]

Additional differences and similarities exist between the traditional performance of electroacoustic music – comprised of multiple audio elements and gestures - through sound diffusion, and the use of *Drum and Bass - Time and Space* to perform with just two electronic sounds in an exhibition space. First, a performance of electroacoustic music in a theatre such as BEAST would likely coerce specific behaviours from both performers and audience so that only the sounds intended to be performed at any given time can be heard within the ideal listening environment. In contrast, the NSMM is expecting a 'lively' audience to attend the exhibition, and therefore the need for keen listening skills when using or observing the

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465 Austin and Smalley, 12; Harrison.
466 Jesse Austin-Stewart, 'Creating Interfaces for Live Octophonic Spatialisation of Sound', *Pūrātoke - Journal of Undergraduate Research in the Creative Arts and Industries*, 1.1 (2017), 37.
467 'Meet BEAST - About - Electroacoustic Music Studios', *University of Birmingham* <https://www.birmingham.ac.uk/facilities/ea-studios/about/meet-beast.aspx> [accessed 26 April 2021].
468 Harrison.
469 Austin-Stewart, 37.
470 Diana Alderoqui-Pinus and Juan-Ignacio Pozo, 'Epistemic Actions in Science Museums: Families Interacting with the Mirror Room Exhibit', *Revista de Psicodidáctica*, 18.2 (2013), 286.
471 Bijsterveld, 88-89.

interactive content of the exhibition is challenged by the addition of other noises produced by both humans and non-humans. These may also be enhanced by the physical qualities of the exhibition spaces, such as the use of hard, concrete floors which cause much reverberation and are, therefore, far from ideal for creating an ideal listening environment comparable to a theatre.

Second, unless the composer(s) of an electroacoustic piece intended for indeterminacy in its performance, the performers (which may be the composers, themselves) would already know the piece and may have already practiced sound diffusion with the composed material. Therefore, they will know what to expect as the composition unfolds (although tracking each sound throughout the composition may prove tricky if similar sounds exist together at the same time). In comparison, although it is unlikely that visitors will know which sounds will be available to engage with prior to their visit, the playback of the Amen breakbeat as a short, one-bar loop in the exhibition will hopefully enable them to quickly build confidence in manipulating this sound with the joystick, in the knowledge that the content will not change over time with surprising consequences. Constricting the sound material to just a percussion loop and a bass (which, as previously explained, is constrained to play through the front two speakers and the sub-woofer, only) should also provide a situation where visitors can easily differentiate between the two elements (as opposed to diffusing many similar sounds across multiple speakers in a larger space).Nonetheless, although visitors of the NSMM are able to experience surround-sound content as part of the museum's iMax cinema experience (and may have also experienced this at home by installing their own surround-sound speaker setups), the ability to choose the speakers which the Amen will emit from may be an entirely new and unique experience.

7.5 Constructing the Exhibit

7.5.1 Six Factors to Consider

We now need to consider the factors which comprise what the exhibit will look like and the content that visitors will engage with. To this end, Birnbaum and others adapted the concept of a dimension space for analysing 'musical devices' (which can take 'varied forms, including interactive installations, digital musical instruments, and augmented instruments').[472] A dimension space exists as a dimension plot 'generated by placing points on each axis, and connecting them to form a two-dimensional shape', which visually depicts

[472] Birnbaum and others, 192.

'a finite space within the space of all possible design options.'[473] Birnbaum and others describe seven axes for analysing musical devices in this way, which account for the exhibit's interface in relation to users' level of expertise, as well as how the sounds and other 'feedback modalities' could be experienced by an audience. These are summarised as follows:

- **'Required Expertise** (the level of practice and familiarity with the system that a user or performer should possess in order to interact as intended with the system)
- **Musical Control** (the level of control a user exerts over the resulting musical output of the system, based on three possible levels of control over musical processes: timbral level, note level, and control over a musical process)
- **Feedback Modalities** (the degree to which a system provides real-time feedback to a user; Typical feedback modes include visual, auditory, tactile, and kinaesthetic)
- **Degrees of Freedom** (the number of input controls available to a user of a musical system. This axis is continuous, representing devices with few inputs at one extreme and those with many at the other extreme)
- **Inter-actors** (the number of people involved in the musical interaction)
- **Distribution in Space** (the total physical area in which the interaction takes place, with values ranging from local to global distribution)
- **Role of Sound** (ranges between three main possible values: artistic/expressive, environmental, and informational)'[474]

Although the authors' seven criteria are useful as a starting point, we also need to consider other factors that will contribute towards the successful redesign of an electronic musical instrument as an interactive exhibit. However, examining every factor that could contribute to the design, use and interpretation of an interactive exhibit – health and safety, learning outcomes, accessibility, the audience's age range, would prove far too exhaustive for this thesis. Therefore, six forms of criteria most relevant to the redesign of electronic musical instruments than other exhibition and interactivity contexts are listed and examined below. These should generate meaningful experiences for visitors who engage with these types of interactive exhibits, helping them to feel confident in (or even (re)discover) their musical abilities and make (more) time to be creative and playful post-museum visit, or even encouraging them to reconsider their relationship with their continuing music and sound activities.

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[473] Birnbaum and others, 193.
[474] Birnbaum and others, 193-194.

7.5.1.1 Form

First, we must consider the form of the exhibit in terms of whether the exhibition teams' intention is to authentically represent a pre-existing electronic musical instrument or not. Both the exclusive and hybrid approaches may be followed in order to design a replica where the form of the new exhibit (which the interface is a part of) reflects a period in history which the original instrument was manufactured and used in. Otherwise, new materials, components, and contemporary digital technologies can be utilised to help create an interactive exhibit that brings older technologies and practices to life, making it more accessible to modern audiences and creating new forms of engagement.[475] The incorporation of technological innovations to 'engage people of all ages and cultural backgrounds' was another example of good practice advocated for in the *New Directions in Interactive Media Symposium* (as mentioned in chapter three).[476]

7.5.1.2 Interface

It is not my intention to suggest that exhibit interfaces should be designed to be as simple to use as possible, but rather that the interface should be designed so that, where possible, there is always an evident relationship between using the controls and producing a sound (or hearing the sound change). Interfaces should be designed so that visitors can access the functionality demonstrated by the exhibit using the least number of controls and navigations possible (or, using the words of Birnbaum and others, the least 'number of input controls available to a user of a musical system').[477] Furthermore, the design of the exhibit should be augmented in a way that creates an experience that is not likely to be discovered elsewhere, in terms of feedback modalities (such as the experience of surround sound, as discussed later and in chapter eight) and the sound and musical content that the exhibit addresses (as explained below).

Additionally, there exists logistical advantages to the consideration of an exhibit's interface and its relationship to other physical parts. Magnusson explains that the introduction of the MIDI protocol helped to produce new digital musical instruments which consisted of the following parts: the controller (or gestural interface), the mapping engine, and the sound engine.[478] MIDI has also provided the means to physically detach the controller from the sound engine, and was key to the evolution of user-centred

[475] Christian Heath and Dirk Vom Lehn, 'Configuring 'Interactivity': Enhancing Engagement in Science Centres and Museums', *Social Studies of Science*, 38.1 (2008), 64.
[476] Govenar.
[477] Birnbaum and others, 193-194.
[478] Thor Magnusson, 'Designing Constraints: Composing and Performing with Digital Musical Systems', *Computer Music Journal*, 34.4 (2010), 66.

design.[479] As Magnusson states, whether an instrument is presented as a 'unified object' or as physically separated components, 'it will always be characterized by the split between the interface and the sound engine, connected by a mapping engine of diversified complexity.'[480] This presents an important advantage to the re-design of electronic musical instruments as interactive exhibits (as opposed to redesigning acoustic instruments) as the interface can be physically dislocated from the sound generating or hosting apparatus: both of which may also be separated from the apparatus that transduces electrical signals into 'sonic feedback' (i.e., loudspeakers or headphones).[481] This allows for the creation of surround-sound experiences, the installation of multiple interfaces that allow more than one visitor to use the exhibit at one time, and the creation of exciting visual content that could provide enhanced feedback to multiple visitors at once. Additionally, this enables exhibition teams to hide much of the 'guts' of an exhibit behind-the-scenes, as was the case with *Drum and Bass - Time and Space*.

7.5.1.3 Audio Hosting / Generating

As stated above, the separation of the interface and sound engine provides several advantages. However, as this thesis argues that exhibition teams should move away from the installation of recently manufactured electronic musical instruments via the manufactured and configured approaches, this also means that they may need to consider where the audio will be coming from, i.e., how it will be generated and/or hosted. Although, in some cases, a manufactured instrument could still be implemented as part of the hybrid approach to interactive design – providing the appropriate means to automatically load and host audio samples or generate electronic signals as sound – exhibition teams might otherwise need to consider the use of computing technologies and software for doing this.

7.5.1.4 Function

The function imbedded within an original instrument that has had the most impact on the music technology industry and the production of music should become the focus for that instrument's re-design as an interactive exhibit. Data collected from designers and users may help us to understand which functions (or other features) of an electronic musical instrument have, at various times, become most popular or significant during that instrument's lifetime. However, focusing on these aspects may not prove

[479] Bongers, 2.
[480] Magnusson, 65.
[481] Magnusson, 66.

to be the best approach when practical considerations are considered (especially if the technology is old and the original components have ceased to be manufactured, or even exist). Therefore, it might be necessary for an exhibition team to attempt to replicate the functionality of an instrument using digital technologies, and also provide a more appropriate form of interface control for accessing that functionality in an exhibition space. For example, we will see, later, that the original hardware sampler that my exhibit represented – the Akai S950 – became problematic to utilise, and therefore its time-stretching function was replicated using Max programming software hosted on a computer.

7.5.1.5 Sound Content

As an extension of the seven axes provided by Birnbaum and others, exhibition teams must deal with sounds and the music they may feature within as separate entities. However, sounds, instruments and musicians may transcend several different genres of music and cultures over time as liminal entities.[482] Therefore one particular sound may exist in several different styles of music (and in other forms of entertainment) and, therefore, visitors may interpret different meanings from the same audio material. Nonetheless, sound may need to be considered in terms of its potential to grab the attention of visitors in an exhibition: whether as part of an interactive exhibit, video footage displayed on a screen, a listening station, or as part of a personalised exhibition audio tour provided by a museum.

7.5.1.6 Musical Focus

Again, the sounds that visitors might hear should be considered separately to the music which the interactive exhibit represents. It may even be the case that, because an older instrument only existed as a prototype and has never been replicated, it has not been used to produce much music and, therefore, it becomes very difficult to associate that instrument with any type of musical genre or culture (as is demonstrated in chapter five). Otherwise, an exhibition team might attempt to associate a particular instrument with a style of music that it has become popularly known for producing. Or, alternatively, visitors may be granted the freedom to use an exhibit’s interface in such a way that every use of the exhibit associates it with a different form of music, which may still be subject to differing interpretations by those audience members who are not using the exhibit but are present.

[482] Pinch, ‘Technology and Institutions: Living in a Material World’, 478-479.

7.5.2 Design Iterations

In this section, I will demonstrate how the exhibit developed across several design iterations towards becoming a finished product for the *Sonic…* exhibition. Table 7.1. below summarises the constants (sound content and musical focus) and variables (all other factors) explored at each design stage, which are described in more detail afterwards.

DESIGN ITERATIONS						
Iteration Short Name	**Form**	**Interface**	**Audio Hosting / Generating**	**Function** (Time-stretching)	**Sound Content**	**Musical Focus**
Mixer	MIDI controller keyboard / smartphone, mixing desk, computer	Novation Remote SLII / smartphone with TouchOsc app.	Max (Version 7)	Max (Version 7)	Amen breakbeat and synthesized bass	Drum and Bass
Instrument	Akai S950 / other manufactured instrument(s)	Akai S950 / other manufactured instrument(s)	Akai S950	Akai S950	Amen breakbeat and synthesized bass	Drum and Bass
Proposal	A newly designed interface connected to a cabinet or plinth, computer	Touch-capacitive keybed for bass, T-bar lever with no middle indent for T*ime and Space.*	Max (Version 8)	Max (Version 8)	Amen breakbeat and synthesized bass	Drum and Bass
Prototype	Exposed electronic components on a breadboard connected to an Arduino, computer	Buttons and LEDs on a breadboard connected to an Arduino. Small linear potentiometer used for *Time and Space*.	Max (Version 8)	Max (Version 8)	Amen breakbeat and synthesized bass	Drum and Bass
Final Design	A newly designed interface connected to a cabinet, computer	Six buttons for bass arranged for exploratory interaction, single-axis joystick with middle indent for T*ime and Space,* small linear potentiometer used for volume.	Max (Version 8)	Max (Version 8)	Amen breakbeat and synthesized bass	Drum and Bass

Table 7.1. A summary of the constants and variables discovered during the process of visualising, designing, and building different iterations of Drum and Bass - Time and Space.

7.5.2.1 Mixer

The concept for *Drum and Bass - Time and Space* (originally titled *Amen Stretch*) was developed in 2016 with the intention of being operated using manufactured instruments and sound technologies. This initial concept was tested using a computer hosting Max (version 7), a Novation Remote 61SL MKII USB MIDI keyboard, and a Midas M32 digital mixing interface. Eight identical monitors were connected to the Midas M32's outputs in order to realise an appropriate acoustic environment and interface for sound diffusion. The controls (rotary potentiometers) on the Novation interface were mapped via Max to control not only *Time and Space* but also the cutoff frequency of a low-pass filter and volume for both an Amen breakbeat and a synthesized bass (separately). Later, an alternative touchscreen interface was also designed using the TouchOSC app (see Figure 7.3. below), allowing both *Time and Space* to be controlled simultaneously using an X-Y pad which users could operate using Android smartphones.

Figure 7.3. The touchscreen interface designed for the original Amen Stretch project using TouchOsc (hosted on a Huawei Android smartphone).

In transferring the ideas from the *Amen Stretch* project to *Drum and Bass - Time and Space*, it became clear that the manufactured technologies used in the original project would not be appropriate for an exhibition setting as they would be too cumbersome, surplus to requirements, and would be vulnerable to misuse. Not only was it likely that the mapped controls of the Novation and Midas interfaces would prove too vulnerable in an exhibition intended for a lively audience, but many of the controls would be redundant (if left exposed). For example, only eight of the Midas' thirty-two input channels would be used, and visitors would not need to access the faders, knobs, and buttons for each of those eight channels. Second, considering the size of the semi-enclosed *Sound Circle* space, and the need to provide all visitors with direct access to, and around, the exhibit (as stated in the requirements), the Midas M32 would prove far too large to install. Third, the total cost of acquiring the aforementioned equipment would extend far beyond the budget offered.[483]

7.5.2.2 Instrument

7.5.2.2.1 Time-Stretching

I considered using a second-hand Akai S-series sampler as the means to host the audio and offer the original time-stretching technology as used in the nineties. However, users of this sampler could only operate this function as an offline process (i.e., not as a continual process), using buttons which afforded the navigation of various menus towards accessing the time-stretch function. As the sampler's manual explains, musicians were required to click on the 'edit sample' button, navigate to page 14 using the page down button, set the 'd-time' parameter, and then save the newly time-stretched sample as a new file.[484] Musician of drum and bass music, and user of the Akai S950, Benjamin Pettit (a.k.a. DJ Zinc) complained that the time-stretching function was 'a bugger to use, mainly because it was so slow,' which may be a reference to how many button presses were needed to access the time-stretching function, or how long it took the sampler to calculate and perform the offline process (or both).[485] Nonetheless, it seemed likely that the operation of the time-stretching function using the original sampler would prove too complicated for visitors to access, and would not offer an instant, continuous manipulation of sample playback.

The reason to why digital hardware samplers such as the Akai S950 necessitated so many button pushes for navigating menus is because they offered users a plethora of functions that were deemed necessary (or at least desirable) for recording, composing, performing, sound design, and sample management (amongst other tasks): all of which needed to be managed through the spacing of buttons and controls on the interface to avoid clutter, and supported by clear visual feedback on the sampler's screen. Alternatively, if the Akai S950 was designed exclusively for time-stretching imported audio samples, it might have been

[483] Successful applicants employed as researchers (myself included) were offered a budget of £1,000, whilst self-employed makers were offered £5,000.
[484] Akai Professional, 29-30.
[485] Christian, 'Cornerstone Tracks: DJ Zinc Charts the Evolution of His Sound', *Fabric London*, 2018 <https://www.fabriclondon.com/blog/view/cornerstone-tracks-dj-zinc-charts-the-evolution-of-his-sound> [accessed 21 May 2020].

defined as a 'time-stretcher' (or, more comically, a 'time-stretcherer') instead of a 'sampler,' and would have probably been designed to offer a much faster, or even immediate, route to accessing this function. However, as the sampler's design dictates, there remains no way of knowing that it provides the time-stretching functionality just by looking at it.

Since the introduction of digital hardware samplers, musicians have been able to control digital time-stretching parameters as an *online* effect via the mapping of tactile hardware controls such as potentiometers, faders, and joysticks to digital time-stretching parameters. Therefore, to help make the phenomenon of time-stretching (and sound diffusion) more exciting for visitors, it was proposed that *Time and Space* would be manipulated in real time using a large robust control similar to those found on contemporary music technologies designed for younger users, as well as retro arcade machines. A T-bar lever was first considered as a fun, over-sized and robust tactile control for affecting *Time and Space* via forward and backward movements (as opposed to using a rotary potentiometer which would be better for simulating the movement of sound from left to right). With this control, the forward and backward motion represents a spatial analogy: providing a natural mapping to the position of sounds emitting from the speakers around the visitor.[486]

7.5.2.2.2 Triggering and Diffusing Sounds

There were other reasons to why the Akai S-series sampler would prove problematic for this exhibit. For example, without the use of an additional MIDI instrument such as a keyboard, the only way that visitors could play sounds from the sampler's front panel would be through pressing the 'P.B' button, which only allows for one sound to be auditioned at any time at one pitch set by the sampler (which would have to be loaded manually from the device's 3.5' floppy disk drive, or manually recorded via the front panel inputs).[487] Additionally, the sampler does not provide any kind of sequencing capabilities and therefore an additional MIDI sequencer would have to be acquired in order to constantly play the Amen breakbeat as a loop (as opposed to manually, and continually, pressing the P.B. button) until someone presses a button to stop it. Nonetheless, even if an Akai S950, or similar digital hardware sampler, was connected to an additional keyboard and sequencer, this would create a problem whereby technicians at the museum would have to manually set-up the interactive so that the samples and sequences were loaded manually every morning, which would not meet the museum's requirement for an exhibit to need minimum invigilation. Furthermore, although the sampler had enough audio outputs to connect it to eight speakers

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[486] Don Norman, *The Design of Everyday Things*, Revised an (New York: Basic Books, 2013), 22.
[487] Akai Professional, 9.

and a sub-woofer, each sample could only be assigned to one of those outputs via another offline process, which would therefore make live sound diffusion impossible.[488]

Although a variety of manufactured MIDI interfaces exist, none were suitably robust or equipped with the appropriate controls that would make them ideal for use as interfaces for the exhibition's mixed-ability audience. For example, although the Blipblox synthesizer (see Figure 7.4. below) was designed to offer a fun, accessible and robust interface for both children and adults - with the inclusion of T-bar levers on either side of the interface - the lack of a MIDI Out socket meant it could not be used to control sounds hosted and generated by additional hardware or software. Additionally, although the child-friendly Dato Duo synthesizer (see Figure 7.5. below) had a MIDI Out connection, this could only be used for sequencing sounds hosted in other MIDI-compatible technologies via the Dato Duo's own sequencer interface. Also, the controls on this instrument's interface were too fragile and surplus to requirements, which may have led to some visitors becoming frustrated with the interface and potentially breaking the exhibit.

Lastly, the Keith McMillen Instruments K-Mix audio interface and programmable mixer seemed to be a practical, cost-effective way of combining a multi-channel audio interface with a touch-strip control surface. Unfortunately, the provision of eight separate touch-strips for modifying the signal levels for each of the eight speakers would likely make it difficult for visitors to move the sound from the front speakers to the back speakers in a way that keeps the sound's volume at a constant level. Further problems arose when considering how to control time-stretching using the interface when the eight touch-strips would already be mapped to control the volume for each of the speakers.

[488] Akai Professional, 9.

Figure 7.4. The Blipblox synthesizer has a T-bar lever on either side of its interface.

Figure 7.5. The Dato Duo synthesizer and sequencer has a two-sided design to encourage collaborative sound design and sequencing.

7.5.2.3 Proposal

As evidenced in the submitted proposal, a decision was made to design a more suitable exhibit exclusively for the exhibition setting. Manufactured technologies – a computer and audio interface – were still used to host the Amen breakbeat, generate the sawtooth bass, and deliver nine channels of sound diffusion, whilst the interface and cabinet were comprised of bespoke materials and electronic components. The Tascam US-20x20 USB audio interface was identified as a budget-friendly and space-saving solution for dispersing nine channels of audio to eight speakers and a sub-woofer. Additionally, a desktop computer was purchased from the Dell Refurbished website. This had the appropriate technical specifications to continually run the Tascam audio interface's driver and mixing control software alongside the patch hosted in Max (version 8). Max also provided the means to time-stretch the hosted audio, diffuse it across eight outputs, and map the interface's controls to these functions via MIDI. Although this could have also been achieved by upgrading my license for the Ableton DAW software to version 10, this would have been significantly more expensive than the acquisition of a one-year educational license for version 8 of Max.

The proposal included a diagram (see Figure 7.6. below) which demonstrated my vision for the interface. Initially, it was designed to not only allow visitors to control *Time and Space* using a single lever, but also the pitch of the Amen breakbeat. Each of these three functions could be turned on or off using three additional buttons, providing the means to modify different combinations of functions at once. Additionally, the bass was intended to be performed using a flattened touch-capacitive MIDI keybed, which was inspired by the Arturia MicroFreak digital synthesizer. A flattened keybed would not only remove the temptation for 'lively' visitors to rip up (or even rip off) the keys of a more traditional physical keybed, but would also be a more accessible interface for visitors who might struggle to press down on the keys of a physical keybed hard enough to produce sounds.

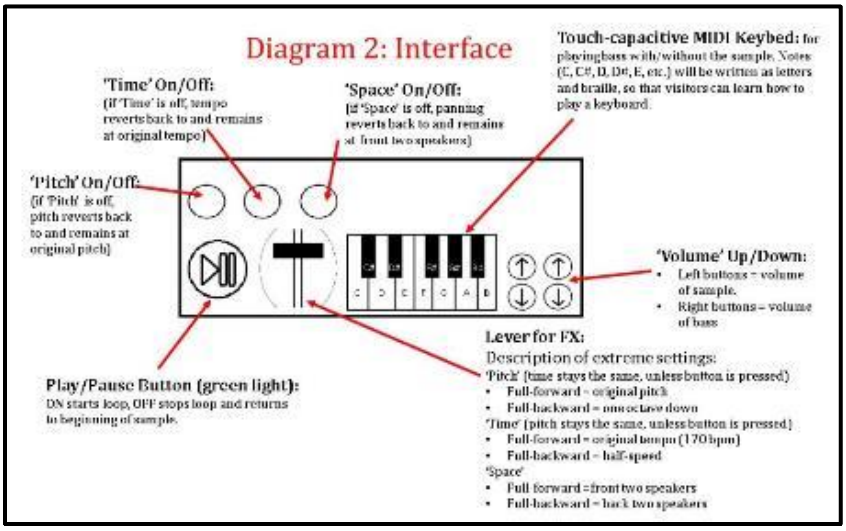

Figure 7.6. A diagram of the interface first proposed for *Drum and Bass - Time and Space*.

However, after the proposal was submitted it became clear that the inclusion of a pitch control might confuse visitors, seeing as the exhibit was meant to focus on demonstrating the *difference* between digital time-stretching and the effect produced from operating the pitch control of a turntable (as was identified in the accompanying interpretational text). Furthermore, it seemed likely that visitors would want to combine *Time* with *Space* anyway, as this would create a much more engaging experience than merely time-stretching audio using just two speakers. Therefore, soon after being notified that my proposal was successfully commissioned, I decided to remove the three buttons and, instead, allow visitors to alter *Time and Space* simultaneously by default, using a T-bar lever (which also helped to create a less cluttered interface on the final design). The choice of a T-bar lever and large arcade-style buttons for the interface was inspired by the child-friendly Blipblox and Dato Duo synthesizers previously shown, as well as the exhibits exclusively designed for the NSMM's *Wonderlab* exhibition (created by Ab Rogers Design) and the manufactured arcade machine interfaces installed in the NSMM's *Games Lounge*.

7.5.2.4 Prototype

After realising that a touch-capacitive keyboard would be difficult to implement into the interface design, I decided to offer arcade buttons as a way of performing with the sawtooth bass - considering that the exhibition team had already advocated for the use of arcade buttons based on their proven robustness in previous exhibitions. This reflected the approach that Caulton advocates for: the use of robust, standardised components which might be re-utilised for other exhibits.[489] At first, it seemed appropriate to offer eight buttons for playing the eight notes of the C major scale - from C to C (see Figure 7.7. below) - as this array of notes would more likely be recognised by visitors (at least in a UK/European museum). These notes were to be grouped as two rows of four buttons on the right-hand side of the interface - commencing with the lowest C on the far left of the bottom row and progressing towards the highest C on the far right of the top row (moving from left-to-right along each row) – whilst the T-bar lever was placed on the left of the play button.

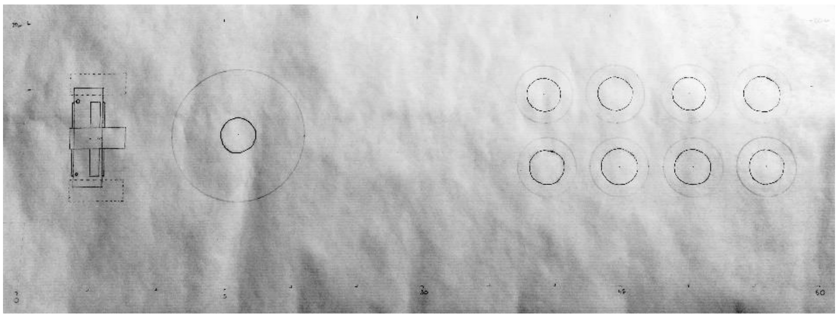

Figure 7.7. The drawing of the first design for the interface.

However, a conversation with the SMG's Senior Audience Researcher, Bethan Ross, indicated that visitors across the SMG's institutions are known to prefer interactive exhibits that offer a more exploratory experience. Therefore, six buttons were, instead, arranged in a seemingly random order, albeit clustered together as a group and separated from the other controls (see Figure 7.8. below). The random spacing and positioning of the buttons was intended as a 'leveller', encouraging all visitors to feel comfortable enough to engage with this part of the interface with a sense of curiosity, rather than providing the means for some visitors to approach the performance of the bass as a way of demonstrating their pre-existing musical knowledge (as might have been the case with a more traditional keyboard). The notes assigned to each of the six buttons were picked from a two-octave range within the C minor scale.

[489] Caulton, 30.

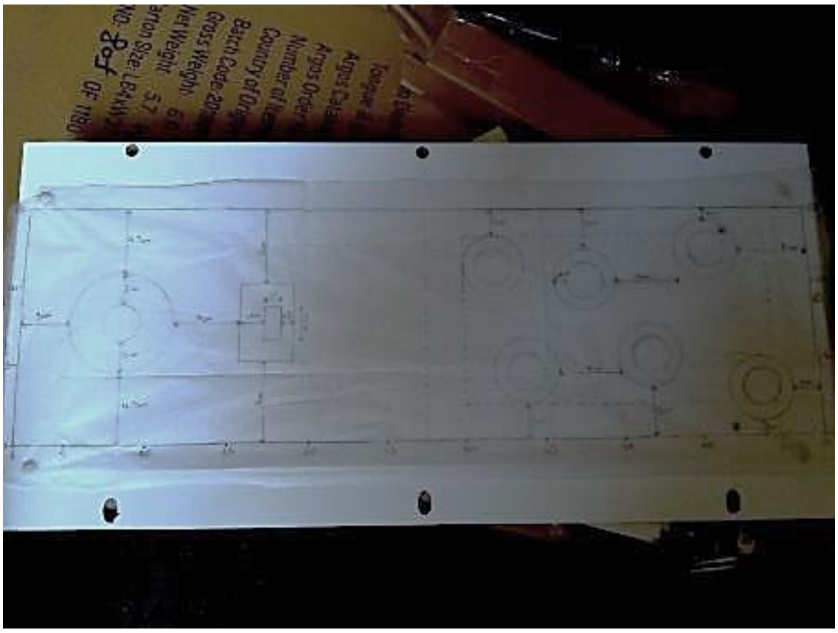

Figure 7.8. The drawing of the final interface, fixed to the front panel.

After deciding on a final design for the interface, I prototyped an electronic breadboard circuit (see Figure 7.9. below) using small buttons, LEDs, and a MIDI Out socket (temporarily fixed into a breadboard). Each of the electronic components were connected to various digital and analogue connection points of an Arduino Leonardo microcontroller. The Arduino's integrated development environment software provided the means to identify which connection points acted as inputs and outputs via code that could be sent to the Arduino hardware. Additionally, a small, external linear potentiometer (not pictured) was connected to the Arduino as a way of testing the control of *Time and Space*. This was determined by connecting the MIDI Out socket to the MIDI In of the Tascam audio interface and observing how the movement of the linear potentiometer affected the time-stretching and sound diffusion parameters set within the Max patch. Once the mapping of controls between the Arduino hardware and Max software had been tested as working, I started to build the final exhibit, connecting the real interface controls and connection points to the same inputs and outputs previously assigned to the buttons, LEDS, MIDI Out socket and linear potentiometer.

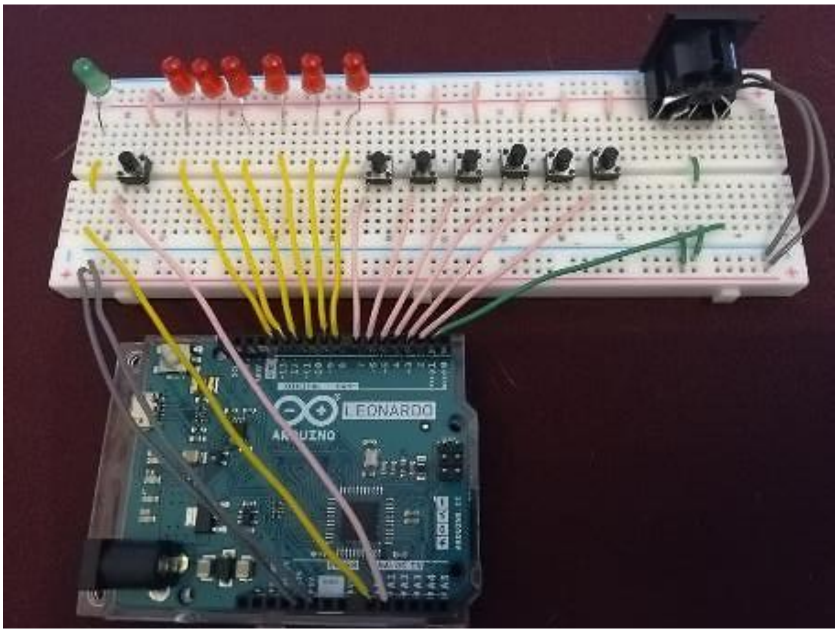

Figure 7.9. The Prototype: a simplified, colour-coded breadboard circuit.

7.5.2.5 Final Design

Considering how much of the budget had already been used, the T-bar lever became too expensive as a means for controlling *Time* and *Space*. However, a consideration of alternative controllers led to the realisation that visitors might prefer to use something that always returned to a central starting point (as opposed to a T-bar lever which would remain in the position it was left in). This central starting point would then represent the playback of the Amen breakbeat through just two speakers either side of the visitor at a constant tempo (around 130bpm). Therefore, a single axis joystick with a sprung-to-centre became the more cost-effective controller of choice for the exhibit (see Figure 7.10. below). This was installed on the left of the interface, to the right of the play button (as indicated by the position of the T-bar lever in Figure 7.8. above).

Figure 7.10. The final interface. The black ‘space’ background was created using a resin pour process.

However, although the chosen model of joystick was designed in a variety of configurations to suit different applications, the configurations on offer from a small selection of retailers were limited. The only option available was a joystick with a gain of +/-40% x Volts, which meant that it was only able to generate MIDI values within a range between 13 – 114 (as opposed to the standard range of 128 MIDI values: 0 - 127). Therefore, the patch created in Max 8 needed to be edited so that the smaller range of values could be scaled to the standard range for MIDI and, therefore, the full range of time-stretching and sound diffusion results could be achieved.

I also realised a better way of connecting USB power to the Arduino using a new socket installed in the back of the chassis near the MIDI socket (see Figure 7.11. below), which was permanently connected to the Arduino’s USB socket inside. This allowed for better modularity and flexibility during installation as both USB and MIDI cables could be plugged straight into the back of the interface’s chassis instead of needing to open the interface in order to connect the cables to sockets inside it. However, I later decided to install a smaller micro-USB socket onto the chassis in order to provide a more universal power option for the exhibition team (i.e., the same socket type as the one found on Android smartphones).

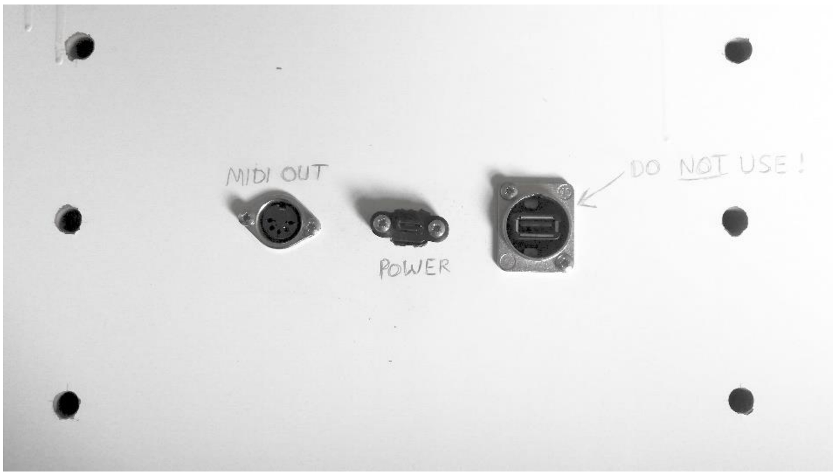

Figure 7.11. The MIDI and USB power sockets fixed to the chassis at the back of the interface, providing better modularity between the interface and the cabinet.

Another benefit of following a modular approach was that the interface and cabinet had the potential of being re-used separately as materials for future interactive content. For example, the interface controls could be re-mapped to represent what was shown on a screen, so that the buttons on the right allowed visitors to choose from six different options, the larger button on the left could be used to navigate 'home' or 'back', whilst the joystick could allow visitors to scroll up or down through information on the screen. The standard mounting holes drilled into the interface could also allow exhibition teams to swop the round-shaped buttons for different sizes and shapes within a suitable range (i.e., neither too small for the mounting holes nor too big so they overlapped). Additionally, both the Max patch and Arduino can be re-coded in order to offer a completely different interactive experience (or removed entirely and replaced by new digital software and/or hardware).

Finally, considering the various iterations of the exhibit's design – in particular, the issues in using an original Akai S950 sampler - a decision was made to produce an exhibit that shared very little with the *form* of the original sampler. The main influence for this decision was the lack of labelling related to the time-stretching function on the original sampler, and the perceived ineffectiveness of the original interface as a robust and intuitive experience in the hands of the exhibition's anticipated visitors. Similarly, due to constraints in the length of interpretational text, I decided not to mention the Akai S950 specifically as much of the space had to be used to explain the exhibit's wider context. Therefore, the text focused on explaining digital time-stretching, sound diffusion, and playing a bass sound in the context of innovation and lived experiences (in relation to analogue turntables and drum and bass music) and the phenomenological experience in the exhibition. Additionally, for those visitors who might already have heard of, or even used, the Akai S950 (or any other music technology that incorporates time-stretching), the explicit textual references to time-stretching and drum and bass – in combination with the sonic aesthetics of the exhibit – might encourage them to connect the exhibit to that instrument anyway.

7.6 Conclusion

Over the course of the exhibit's realisation, *Drum and Bass - Time and Space* was visualised and materialised in various forms before a final product was designed, in the hope that it would offer the most rewarding learning and entertainment experiences for visitors, whilst meeting the museum's requirements. The staff at the museum had anticipated visitor's needs and behaviours based on their previous experiences of visitors, both in exhibitions and as part of other activities such as workshops and Lates programmes. Their concerns and desires were disseminated through the application process in the hope of encouraging submissions to the micro-commissions programme that addressed potential issues and opportunities. Throughout the process of constructing the exhibit in parallel to the construction of the exhibition, the exhibition team (which included myself) attempted to manage the anticipated behaviours of visitors through interactive design, instructional design, and exhibition design. Nonetheless, as we will see in the next chapter, differences between what an exhibition team anticipates of visitors, and what visitors actually do once an exhibition is live, can still be realised – in ways that might be useful, surprising, or detrimental to each subsequent visitor's experience.

Furthermore, whilst my exhibit and its supporting interpretational resources were created in collaboration with other members of the exhibition team, the exhibit could not have been realised by either party working alone as neither party had the complete skillset to complete many of the tasks needed to realise both exhibit and exhibition single-handedly. For example, although the NSMM's Interpretation Developer Sarah Rawlins had established an expertise for delivering appropriate and focused interpretation text for museum exhibitions, she requested my aid - both as the designer and as an expert on the content which the exhibit represented - to help explain how the exhibit worked and how drum and bass music and time-stretching were related. This further demonstrates the continued importance for museums to collaborate with researchers and designers towards the co-creation of content and knowledge in support of disseminating the history of electronic musical instruments in exhibitions.

8 Evaluating the Exhibit's Use and Interpretation by Visitors

8.1 Introduction

Both the *Sonic: Adventures in Audio* and *Boom: Experiments in Sound* temporary exhibitions were intended to attract family groups of visitors and were created as testing grounds that could potentially inform the construction of the later *Sound and Vision* permanent galleries (which the NSMM secured first-round funding for from the National Lottery Heritage Fund in 2021).[490] My exhibit *Drum and Bass – Time and Space* was available to use since the exhibitions opened (July 16 2021) and was decommissioned seven weeks later (September 3 2021) to make way for the next exhibit in the micro-commissions series. Whilst the key findings of chapters two to four were generated from my exploration of interactive design through using exhibits designed by others (as the 'expert investigator' –discussed in chapter one) and interviewing members of the exhibition teams responsible for them, we are yet to explore insights captured directly from visitors other than myself on how exhibits might be engaged with and interpreted.[491] By doing so, we can better understand the range of skills and roles that family members (and other visitors) could present and develop. In relation to *Sonic…* and *Boom…*, these might challenge the suggestions made in the call for submissions for the micro-commissions project regarding *ideal* design approaches for exhibits aimed at families. Additionally, by observing and questioning visitors, we can gain insights into the effectiveness of interactivity, alone, in realising a sound genealogy methodology towards framing electronic musical instruments, as well as how visitors might develop positive experiences from using exhibits – whether these align with an exhibition team's learning and entertainment goals or not.

In this chapter I will explore the final part of the *practice-informed* research methodology adopted for this thesis. First, a *research-from-creation* methodology is discussed in relation to the construction of an exhibit (as discussed in the previous chapter) and the subsequent data collection which that creation enabled.[492] The actions and responses of visitor groups – as determined by the visitor observations and questionnaire data collected in the exhibition - will then be compared in order to highlight typical and atypical scenarios. These comparisons are followed by three case studies, chosen based on the quality of observations and responses collected which indicate how well these groups of visitors followed the instructions and understood the exhibit's context in relation to sound. Finally, these new and unique insights are discussed and compared as evidence that supports the various theories and concepts discussed in chapters five and

[490] Canning; Burns, 7-8.
[491] Jordan, 79.
[492] Chapman and Sawchuk, 16-17.

six. By doing so, we can determine the effectiveness of the exhibit and its interpretational text in teaching visitors about instrument sounds and functionalities through engaging with an interface in ways that do not compromise the abilities of future visitors to reach positive learning and entertainment goals. This will allow us to reflect on the previous case study chapters and make comparisons between *Drum and Bass – Time and Space* and the ways in which other interactive exhibits have been used and interpreted, in order to help determine what the original contributions to knowledge have been from following a practice-informed research methodology.

8.2 Collecting Data

Both the *Sonic: Adventures in Audio* and *Boom: Experiments in Sound* exhibitions opened on July 16 2021 and ran until December 5 2021. Considering my exhibit's installation in the *Sonic…* exhibition extended beyond the summer holiday period that school-aged children were granted, it felt necessary to conduct research during this period in the hope of engaging with more younger visitors and groups of families– the museum's core audience group – per day to help build a larger and more authentic data sample.[493] Therefore, visitor data was collected on the day after the August bank holiday finished (August 31 – a Tuesday) between 11:30am and 4pm: during the institution's summer opening hours (10am to 4pm) which were restricted due to COVID-19, and during what was the final week of the summer holidays for most school children.

As highlighted in chapter one, visitor data was collected through observations of behaviours whilst the exhibit was used, and responses to questionnaires afterwards. Eighteen attempts were made over the course of a day: eleven involved questionnaires, four involved observations, and three consisted of both. Out of the eighteen observations and questionnaires conducted, seventeen took place between 11:30am and 2:30pm, during which time there was a constant flow of visitors moving through the *Sonic…* exhibition (prior to attending the museum to collect data, the busiest period was reported to me as being between 11am and 2pm, with a peak between 1pm and 2pm). The final observation (Observation 18) was captured at 3:30pm (half an hour before the museum closed, when the exhibition was noticeably quieter).

Whilst the original call for submissions to the micro-commission programme made assumptions as to the skills, actions, and behaviours of families in respect to how to design exhibits for them (as discussed in the previous chapter), the SMG's Audience Development team continue to develop a greater understanding of who their visitors might be and how to design exhibits and exhibitions for them. For example, their

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[493] Mansell, Little, and Jamieson, 8.

audience segmentation document for 2018 to 2019 demonstrates several areas that family groups and individual members might fall into and provides a profile of the SMG in terms of the percentage of each segment's membership that constitutes the total attendance of each institution.[494] At the NSMM, nearly half of their visitors (48%) were described as 'engaged community drivers' (those who shared experiences with family and friends, were informed on a wide range of subjects, and were keen to be involved and very active), whilst the segment with the lowest attendance that year (3%) was described as 'time-poor aspirers' (those who consider themselves too busy to commit to anything beyond the essential, and expect everything to run like clockwork, with little tolerance for anything that goes awry).[495] However, bearing in mind that the data provided in the SMG's audience segmentation document consisted solely of qualitative responses from visitors, we can only attempt to segment the questionnaire responses discussed in this chapter and not the observations.

The length of time in which a visitor (or group of visitors) spent in the *Sound Circle* ranged from fifty seconds to fifteen minutes: some, of which, was spent queuing to use the exhibit. The experience of using the exhibit and understanding the underlying concepts was facilitated by the interpretational text on the wall near the entrance, which identified key musical and technological contextual information through providing both a title and description of the exhibit (see Figure 8.1. below). Additionally, separate text instructions were provided behind the interface which aimed to guide visitors towards the exhibit's intended use (see Figure 8.2. below). Considering that most visitors were expected to look in the direction of the interface in order to visually explore its affordances, it was hoped that this would make it easier for them to spot the instructions as they were fixed to the top of the cabinet behind the interface at the same height (rather than being displayed by the entrance to accompany the interpretational text).

[494] Science Museum Group, *Getting to Know the Segments*, 2019.
[495] Science Museum Group, *Getting to Know the Segments*, 2019, 2, 3 and 73.

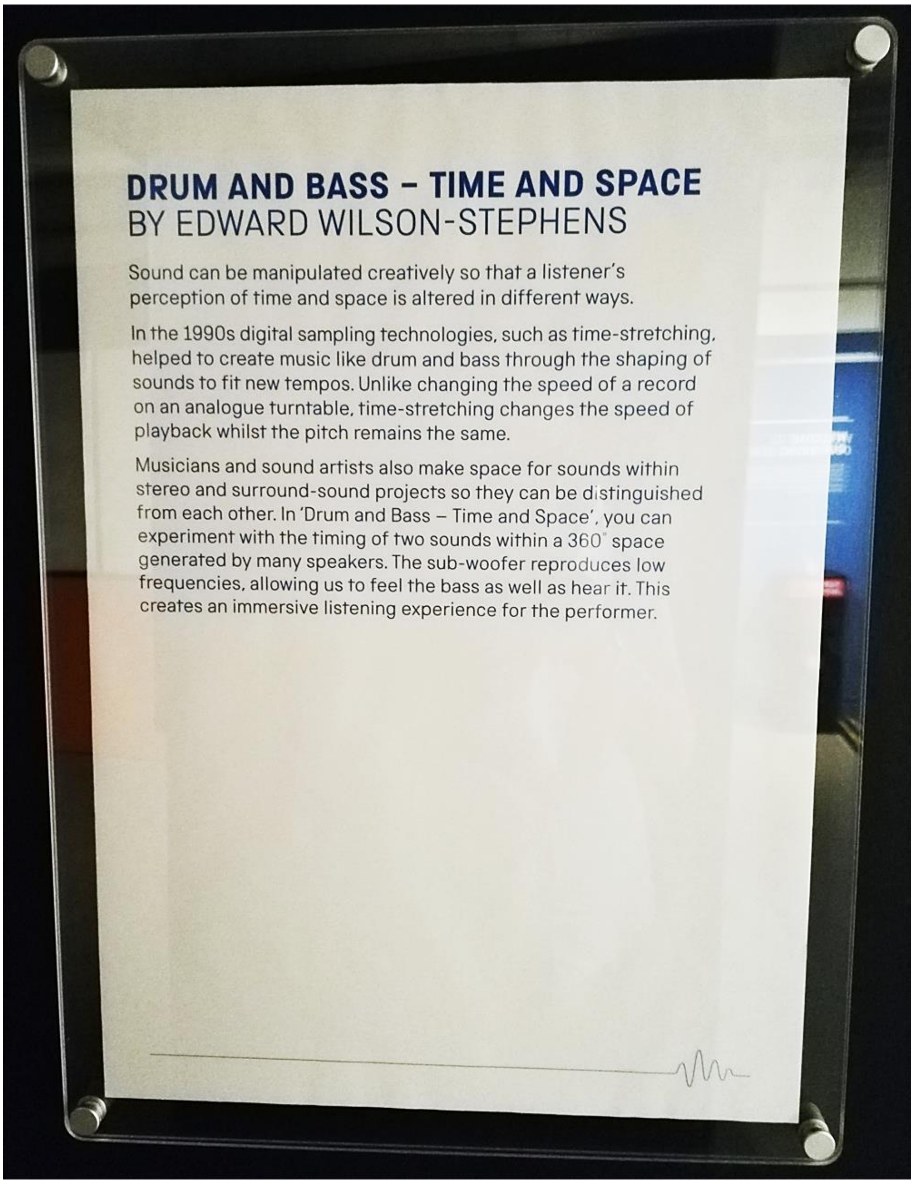

Figure 8.1. The interpretation text which accompanied the exhibit, displayed at the entrance to the *Sound Circle*.

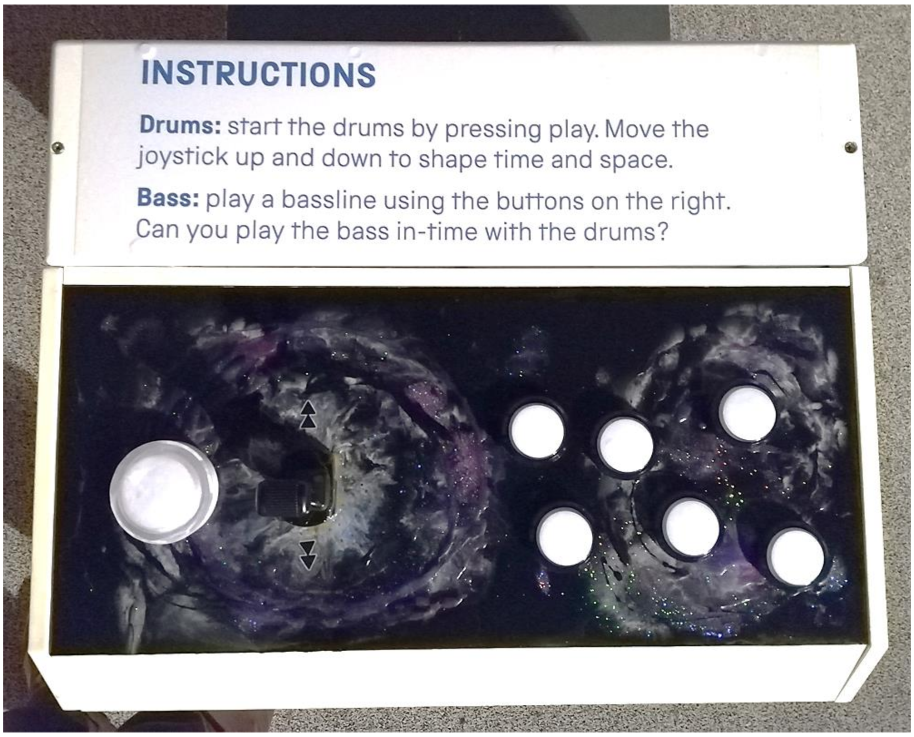

Figure 8.2. The instructions fixed to the cabinet behind the exhibit's interface.

Various other factors may have influenced the actions of visitors, as well as the quality of attention they gave to objects, text, and exhibits. First, the government guidelines for coronavirus-related health and safety meant that the flow of the exhibition was determined by a path created around a wall which extended along the middle of the room, which visitors had to move along in an anti-clockwise direction. This, in conjunction with the amount of people allowed in the room at any time - as determined by the need for visitors to book tickets to attend both *Sonic…* and/or *Boom…* at specific times of the day – may have influenced the order in which content was engaged with, as well as the quality of engagement. Second, the intimate, semi-enclosed space in which the exhibit was installed - the *Sound Circle* (see Figure 8.3. below) – and the positioning of *Drum and Bass – Time and Space* at the end of the exhibition route, away from most of the other content (and visitors) - may have helped to reduce background noise and, therefore, distractions. Third, the addition of a bench inside the *Sound Circle* provided a resting place for those who were not currently using the exhibit, allowing adult family members to get down to the same level as the children and help them engage and communicate and, potentially, stay for longer.[496] Being able to rest in this way may have provided more time for visitors to notice and understand what was happening to the sound when others engaged with the joystick and other controls.

[496] Vicky Cave, 'Planning for Young Children and Families in Museums', in *The New Museum Community: Audiences, Challenges, Benefits* (Edinburgh: Museums Etc Ltd, 2010), 115-116.

Figure 8.3. *Drum and Bass - Time and Space* installed in the centre of the *Sound Circle*.

8.3 Results

As previously stated, eighteen attempts were made to collect data from visitor groups: eleven, of which, involved questionnaires, four involved observations, and three involved both. Whilst I felt it was important for visitors to *tell me* what they did when participating in questionnaires - in order to help me make comparisons between how they interpreted their actions and what I *observed* of these actions – it was clear that several visitors demonstrated confidence in using the exhibit but struggled to verbalise their experiences during the questionnaire process.[497] This suggests that although some people might have been musically confident and expressive, they may have been shy in social situations. For example, there were cases - such as during Questionnaires 9 and 10 - in which participants (often male children) could be seen and/or heard using the exhibit in a confident, musical way, but then struggled to verbally communicate their experience afterwards during questionnaire participation. However, it was less often the case that female children felt able to express themselves musically during observations and questionnaires (let alone, verbally).

This reflected similar results identified by Hein in which 'most visitors could not articulate what they had learned.'[498] Further to this, Hein states that researchers should be aware of the differences between the factors which influence verbal responses and those which influence physiological behaviour – or, in other words, the differences between 'what people *tell* you they do and what they are *observed* to do.'[499] This

[497] Hein, 71.
[498] Hein, 123-124.
[499] Hein, 71.

helps to demonstrate the importance of interactivity in museums towards providing opportunities for such people to express themselves during their visit through tactile performance, rather than only through verbally communicating feelings and ideas, which might be challenging for some. Aside from tactile performance, the *Sound Circle* also provided a space in which women and men evidently felt safe enough to react, dance and have fun as a response to the multi-sensory experiences (see Observation 17).[500] Additionally, the more verbally confident respondents felt comfortable in taking the opportunity to offer stories and insights into their exhibition and exhibit experiences (if they so wished). Some visitors offered these in the form of constructive insights and critiques of their experiences, whilst others took the opportunity to complain (both, of which, provided useful feedback). These responses reflect the research summarised by Sacheti who acknowledges that women – in particular – often perceive museums to be 'nurturing environments' within which they feel safe and can 'easily articulate themselves without being silenced.'[501]

As previously highlighted, the length of time that visitors spent in the *Sound Circle* ranged from fifty seconds to fifteen minutes. However, the length of time in which the exhibit was used did not necessarily correlate with the amount of confidence gained during the experience (if any). For example, in the space of fifty seconds (the fastest observation time recorded), the younger participant of Observation 16 not only verified via his actions that he had understood how to operate the exhibit without reading the instructions, but also demonstrated that he was capable of performing confidently with it (without the assistance of adults within his group). In comparison, the participants of Observation 15 used all the controls but struggled to make sense of how to operate it, leading them to become confused and frustrated and, ultimately, leave the space after just one minute and fifteen seconds.

Nonetheless, many visitors responded positively when asked 'do you feel that using the exhibit has enhanced your experience of the exhibition (*Sonic: Adventures in Audio*) today? What makes you say that?' (Q. 8). In fact, members of every group that answered that question responded with 'yes' or 'definitely.' Additionally, certain responses to Questions 7 and 8 indicated preferences towards this kind of material being more demonstrable in museum exhibitions. For example: participants of Questionnaire 2 stated 'anything that explains surround sound is good' (Q. 8); the male adult respondent of Questionnaire 12 expressed that interactivity is good because their kids 'prefer to be hands-on and won't stand and read things' (Q. 8); whilst the respondent for Questionnaire 14 explained that it had made him 'more interested in music mixing' (Q. 7). Comments such as these demonstrate that interactivity can be key to helping visitors understand and interpret sound in exhibitions, which therefore suggests that building interactivity into a sound genealogy methodology for interpreting electronic musical instruments would be valuable.

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[500] Priyanka Sacheti, 'Gendering of Museums: The Role of Women in Museums', *ReReeti*, 2017 <https://rereeti.org/blog/2741-2/> [accessed 20 December 2023].
[501] Sacheti.

In order to better understand the results in the context of this research, the following three case studies derived from this data collection document both typical and atypical scenarios in more detail. Although the unique situations within each case study signify that these visitor behaviours were atypical, there were other situations where the behaviours experienced could be supported by similar evidence from other parts of the data set: helping to identify that these behaviours were, instead, typical. Additionally, the latter two case studies also identify situations which were either unexpected or undesired (or both), which demonstrates the importance of following these research methods to gain insights that could not have been obtained in other ways. The details within each account are chronologically ordered, with a focus on how visitors engaged with and reacted to sound, how they interpreted the exhibit's context, and how their ability or desire to follow instructions, troubleshoot, and physically engage with the interface affected their behaviour with the exhibit.

8.3.1 Questionnaire 11

Questionnaire 11 consisted of male and female adults, both aged 40-55: from hereon in referred to as respondents 11a and 11b, respectively. Shortly following the usual peak period of visitation, the respondents entered the *Sound Circle* and joined the back of a queue of visitors (which consisted of two parties: members of one were already using the exhibit). Although the two respondents spent just over fifteen minutes inside the *Sound Circle* (longer than any other visitors involved in this research), I observed that nearly half of this time was spent waiting to use the exhibit, during which they had the opportunity to experience and interpret the exhibit as observers (they later confirmed when interviewed that they had spent more time with this exhibit than any other during their museum visit). Additionally, because of where they stood in relation to the queue, they had the opportunity to read the interpretation text (Figure 8.1.) installed at the entrance. Therefore, due to their dedication towards wanting to use the exhibit, and the opportunities available for understanding its context, it seemed likely that these respondents would be equipped to provide much information on their experience of the exhibit.

After using the exhibit and leaving the *Sound Circle*, they agreed to complete a questionnaire and were both keen to share their experiences. Due to the lack of visitors trying to move past them in relation to where they were stood, as well as the time that was left to explore the museum before it closed, they seemed happy to complete the questionnaire unhindered. Similarly, the lack of visitors meant that the sound-emitting exhibits nearby were not being used and, therefore, the respondents did not need to talk loudly over the top of other sounds in order to be heard (which, for some of the other questionnaire respondents, impacted negatively on the time and effort they were happy to dedicate to answering questions). Therefore, these lack of constraints, combined with the respondents' enthusiasm, helped them to provide elaborate answers, often constructed through discussions and debates between themselves.

The respondents identified themselves as music lovers, whilst respondent 11a also considered himself a musician: experienced in playing the guitar and other instruments. Due to their age, they also identified themselves as knowledgeable of the historic context that the exhibit represented, stating they were 'familiar with drum and bass […] we are from that generation.' (Q.6) Additionally, the respondent 11a confirmed he had read the interpretation text through stating that 'the exhibit illustrated the interpretational text well' and that it demonstrated 'the extra affordances of digital compared to analogue.' (Q.5) Responses such as these suggest that the respondents could be categorized under the 'engaged community drivers' segment of the SMG's audience segmentation document.[502]

Although they scored the exhibit eight out of ten for ease of use (Q.2) and ten out of ten for how much they enjoyed the experience (Q.3), they were also keen to discuss issues experienced as well as improvements they believed could have been made. For example, respondent 11a felt it was confusing for visitors to have to let go of the note they were playing before they could activate the next one, and therefore could only operate the *Bass* one note at a time (Q. 2). Respondent 11b suggested that the controls for *Drum* and *Bass* were too far apart from each other and felt that more than one person was needed to operate the exhibit at a time (Q. 2). She also would have preferred to hear and/or control another drum loop, so that comparisons could be made between manipulating the *Time* and *Space* of the Amen breakbeat whilst another was left 'dry' (Q.9) However, this would prove difficult as the drum loops would likely go out-of-sync with each other, which would sound confusing. Respondent 11b also suggested that the experience of *Space* could have been better realised if visitors were able to move around the room whilst operating a mobile interface, rather than remaining in the centre tethered to the stationary interface structure (Q.5). However, again, this would be problematic because the mobile interface would still need to be tethered to something, otherwise the potential would exist for visitors to leave the museum and take it with them.

Regarding the playback of sound, Respondent 11b wished the bass frequencies were louder so that the experience in the room *felt* more like a nightclub (Q.7). Here, she could have been referring to the vibrations produced by the bass - which would be felt more in the body - or the balance of sounds which better represented what is often experienced in nightclub spaces (or both). If this was based on her lived experience of drum and bass music played on a nightclub sound system that effectively reproduced the bass frequencies of that music, then unfortunately the experience of sound in the *Sound Circle* did not align to the visitor's expectations in relation to the exhibit's musical context. Nonetheless, she acknowledged that this was probably due to the challenges of managing sound levels in exhibitions (which was the case).

[502] Science Museum Group, 3.

Whilst their constructive feedback could be useful in helping institutions such as the NSMM understand how similar exhibits could be improved, the respondents' encounter with *Drum and Bass - Time and Space* was a positive one, which was confirmed with the following statement: 'we could have stayed the whole afternoon, it was very fun!' (Q.3) This was likely influenced by their preference towards the addition of interactivity in museums, and how they valued its usefulness for exploring musical practice: 'what I like about sound is actually doing something with it […] it is a primal experience […] interactivity in exhibitions is better!' (Q.8) Additionally, they commented positively on the provision of the semi-enclosed *Sound Circle* space, acknowledging that 'with this exhibit it was your own space and you felt like you could spend longer with it.' (Q.9) Respondent 11a also expressed his interest in the ability to slow down the *Drum* audio with the joystick and wanted to 'try to slow things down when creating music in the future.' (Q.7) This demonstrates that whilst musical practices can be used to frame music and sound objects and other forms of content in exhibitions, the unique ways in which sounds can be manipulated through museum interactivity can, conversely, impact on the approaches that musicians take to creating and performing music after visiting a museum.

8.3.2 Observation 17

Observation 17 involved a female carer with a male child: participants 17a and 17b, respectively. The participants waited in a queue inside the *Sound Circle* before using the exhibit for five minutes and five seconds. When asked whether they minded being observed, participant 17a's response indicated that she was unsure as to how useful their engagement with the exhibit might be. Nonetheless, once it was their turn, participant 17a briefly read the instructions and demonstrated how to use the exhibit by pressing the play button and moving the joystick so that participant 17b might pick up on her cues (rather than the museum's) as to how to use it. However, participant 17b was not interested in (or perhaps did not understand) them and started to press the *Bass* buttons at random. The participants then swopped their positions so that participant 17b controlled the drums and the carer controlled the bass. The use of the exhibit was mostly collaborative. The participants either worked together, or they entered into a 'versus' situation as prompted by participant 17a, although at one point participant 17b moved the joystick up and down at random whilst participant 17a danced around the *Sound Circle*.

Both participants demonstrated that they became more confident in using the exhibit over time. Participant 17a attempted to play the *Bass* buttons in time with the *Drum* audio, whilst participant 17b realised how to turn the *Drum* audio off through observing participant 17a pressing the play button and turning the sound on and off. Additionally, as participant 17b became more focused on the *Drum* section of the interface - using the play button and joystick from the front and from behind the interface - he moved the joystick towards him (backwards) and held it there for some time, in order to enjoy the heavily time-stretched sound of the *Drum* audio. Exhibiting these specific actions provided evidence of a learning style which Honey and Mumford describe (in Black's book *The Engaging Museum: Developing Museums for Visitor Involvement*) as activist: involving themselves 'fully and without bias in new experiences.'[503]

It was not until the final two minutes of the observation that behaviours were demonstrated which I had not expected. The participants stopped using the exhibit as it was intended and decided to play a game which involved dancing around the space (either together or separately, facing the boundaries of the *Sound Circle* enclosure) to the sound of the *Drum* audio. They danced until one of them secretly pressed the play button to stop the music, at which point they both fell to the floor as quickly as possible, forming seated positions with their legs crossed. Whoever reacted the quickest and sat on the floor cross-legged first was announced as the winner by participant 17a. Additionally – once they had finished their game – they stopped the *Drum* audio and left the space. Through doing this, it seemed as if the participants may have felt a responsibility towards leaving the exhibit as they found it.

8.3.3 Observation 18

Observation 18 took place at 3:30pm, shortly before the museum closed at 4pm. Two male carers, one female carer, and four young children (boys and girls) – from hereon in referred to as participant group 18a, participant 18b, and participant group 18c, respectively – entered the space with different levels of enthusiasm. Participant group 18c seemed excited with the prospect of engaging with a new form of interactivity, whilst participants 18a and 18b seemed uninterested (perhaps tired). Whilst participant group 18c used the exhibit the most, they gained the most pleasure from pressing the buttons as hard and fast as possible and rapidly moving the joystick up and down with force, without needing to wait for something to happen as a result. It is worth mentioning, here, that these actions were not an anomaly: the child participants of Observations 12, 13, and 15 also chose to hit the *Bass* buttons hard and fast to begin with, before adults demonstrated how to operate the exhibit as per the instructions. Whilst all of participant group 18c used the exhibit - often all at once - they showed no obvious signs of working with, or against, each other. Unfortunately, because they continually pressed the play button on and off, they did not allow time for the *Drum* audio to commence and therefore did not understand what the button was for, nor did they understand what the joystick was for as there was no audible sound to modify. Therefore, the participants were unable to experience both the surround-sound and time-stretching phenomena.

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[503] Black, 136.

Additionally, a member of participant group 18c lent over the interface and held down at least three of the *Bass* buttons at once, which meant that the sawtooth bass sound couldn't be triggered from any of the held notes, nor could it be triggered by any of the buttons that were still available. This was evidenced by the fact that, when pressing down on the buttons that were still available, the lights behind them ceased to function. A similar situation occurred during Observation 15. A female carer kept accidentally (and unknowingly) pressing the play button, which compromised the potential for the Amen breakbeat to be modified by the joystick (which she continued to operate). Additionally – during Observation 15 - a child kept leaning on one of the *Bass* buttons, which removed the possibility for the sawtooth bass sound to be re-triggered by any of the other buttons. This suggests that the exhibit might have benefitted from being designed for polyphony, which would have allowed for more than one note to sound at any time.

The involvement of participants 18a and 18b in the use of the exhibit was limited. Participant 18b read the instructions out loud to participant group 18c and tried to show them how to use the exhibit as it was intended to be used (as per the instructions), but they were not interested in her short demonstration. Additionally, a member of participant group 18a spent a few seconds trying to use the exhibit before giving up. Participant group 18a and participant 18b seemed surprised that the exhibit did not work as a result of their actions. Whilst a member of participant group 18c was leaning over and holding the *Bass* buttons down, a member of participant group 18a looked over to me and asked, 'why isn't it working?' I then explained that they needed to let go of all the *Bass* buttons, which needed to be pressed down and held one-button-at-a-time in order to play a melody, which I demonstrated to them. Unfortunately, this made little difference to their experience and participant group 18c banged the buttons at random again. Towards the end of the observation, participant group 18c became frustrated with their experience and started twisting the button fixings around to loosen them before attempting to pull the buttons off which, if they had been successful in doing so, would have broken the exhibit. Thankfully, the participants decided to stop using the exhibit before any damage was done and left the *Sound Circle* after spending two minutes and forty-three seconds inside.

8.4 Discussion

8.4.1 Validity of Methods and Findings

The potential for visitors to perceive power imbalances may have affected the data collected through visitor observations and questionnaires. As Foucault observed, difficulties arise when collecting data from communities in situations where the researcher is noticeably not a part of that community and, therefore, as Mills states, 'in the process of collecting data and information […] they cannot but establish power relations between them and the group.'[504] One of the factors that may have influenced this was the wearing of an SMG name tag – identifying my alliance with the institution but not highlighting that I was the exhibit designer – which may have influenced visitors to demonstrate certain behaviours in my company, or encouraged them to provide feedback they thought I wanted to hear, or thought would be useful. Additionally, I noticed that some children were intermittently looking in my direction whilst hitting various buttons. This behaviour suggested they may have wondered whether they were 'doing it right' and were looking at me to seek approval, or that they may have tried to gauge whether they had gotten away with bashing the buttons or not (as was the case with Observation 18). Behaviours such as this evidenced that my affiliation with the SMG - or just the fact that I was there conducting observations - had the potential to influence the power dynamic between myself, the museum, and its visitors in various ways.

Additionally, asking visitors if they were happy to be observed whilst standing at the entrance to the *Sound Circle* may have potentially distracted them from reading the interpretational text. Nonetheless, whilst participating in questionnaires away from the entrance afterwards, some of the visitors revealed they had at least noticed the text as some of the questions prompted them to look in that direction in search of the answers. However, Falk and Dierking suggest that whilst some visitors are not aware they do not know an answer and therefore do not check for accuracy, others may feel that the interpretational text does not provide the information they were interested in anyway.[505] This also helps to demonstrate that some visitors may wish to follow their own learning agendas or desires regardless of the cues that museums provide to direct their attention towards certain learning goals.

8.4.2 Family Groups and Complex Dynamics

Whilst research has identified that family groups comprise a major part of many museums' audience demographics (see Figure 8.4. below), the results demonstrated a complexity of abilities and influences amongst family members.[506] This reflected the findings of Falk and Dierking who argue that family dynamics and relationships are complex, involving individuals with different abilities, interests, and prior knowledge.[507] Furthermore, they suggest that each family member may also hold assumptions as to the abilities and roles of others, which may be negotiated during an interactive exhibit experience.[508] As we saw

[504] Mills, 77.
[505] Falk and Dierking, 124.
[506] Falk and Dierking, 149-150.
[507] Falk and Dierking, 149-150.
[508] Falk and Dierking, 153.

with Observation 18, whilst the participant group 18a and participant 18b assumed that participant group c needed to be guided in using the exhibit to begin with, the exhibit's apparent malfunction coerced them to think that participant group c had, instead, perhaps used it as the exhibit designer had intended and it was, therefore, the exhibit and those responsible for building and maintaining it that were at fault. Therefore, visitors' understandings of a situation in which they and others in their group are encouraged to act (e.g., through the existence of an interactive exhibit in an exhibition) may affect their assumptions of their own skills and the skills of others: not just in performing and troubleshooting, but in determining whether a fault exists due to human error or a technological malfunction.

Families are also known to visit museums with various agendas and goals, which could include – as Falk and Dierking suggest – socialising, convenience, supporting their family identity, having fun, and learning.[509] For example, Observation 17 demonstrated a scenario in which a family engaged with the exhibit in a fun, independent, and spontaneous way (as directed by participant 17a): suggesting that participant 17a could be categorised within the 'trend-awares' segment of the SMG's audience segmentation document (perhaps seeing herself as 'spontaneous, adventurous, independent and ambitious').[510] Additionally, Falk and Dierking acknowledge that adult family members may choose to facilitate a child's exhibit experience, or they might also take the time to explore the exhibit themselves (as a lay visitor or an expert).[511] This was identified in various observations, during which both male and female carers offered advice to children through oral instructions, or by demonstrating how they believed their children should use the exhibit. However, during Observation 17, participant 17a chose to facilitate participant 17b's exhibit experience to begin with by exploring the exhibit herself, before encouraging a different set of actions from participant 17b which involved playing their own game and having fun. In this instance, the visitors' actions helped them to experience the exhibit in a new, positive, and gamified way, without having a negative impact on the experience for future visitors.

The example above demonstrates the potential for family visitors to move beyond one static use of a technology as originally conceptualised in Akrich's script metaphor (discussed in chapter six). Considering that the interactive exhibit was, itself, a technology, we can theorise these behaviours as the adoption of further scripts: as imagined either by the designer of the exhibit and the museum, or by the visitors. In contrast, the scenario depicted in Observation 18 evidenced a form of anti-program (as discussed in chapter six) in which neither the participants, future visitors, the museum, or any other stakeholder would have benefitted from if they had managed to break the interface. However, considering that the exhibition was likely to attract a 'lively' audience (as stated in the call for submissions for the micro-commission project), and considering that members of the exhibition team recommended that I purchase similar arcade

[509] Falk and Dierking, 150-151.
[510] Science Museum Group, 13.
[511] Falk and Dierking, 153.

buttons to what they often use for interactivity, it may be safe to assume that those members were expecting some visitors to behave in this way. Nonetheless – as was experienced during this data collection – the idea of a lively audience seemed, in reality, to depict a worst-case scenario, where in fact most of the visitors encountered behaved in such a way as to help ensure that the exhibit continued to work as desired.

Figure 8.4. A family using and discussing the exhibit.

8.4.3 The Influence of Text on Pedagogic Outcomes

The interpretational text aimed to assist visitors in understanding what the context and purpose of the exhibit was: both in isolation, and as part of the learning and entertainment goals of the *Sonic…* exhibition. The collection of qualitative data through questionnaires provided the means to determine whether the application of a sound genealogy methodology towards the exhibit's interpretation was acknowledged and understood by those who used it, leading to successful pedagogic outcomes as intended by myself as the exhibit designer. However, the length of interpretational text (a maximum of 140 words for the main interpretational text, and a maximum of 40 words for the instructions) – as well as feeling the need to briefly describe the context behind the surround-sound experience within the word count – did not allow for the full sound genealogy context to be stated. Nonetheless, it was clear that many visitors had realised and understood the learning goals in relation to what *was* stated in the text. For example, in response to Question 5 - 'What did you think the purpose of the exhibit was?' – most visitors stated they had learnt about tempo (Questionnaire 4: 'mixing different sounds at different speeds'), about triggering the two sounds at different times (Questionnaire 9: 'you can mix sounds together'), and about surround-sound (Questionnaire 7: 'How to mix different sounds into each other, and front to back surround sound'). Therefore, if we focus solely on what visitors learnt of the exhibit's context via the supporting textual cues, the pedagogic outcomes seemed realistic and achievable. Additionally, we must also consider that the mention of time-stretching and drum and bass in the same sentence could have been enough for an 'expert' visitor to connect the exhibit to the Akai S-series of digital samplers anyway (with the timbral quality of the exhibit's audio hopefully confirming this link).

8.4.4 The *Sound Circle* as an Auditory Liminal Space

However, it could be argued that responses such as those above could have, otherwise, been constructed empirically from the use or observation of the exhibit, without the need to read the interpretational text before or afterwards. In other words, visitors who did not read the text and were not familiar with the themes represented by my exhibit could have constructed a personal meaning-making experience from uncovering sensory information whilst operating the joystick and buttons. By facilitating the opportunity for visitors to 'organise what he or she has discovered and construct new meanings as a result,' the museum may have created a learning experience that was, for some visitors, less didactic and more constructivist (as previously discussed in chapter six), which Black argues 'supports active engagement and fosters curiosity.'[512] For example - in the case of Observation 17 - the behaviour of the participants suggests they may have realised their own learning and entertainment outcomes and - through following the carer's lead - the child may have learnt that sampled and electronically-generated sounds help to create music that encourages people to dance. Therefore, regardless of how much or how little of the sound genealogy methodology was applied as text, visitors may have still constructed their own knowledge from using or observing the exhibit and may have even constructed their own judgements as to the exhibit's effectiveness as a tool for learning and entertainment.

The multi-sensory conditions of the *Sound Circle* space and the exhibit influenced the constructivist learning experience as well as the behaviours exhibited by visitors. As interactivity has disseminated across various types of museums and galleries, the concept of ritualistic behaviour within institutions - as explored by Duncan – may not only be applied to the 'special quality of attention' visitors are expected to perform in relation to visual art and object collections, but could also be applied to visitors' performances with interactive exhibits and the spaces in which they are installed.[513] Although both the exhibition and the NSMM in its entirety could be described as ritual sites – places 'programmed for the enactment of something' - the semi-enclosed *Sound Circle* created an additional, internal ritual site.[514] This new liminal space may have coerced behaviours from visitors which differed from those presented in the rest of the exhibition space, temporarily suspending 'the constraining rules of normal social behaviour' as encountered in the rest of the exhibition.[515] In this way, the *Sound Circle* represented an experimental space in which behaviours may alter in ways that neither the NSMM, the exhibit designers, nor the visitors anticipated.[516]

Based on her experience in developing galleries for young children in museums and science centres, Cave argues that 'creating spaces which are inviting to both carers and children were seen to promote, support and extend opportunities to play, communicate and imagine together.'[517] This was evidenced with Observation 17 which demonstrated that the qualities of the smaller, more private space had the potential to encourage unique, playful and imaginative behaviours that may not have otherwise been exhibited elsewhere in the *Sonic…* exhibition, or elsewhere in the museum. However, although these participants demonstrated an understanding of how to operate the interface and how the controls affected the sounds, it was difficult to ascertain what they might have learnt of the association of time-stretching technology with the formation and shaping of drum and bass music from observations alone, especially considering that they did not read the interpretation text on entering the space. In comparison, the respondents for

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[512] Black, 138-139.
[513] Duncan, 425-428.
[514] Duncan, 428.
[515] Duncan, 427.
[516] A similar space was discovered in the *Gibson Interactive Studio* inside the British Music Experience, Liverpool. The space consisted of a separate, enclosed vocal booth in which the exhibit inside prompted visitors to sing over the top of famous songs (following the karaoke paradigm) as loudly as one wished – a behaviour which was less likely to be experienced in the rest of the museum.
[517] Cave, 115.

Questionnaire 11 not only commented positively regarding the intimate space ('you felt like you could spend longer with it'), but also highlighted that they had read the accompanying text, which demonstrated an interest in the exhibit's context. Nonetheless, by separating pedagogic outcomes from experiential ones, we may conclude that in instances such as with Observation 17, visitors may realize 'successful' engagements with exhibits based predominantly on multi-sensory, kinaesthetic, and social experiences, which help them to reach the entertainment goals of the exhibition team, or their own.

Additionally, whilst the concept of liminal spaces is usually identified by visual cues – and, in this instance, with the kinaesthetic behaviours instigated by the installation of interactivity within a smaller, separated space - we must also highlight the importance of *sound* in constructing the unique liminality of the *Sound Circle*. This was achieved through both the museum's management of sound and the provision of sound manipulation controls for visitors. For example, the use of sound-dampening materials to reduce the experience of noise from elsewhere in the exhibition whilst helping to contain the exhibit's sound within the *Sound Circle* helped to create a unique listening experience in that space, allowing visitors to make sense of the surround-sound phenomena without external noises breaking their concentration. The carpet on the floor and grey panels around the circle also helped to absorb the sounds emitted inside the space. Also, the play button, joystick and the *Bass* buttons provided the means for visitors to control when (and where) the different sounds should be triggered and heard, enabling visitors to either control the acoustics of this space or chose to sit in silence on the bench which ran between the exhibit and the boundary of the circle. Therefore, these factors helped to create an environment that could have either been quiet or loud, passive or active, or controlled or chaotic, demonstrating ways in which social and musical practices can be effectively *displaced* into exhibition settings through not just the design of 'break-out' physical spaces, but also as the result of sensory feedback produced through interactivity.

The auditory liminality of the *Sound Circle* was mainly identified by the Amen breakbeat for the *Drum* section, and its manipulation within the parameters of *Time and Space*. The combination of tactile performance and sonic feedback (as well as visual feedback from the buttons – see Figure 8.5. below) encouraged visitors to engage with the exhibit in different ways. For example - as was witnessed in Observations 13 and 14 – visitors that were not using the exhibit followed the Amen breakbeat as it was moved around the room by the person using the joystick. Additionally, their observations may have subsequently influenced their actions, in terms of whether they had become interested in engaging with the exhibit in a more musical or scientific way. Whilst some visitors focused on *performance* - influenced by those who used the exhibit before them (dependent on whether they felt the previous performance was 'successful' or not) - others were more interested in understanding how to replicate the surround-sound phenomena when it was their turn to *experiment*, based on the actions that seemed appropriate in response to the auditory feedback produced.[518] This demonstrated that experiences of physical

[518] Falk and Dierking, 154-155.

engagement and aural feedback were not just important to the visitor using the exhibit, but also to those witnessing both their actions and the results of their actions.

Figure 8.5. A visitor pressing down on one on the Bass buttons of the exhibit, causing it to light up.

As far as the learning outcomes of the exhibit were concerned, both the audio content and its delivery helped some visitors to connect the sound of time-stretching and drum and bass composition to things other than instruments and their functions. This was aided by the provision of a simple joystick control, which helped visitors to engage with time-stretching and sound diffusion in real time. As discussed in the previous chapter, since first appearing as a recorded drum solo by The Winstons in their funk track ‘Amen, Brother’, this audio material has since been sampled and re-interpreted by musicians of hip-hop music and within a large variety of electronic dance music sub genres (including drum and bass). In relation to the application of a sound genealogy methodology, this concept of multi-sensory liminality is significant as it evidently helped visitors to make the leap from one strand of sound genealogy; the dissemination and shaping of a particular sound through instruments and their functions (as highlighted in the interpretational text), to another; the dissemination of a sound through recorded media, live music, and DJ culture (which was not explicitly mentioned).

This seemed the case with Questionnaire 3. When asked ‘had you encountered the exhibit’s themes, sounds, music or technologies either in this exhibition, in any of the museum’s other exhibitions, or outside the museum?’ (Q.6), the adult responded ‘yes - at the festival and at various other events’ (acknowledging the *Beautiful Days* festival which she had recently returned from). Furthermore - in combination with the darkened space and use of a sub-woofer - an association with recorded media, live music, or DJ Culture may have encouraged the visitors of both Questionnaire 3 and Observation 17 to start dancing: a behaviour more often associated with spaces of live music and DJ culture than with museums. This demonstrates that it may not be necessary to account for all the elements of sound genealogy within the interpretational resources that accompany an interactive exhibit, as visitors may be able to connect an exhibit to other sound genealogy related factors themselves.

8.5 Conclusion

In this chapter, we have seen how the exhibit was eventually used and interpreted by a cross-section of visitors at the NSMM. Whilst the exhibit was designed to meet the requirements specified in the original call for submissions (as discussed in the previous chapter), the subsequent collection of data from visitors evidenced the facilitation of these requirements. For example, whilst a small number of remedial repairs were made by the museum’s technicians, the exhibit did, in fact, remain on gallery for the time required and endured the actions of the anticipated lively audience. Additionally, both individual and group experiences were encouraged and facilitated, whilst the ‘in-your-face’ multi-sensory experience of the Amen breakbeat and bass sounds were evidently not missed. Furthermore, it was clear that the exhibit and its context appealed to a range of visitors, both in age and specialism. Nonetheless, the extent to which visitors could be considered ‘critical listeners’ remained debatable. For example, whilst the call for submissions claimed that visitors were *not* critical listeners, I observed several of them acknowledging the relationship between their actions with the exhibit’s interface, and the aural results across the eight-speaker configuration.

Whilst family groups were the target audience for both the micro-commission content and the exhibition as a whole, the range of behaviours and social interactions exhibited by individuals of mixed ages and backgrounds within each group evidenced the complexity in understanding family dynamics in relation to who might be better prepared - or more musically or technically capable - of supporting, demonstrating, and developing confidence in using the exhibit. This demonstrates why it is important for exhibition teams to develop their understanding of the value of interactivity from the perspectives of family units, the perspectives of individuals who comprise those families, and the impact that family members have on each other's agendas and goals. To this end, Falk and Dierking advocate for museums to consider group or family agendas alongside their own, in order to accommodate the meaning-making experiences of members of this valuable audience sector, and the family as a whole.[519] Nonetheless, complex family dynamics, as well as variations between different family groups in terms of their varying agendas, expectations, and behaviours, further challenges the notion of what a 'successful' exhibit experience could, or should, be.

However, through developing a clearer picture of the degree of knowledge and skills that visitors could hope to achieve from using and interpreting an exhibit, exhibition teams may be in a better position to control the level of context provided to visitors through the medium of interpretational resources, in respect of what visitors might understand empirically. In the case of *Drum and Bass – Time and Space*, whilst it felt important to use text to describe sound diffusion in the context of using mixing practices to make space for sounds, the data collected evidenced that some visitors had understood the exhibit's purpose as demonstrating both tempo and surround-sound solely through empirical means. Nonetheless, whilst the word count for the interpretational text could have been fully dedicated to sound genealogy – tracing the history of the Amen breakbeat back to The Winstons and linking the timbral qualities of the time-stretching function to the Akai S950 digital sampler - there remains the challenge in knowing whether 140 words of accompanying text could have fully explained the history of the Amen breakbeat in terms of how it has been disseminated through material networks, and who else was responsible for creating and recording the original sound and subsequently modifying and disseminating it. Therefore, exhibition teams should be careful not to make assumptions over pedagogical outcomes: whether visitors will absorb the knowledge that is expected of them, whether this will be done empirically or through consuming interpretational resources (or both), and whether visitors will be willing to absorb and understand the quantity and complexity of knowledge available to them.

Nonetheless, the exhibit creation and subsequent data collection has clarified that it is not just visitors' passive experiences of sound that needs to be considered by exhibition teams, but also the active experience of controlling sound and reacting to it. Additionally, this practice-informed research has identified the benefits of providing breakout spaces that help frame and contextualise the sounds that visitors create, trigger and shape. Further to this, visitors also expressed that the *Sound Circle* provided a better space for interactivity due to factors such as privacy and sound management. Considering that some visitors were also able to understand this from the perspective of the exhibition teams responsible (as identified through Questionnaire 11), there may be more to understand – and consider - in terms of how

[519] Falk and Dierking, 154-155.

much knowledge visitors have of the challenges that museums face in providing active, multi-sensory experiences.

However, the fact remains that, in order to ensure that all museum visitors gain learning and entertainment value from using an exhibit, it must be built to withstand destructive behaviour. In the case of Observation 18, it was easy for the child participants to loosen the buttons and, if allowed to continue, to remove them completely. If this had happened earlier in the day, the exhibit may have been closed to the public for repairs, resulting in the exclusion of this exhibit from subsequent visitors' exhibition experience (as well as the extra work added to the technicians' busy schedule to repair it). Considering the behaviours during Observation 18 - and the fact that the joystick was pulled off the interface during the exhibition's first week (due to continued attempts to operate the joystick left and right, which it was not designed to do) - it is, therefore, important to recommend that interactive designers explore ways of attaching physical controls to an interface *beyond what the manufacturers of the controls have suggested for mounting*. In the case of this exhibit, although the controls were mounted following the advice of the manufacturers (the joystick was mounted using the supplied screws, whilst the buttons were fastened using the various supplied parts), the addition of a strong adhesive (such as Araldite glue, which the technicians used in repairing the joystick) may have extended the life of the exhibit without the need for visitor-induced repairs. Therefore, following this recommendation should help to ensure that exhibits are better suited for 'lively' audiences.

9 Conclusion

9.1 Sound Genealogy: Sounds, Instruments, People

As stated at the beginning of this thesis, my aim has been to explore the digitisation of electronic musical instruments for museum interactivity and review the demonstrative value of contemporary exhibits in uncovering, communicating, and framing the often-hidden sounds of these instruments (which may – themselves – be considered significant). In both the case study chapters, as well as the previous two chapters which focused on my original contribution - the exhibit *Drum and Bass – Time and Space* – I identified how sounds can be created through different means and interfaced with by visitors. In chapters two and four I explored the analogue oscillators and transistors of Hugh le Caine's Electronic Sackbut keyboard instrument and the Roland TR-808 drum machine: producing melodic tones and percussive noises, respectively. In chapters three and seven I demonstrated examples whereby electronic sampling instruments - the Mellotron M400 keyboard and Akai S950 digital sampler – were capable of triggering and shaping sounds that were previously performed acoustically. Furthermore, through different digitisation processes, we have seen that both analogue recordings of acoustic instruments and electronically generated sounds can be further embedded or even re-imagined for later electronic instruments – as was the case with the Memotron M2K and the instruments created since the manufacture of the Roland TR-808. Additionally, within various museums we have seen how exhibition teams have been able to re-associate sounds with instruments using new interfaces created for interactivity, as well as the purposeful design and digitisation of exhibits to look or sound like the instruments they are based on (which was particularly true of the MR-808 drum robot in chapter four). We have, therefore, seen evidence of the various ways that exhibition teams can facilitate different interpretational focuses for these exhibits (in terms of the case studies: interface, sound, and function).

As part of the field of Sound Studies, sound genealogy has been constructed and applied in this thesis to frame electronic musical instruments and recorded media in museum exhibitions as forms of the 'material production and consumption of music, sound, noise, and silence, and how these have changed throughout history and within different societies'.[520] In other words - as explained in chapter one - the purpose of sound genealogy is to go back and forward in time and follow a sound to find the people and artefacts responsible for creating, triggering, and shaping it: helping us to better understand how factors such as the usefulness of a sound for musical applications, as well as the means of disseminating that sound through material networks, have influenced its popularity over time. Through focusing on the sounds of

[520] Pinch and Bijsterveld, 'Sound Studies: New Technologies and Music', 636.

instruments, we have uncovered networks of people, instruments, and technologies responsible for generating, triggering, designing, and modifying sound: similar to 'following the instruments' which Pinch and Bijsterveld advocated for in the field of STS.[521] This is important because not only have the sounds of electronic musical instruments been hidden within the instruments themselves - whose physical features present few visual clues that indicate their full sounding potential – communities of sound (such as the sound designers responsible for creating presets) have also remained comparatively hidden due to an identified lack of research that could have exposed the people responsible for creating and shaping them. Therefore, the construction and testing of sound genealogy presents an original contribution to literature: not just to museology, but also to the study of instrument sounds more generally.

Applying a sound genealogy methodology towards the interpretation of instrument sounds could help exhibition teams to expand upon more traditional interpretations of instruments that focus on designers and significant users, to also acknowledge the various people responsible for providing each of those instruments with their sounding purpose (for example, preset designers) or uncovering an instrument's sounding potential through music and sound practices (for example, sound designers for sample libraries). Through the case study chapters, it has been acknowledged – for example - that the sounds produced by the Mellotron are not only the results of different material and electronic component assemblages but also the tapes hidden within. By focusing on the tapes, we can uncover communities of acoustic instrument performers, sound designers (for its sound effects tapes) and sound engineers: all of whom were responsible for creating and recording that which could be triggered by the instrument's keys. For an exhibition team, the opportunity therefore exists to construct explanations of how these recorded sounds were later used by musicians, as well as highlight who was responsible for subsequently digitising those sounds for more recently manufactured digital instruments (as was the case with the Memotron M2K). These and other processes towards interpretation represent the depunctualization of instruments - as discussed in chapter five - to uncover communities of sound from what may otherwise have been considered black boxes.[522]

We have also seen that sounds may follow historic trajectories which may seem intrinsic to a particular instrument or divorced or branching from an instrument closely associated with it. For example, sampled sounds have their own histories of use which may extend beyond the instruments closely associated with them and can be distributed further within new material networks of instruments (as has been the case of the Amen breakbeat and the Akai S950 sampler). Additionally, due to the technologies and functions implemented within each instrument for generating, triggering, and modifying sound (such as Roland's Analog Circuit Behaviour – ACB – method of digital signal processing, as discussed in chapter four), each subsequent instrument also has the capacity to alter each of these sounds in minute or substantial ways,

[521] Pinch and Bijsterveld, 639.
[522] Pinch and Bijsterveld, 638; Bates, 'Actor-Network Theory and Organology', 45.

producing a variety of iterations that branch-off from a supposed original.[523] The same applies to the different processes involved in the distribution of sounds as music and other forms of popular culture, leading to further avenues for sampling which other musicians can engage with. However, whilst moving forward in time can challenge the notion of a sound being a true representation of an original, the authenticity of the original is challenged further when we consider the origin of a sound's creation and how and when it was experienced. Again, using the Amen breakbeat as an example, the sound's origins extend beyond the point in which consumers heard the original recording of 'Amen, Brother' by The Winstons to a time when the musicians and recording artists heard the sound performed during the recording process, or perhaps further back to incorporate conceivable practice performances of this breakbeat prior to that recording. Therefore, it is conceivable for exhibition teams to focus less on communicating originality (e.g., associating the Amen breakbeat with Gregory C. Coleman of The Winstons) in favour of creating a better, more user-friendly interactive experience where the instrument associated with that sound is not involved (as was the case with the digitisation of the Electronic Sackbut, as well as the reproduction of the Akai time-stretching function using Max software, rather than the original sampler).

On the subject of reproducibility and authenticity, we must also account for the role of recorded media and broadcasting methods towards the dissemination of sounds over time and space (as discussed in chapter five). For example, whilst there exists only a small quantity of recordings of the Electronic Sackbut instrument's performance, both the analogue percussion sounds of the Roland TR-808 and the digitally sampled Amen breakbeat have not only proliferated various styles of electronic music but have also helped to soundtrack other forms of popular culture. Therefore, not only has the timbre of these sounds been modified through their dissemination across material electronic musical instrument networks, but also through manufacturing processes and communication methods such as vinyl production, MP3 conversion, and FM broadcasting (for example). By searching these methods of dissemination to find new sounds, musicians may further alter the timbres of these sounds through their use of technologies for recording, composing, and performing, helping them to create new versions of these sounds and, potentially, new music. These practices could provide exhibition teams with additional sound-focused contexts for framing and interpreting sounds and instruments.

[523] OV Valle, 'What Is Analog Circuit Behavior (ACB)?', *Roland U.S. Blog*, 2014 <https://www.rolandus.com/blog/2014/02/14/analog-circuit-behavior-acb/> [accessed 29 October 2022].

9.2 Practical Considerations for Applying Sound Genealogy in Exhibitions

When considering the quantity of linkages within networks of sounds, materials, and people, it may be the case when applying sound genealogy to exhibition interpretation that a single object or exhibit may not suffice. Whilst the content within the exhibition *Sonic: Adventures in Audio* was very much sound-focused - delving into 'the world of sound with exciting new installations and interactive sound works' - the exhibit *Drum and Bass – Time and Space* was designed and installed in *Sonic…* as a means to test the sound genealogy methodology – specifically - within an exhibition (as the practice-informed part of this research).[524] However, as we saw in chapters seven and eight, the museum's restrictions on word counts for interpretational text, the need to justify and contextualise the facilitation of sound diffusion, and the understandable and expected lack of additional content in support of my exhibit, presented a challenge in constructing a fuller narrative around the history of the Amen breakbeat. Whilst many of the visitors evidently achieved learning outcomes which aligned with what was identified in the text – whether this was because they had read it first, or because they had reached these outcomes independently through the exhibit experience – perhaps more could have been achieved had this exhibit been installed within a larger thematic display, accompanied by other forms of exhibition content in that space.

However, when comparing the learning outcomes of *Drum and Bass – Time and Space* to the outcomes envisioned for the interactive exhibits explored in the case study chapters (as stated in each museum's use of interpretational text or confirmed by those interviewed), the degree of knowledge which visitors were intended to attain with each exhibit seems comparable. In each of the case studies, visitors were provided the tools to understand what the different controls on each interface did, what the underlying functions could achieve, and how they could be used to trigger and modify sound. It was only in the case of the Memotron M2K where the interpretational text also highlighted the instrument's use by popular bands such as The Beatles, Genesis, and Tangerine Dream: which may have served to help visitors identify where they may have previously heard the instrument's flute sound- 'Strawberry Fields Forever' - for example (if they happened to find and use it). Therefore, it is perhaps too ambitious to think that one interactive exhibit could be solely responsible for communicating a sound genealogy methodology based on one particular sound, which is why additional exhibition content is likely to be needed.

Nonetheless, exhibition teams should consider that not every sound will lend itself towards a sound genealogy methodology for interpretation. This is due to a number of factors, such as whether a particular sound has been – or can be – closely associated with significant objects and people of sound and music, as

[524] 'Sonic: Adventures in Audio', *National Science and Media Museum*, 2021 <https://www.scienceandmediamuseum.org.uk/what-was-on/sonic-adventures-audio> [accessed 27 November 2022].

well as the probability of the sound being recognised by visitors which exhibition teams intend to attract. Using the example of 'Strawberry Fields Forever' above, it may be likely that older British and American people will have heard the flute sound of the Mellotron M400 instrument prior to a museum visit, as they will have experienced it within a single popular song performed by, arguably, one of the most significant Western rock bands of all time. Not only has the cross-continent distribution and reimagining of the Mellotron by designers such as Harry Chamberlin and Streetly Electronics helped to guide the instrument into the hands of The Beatles, but also the later global distribution of 'Strawberry Fields Forever' through various recorded media and broadcasting methods will have helped to ensure that Western audiences were exposed to the flute sound applied to this song.

In comparison, whilst the time-stretching function of the Japanese company Akai's S series of samplers was deployed extensively on sounds such as the Amen breakbeat on thousands of mostly British-made songs from the early nineties (and beyond), it may be less likely that visitors will have previously noticed, or even heard, this effect due to the popularity of these songs remaining comparatively low compared to the sounds of popular songs recorded by bands such as The Beatles. Furthermore – if we consider Hugh le Caine's Electronic Sackbut – not only were very few iterations of this instrument designed in Canada, but comparatively few recordings were made of the instrument's sounds. However, there may also exist instruments that help to support this form of interpretation due to their limited repertoire of sounds. The Roland TB-303 synthesizer is a good example of this as it can only generate two basic oscillator waveform shapes (triangle and square): both, of which, have been responsible for creating and shaping the signature sound of various forms of 'acid' music (as was discussed in chapter two) and have become completely interwoven into the fabric of electronic dance music. These examples demonstrate that exhibition teams should, therefore, consider the complex relationships between the design and distribution of instruments, and the ways in which its sounds have been used and distributed through recorded media and broadcasting methods, on a per-instrument or sound basis.

For an exhibition, a single sound or multiple sounds could be interpreted within entire exhibitions or single thematic displays (for example). Content such as objects, sounds, photography, videos, and interactivity could help unpack the history of a sound's design, dissemination, and use for music and sound applications. For example, exhibition teams could use this content to help identify things such as instruments, recorded media, styles of music, popular material culture, users, sound designers (such as Don Lewis in chapter four), sound engineers, and instrument designers (such as Harry Chamberlin and Streetly Electronics in chapter three), which enable them to share interesting stories that bring sounds to life and make them relatable to visitors' experiences of music. Furthermore, these stories may help to highlight provenance within a museum's collection: for example, in the case of an instrument object previously being used by a popular musician to create a specific sound which has gained significance in relation to a certain song or style of music, often associated with the museum's geographical location. Therefore, it may be conceivable to design or structure an exhibition as a series of displays - each one dedicated to exploring the history of a different sound – which can, overall, help to demonstrate the different ways in which visitors may have come to hear these sounds through the influence of various people and material networks.

The following sections can be used by exhibition teams as a guide towards constructing and applying a sound genealogy methodology towards the interpretation of sound within a future exhibition. Whilst the following guide uses sound as a starting point, this is not to suggest that exhibition teams should always start with sound as it may be simpler to research the musical objects within a collection – through material readings or conducting interviews with the previous owners of instruments, for example - in order to find an appropriate sound to explore. Nonetheless, visitors may still pick and choose which parts of a sound genealogy narrative to give their attention to, whilst others may still leave a museum with very different opinions of the sounds they have heard to what an exhibition team intended.

9.2.1 Sound

As previously discussed, not every sound will lend itself well to sound genealogy. Additionally, the isolation of certain sounds from pieces of music and the association of these sounds to particular instruments may be a challenge to achieve. It may be necessary, therefore, for exhibition teams to conduct or commission their own research into discovering what the sounds generated or associated with the instruments in their collection actually sound like, as well as what they are called, and how they have already been used in recorded music (and by whom). Unfortunately, as we are dealing with museum collections, this may not be as simple as turning on the instrument in question and playing with it. Whilst some museums allow for commissioned musicians to deliver public performances of their instrument objects – perhaps as an approach to creating further interpretive materials through video and audio recordings of these performances - many museums stipulate that their electronic musical instrument objects remain turned off, with minimal tactile engagement, to help maintain their material preservation (whether they are in working order or not). Therefore, exhibition teams may have to look elsewhere for sound examples from these instruments or consult other written or oral resources such as lists or descriptions of instruments' sounds (such as patch lists for digital instruments) or arranging for previous owners to be interviewed. Otherwise, museums might be fortunate in acquiring an instrument that lends itself to a material reading (for example, one that labels the sounds it can produce on its interface): presuming that somebody is available and capable of making that reading.

Exhibition teams will then need to consider how to communicate the instrument sound in question to visitors, whilst bearing in mind the potential for sound bleed between sources (as discussed in chapter six).

First and foremost, it would be ideal to consider pieces of music that not only best represent the sound but are more likely to be recognised by visitors. However, not only do sounds need to be isolated from the recorded music they were used in (as previously advocated with the example of the *Souvenir: 40 Years of OMD* exhibition at the BME, discussed in chapter six), the link between sound, music, instrument, and musician also needs to be made explicit to visitors to help ensure they make and understand these connections. In cases where exhibition teams are unable to incorporate interactivity, sound could be triggered manually by visitors via some form of playback device such as a listening station, or automatically as part of a video or as ambient, background content. In the case of a video, a recording of a musician performing a sound used within a popular and recognisable song of theirs - on the original instrument they used to produce it - could be a really valuable demonstrative tool in an exhibition. Otherwise, there may be instances where an official music video for a song clearly demonstrates an instrument's use to create a particular sound that can be heard (and differentiated from others) at a specific time during the song – as is the case in the video for the song 'Light Up The Sky' by The Prodigy which displays an image of the Roland TB-303 Bass Line synthesizer each time the instrument's sound is audibly heard (see Figure 9.1. below).[525] Additionally, visual materials could be useful in helping to demonstrate sounds, such as audio waveforms or images of the objects responsible for creating and triggering sounds that can be heard.

Nonetheless, it may be worth considering how long the sound will play for. If it is performed over too short a time period, visitors might not gain the best understanding of how the sound has been used, whereas too long (or repeated too often) and it may become irritating to visitors if emitting publicly through speakers (which may also depend on the type of sound that can be heard). This may be especially true if the sound in question is linked to a particular piece of music that it was used within, in which case the sound should be performed – whether as a melody, a percussion sequence, or as an intermittent sound effect (for example) – for long enough to represent and communicate that piece of music effectively. However, creating an audio file in which a sound is isolated from its musical context may be tricky if the musician responsible for composing and performing that sound is not able to reproduce it for the museum. Furthermore, exhibition teams may encounter legal issues with copyright and sample clearance, depending on how the sound recording is obtained.[526] Otherwise, there may be instances in which a patent has expired, allowing exhibition teams to re-create the sounds of instruments and perform with them as appropriate (as was the case for Weissenbrunner and Lemouton who attempted to recreate the sounds of the Yamaha DX-7 synthesizer due to the fact that the patent for FM synthesis had expired and the data was made publicly available).[527]

[525] The Prodigy, 'The Prodigy - Light Up the Sky (Official Lyric Video)', *YouTube*, 2018 <https://youtu.be/GAm48rkUBl4> [accessed 20 November 2022]; 'The Prodigy - No Tourists', *Discogs* <https://www.discogs.com/master/1446149-The-Prodigy-No-Tourists> [accessed 20 November 2022].
[526] Naomi Korn, 'Museums & Galleries - Copyright', *Copyright User* <https://www.copyrightuser.org/educate/intermediaries/museums-and-galleries/> [accessed 17 December 2022].
[527] Akkermann, 91.

Figure 9.1. The Roland TB-303 Bass Line synthesizer shown in the music video for 'Light Up The Sky' by The Prodigy.

In comparison to using a playback device, one of the benefits that interactivity provides is the ability for visitors to control how often sounds are heard by triggering them on a per-note or per-step basis, as opposed to triggering a pre-recorded sound file to play in its entirety. However, interactivity introduces new conditions for exhibition teams to consider. For example, will visitors find it too easy (as Allen and Gutwill explained: 'interaction that is so limited or mundane that it frustrates or bores visitors') or too difficult (e.g., too many controls to operate, as was the case with *Play the Electronic Sackbut*) to trigger and modify sound?[528] Otherwise, could the visitor's performance or experimentation with the exhibit be augmented to make the experience more entertaining - perhaps at the expense of authenticity (as was the case with the surround-sound experience of *Drum and Bass – Time and Space*)? Conditions such as these are not just important to consider for tactile performances with instrument exhibits in a museum, but also apply to non-tactile interactivity: as we saw in chapter six with the various ways in which the theremin instrument was installed in exhibitions, which addressed potential visitor actions and levels of skill.

9.2.2 Material Networks – Instruments

If an exhibition team wishes to link a particular sound to an instrument, I would argue that it is justifiable to display that instrument to help make that link explicit. Furthermore, by following a sound genealogy methodology, exhibition teams should associate a sound with more than one instrument to help demonstrate the ways in which a sound might travel through time and space within a material network. Cases where an instrument has been distributed to various countries, resulting in one of its sounds being used by different musicians to help construct various genres of music, could also be of particular interest to

[528] Allen and Gutwill, 200.

visitors. For example, whilst the sound of the Roland TB-303 is mostly associated with the creation of 'acid' forms of dance music such as acid house in Chicago, there also exists significant instances of the sound's use by disparate musicians such as Bollywood session musician Charanjit Singh in India and the post-punk band Orange Juice in Scotland (both around the same time that the instrument was originally manufactured).[529] The subsequent distribution of the Roland TB-303's acid sounds within multiple analogue and digital instruments provides further opportunities to demonstrate various ongoing strands of distribution in an exhibition, which could also help to justify the significance of including the sounds from this instrument's analogue oscillators in an exhibition setting.

However, as previously discussed, exhibition teams are faced with the challenge that not every instrument was designed so that its sounds could be labelled on the chassis in a way that everyone could understand. For example - as discussed in chapter five - most analogue instruments only label their oscillator sounds as waveform shapes, whilst many digital instruments do not have the physical space to list their full patch list somewhere visible. Therefore, exhibition teams will need to consider additional ways of demonstrating a particular sound that a person created for, or with, that instrument: beyond the instrument object, itself. This may involve labelling the name of the sound as text and providing an audio example of its use, or – better still – providing some form of related interactive engagement which allows visitors to perform with it.

9.2.3 Material Networks – Recorded Media

Displaying forms of commercially-released recorded media should help visitors to connect the sounds of instruments to songs they've heard prior to, or during, their exhibition visit – some of which may even exist in the music collections of those visitors. It could also be the case that visitors may not have heard a particular song before but are swayed towards interpreting the music they can see or hear in an exhibition as important in the eyes and ears of others. However – similar to musical instruments – the same issue exists whereby it is often not the case that the media's artwork (on the media, itself, or its material cover) visually depicts – or lists – the instruments used in the music recorded onto it (let alone where each sound on each song came from). Nonetheless, the inclusion of recorded media in an exhibition could help to show visitors that when sounds are recorded and published onto different forms of media – as constituent parts of songs – it can then help to enhance the popularity of that sound as more listeners become exposed to it,

[529] Malcolm Jack, 'Orange Juice and Edwyn Collins – 10 of the Best', *The Guardian*, 2016 <https://www.theguardian.com/music/musicblog/2016/jul/20/orange-juice-and-edwyn-collins-10-of-the-best> [accessed 13 November 2022]; Stuart Aitken, 'Charanjit Singh on How He Invented Acid House ... by Mistake', *The Guardian*, 2011 <https://www.theguardian.com/music/2011/may/10/charanjit-singh-acid-house-ten-ragas> [accessed 13 November 2022].

and other musicians become interested in using it. Therefore, the opportunity exists for exhibition teams to demonstrate the potential impact of material networks on the popularity and significance of sounds by displaying different types of this media – as singles, albums, live recordings, CDs, vinyl records, MP3 files, etc. – that represent different musicians who gained access to these sounds and interpreted and used them in different ways.

9.2.4 Music

Importantly, whilst the distribution of sounds as music can be communicated through linking items of recorded media, there still exists the opportunity for visitors to actually hear the music in question. Providing music in the form of audio examples may provide exhibition teams with certain benefits. For example, whilst some visitors might not recognise the name of a musician, the title of a song, or the album artwork of the recorded media displayed, they might recognise a song if they hear it, and then connect what they hear to what is visually displayed in front of them. However, there remains the issue of separating and identifying a particular sound used within a song. Therefore, excerpts of music may not be appropriate tools for interpretation in an exhibition: depending on how easy it is for visitors to differentiate one sound from another within a musical excerpt. Where possible – to help visitors link a particular sound to a piece of music or form of recorded media in which an instrument features – it would be better to use that sound to perform a particularly recognisable melodic or percussive excerpt in isolation (as previously discussed). This could even involve a recorded performance of an instrument's sound by the original musicians, commissioned specifically for an exhibition. Better still – the installation of an interactive exhibit could allow visitors to perform the excerpt themselves by following a score, or perhaps control the sound of a recorded excerpt or pre-sequenced phrase using various sound modifying controls.

9.2.5 People

As previously identified, following a sound genealogy methodology may provide the means to uncover stories associated with those responsible for creating and shaping instrument sounds: some, of whom, may be considered the unheard voices of electronic musical instrument design and use. For an exhibition, fully-analogue instruments (i.e., analogue instruments without digital presets built-in) may be easier to interpret in this way because their sounds are generated and shaped by oscillator designs, electronic circuitry, and materiality. Therefore, the sounding potential of these instruments can be attributed to the instrument designers. Using Robert Moog as an example, an exhibition team could display a Moog synthesizer and discuss the work of Robert Moog as a product of instrument and sound design, simultaneously. This could then be enhanced through the use of further interpretational tools to identify those who worked in Moog's factory, as well as the musicians who collaborated with him on instrument design (such as the inclusion of a portamento control, as suggested by Wendy Carlos - discussed in chapter five) and the musicians who used the instruments and explored their sounding potential further.[530] Additionally, popular material culture could help demonstrate the recordings in which the sounds of Moog's instruments were used. Furthermore, there could be space to include the work of musicians in using Moog analogue instruments to replicate older acoustic instruments. This could lead exhibition teams to provide visitors with 'before and after' sound comparisons between the sounds of acoustic instruments and the sounds of the analogue electronic instruments used to imitate them.

The use of interpretational tools with digital instruments provides additional opportunities for exhibition teams to uncover communities of sound design and recording practice. For example, various practitioners have been involved with performing and recording sounds to be used as sample-based digital presets, or digitally coding electronic sounds from scratch, or developing banks of preset sounds using pre-installed sound materials (such as oscillators and samples). These approaches have provided digital instruments with sounds either at the point of manufacture, or as plug-in or add-on forms of media and files that can be manually loaded in by users. Additionally, there has existed the potential for musicians to utilise these 'starting points' to create their own timbres and patches. If we take the Korg Prophecy digital synthesizer as an example, an exhibition team could structure their interpretational tools as a way of uncovering stories of digital instrument design, preset sound design (which, in this case, interviewee Drew Schlesinger was responsible for), and sound design by musicians. Both the people and the instruments can then be linked to specific sounds heard in recorded music. Therefore, whilst some digital instruments have provided few visual clues as to the sounds they are capable of producing, they may – perhaps through further research – offer exhibition teams additional avenues for exploring the people behind the sounds hidden within.

9.3 Further Considerations for Applying Sound Genealogy

The most fundamental observation we can conclude from this research is that sound can be used to help interpret electronic musical instrument objects. The various case studies, as well as the chapters on *Drum and Bass – Time and Space*, have provided examples of how sound – as well as the interaction with sound - has demonstrative value in helping visitors understand the significance of instruments on display. This

[530] Pinch, 'Technology and Institutions: Living in a Material World', 471.

suggests that the recording and archiving of electronic sounds from instruments and other forms of material dissemination (similar to the *Save Our Sounds* project at the British Library, as discussed in chapter five) could be a vital means of helping to preserve what these instruments were capable of, which could later be used to help bring life to each instrument's story.[531] However, the exhibiting agendas of different museums may, nonetheless, alter the ways in which each instrument and sound is interpreted by visitors. For example, a science museum exhibition team may choose to focus on a different aspect of sound – or link it to a different set of objects and histories – to what a musical instrument museum exhibition team might work towards. Additionally, situations such as this are made more complex when we consider the potential for science-focused exhibitions to exist in musical instrument museums, and vice-versa (as was the case with *Sound by Design* in the Canada Science and Technology Museum in chapter two, and *The Dr. Donald W. Collier STEM Gallery* in the Musical Instrument Museum, Scottsdale). Therefore, further research into the polysemic interpretation of instruments and their sounds may prove useful in helping exhibition teams understand which initial approach to take when considering the application of a sound genealogy methodology towards interpretating instrument sounds.

Whilst the boundaries of this thesis have limited the exploration of sounds in museums to electronic musical instruments and musical applications, the sounds of acoustic instruments and other forms of instruments can also form the basis of exhibitions. The advantage of these types of instruments over electronic ones is that – for many of them - their means of producing sound are often visible and intrinsically linked to the vibrations produced once the parts intended for performance are used. Furthermore, the ways in which humans are meant to engage with them (for example, by strumming them with one's hands, or blowing into them with one's mouth) also provide clues as to the types of sounds these instruments are likely to create. Therefore, perhaps it would be useful for more research to be conducted into the impact of performance methods and interfaces on sound creation and modification with electronic musical instruments, and how this can be interpreted effectively in museums using interactivity, objects, and sound.

There also exists space for further research that could challenge the status quo of how sounds have been historicised, in similar ways to how research has helped contest the histories of musical instrument design and use. Articles of STS literature have already helped to identify situations in which electronic musical instruments have been used and appropriated – or gained significance over time - which differ to what the instrument designers intended – or what more traditional historic accounts have documented. This has helped to demonstrate that the ways in which we previously understood technological inventions and innovations can be contested. These expanded insights can also help to enhance our understanding of the factors that contribute towards the successes and failures of technologies. As a result, exhibition teams

[531] The British Library.

may use these forms of insights as a way of framing the interpretation of technologies in an exhibition, attempting to contest more traditional visitor perspectives.

Additionally, by expanding on existing research into musical sounds, researchers might uncover additional contested histories. This could lead to explorations into how such contested histories are exhibited and interpreted in exhibitions of electronic musical instruments and their sounds. For example, in this thesis we have highlighted instances such as the sampling of the Roland TR-808 drum machine's kick drum to re-use melodically to create a bass line, as well as the sampling of the Amen breakbeat to re-use in the construction of new forms of electronic dance music. These examples not only demonstrate the use of sounds in ways that the instrument designers did not intend, but also the subsequent reuse of sound material through sampling practices which the original performers of sounds may not have imagined. Therefore, researchers may wish to adopt a similar methodology to Akrich's (as discussed in chapter one) and interview those involved in sound design and programming for instruments (such as DS, who was interviewed for this thesis), as well as those who later used those instruments, to see if discrepancies exist 'between the [sound] designer's projected user and the real user, between the world inscribed in the [sound] and the world described by its displacement.'[532] By doing so, users' reactions and interpretations of sound may help to 'give body to the [sound] designer's project.' [533] This may also uncover different strands of use, which may depend on the musicians involved and the styles of music in which they composed.

9.4 Interactivity: Challenges for Exhibition Teams

Throughout this thesis, I have advocated that interactivity is the most useful way of helping visitors to connect electronic musical instruments to sounds. By visiting museum exhibitions, using interactive exhibits, and interviewing those responsible for their creation, installation, and management, I have been able to apply the methodologies associated with researching the histories of electronic musical instruments found in STS literature to the construction and interpretation of interactive exhibits that represent these instruments. In other words: as an original contribution to STS and museum studies, this research has drawn upon the theories and methodologies of STS to help understand how interactive exhibits – as a form of technological artifact - might be used by a new set of users – museum visitors.

Furthermore, through constructing my own exhibit, I have not only uncovered the processes and challenges of building an exhibit and aligning its use and context to the intentions of an exhibition team, but also – through collecting data from visitors – been able to draw comparisons between how the exhibition team

[532] Akrich, 208-209.
[533] Akrich, 208-209.

envisioned the behaviours and interpretations of visitors, and how visitors actually behaved with, and interpreted, the exhibit in the exhibition setting. However, following different methods towards conducting this research has made it apparent that the depth of insights gained from an interview with a member of an exhibition team differs vastly from that gained through comparatively brief observations and questionnaires conducted with visitors. Nonetheless, as this was the first time that the NSMM had organised a micro-commissions programme, it is hoped that future exhibition teams at the museum might find this research useful in considering the installation of interactive exhibits involving a similar cohort of commissioned designers and a similar theme of exhibit. There is also much wider potential for this research to be valuable to museums and interactive designers, globally, in understanding how best to design multi-sensory interactivity (particularly for break-out exhibition spaces, like the *Sound Circle*): especially when we consider that a number of similar issues were experienced with exhibition teams in different parts of the world. Therefore, adopting these methodologies could create the potential to go back and forth between designers and users – similar to Akrich, again - to help determine whether an exhibit could be considered a success for both exhibition teams and visitors.[534]

Through conducting research with those involved in interactive design, we have also uncovered various challenges in creating exhibits that visitors might enjoy using. As forms of technological artifacts, there seems to be space for further investigations into how these unique tools of performance and interpretation were created, and how they have helped to enhance exhibition experiences. Whilst much museology literature exists on the roles of preserving, collecting and interpreting objects, the roles of exhibit designers and technicians – for example – could perhaps be considered as, comparatively, underrepresented. In other words – that which a museum *creates* is perhaps less understood and researched than that which a museum *acquires*. To this end, the information collected through interviews with exhibit designers for this thesis has provided an original contribution to museology research: especially considering that much of the literature on museum interactivity usually focuses on science exhibitions for children, rather than music exhibitions for adults and families. Furthermore, as interactivity continues to be a popular form of content in various museum and exhibition contexts, museology research may become more balanced between the study of objects created elsewhere, and the study of interactive exhibits created by, and for, museums.

However – as we have seen with the examples in this thesis – the facilitation of sound and touch modalities (or – in the case of instruments like the theremin - the corporal experiences induced through performance) alongside what is visible may create new challenges that exhibition teams could face. For example – as previously discussed – the inclusion of sound may necessitate boundaries and precautions as an attempt to manage its public broadcast in an exhibition space and avoid bleed. Additionally, whilst interactivity can afford visitors new learning and entertainment opportunities, they are also given a certain amount of control over the continued operation of that which they can perform with. Therefore, additional resources

[534] Akrich, 208-209.

and extra precautions should be taken to try and ensure the longevity of an exhibit so that a larger quantity of visitors can benefit from using it. These might include a remedial budget for repairs, the acquisition (or construction) of replacement parts, the use of enhanced fixings and adhesives, and the use of instructional cues to highlight the responsibility that visitors should take towards helping to keep an exhibit 'alive'.

However, it does not matter how many replacement parts an exhibition team has at their disposal if visitors continue to break the same parts over and over again. Similarly, whilst instructions are usually intended to help guide visitors in using an exhibit in the way that an exhibition team intended, it should not be taken for granted that visitors will actually read this information or follow the guidance they have read (or, as was demonstrated in chapter eight, follow the instructions and cues from other visitors). With this in mind, regardless of whether exhibits are designed internally or externally, museums should advocate for regular communications and updates between the different parties responsible for constructing exhibits and curating exhibitions, both prior to the final product being installed and during its use and possible repair in the museum. If external designers are commissioned, this should involve some form of handover of knowledge and resources to help those responsible for curating and interpreting an exhibition – as well as those involved in repair work – to understand what the exhibit represents and how it should work: both from a potential visitor's point of view, and the perspective of design and repair.

Additionally, the case of Hugh le Caine and the Electronic Sackbut highlighted how important it is for instrument and sound designers to document their processes and record and archive the sounds of instruments, as this could help future interested parties to understand how sounds were produced and what they sounded like. This could be particularly crucial if an instrument becomes inoperable over time, or if very few iterations of an instrument exist. The same applies to the design of interactive exhibits. For example, whilst TE provided a detailed account of how the *Play the Electronic Sackbut* exhibit was used and interpreted by visitors, and how well its design aligned to the expectations of the museum, there may, nonetheless, exist very little evidence of the existence of this exhibit (let alone how it was designed) beyond this thesis, once the exhibition *Sound by Design* has finished. Therefore, it is vitally important for interactive design practitioners to document and disseminate their design processes, their relationships with museums, and how audiences use and interpret their exhibits. Similarly, museums should research and document how well their exhibits are received, to assist with audience development work and possibly influence the design of future exhibits. This work could help ensure that exhibits have value beyond the lifetime of the exhibitions they were designed for, or even beyond their working condition.

Appendix A: Interview with Benedikt Brilmayer

Phone interview, 25 September 2019

EWS: Prior to the Good Vibrations exhibition, had some of the electronic musical instruments collected by the museum already been exhibited?

BB: Yes indeed. We had just a few of them in the permanent exhibition. There was, for example, our Mixturtrautonium according to Oscar Sala, which actually is a copy of the original Mixturtrautonium. This is one of our most precious electronic instruments because this is an absolutely unique instrument, it only exists once in the world. In addition to that we also had in our permanent exhibition a VCS 3, for example, and also the older Trautonium, the so called Telefunkentrautonium from the early 1930s. There was actually no real scientific background within our staff in earlier years, so since I arrived, I was the first one who really had a little experience in research and all of the history of electronic instruments, so that's the main reason not all of our electronic instruments were exhibited.

EWS: So were they exhibited in the same space that they are now, or were they previously somewhere else in the museum?

BB: Actually they were exhibited in the same place that as they are right now. For the special exhibition, Good Vibrations, we had all of them placed in our space for special exhibitions, but before that they were at the end of our museum tour, which is a chronological tour, and the tour ends in the twentieth century on the first floor of the museum.

EWS: In the preface for the Good Vibrations catalogue Conny [Restle] explains that the conservators and the design team wanted to take the visitors on an unconventional time journey through the making of instruments in the twentieth and twenty-first century. Could you explain how this was realised for the exhibition?

BB: Yes. We decided after several discussions that we don't want to show a chronological kind of presentation because the different categories of electronic instruments developed at almost the same time, around the 1960s roughly speaking. We aimed to show our visitors that the whole universe of electronic musical instruments, for example drum machine or rhythm machines as we call them, as well as synthesizers and sample instruments, developed parallel to each other, so we decided to make an exhibition with systematic grouping of the instruments.

EWS: So is that the same thematic framing as what is presented in the catalogue?

BB: Yes. There was a little chronological order in our presentation of the special exhibition, which starts with the beginning of electronic musical instruments, with the first objects like the Theremin and a little later the Ondes Martenot or also the Trautonium. Then we had Samplers with Synthesizers, Rhythm Machines, then alternative controllers, then computer instruments, then the last group was, again, a chronological thing because that was a small view into the future of the development of electronic musical instruments. In our special exhibition, you could say that from these seven groups that we had, only the first and the last group were somewhat chronological, and the five groups in the middle almost developed in parallel with each other. For example, when you take a look at our catalogue, with the computer part 'Virtually Playful' we were only able to show instruments from the early 1980s onwards, but as we all know the first computer music was produced back in the 1950s. We didn't manage to get some examples of the first kind of computers used for electronic music because they are either not available anymore or they would have been too big to transport.

EWS: Were relationships between the instruments, the designers who created them, the musicians who used them, and the music created by them, stated within the exhibition?

BB: Yes. As a museum of musical instruments, we always try to put a special focus on the design of electronic musical instruments, so this was a main issue. We tried to provide additional information on the artists who used those instruments and the music they created with those instruments. As we always have the problem that parts of written text are not read by our visitors when they are too long, we included a lot of that information in our audio guide for the special exhibition, as well as additional text presented through our digital museum guide.

EWS: So moving on, what were the reasons for acquiring the instruments on-loan for the exhibition?

BB: For the list of objects we wanted to present for the special exhibition, we tried to fill the list as much as possible with our own instruments, but we sometimes had huge gaps with our electronic musical instruments. For example, with our computer part, everything from there was on-loan because we didn't have the platforms as well as the software itself. Platforms like computers or tablets. So we tried to fill up the gaps with instruments on loan. For example, for the early history of electronic instruments, we had to have a Theremin and we didn't have a Theremin in our collection, so we borrowed it from Paris, as well as the Ondes Martenot. Also from Paris, for example, we had the Mellotron sample instrument, which we now have in our permanent exhibition. A short time after the exhibition, we were able to acquire a Mellotron. Also, in the Sample Instruments section, we were able to acquire the Special Purpose Tape Recorder by Hugh Le Caine from Canada. This, for example, was an instrument that we knew we should try to get as its iconic. It is not very popular, but people who know the history of electronic instruments know that Hugh Le Caine built some very interesting and influential instruments so we put a special focus on acquiring that instrument.

EWS: Okay, so it was really interesting to see in the catalogue that you had collected software. I was really interested in finding out how you decided to exhibit software in the exhibition.

BB: Yes. Actually that was also quite a discussion, because how do you want to present software? Do you want to present something like a screenshot which actually is not very self-explanatory, so we would have to use a lot of text, for example, or a lot of audio information for that part. We decided to try and get the real software or emulations of the real software that could be played on tablet computers. Music Mouse was playable for our visitors on a regular computer, which actually was not the real Music Mouse but an emulation. We were in direct contact with Laurie Spiegel for that. She supported us with the software. The main thing was to support our visitors with the possibility of trying out those software instruments.

EWS: That's really interesting about asking Laurel Spiegel to help you with installing a replica of Music Mouse. That must have been a really good experience.

BB: Definitely. Very very supportive, as was every one of the private collectors. When I started to reach out to all those people, it was a very positive way to work because we have been supported so much by all those private collectors and it really was great. For example, we were able to acquire a Buchla Music Easel and those instruments were not built for the European market so we had a special contact with a film composer who is working for Hollywood but is a Berlin resident. He borrowed us his own private Music Easel which he actually used for his work. He had a special part in his contract that, if he would need to use his instrument, he would have been able to take it out of the exhibition to be able to continue his work.

EWS: So, was there a focus on Berlin-based and German electronic musical instruments within the exhibition?

BB: A little bit, yes. It is part of our duty as a museum to put at least a part of our working focus on our regional developments. Of course, in Berlin you have a lot of sources for that, so that was the reason we reached out to the Ableton company and they were very happy to support us with the Ableton Push and the Ableton Live software for it. They even supported us with the complete hardware, so we not only got the Push but also a working computer on which we were able to run the Ableton Live software.

EWS: So you briefly talked about visitors being able to use computers in the exhibition. What kind of interactive exhibits were installed for the Good Vibrations exhibition?

BB: That was a very important part for us. We tried to present in every section of our exhibition, so at least seven interactive instruments for our visitors. Unfortunately, we didn't manage to do this. We discussed a lot about the third section, the Synthesizer, how, or if at all, we could present a playable synthesizer in the exhibition. We left the synthesizer out because it was, in our view, it would have been too complicated for visitors and the danger of damaging the instrument was, we thought, the danger was too big. We managed, for example, for the first section Early Instruments we simply bought a Theremini by Moog, a modern digital replica of the Theremin. In the second section we had a digital replica of the Mellotron, which both of them: the Theremini and the Memotron as it is called, the digital replica of the Mellotron, those instruments still are in playable condition in our permanent exhibition. For the third section, Synthesizers, we left that out because we thought it would be too complicated for the average visitor. For the fourth section we had the Native Instruments Maschine running, and they left it. The fifth section, for example, we had the Instrument One by the American Company Artiphon together with a tablet computer in playable condition. In the Computer section, we had all the software on tablet computers and Music Mouse on a regular laptop in playable condition for our visitors.

EWS: Sure. It's so interesting what you were saying about not including an interactive synthesizer in Good Vibrations because, from my travels to Canada and America, from what I experienced there in different museums, that's definitely the conclusion that I've generally come to. If you give a visitor, presuming that they've not come across a big synthesizer before, its kind of thinking 'what on earth would they do with this'? 'How would they use it? Some of them are so complex. So I'm kind of in the same headspace as yourself with that.

BB: Yes, actually we could have had the emulation of a Minimoog on a tablet but we didn't do that because all the tablets we bought were used on the Computer section, and actually we should have tried, so that would have been a reflection after the finish of the exhibition, we should have tried to buy a Minimoog, a modern replica of a Minimoog, for letting people play on it, because that's the problem: its too complex. Actually, after the exhibition I also discussed with the guy who gave us the regular Moog system, and he said 'well, with a little more time, so roughly speaking half a year for preparation, he could have built us a very very simple system with just some modules where visitors probably would have managed to get behind the technical things to produce some kind of sounds. But in preparation for the exhibition we really didn't have the time to discuss and to think about that.

EWS: So, last question about Good Vibrations specifically, how was sound managed in the exhibition space?

BB: This is, for our museum, a very special problem: you've seen it, it is one huge exhibition hall. If you make just a small noise or sound in some corner of the museum, you'll hear it throughout the whole museum. For this special exhibition, we decided that, for example, all the software was playable without headphones but all other interactive instruments were equipped with headphones. It was just to keep the noise level a little lower than what the average would have been. We could have used, for example, with the Memotron we could have used loudspeakers but that would have been too powerful and also the problem of visitors fiddling around with the volume of the Memotron which would have been a little…yeah, not stressful but could have disturbed other visitors too much. All the tablets , if you turn the volume up to maximum they are not so loud that they really disturb too much.

EWS: So, when I saw the exhibition area of electronic instruments currently in the museum, are there similarities between that and how Good Vibrations was displayed?

BB: Yes, a little bit. Yes and no. A little bit because as the regular tour of the museum is laid out, we also have the Mixturtrautonium on a very special place so it can be seen as the first electronic instrument from quite a distance to give some kind of an introduction to the complex world of electronic instruments. According to our special exhibition of Good Vibrations, we now tried to group those instruments in the same groups, so the early instruments and the sample instruments, synthesizers and so on. So for example, out of a very practical reason, we now added the newly acquired Ondes Martenot to the stand where our Mellotron also stands, so that's actually not within our systematic scheme but we had to place the Ondes Martenot there because that's the safest place for this quite fragile object.

EWS: So, last question, it's really about the three interactive instruments I noticed in the museum, the Memotron, the Theremini and the Dato Duo: what has been the feedback from visitors about these interactive instruments?

BB: Yep, actually we mostly have a very positive feedback. It is quite interesting because the feedback is mostly around the point that they have some interactive elements in our permanent exhibition. On the other hand, it is a little sad that they don't really get the connection that the Memotron, for example, is the digital replica of the Mellotron, and both instruments are both just five meters away from each other, and the instrument design is almost identical. It is quite interesting that the positive feedback only is on 'we now have some interactive instruments' but not 'ah, you see that you can play an instrument, a modern replica of a Mellotron', for example. Which actually is quite an interesting instrument because everyone knows it through The Beatles.

Appendix B: First Interview with Tom Everrett

Canada Science and Technology Museum, 21 January 2019

EWS: You mentioned Provenance a couple of times in a museum context; how does that play a part in how your communications objects are managed and acquired?

TE: When the museum was very young it was very different to what it is now. The idea early on was to establish a base museum collection that we could use for exhibition purposes and teaching, but over the last few years provenance has become really important. So typically, when we go to acquire an object, it's one thing to assess that object for its historical importance but what we're really trying to do is make sure that the object also has provenance or has a story that we can use to dig a little deeper into that object. For example, we would be less interested in acquiring a Moog synthesizer from an auction site where they do not know where it came from because it has changed hands many times. That would be what we call a 'type' example. It would be a piece that we were acquiring because it fits in with a certain chronology of the development of, or popularisation of, electronic music. We are a lot more excited when we acquire an object from someone who toured with that object, for example. So, it's one thing to have the object and be able to say "okay, we can look at the history of Moog synthesizers and this fits in here and that was super important from the Moog perspective", but it's a whole other thing if we can tie that to a specific user-story. If we can say "this particular person used that object for this purpose", that shows how the object's use value is actioned in real life, in addition to some of the evidence in the instrument itself: if certain knobs are more worn than others, or there's different scratches or different features which could suggest different kinds of usage, for example. If we could actually talk to the person who used that object we can learn a lot more about the materiality of the object as we acquire it, rather than just purchasing it from an auction site or an antique dealer where we really have no idea who used it and we have to infer everything from a material culture reading of that object. We can get pretty far with that, but it is so much better when we have a story attached to an artist: a real user, that we can use to anchor the material culture stories of that object. For now, that is one of the main questions that I ask when I go out to acquire an object: "where does this fit with that broader technological story?" and "what is that specific user's story that can help us understand that object and it's use function in a deeper way?" So in terms of provenance, typically we'll do some sort of aural history. When we make the acquisition we'll interview the person who's donating that object to the museum about where they bought it, why they bought it, how they used it, and we'll collect any supplementary materials that can help. For example, if they still have the manual or they recorded music with that object or they have images of themselves using that object in contexts that either show it in a studio or whatever. Anything that can help us fill-in that story, so that when we eventually do have researchers looking into that object you can anchor the research in a very specific use context. Or, if we are going to exhibit that object we can also pull these other resources together to tell a richer story about it and get outside of just the ‘type’ examples which speak generally about the history of that technology, so we can focus that more and really use these stories too because it’s a lot more information to work with.

EWS: You also worked on a Wearable Technology exhibition. Did your work on that exhibition influence what you did on Sound by Design, or vice versa?

TE: Both of those exhibitions were realised simultaneously under very crazy timelines. I’m sure there were cross-influences. The main thing they both had in common was they were two similar exhibits. When colleagues have gone through both they have said that they have a certain style, which I didn’t think about before. I think the style they’re pointing out is they are both very object-focused. The idea was not to overload the exhibits with too many objects, so that it becomes case-on-case-on-case with tons of objects, which can become quite intimidating for visitors. It’s a little more toned-down, using the idea of the ‘hero’ object. That word came from one of the designers of the Wearable Technology exhibition. The idea is to treat all the major objects as heroes in a sense that we want to give them a podium, give them some space to breathe, and make sure that when visitors walk past, they know that these are special things. They’re not too concerned with comparing them with other things. It’s more about trying to put the focus on those single objects and those single object stories, and not dilute those stories by putting too many things on display or too many objects in a case. I think that’s one way that the two influenced one another because we took that terminology of the hero object from the Wearable Technology and we ported that over to Sound by Design. When we spoke to the designers we used that terminology: “we want these things to be seen as hero objects”. It helped us with the artefact selection so that we didn’t select too many objects. We helped the design team with really focusing on how they could design case work and the layout of the space too, to give those objects room to breathe and to highlight them and focus on them as special pieces which deserve special attention. That was probably one of the major influences.

EWS: You’ve used some really large, colourful props such as the speaker cones and the backdrops for the design icons. They’re really eye-catching as you’re approaching the exhibition. Have you considered that they may distract visitors from the objects that they are highlighting?

TE: I hope not. One of the first myths about a sound exhibit that we wanted to do away with was that, just because it’s about sound, this doesn’t mean that sound is the only or the most important thing to highlight. The history of sound technology is every bit as much about the visual history as it is to do with an auditory history. We wanted to feature both of those factors of the history of sound technologies in the exhibit. The one way was to obviously have sound introducing the space. We knew that it would be a problem if we had too much sound in a space: we knew that this would be harder to control. One thing that helped us with that was to pay close attention to the visual aspects of the history of sound technologies. So there are all these techniques for trying to show the visual and the auditory together and talk about the importance of each. When it came to designing display cases, we tried to use them to evoke aspects of sound culture and musical culture. For example, the big cones were supposed to be modelled off the idea of loudspeakers and speaker cones. Those decisions were made to tie-up the overall theme, but hopefully not take away from it and become distractions. That was always one of the things we talked about in the design meetings. The idea was to use these big speaker cones, or I should say horns, as the display cases to make sure that the display inside was equally on-message and equally striking, to make sure it was lit really beautifully, that the artefacts really stood out, that the back treatments were done in a way that they mirrored the actual audio formats that we were talking about. If we had a vinyl record on display, we would have the machine with the vinyl record and then inside the cases was detailed to look like a vinyl record. All of these are ways to ensure that those stylistic design decisions did not detract or distract from the main message and make sure that everything came together to focus on the objects and the object stories. The same can be said with the Design Icons section. We have the objects there and we talk about the industrial design and form, function, and aesthetics, but then those background treatments were meant to evoke the era of which those things came out. We had meetings where we had different materials and wallpapers from different eras to try and subtly evoke different time periods through the graphic treatments on the back or those backdrops, so they're supposed to be bright and inviting and striking, visually, but when you get up close to them they're supposed to fade away, so that the object becomes the main focus of attention. Going forward, there have definitely been concerns that the space might be over-engineered from a design perspective, although every effort was made through the different treatments. For example, lighting, in the sense of the artefact lighting but also the ambient lighting too, was considered in order to make sure the focus was always on the object. I think, in the end, we got the balance right: the design team got the balance right. I don't think that those objects are a distraction, that you walk into the space and have the sense that the designers went a bit crazy. I think it all holds really well together, but that was definitely a concern that we were able to work through, and I'm fairly happy with it.

EWS: You can see behind the electronic instruments but you cannot see behind any of the other objects. Was that intentional?

TE: The Electronic Instruments section was based on designing sounds that didn't exist in the world before those instruments, but it was also about designing the technologies themselves that you would interface with to make those sounds and control them. The important thing for us was to not have these black boxes on display, so that you see a bunch of knobs on the front and nothing on the inside. The idea was to put them on wooden stages to give visitors the sense that these are performance objects and they are designed for making music, but we also wanted to make it so you could get behind the scenes, see inside the black boxes and get a sense of the circuitry and how complex these instruments were, so you can draw a relationship between the innards and the front-facing knobs. Get a sense through the interactive exhibits of how this all comes together to create different kinds of sounds. That was very much the focus of that. Right from our very earliest design drawings, we had to make it so you could see the back. There was actually one area where we wanted to do more of that but we didn't and that was the Theremin. The Theremin is kind of a wooden box. You can open the back doors and see the vacuum tubes inside. We had mocked it up with those doors open and, in the end, it looked bizarre having the doors open. It looked like it didn't fit the aesthetic of the space, and you'd never have those open whilst you were playing the instrument, so we made a decision at the last minute to have the back closed. It was a bit unfortunate that we weren't able to show both, or have some mechanical means where you could have them open sometimes and closed other times, but in the end we made the decision to keep them closed. For all the other ones it was important and that's why we had them lit from the back so you could get a view from all angles.

I guess with the Theremin, if the visitor has an archetype or a pictogram almost, in mind, of what it looks like, having the hood open would go against that and would jar against their expectations, even though the intention was to show them the inside.

It was tough and it was sort of a split-second decision about….and that was also a challenge too with the casework we had. We didn't want to make the cases too big. And those are all r-h controlled, so we control the relative humidity and everything inside to make sure they're preserved. As soon as we started to expand the case to have it open, it kind of looked chunky. There's always that balance between what you want to show and those other design considerations. Also, as soon as we opened it up we didn't have any information about those pieces. People could see but they had no idea about what they were looking at. If they wanted more information, that would be challenging too; we didn't want to introduce yet another text panel. And then there's the balance: if we were going to introduce internal components here, are we going to have to do that for every other object, and then it becomes really text-heavy and you start overloading people with text then they stop reading. It's like having too many objects in a case. There's always a balance to strike, but for the most part in that display area we did at least want people to get a sense of what the insides are.

EWS: The electronic instruments on display were built by pioneers, both locally and internationally known. If you wanted to collect earlier instruments from companies like Roland, Korg and Akai, more Japanese-based companies, leading to exhibiting them in a way that more contemporary bedroom producers would have a connection to?

TE: One thing we haven't talked about much is…when I came into the museum, in my first week in the job, the idea was to come up with two exhibits. That was before I really had any idea of what was in the collection. The two exhibitions were to do with wearable tech and an exhibit on sound. We've always had this electronic instrument collection, but it hasn't been developed in a very careful, thorough way. It's just been collected as a part of this general history of the development of sound technology, so there was never a dedicated electronic instruments collection, per-se. When it came to developing the exhibit, I had to select from objects we did have and I couldn't do much collecting to supplement what we already had in the collections, so one of the early challenges with drawing up the artefacts list was "what has been collected from previous curators in the past". So we don't have a very representative example of, for example, the Japanese innovations, we don't have a very good collection of anything related to bedroom recording. These are things that have not been on the priority list of previous curators, but these are definitely far more on my priority list now, especially now that the exhibit is on the floor. We're going to continue developing that exhibit over the next ten, fifteen, twenty years and develop the collection to better speak to elements of that exhibit. We're going to be looking a lot more into that now, but when the exhibit was put on we just didn't have much of that stuff. We are a National Canadian museum, so typically we're not out to have the best collection of the history of electronic instruments. What we're trying to do is try and have the best collection of electronic instruments that speaks to the Canadian experience and the involvement of Canadians in that history. If we did start branching out in concentric circles to look at what Canadian musicians have done over the last, say, seventy-five years, then we could start to talk to musicians, reach out, and make those acquisitions, and I'm sure a lot of that electronic gear will be Japanese or American, so we're not strictly just talking about Canadian inventions and innovations. So yes, we're going to start branching out, but there's also the challenge too of being a Science and Technology museum. There are museums like the National Music Centre (NMC) in Calgary that really deals a lot more with music production, so because we're one institution and I'm just one curator and we have to represent so much, I can't just all of a sudden develop one of the world's best, most comprehensive electronic instruments and music production collections because it might overlap with our collections that are already existing in Canada. We don't want to repeat too much of that. For example, if we wanted to expand into that area, it might be easiest to just loan stuff from the NMC and bring in some of those pieces to do displays, or if people are looking to research that area we could loan that material over here to do hands-on research seminars. So that's a nice thing about being partners with other museums as we don't necessarily have to have our own duplicate collections, we can take advantage of the strengths of other museums. But that is one of the areas we are going to look into, for sure.

EWS: With the Build a Song interactive, with the ease of which a piece of music is built and the fact that you can't necessarily get it wrong, was there a concern over how composing electronic music may have been represented as being that easy, using laptops, hardware sequencers, etc.

TE: No, and that's one of the challenges too about designing in a three-dimensional space is that you don't know what people are going to bring to the experience and how they are going to interpret the experience in relation to other things in the museum. So that disc was actually not meant to be interpreted as an electronic instrument. What it was meant to do was to speak to the organette and the music box: a different way of consuming music in the home. There are two general ways; one is that you buy something like a shellac record which has music inscribed on it as grooves that are physical inscriptions, representing those original soundwaves. However, the music box has everything in there to create the music: all you need to do is program a disc or a piece of paper that tells the machine what notes to play and when to play them, so that's what that disc was meant to do. That machine already has the ability to play all those notes, all you're doing is programming it and letting it know what notes to play when, so it was not meant to be interpreted as something like a sequencer, it was meant to be interpreted like a music box. You're meant to select what notes you want it to play and what order, you spin the disc and the machine plays the notes you told it to play. It is electronic, but the lesson learnt was supposed to be the speed of those analogue forms. And that's the thing with those analogue forms: usually there are a finite set of things you can do so there isn't much dissonance to fit in, it's almost like a harmonica. Or you have individual notes for hypothetically creating some dissonance, but usually it would be one-note steps and therefore things are designed to sound pretty. No matter what notes you play, it's not going to play very dissonant. If we had simplified the process and people relate it to electronic music, that's an unfortunate outcome. That's not what we wanted, but it happens for sure.

EWS: You mentioned there was an exhibition where people's data was collected and sent to them as an email after they left.

TE: Oh, that was Cooper-Hewett in New York. So you would have a pen and, as you went through, whenever you liked something you would touch the pen to it and it would download onto the pen. There were areas where you could design something like a vase and you could move the pen on a touchscreen and it would change the design of the vase and as soon as the design was done, you could save it. At the end of the visit, you could go over to a computer, press your pen down and it would show you everything on it, which you could email to yourself. That was a more visual design exhibit with not much sound content. But you can definitely imagine, even with an RFID bracelet you could create different musical sounds or play with different things and save all of your recordings and email them to yourself. But the Cooper-Hewett was pretty innovative with that. A lot of museums have loved that model. The pen was cool because of its design, but you could have any RFID thing like a bracelet or a drum stick or something.

EWS: Was it important to connect the electronic instruments to electronic music, without bringing in electronic guitars or electronic drum kits, for example?

TE: We do actually have an electronic drum kit which we were considering for the exhibition but it got trimmed. Once we had the layout setup, we could only have a set number of experiences in there. That was one of the ones that was going to be on display, but it got cut. We don't get MIDI in at all and that was something I really wanted to do with our Yamaha….I guess its like a Sax MIDI controller. We've also been looking into Dagger Pipes too: a MIDI controller for Bagpipes. You plug in the Chanter, which is the thing that you play without the Bagpipes. We were looking at bringing that in to show all these ways you could work with a MIDI controller to make cool new types of music, but that all just got cut for space reasons. The same with the Early Audio Format theme: we had a whole section on wax that we just couldn't fit in. There was one too many, and we had the same problem with the Music Box roll, we just couldn't fit it in. Those were some of the unfortunate cuts that were not for any conceptual reason: it was more down to limitation of space. That's why we focused on the Theremin and the La Caine collection, and then the Moog was just to see that sort of early and crazy way of trying to think of making electronic music, and then you've got the La Caine section which condenses all of that into thinking about keyboard controlled musical objects, and then that all just gets condensed into the Minimoog for mainstream introduction. So it created a tighter narrative without those pieces: as soon as you put MIDI in it gets a bit complicated. In the end it made a tighter message, but we would have liked to have included that stuff.

EWS: The wiring and the open case on the original Sackbut prototype is a prominent feature of it. Was the wireless look of the Sackbut interactive a practical consideration so that visitors could not pull out any of the wires? Could the wires have been displayed behind glass?

TE: As much as the Electronic Instruments section was about the machines themselves and looking under the hood, we found it really difficult to convey information about that and talk about the historical context of the pieces. For the Theremin, for example, it was difficult to talk about what it is and what it does, the historical context about how it came about with experiments and proximity alarms and everything else, and then how those ideas were brought together to create this thing that you play without touching it, and then Clara Rockmore's position in terms of refining that into a tool that real musicians could use. And that's just for context. So as soon as you're getting into unpacking those stories the next layer is "how does this thing actually work from a technological standpoint?" So talking about how vacuum tubes work, how oscillators work, and how they would create this feel as you move your hands: that extra technological information was so difficult to try to explain, especially with all the other information we had to put in, that we decided to do away with it and really focused on the human interface design. We asked questions such as 'how do you work with that to make music?' and 'why was it weird?' and 'why was it innovative?' We didn't really talk too much about the under-the-hood stuff. For example, again, getting into the nuts and bolts about how voltage control works with Hugh La Caine electronic Sackbut and how all those components work: the next thing you know we're talking about modulators and envelopes and filters and touch sensitivity and it just got really technical really quickly. Instead, we simplified it to "it was created at this time before anyone else did it", "this is why it was so innovative", and "this was what he was trying to accomplish" in terms of having keys that you could press and then you could mimic other types of instruments just by manipulating certain knobs. That's as deep as we could go. When we developed the Sackbut interactive we didn't use that as an opportunity to delve deeper into what was happening under the hood. It was complicated enough for people to figure out that they play the keys and then adjust the sound with these different features. We labelled things, so you have your modulator, you've got your filter, your envelope, octave switch, glide and all of that. The main names are there and we do have a little description of what each of those features do, but we weren't really getting into the under-the-hood about how electronic synthesis happens. If we actually displayed all the wires, we didn't think they would add too much because we weren't talking about how those wires interface and what they were actually doing, so the whole design was black-boxed. It was just all about the playability and the control of these different features, without worrying about what's going on under the hood. These are things that come out on our tours and the guides can help people understand a little bit about what's going on under the hood, but it just seemed like it was one layer too deep for what we could accomplish in that space, so it was easier to black box it and just have an interface and controls, and even that has been difficult for people. You see people playing and then turning things and then playing, but you need to do that at the same time to actually notice the effect. We were even going to update the information on the panel to show people, maybe with a video screen, that you're supposed to be doing it simultaneously. So that's the challenge when you're dealing with multi-generational audiences, people may have never come across this stuff before. You've really got to limit the information and then limit the complexity. Certainly if we had added that layer of showing all the wires and everything, it might have gone against what we were trying to do because it might have made it excessively intimidating or seem excessively technological, whereas in its current state it's a lot more inviting for visitors to go and play with. Another thing is, with all of those interactives in the space, they are not analogue. We have not made analogue reproductions: and that's why we do not call them reproductions, we call them interactives. Anything we showed under the hood would have been a lie because it's not vacuum tube based, it's all just computerised. So we would be lying first of all, and I don't know how much it would have added to the story. We could have done that a different way. If that had been a whole exhibition on electronic music, for example, we could have had sections which have dealt with the cultural history, the social history and the playability and interface design, but we could add a whole other section which was all about what was going on under the hood. We could have added vacuum tubes and oscillators and synthesis. Then we could have had interactives where you could either change the patch work or have different things light up to show you things. For example, when you turn it on, the oscillators start to glow. You could do a bunch of different stuff. But it's all about choices.

Appendix C: Second Interview with Tom Everrett

Video interview, 29 October 2020

EWS: What is the story behind how the Electronic Sackbut ended up at the museum?

TE: I actually don't know the answer to that question. I can find the answer to it as I can get in touch with the previous curator. I do know that we got it in 1975, he died in 1977 in a motorbike accident. He donated it, or his wife donated it. Gayle [Young] might know as she spent time with Trudy [Hugh Le Caine's wife] so between Brian [previous curator]and Gayle I should be able to answer that question.

EWS: You talked in the last interview about how difficult it may be for an exhibition's audience to understand the different controls and parameters of the instrument. Is this based on user-testing the interactive version prior to Sound by Design opening to the public?

TE: No. Its based on participant observation on the floor of the museum. Unfortunately the design process, by the time we started looking at the interactive design it was getting late in the game, so they contracted a design firm, so it was a sub-contract, so we were dealing with the big design firm for the exhibition and they had sub-contractors that were developing the interactives. So the museum had no contact with the sub-contractors who were designing it. All we did was I prepared some briefs that I made in consult with John as well as my father-in-law who used to teach electronic music production at Carlton: Jack. We together on a phone call worked out the details and then I sent it to John before sending it onto the design firm. They took it to their sub-contractor and said 'deliver this product'. What happened from then on: we were kept out of the loop…sorry, it wasn't that we were kept out of the loop, it's just that there were so many things going on in at that stage of the exhibition development process that, when we tried to enquire about it, we weren't really getting those answers. We actually travelled to meet the team in Montreal and we went and met with the subcontractors and we got to see some of the prototypes as they were being developed, and part of the feedback that I had was that I was surprised over some of the materials that they were using for the keys and some of the other things. It wasn't what I had asked for, or what I expected, but at that point it was clear that we couldn't turn the ship around. It was going to be delivered that way, or else we'd have nothing. So I remember returning from Montreal feeling very disappointed. When we were up, it was disappointing for me because it was lacking the mechanical qualities that I felt were important. I wanted something that had proper keys: the original keys were made out of wood, so I thought it would be nice to have that wood feel. I was hoping for something with wooden keys, I was hoping for the left hand control, the pinky and the thumb control, I was hoping for hinged actual mechanical components, I wanted it to be as similar as possible, so that was what I was expecting. So we went and saw it and the timbre plate: there was nothing that moved on the interactive, it was just flat. So that was really disappointing as there was nothing to clue in the visitor as to, like, 'how do you use this thing?' It was just a flat circle, so there was nothing to indicate how to use it. The pinky and the thumb control, also, were very flush with the surface, they did not have much movement, they were nothing like the original, so even to know how the pressure…the whole thing, to me, was not very intuitive. It looks cool, but it wasn't intuitive in that it didn't have any of the feel of the original, so that's what I was hoping for and that's what disappointed me. In terms of the sound, when I started playing it…they based it off of our recommendations as to how this thing should sound and when I heard it for the first time playing it I was quite amazed by how much it sounded like a modern synthesizer. Whether or not that is accurate to the original is impossible to say for now because it is missing a lot of the controls that we would need to begin mimicking some of Le Caine's steps, so we could adjust the timbre slightly with that, we could modulate it a little bit, filter it a little bit, adjust the octave, that kind of thing, but there are a lot of controls such as the attacks and decays, all of that that are in the original, that aren't on the interactive, so its hard to say how close it looks to the original. Also, because of all those timelines…people only arrived in time for the installation, so we couldn't do the kind of user-testing that we would have loved to have done, that was part of the rebuild. Because of all the exhibitions happening simultaneously, things were just too hectic. We did testing for other things, but we didn't do testing for that. What we did do is visitor observations, and what you could see was that people didn't know what to do with the centre bed, they did not know that you could put your fingers on there or how that moves: you could tell that they were confused. A lot of people, rather than using the pinky and the thumb controls as you would be expected to if you played the Sackbut, a lot of people were putting their fingers on and sliding up, because they thought that it was a slide-up action as opposed to a pressing action, that kind of thing. So what they would do is they would play with this hand and they would touch with the same hand. So you would hear the sounds of the keyboard and it would go quiet when you removed your hand, and then touch and nothing would happen because that's changing the sound and you need to do both things simultaneously. So we noticed a lot of that, that a lot of people are confused by it. We also noticed some wonderful things too, where one person would play the keyboard and other people, or kids, would be adjusting the timbre controls: fun stuff like that. But in terms of the goal of trying to give people a real sense of the playability of the original, I think we missed the mark on some of that. But the way the people who built it rationalised it to us, it was about durability. If they did do something more mechanical, it would be getting destroyed all the time, so I think that's why they made a lot of the decisions to use what they used and do what they did. But of course the irony is that it does break down, and kids are always breaking those keys off anyway. So it was cool to be able to hear it and play around with it, which is something that we hadn't been able to do, and we'll realise in the next project how close we were, when we have more controls.

EWS: Has your understanding of the Sackbut developed since Sound by Design opened, and if so, if you could install a new interactive version of the instrument now, would you change anything? If you could design it yourself now, would you design it differently?

TE: The answer I give you now will be a different answer to what I'd give you in two years, as we progress on the project. If I could change anything now, it would simply be to introduce some of those haptic elements and those mechanical elements. I'd love to swop out that keyboard and put in a more traditional keyboard or a modified keyboard with wooden keys, that would be super interesting. And I'd love to change those controls to make it…that's one of those things that we're hopefully going to have the opportunity to do at some point. Things have been delayed due to COVID, but we were talking about how to make the interactive a little bit more intuitive. So we were looking at having a video that shows you where to put your hands and all of this, but my opinion on the matter was that…'what if we prototyped a new design?' where we actually have it looking and feeling a little bit more like something that people might recognise. Will they more intuitively be able to grasp it? I'm used to seeing controls on the inside that are the same digital components and software that they developed…so that would be my synth, that is one of those things that is on our list of things to do, but money and COVID and a few other things have delayed it. What I'd prefer to do now is work on a better physical design rather than supplement a poor physical design with more information, like a video, which would get us closer to the mark in a few different ways. But that'll be further down the road once we've completed the reconstruction of the Sackbut that we're working on now to form a professional model, what I would like to do is take what we learn from that and apply it to the interactive. So we might learn that all we need to do is introduce these two additional knobs that allow you to control the attack or the decay, for example. By introducing those all of a sudden we might be able to get close to demonstrating 'oh, if I move the timbre plate over here, it sounds more like a flute' 'if I move it here it sounds more like an oboe' so that could be some things that we learn, or we might learn that its too complicated to actually achieve any of that: he simple version was better, lets keep it simple and just allow people to play with just the main controls. Or we might learn that what we thought were the right ways of blending the voltages, or what the design team achieves…because I haven't seen their software, we're going on faith that they're following our directions, but we don't know…so what we might learn from developing the professional version is that actually under the hood its all wrong and that's not how it would have sounded or how it would have worked. So then we can make those adjustments. Things that I can say with some confidence is that sometime within the next five years, that interactive will be eventually changed. So its cool because even with the model we have now, there was nothing there before and its been an excellent project. People are engaging with it and having a lot of fun with it, so the fun factor is high. The interactive factor is high. As a teaching tool its wonderful for me when I do tours or I do classes in there, by being able to actually play an instrument and have people listen to it, with the original Sackbut beside, it really increases the engagement and helps with the teaching. It's imperfect, but its miles ahead of what the exhibition would have been without it, I feel.

EWS: There's a really interesting point you make there, as an aside: whether interactive exhibits are designed with the idea that they're finished when they're installed in an exhibition, or whether there's always the ability to continue tweaking it. They're always in a kind of prototype state. Is that how it is generally in the museum with interactives? Are they installed with the idea that they're going to be tweaked further?

TE: I think there's a recognition that you're never going to get it completely right, and what you open with is not going to be completely perfect, and I think there's always an openness for making as many changes as possible. The enemy a lot of the time is budget and expertise. There's another interactive in another exhibition that I did where you compete with a patient to see how good you are with it, see if you can keep pace with the patient's heart and pacemaker, and it was simply too easy, so we were able to very quickly work with the design team to increase the difficulty of it a bit to make it a little bit more intuitive, and I seem to recall…I remember there was an issue with people touching the screen, and it wasn't a touchscreen. For accessibility reasons we wanted to not have a touchscreen, so I think there were some additionally instructions to help people understand that they had to push the button. Those were fairly cheap and easy to achieve. More substantial things like this one where we're talking about a complete redesign, it's very difficult sometimes to make those changes or it can take a long time because there are always other priorities to think about. Ideally you test and you test and you test ahead of time, and then you deliver it, but in those cases we weren't able to test ahead of time.

EWS: In terms of the music that the Electronic Sackbut has featured in, did you consider linking the instrument to the recorded electronic music it featured in within the exhibition, as with the Minimoog?

TE: That's a good question. Because of the limitations of the amount of text that we were able to include, we opted not to. The thing with the Minimoog is that it was literally used on these recordings, so if we take for example Dr Dre, that is the instrument that was featured. The difficulty with the Electronic Sackbut is that it wasn't featured on any recordings other than the ones made by Le Caine and his friends. We didn't wanted to start referencing generic synthesizer music and connecting it to that because there's too many gaps there, and nobody would know the Le Caine recordings because they are so obscure: home recordings, that sort of thing. We did want to share those recordings, so 'do you want to hear what it sounded like? Well listen to this'. The thing with some of those recordings is we didn't want to add another sound station in the exhibition, nor introduce headphones. The whole idea was, as soon as the exhibition was opened, we were going to start developing an app where for all the different instruments and all the different components in the exhibition you don't have the chance to listen to, here is your chance to listen to them. And that would have worked across the whole exhibition, so with the Design Icon section where we have all these things like phonographs and other things: you can't listen to any of that, so we had these ideas of playing recordings. So anyway, I thought that instead of having a button that you click and you listen to the Sackbut being played, or you can listen to Hugh Le Caine talking about the Sackbut, we will give you a Sackbut to play and that's how you hear the sounds. So 'here it is, do you want to hear what it sounds like? Step two feet over and play it yourself' and that's the way you can hear what it sounds like. So that was the approach, had we had more money: a bigger budget and more time, that is for sure. There is a wonderful recording of Hugh Le Caine actually talking through the Sackbut and the different sounds that it makes, which is really amazing, so having that stuff there especially, like, kids might probably be bored with it, but it would tick some boxes for an older audience.

Appendix D: Interview with Thorsten Feuerherdt

Video interview, 3 June 2020

EWS: How and why did Manikin Electronic start?

TF: It sounds a bit like an accident but Marcus, my business partner, and me were employees as engineers for a long time. I think it was in early 2000 that the IT venture capital bubble exploded and a lot of companies went bankrupt and we both became unemployed. We met originally at University so we'd known each other for a long time and we both have a strong interest in music instruments at this time, and a lot of friends who were also designing instruments or playing instruments: musicians, record label owners, in our friendship. We had the idea to go for a product because we had enough time at this point. There were no jobs. So in the end it was an accident due to no work and a strong idea. We started in 2003 with the Schrittmacher Step Sequencer that was mainly the idea of one of our musicians who I know very well, who was very up for playing live and I did their front of house mixing very often. One time he came back from The States and said 'hey, my step sequencer has crashed again, maybe you can design something that works better?', so. These two reasons: musicians with ideas and two engineers with no job were the basis for starting a company.

EWS: So with the re-making of the Mellotron as the Memotron M2K, did that come from the same need from musicians for that instrument as a modern iteration?

TF: In the end it was the same. It was the same musician who was playing Mellotron samples on a sampler on stage, and he glued a big Mellotron sticker on his keyboard, and I was sitting at the mixing desk and I said 'hey, this looks a little bit strange.' And he said 'yeah, maybe you can design a controller that looks like a Mellotron', and I said 'designing a controller is not the biggest challenge, but where are we getting the sounds from?' and he said 'hey, I know someone who is refurbishing old Mellotrons who knows a lot about what the Mellotron should sound like'. He said that he would introduce me to Klaus Hoffman-Hoock who was our sound designer for a long time. He said 'I have the sounds, you have the knowledge, lets do it!' So that was, again, a musician-driven start.

EWS: So I've had the pleasure of seeing your Memotron M2K in the Berlin museum, but for the benefit of this recording would you be able to explain what features of the Memotron are the same as the Mellotron and what you have added to it?

TF: Basically, it's a white keyboard playing Mellotron sounds. The main difference is, of course, the Mellotron is using tapes and we are using samples. It sounds nearly the same: samples are always a little bit different, but we are getting a lot of feedback from musicians and from the guys in England, Street Electronic, who are the company of John Bradley, and they are saying the sounds…if you are closing your eyes, it is very hard to hear what is a tape driven old M400, or what is a Memotron. We tried to leave the character of the sounds, which is done using samples key-by-key of really old frames, so we are not dealing with the original master tapes, we are dealing with sampled vintage instruments. As I say, Klaus Hoffman-Hoock was refurbishing, in his life, more than fifty M400s and had more than two hundred tape frames and he was a musician, he knew exactly what a Mellotron should sound like, and he was designing the sounds. We tried to leave the user-interface as close to the old M400. Of course, the Memotron is a digital instrument so it needs a digital screen to make it usable, to enter sounds, to go into setups. We added MIDI: you know, a modern instrument needs to be controlled from the outside. Meanwhile, we added to the M2K two additional keys, because the original Mellotron has 35 keys and we have 37. It's easier to get keyboards of this size. We added an effects processor which deals with amplifier modules and phaser, chorus, delay and reverb stuff, which makes it easier to use the Memotron as a stand-alone instrument in a small setup. The main thing that is different is, if you want to change the sounds on the original M400, you have to change the whole tapes, the frame, and the frame always has six sounds on position A, B and C. With the Memotron you can do something similar: you can load sounds from the memory but you can say 'I want violins on position A, on position B sounds like strings, and something strange like a Harpsichord on position C, which is a combination that was never available on the original frame for the M400. The flexibility is much larger than it was on the M400 and it only takes a finger slide to change the sounds, not half-an-hour. Then we also decided to remove the complete body of the M400 because, as anyone who has an M400 knows, its a large, very heavy instrument. Nowadays, a digital Mellotron should look like a keyboard and be light weight. The old one was 70Kg, maybe 60Kg, whilst the new one is 12Kg so much easier to handle.

EWS: Looking at your website there is a really impressive client list of users of the Memotron M2K. Out of curiosity, have you received feedback from the museum in Berlin as to how visitors interact and interpret this instrument?

TF: Yes, I just had a chat with Benedikt yesterday actually. The feedback is mainly that visitors want to touch something, especially if we are talking about instruments that are making noises, sounds or whatever. If you're just standing in front of a Mellotron and someone is making sure that nobody touches it, it's a beautiful piece of hardware but without sound it is only 25 or 50% of an instrument. The M2K in the museum in Berlin gives visitors the chance to check out the sounds of a Mellotron. Due to the fact that the Memotron sounds very very close to an M400, based on the samples, the visitor is getting a real feeling, especially the guys who grew up with The Beatles or some Brit Pop stuff or Jean-Michele Jarre, they are loading sounds like the flutes that play in Strawberry Fields…so they know 'ah, this is the instrument from my youth.' My personal feeling is every time I am in a musical instrument museum, I want to touch something, but normally it is forbidden. With the Memotron, the feedback from visitors is its cool we can touch something. If something is not working, because we have built the instrument it is easy to repair.

EWS: Yes, so do you think the visitors at the museum are interested in that authenticity of what the Memotron represents? The sounds that it has?

TF: Yes. It gives the visitor a chance to not only look at something but also to touch it and feel it. Musical instruments are more than only a short view of how they are built.

EWS: Which specific skills and knowledge have helped you design musical instruments?

TF: That's a good question. You have to be a music nerd. If you're designing instruments, especially for musicians as clients, they are often very special, you have to be into music. There are different kinds of music that I listen to, from classical electronic music to progressive rock, heavy meal…I'm a collector and my business partner Marcus is as well. You need to know a lot of music. The basic knowledge, or what helps us very much, is being a technical engineer. Instruments are mostly a piece of hardware, something like a computer, therefore you need a lot of knowledge about designing cases: production of housing and cases for instruments. You need knowledge of electronic design schematics. You need a lot of knowledge of laws if you want to sell electronic stuff. All governments worldwide are looking at instruments as a special kind of waste: electronic waste. This is a very strong discussion in our scene, that musical instruments are not built for the trash after a few years, they are built to help musicians for a long time, so they are completely different compared to a laptop or a smartphone.

EWS: Have you made sure that your instruments are designed to be sustainable?

TF: In the end, if you are looking around in our market you will find that some instruments are designed to be cheap on the market. There are some companies that are producing masses of instruments for a low price, especially in Asia. We are designing and building everything here in Germany. We know that Manikin Electronic products are a little bit more expensive than others, we know it! But, if we know that some parts are a little bit more expensive than others but are more reliable, then we will use them and say that we need to raise the price, but we'll know that they'll work for a long long time. As I said in the beginning, we started in 2003 and we published our first Schrittmacher Step Sequencer in 2004. I know from a lot of customers that these units are still working: that's sixteen years. For electronics, that's a long long time. Something that we really want to do is to build instruments that are not dying in the next five years. We want to build something that will work longer, but we also know that electronic parts are becoming very old very fast when you are using them, and of course we know that electronic instruments will die earlier than mechanical instruments. I think if you spend a little bit more time thinking about the design, make some parts a little bit bigger, more reliable than needed, then you will have an instrument that will work a longer time.

EWS: Have you encountered challenges in working with different materials when designing instruments? When working with woods, metals, that kind of thing?

TF: Yes we did. The first version of the Memotron was made in a wooden case. The M400 was also mainly a white wooden Mellotron, so we said we should go for a wooden case with some metal front panels, and what you can recognise there is that metal will be cut with a laser. We are taking about such tiny differences in production, against wood. If someone is working with wood, if there is half a millimetre difference they will say 'who cares?' Then you have the problem with putting those two materials together: wood with plastic, wood with metal, you will always have the problem with them not fitting together precisely. Then a lot of special hacked work with each instrument needs to be done so that it looks beautiful and everything fits. This was also the reason why we decided to go for a complete metal housing of the Memotron and laser cut it, with a bending bank also made from laser control: these housings fit every time. You can also mix from different production lots. The bare-board and the top cover: you can mix it and it always fits. If you work especially with wood, you will very often have the problem that it's a millimetre more or less, or if you're not putting a complete finish over it, if you're just putting some oil on it for structure, then you very often have to decide 'are these parts really fitting each other? They're looking in colour and in structure a little bit different?' It makes an instrument very beautiful and interesting, but its not the cheapest way of designing cases and housings for instruments.

EWS: Have you encountered any problems when working with older, vintage electronic musical instruments? For example, with replacing older electronic components, finding documentation, that kind of thing?

TF: Yes, although we're designing new instruments we have a lot of musicians around us who have old instruments and they know that we are a firm of electronic design and we are repairing things around us, so from time-to-time we are getting old instruments. It's strange because…one story, we got a Solina String Ensemble two years ago from a friend who said that one key was not working. We opened the case and looked inside and saw a lot of dust: not just the ordinary dust lying around, but we saw a lot of plastic dust from capacitors. They are becoming old, they are becoming dry, and then they are dying. My first words to my employees were 'don't touch and don't kick this unit!' We will very carefully find out what the problem is, and then we will repair it and close it properly and send it back. The main problem is that, especially if we are looking at the early synthesizers, generations from the seventies and also from the eighties, a lot of parts are not available anymore. Especially the Sequential Circuits stuff, Oberheim, and other companies use chips from Curtis Electronics which are special chips for VCOs, filters, stuff like that, and the company hasn't existed for around fifteen or twenty years, and these chips are not available anymore. From time-to-time you can find used chips on eBay, but these chips are not available anymore so you cannot replace them. In the end, they are the heart of the synthesizer, so if the voltage-controlled oscillator is not working then the synthesizer is dead. It is very hard to find replacement parts. Meanwhile, some companies are building these chips again, but they are not sounding exactly the same. This is because of much better production abilities that silicon companies have now. We can make much tiny-er, cleaner silicon than in the eighties, which makes the behaviour of the chips a little bit different, and what makes it different….at the end of the oscillator, the replacement is not having exactly the same waveform as the old one. I'm sending it through a filter: it sounds slightly different. I think this is a large challenge when you want to replace something. Another example, I got a distortion pedal from a friend and the rectifier was defective. I said 'it's okay, it's easy, it's a part that is easily available and costs just two euros.' I ordered one, I replaced it in the back, and he said 'hey, it's working but it doesn't sound like it used to?' and I thought 'what could be the issue?' And then I found out that the old rectifiers were much dirtier in production. The basic parameters are the same, but due to the silicon production capabilities these companies had in the eighties, against today, some side parameters seem to not be the same. Perhaps they are not noisy like the old rectifiers? So I went to a recycling area, here, and grabbed some old radios and stuff like that from the eighties and looked for this part, which I found, and used it as a replacement…and the musician said 'hey, now it sounds cool.'

EWS: What have been your favourite interfaces on electronic musical instruments? Keys, knobs, faders on synthesizers and drum machines, for example.

TF: It depends on how old you are. I am in the age when I want to touch something. Instruments with controls and real knobs for every parameter and a keyboard are giving you more inspiration than touching with a mouse on a screen. If you're looking at the younger generation, a lot of those customers are not concerned with touching keys. They want to use a mouse or a touchscreen, but from my point of view, if I'm sitting in front of an instrument, I don't only want to use presets, I want to find out what the sound can also be, and then it's very cool to have knobs that you can turn for every parameter and a keyboard that you can use immediately. That's my point of view.

EWS: Previously, you talked about the music you listened to and how that affected your work on instruments, but I was wondering if you played instruments as well?

TF: No. I am able to play some chords on the keyboard and my employees are wearing headphones whilst I am doing this [laughs]. But no, I don't have a classical education in music. I'm an engineer…and if you're looking in our business, especially at the tiny and mid-range sized companies, you will find two kinds of developers: engineers like me and Marcus, you will find those who are coming directly from an engineering background, and then you will find musicians who have figured out that they are not able to buy an instrument that fits, exactly, their ideas, and then they are starting to design their own instruments. The best way is to put both of them together, and this is what we are doing at Manikin Electronic. We have a lot of musicians around us who help us to make ideas better, to make our instruments better. We have a lot of contact with professional musicians worldwide who are giving feedback, and we are also getting ideas from them. They are saying ‘this kind of controller is missing’ or ‘I want to do *this*…maybe this could be a product?’ If we can figure out that this idea is good, and maybe the idea will have a market, we can ask our retailers worldwide what they think about this and then maybe we will make a decision to say ‘okay, lets design an instrument or controller or something.’ From time to time, we are also getting ideas from musicians who say ‘okay, I know exactly what person in the world would need this, and that’s you.’ So do we really want to put thousands of euros into development just to have a knob that is turning in another direction? It will be helpful to play an instrument, but I’ve never had the chance to learn one.’

EWS: So when we met about a year ago at the electronic musical instrument symposium, you were able to share a lot of opinions about how museums work with older musical instruments. Would you mind sharing that advice on what you’d give to museums that collect vintage electronic musical instruments?

TF: Yes, I think it’s a very large challenge. We are working with electronic musical instruments not only with basic materials such as wood, steel, metal, something that grows in nature…we are working with very special specialised parts: microcontrollers, memories, operational amplifiers, things like this. Due to our very fast world, a memory or microcontroller that you can buy today is definitely obsolete tomorrow. Especially if we are looking at the lifetime of electronic components, like capacitors have a lifetime of ten thousand or fifty thousand working hours or so….with a lot of other parts, if you are using them within the correct specifications they will work for up to ten years and then they will start having problems. It’s not so easy to make instruments playable for a very long time. A Minimoog will die by itself. If you want to keep it playable…if you’re buying something now you have to make sure that you also have replacement parts for it in the future. But then we have another problem. Electronic integrated circuits cannot be stored for a very long time. I found that storing electronic parts for ten or twenty years…if you make a high security, dry environment then maybe thirty years, but then they are also not usable anymore. In comparison to a Stradivarius stringed instrument, what is thirty years? Nothing! In the end, I see that if you really want to have these instruments in a museum, maybe you’ll have the instruments themselves but they won’t be working anymore. Museums have to take care to collect everything around, like schematics, documentation of the housing, maybe ideas behind why it is designed in this way and not in another way, maybe the sound: what can be recorded. Maybe also the musical usage: if we have the Mellotron, if we are talking about the Mellotron flute, we have a lot of music pieces like Strawberry Fields by The Beatles, or Pink Floyd, where this was extensively used, so you can put it in this context to share with the next generation and say ‘okay, this instrument isn’t working anymore, but if you look back to the seventies you can hear it here in the musical context.’ But I’m pretty sure that we are losing a lot of instruments in the next thirty or forty years.

EWS: Which electronic instruments would you like to see displayed in a museum exhibition and why?

TF: We know about some older instruments like the Minimoog, ARP, Buchla: these pioneering instrument designers made a lot of very interesting instruments with new ideas in the past, but if we're designing instruments now, who knows? Maybe our next product is the product that people are talking about in the next one hundred years, or maybe it's gone in five years? The large amount of instruments available at the moment, especially if you're looking at the modular market at the moment…if you're looking in shops like SchneidersLaden here in Berlin, they are offering more than a thousand modules from different manufacturers: which ones do you want to collect? If I want to see something in a museum, I want to see something in the context of it being new at the specific time it was published. So the Minimoog was the first reliable, lightweight, and affordable instrument that musicians could carry around, and the filter in the Moog synthesizer was unique and new at this point, so it is a very interesting instrument for a museum because it was the beginning of a new time. If I'm looking at the Oberheim stuff, these also represent very unique new ideas. Or the FM synthesis in Yamaha's DX7, this is also a very new and unique. To describe the development of electronic musical instruments in the past, I think the view should go in this direction: what was new, what was unique, a new stand-out in sound in development for the next years. For the moment, we are grabbing old ideas and putting them together. We have additive synthesis, we have subtractive synthesis, with have FM synthesis, we have the bear analogue stuff: in the end, everything is set.

EWS: So maybe a different question would be, what interactive instrument would you like to play in a museum?

TF: A Trautonium would be cool! I like it very much. This is also one of those instruments I was talking about, it was very unique, and it is still very unique. The idea was how to make these generators playable and usable as an instrument. At this point, it was a very brand-new idea. A theremin was also interesting because it made weird and strange noises. The Synclavior is also very cool. There are some milestones in the past of these kinds of instruments. With the DX7, it's not my kind of sound, but it was a milestone in developing electronic synthesis systems, like the Synclavior or the Minimoog or the ARP 2600, or maybe a lot of these stringed….the idea of making electronic stringed instruments. If you asked a violin player to play this, he would say 'what the heck is this? It's not a string, a violin is a string.' These are milestone instruments and technologies and ideas. There were also a lot of interesting breath controllers that were available in the eighties. I think one was called a variaphone? This is also interesting. Especially if I can touch and play one of these instruments, that would also be interesting. Also not just to get a technical background but a cultural background…the Trautonium was used by Hitchcock in film. It would be great to have this as a visitor: the historical context as well as the technical background. It is not only a bit of hardware that is making noise.

Appendix E: Interview with Moritz Simon Geist

Email interview, 24 January 2022

EWS: For the exhibition in Paris, did the museum stipulate any specific learning or entertainment outcomes that the MR-808 had to help visitors reach?

MSG: When I developed the MR-808 in 2012 I had in mind to create a visualisation of music with the help of mechanics. My background is in classical music, playing clarinet and piano, and when I switched to making electronic music with a computer I felt that something was not right: At some point I noticed that I need to have a haptic and more physical feeling for music which is lacking in my opinion when you make music with computer. So for me the obvious connection was to combine physical computers with electronic music to make the sound creation more visible and understandable. This is also the main idea behind the installation when it's displayed as an interactive piece. I want a general audience to understand how electronic music and its rhythmic structures can be visualised. A computer or synthesiser is a blackbox to most of the general public and its much more educational to see the sounds evolving in front of your eyes.

EWS: With the touchscreen interfaces, what were the reasons why you chose to focus on step sequencing rather than how each drum sound could be altered (decay, snappy, level, etc)?

MSG: Creating interactive Artworks for an audience with varying knowledge about how music works can be challenging. On the one hand one wants to give the audience a big control and impact of what is happening and what they can control. On the other hand, people with limited knowledge of music (“uneducated players'') often create structures which sound ‘chaotic’, which is unsatisfying for the other attendees as well as for the (uneducated) player. With a fixed grid like a step sequencer, the rhythm possibilities are limited, but the outcome is always of certain quality, quickly giving the player a feeling of achievement. Without the Grid sequencer - which runs on a webserver - it's actually possible to manipulate some more of the MR-808s sounds like velocity for each instrument and also OpenHighHat / ClosedHiHat. Than the instrument is purely controlled via MIDI, e.g from Ableton Live.

EWS: From the pictures, it looks like microphones were used to pick up the sounds from the mechanical actuators and physical tone-makers. Did you consider using the actuators and tone-makers to trigger electronic drum sounds that sounded more like the TR-808 instead?

MSG: The microphones were used to amplify the sounds when I played on a bigger stage. But the main idea is to create all the sounds mechanically - this is a main dogma in the use of my installation. In this work, I am using purely physically created sounds, like a snare which is being hit by a motor. I carried out a lot of experiments to match the sound of each of the instruments from the original 808, comparing the original sounds to those of the robots. With some instruments that work better (the Bassdrum for example) for some it was a challenge: the original 808 clap sound for example is a very iconic instrument, consisting of a series of white noises spiked with an envelope. This is very hard to replicate as a physical instrument.

EWS: Have you altered the MR-808 in any way to make it suit each place it has been installed in (to suit different audiences, for example)?

MSG: When I started building the MR-808 in 2021 I did not have any connection to the art world, and I could not imagine if and where the instrument would be showcased, so I did not think about this. Eventually it would then be displayed over 200 times in 2012 to 2015. But what we did take into consideration during the build was that it should be "easy" transportable, e.g. not being one single body of wood, but 5 pieces which fit into a Mercedes sprinter. I modelled the whole installation in 3D CAD, and calculated that it fits in a car. Its only later that I did more site-specific works, for example my latest work "Vibrations", a 4x6 m big robotic vibraphone, which is flexible in the setup and can be adapted to fit the room acoustics and aesthetics.

EWS: Did repairs have to be made whilst the MR-808 was installed in each place, and if so, how was that handled?

MSG: That is the nice part of working with Robotics: there is always something that breaks. In the beginning I even took a 3D printer to my shows so I could replace broken plastic parts on the fly! Now that the installation runs for over ten years already, all parts that could break have already been fixed Numerus times and the installation continues to amaze people.

Appendix F: Observation Prompts and Questionnaire Questions

List of prepared prompts to refer to whilst observing visitors using *Drum and Bass – Time and Space*

1. Initial reaction:
    a. Engaged
    b. Confused
    c. Uninterested
2. What controls did they engage with first? Did they look like they had managed to ‘start’ the exhibit?
3. Is it too loud/too quiet? Did they find the 360o experience disorientating?
4. Did they read the interpretational or instructional text?
5. Single player or collaboration/versus? Did anyone help them to use it? Was an informed expert present?
6. Were there any surprises?
7. Did they build confidence in using it over time? Did anything continue to confuse them?
8. What controls did they use the most?
    a. Drums / Bass
    b. Position of joystick
9. Did they get annoyed or ‘misuse’ the exhibit?
10. Did they say anything to indicate that they understood the purpose of the exhibit and why it was in this exhibition?
11. Any specific comments or reactions?

List of prepared questions to ask visitors after they had used *Drum and Bass – Time and Space* (arranged in sequential order – words in parentheses were used as further prompts where necessary)

Age. 01-15, 16-26, 27-40, 40-55, 56+

1. How would you describe your level of interest in, and knowledge of, music and sound prior to visiting the museum today?

2. On a scale from 1 to 10, how did you find using the exhibit (with 1 being I found it very difficult, and 10 being I found it very easy)? What makes you say that?

3. On a scale of 1 to 10, were you entertained by the exhibit (with 1 being I really disliked it, and 10 being I really enjoyed using it)? What makes you say that?

4. Did you feel you explored the exhibit's full potential? (Did you feel that you used all the controls?) What makes you say that?

5. What did you think the purpose of the exhibit was? (What did you learn from using the exhibit?)

6. Had you encountered the exhibit's themes, sounds, music, or technologies either in this exhibition, in any of the museum's other exhibitions, or outside the museum?

7. As a result of using the exhibit, is there anything that you will try to learn more about? Has it encouraged you to want to listen to or make music?

8. Do you feel that using the exhibit has enhanced your experience of the exhibition (Sonic: Adventures in Audio) today? What makes you say that?

9. Any other comments?

Appendix G: Visitor Observations

Observations are ordered chronologically.

No. 12 (Observations and Questionnaire)

Situation	Male adult used the exhibit, whilst a female adult supervised two children using it also: the first to use it was the male child, the second was the female child. Male answered questions.
Time Spent using Exhibit	2 minutes 30 seconds
Prompt 1	Children were engaged in pressing the buttons
Prompt 2	Children just banged the bass buttons straight away. Adult pressed play and used the joystick first, to explain to children how the exhibit worked.
Prompt 3	They did not show any signs of noticing the 360 sound.
Prompt 4	Male read the instructions first but the children started using it straight away. Did not read interpretation text.
Prompt 5	Male tried to explain to children how to use it - demonstrated how the joystick worked with the buttons, collaborating with the children to help them learn. Children were asked to take it in turns. Adult had a go on his own afterwards.
Prompt 6	N/A
Prompt 7	When using it on his own, the male became more confident and started playing melodies in time with the drums.
Prompt 8	The second child, especially, just banged the bass buttons as hard and fast as possible but banged them in time with the drums once the male started using the joystick to help demonstrate how it worked.
Prompt 9	Children were banging the buttons hard and fast.
Prompt 10	N/A
Prompt 11	N/A
Other Comments	N/A

No. 13 (Observations and Questionnaire)

Situation	I female adult, two male children.
Time Spent using Exhibit	1 minute 33 seconds
Prompt 1	Interested, but they wanted to read the instructions before they started using it.
Prompt 2	Started with the play button.
Prompt 3	They were stood by the side of the exhibit, facing to the left, with one child engaging with the exhibit from behind it, looking over the top. As they moved the joystick, their heads looked up towards the direction in which the sound was coming from, following it around the room. Where they were stood seemed to encourage this.
Prompt 4	They started with the instructions. Female read them for a while and then read them out to the children before they started to touch it. Did not read the interpretation text.
Prompt 5	Collaboration between the children. Female informed them of how it worked by reading the instructions to them.
Prompt 6	They looked genuinely surprised when they noticed the sound shift to a different playback position in the room.
Prompt 7	The children were pressing the bass buttons fast but not hard. They seemed to really like it and quickly became confident with using it through diving in and finding out how things work, after reading the instructions. They started to play melodies in time with the drums.
Prompt 8	Once confidence was built, they used the joystick as much as the bass buttons.
Prompt 9	At first, pressing the buttons fast but not hard for the sake of it.
Prompt 10	N/A
Prompt 11	N/A
Other Comments	N/A

No. 14 (Observations and Questionnaire)

Situation	One teenaged male used it whilst one teenaged female observed.
Time Spent using Exhibit	1 minute 45 seconds.
Prompt 1	Teenage female looked uninterested from the start. Teenage male looked interested from the start.
Prompt 2	Started with the play button.
Prompt 3	Once they started playing the bass, they both looked up to see which speakers the bass sound was coming from. His head movements demonstrated he was aware of the surround sound experience.
Prompt 4	Teenage male read the instructions at first, but just for a short while. Did not read the interpretation text.
Prompt 5	Solo performance - just the teenage male using it whilst the teenage female observed. Teenage male explained what was happening with the joystick movements and the slower/faster speed and surround sound, as well as how the exhibit worked, to the teenage female.
Prompt 6	N/A
Prompt 7	Teenage male was quite content with just pressing and holding one bass button for a while whilst figuring things out. He then moved the joystick fully backwards and listened to the slower playback speed and realised that the bass LFO was cycling at a slower rate as well. He then did the same but with the joystick moved fully forwards.
Prompt 8	Teenage male was mostly interested in the bass, but used both the joystick and the bass buttons to change the LFO rate whilst the drums were also playing.
Prompt 9	N/A
Prompt 10	N/A
Prompt 11	N/A
Other Comments	The teenage male pressed the play button at the end to stop the experience. May have done so to reset it for the next visitor.

No. 15 (Observations)

Situation	One female adult, one male child.
Time Spent using Exhibit	1 minute 15 seconds.
Prompt 1	Interested.
Prompt 2	Female read the instructions first to male child, but he had already started pressing the bass buttons and was not listening to the female.
Prompt 3	The female seemed to notice the 360 surround sound, but neither of them seemed bothered by it.
Prompt 4	Female read the instructions to the child, but he did not listen. Did not read the interpretation text.
Prompt 5	Both used the exhibit but it was not a collaboration - both doing different things for their own benefit. Female tried to get the child to operate the exhibit in a certain way but it seemed as if neither of them understood what to do, so they couldn't make it work as it was intended, or in the way they expected it to work.
Prompt 6	N/A
Prompt 7	Male child moved the joystick up and down for the sake of it. He also pressed the bass buttons and got annoyed that they were not doing anything, which was because he was leaning on one of the bass buttons the whole time, which was pushed down. Female also kept accidentally hitting the play button whilst trying to operate the joystick. Due to the male child's disconnection between moving the joystick and pressing the bass buttons, he got frustrated that the joystick did not seem to do anything.
Prompt 8	The female used the play button and the joystick the most, whilst the male child used the bass buttons the most. Joystick was just waggled up and down randomly.
Prompt 9	They seemed to get fed up with it and did not seem bothered by the surround sound or any other features.
Prompt 10	N/A
Prompt 11	N/A
Other Comments	N/A

No. 16 (Observations)

Situation	One male adult, one female adult, one male child. The child used it.
Time Spent using Exhibit	50 seconds.
Prompt 1	Both the male adult and the male child looked engaged. The female adult just observed, uninterested.
Prompt 2	The male child started using all the controls straight away. He pressed and held the bass buttons down and then pressed them in sequences. The male pressed the play button to start the exhibit - demonstrating that he had read the instructions and was following them.
Prompt 3	Nobody demonstrated any notice of the 360 surround sound.
Prompt 4	The male started reading the instructions to himself whilst the male child had already started using the exhibit. The male child demonstrated that he understood how to operate the exhibit very quickly, without the need to read or hear the instructions. Did not read the interpretation text.
Prompt 5	Male pressed the play button whilst the male child had already started using the bass buttons, but there was no collaboration after that - essentially a solo performance by the male child.
Prompt 6	I was surprised that they ended their exhibit experience so quickly, especially considering that the male child was really enjoying himself.
Prompt 7	The male child developed confidence very quickly but did not demonstrate how the joystick affected the bass, but may have done if he had spent more time with the exhibit.
Prompt 8	The male child used the joystick and the bass buttons but not necessarily at the same time - did not hold the bass buttons down for long enough. The joystick was used to control the bass.
Prompt 9	N/A
Prompt 10	N/A
Prompt 11	N/A
Other Comments	The male child pressed the play button at the end to stop the experience. May have done so to reset it for the next visitor. Before entering the Sound Circle, the male had asked the male child to abruptly stop playing with Gramophony, which may have influenced the short amount of time with this exhibit.

No. 17 (Observations)

Situation	One female adult, one male child.
Time Spent using Exhibit	5 minutes 5 seconds.
Prompt 1	They both seemed very happy and interested in using the exhibit. They decided to wait in the queue, in the room, to use it. The time recorded started from when they first started to actually use the exhibit.
Prompt 2	The female adult read the instructions and then pressed the play button and moved the joystick to show the male child how to use it.
Prompt 3	They definitely noticed the 360 surround sound and enjoyed that aspect of it.
Prompt 4	The female read the instructions before pressing the play button, but didn't spend a long time reading them - wanted to get stuck in. The male child was very young and did not understand the instructions that his mum was giving him - he just wanted to press lots of buttons. Did not read the interpretation text.
Prompt 5	The female adult read the instructions and then pressed the play button and moved the joystick to show the male child how to use it. The male child waggled the joystick up and down whilst the mum danced and pressed the bass buttons. At times it was a collaboration, and at times it was more of a friendly 'versus' situation.
Prompt 6	The young child realised how to restart the exhibit after the female had turned the drums off. The female often came away from the exhibit just to have a dance around the Sound Circle in time with the drums that were playing whilst the joystick was in the neutral position.
Prompt 7	The female started to play the bass in time with the tempo of the drums.
Prompt 8	The male child used the bass buttons the most at first, but then became more focused on the joystick. At one point, he went around to the back of the exhibit and moved the joystick around from behind the exhibit, looking over the top. The female was more interested in the bass buttons. Before playing their own game, the male child pushed the joystick backwards and held it there and enjoyed listening to the slower tempo.
Prompt 9	N/A
Prompt 10	N/A
Prompt 11	N/A
Other Comments	At the end, the female and the male child stopped using the exhibit as it was intended to be used and decided to play a game where they danced around the room to the sound of the drums until one of them pressed the play button to stop the music, at which point they both fell to the floor as quickly as possible: the aim being whoever could drop to the floor the fastest was the winner. They danced together or danced separately against the wall, facing it, whilst still playing the game.

No. 18 (Observations)

Situation	Two male adults, one female adult, four children. Four children used it the most.
Time Spent using Exhibit	2 minutes 43 seconds.
Prompt 1	Children wanted a new thing to play with. Adults seemed uninterested.
Prompt 2	The four children pressed all the bass buttons straight away. They then pressed the play button but they pressed it hard and fast which rapidly started and stopped it so they did not get the drums to play for more than a split second.
Prompt 3	Did not engage with the exhibit in such a way as to let the surround sound experience present itself. Pressed the play button on and off too fast to let the drums play for long enough so that the joystick could move the drums around the room.
Prompt 4	The female read the instructions and tried to explain to them how the exhibit worked by showing them, but they were not listening to her and carried on just randomly pressing the buttons. Did not read the interpretation text.
Prompt 5	All four children used the exhibit at once, but there was no sense of collaboration or versus - just random button pressing. The female and one of the males attempted to use the exhibit for about five seconds but then gave up.
Prompt 6	They seemed surprised that the exhibit did not work.
Prompt 7	There was no sense to how the children used it - it was just a matter of pressing the buttons as hard and fast as possible and pushing and pulling the joystick fully forwards and backwards with force.
Prompt 8	The four children used everything, but not in a way that made any sense.
Prompt 9	One of the children was leaning on one of the bass buttons which stopped the other buttons from working. The other chlldren were trying to remove the buttons from the interface by turning them to loosen them and then trying to pull them off. One of the male adults asked me "why isn't the exhibit working?" I then came over and intervened by demonstrating that you had to let go of all the bass buttons in order to play them one at a time. They did not listen and just started banging all the buttons again.
Prompt 10	N/A
Prompt 11	One of the male adults asked me "why isn't the exhibit working?" when one of the children was leaning on the bass buttons which stopped them from lighting up and making a sound.
Other Comments	N/A

Appendix H: Visitor Questionnaires

Questionnaires are ordered chronologically.

No. 1 (Questionnaire)

Situation	Male adult on his own. No queue.
Time Spent in the Sound Circle	3 minutes.
Age	40-55
Question 1	'Good - I sing and write music.'
Question 2	7 – 'The notes cut out [because of the monophonic bass]'
Question 3	6 – 'It was alright.'
Question 4	'There wasn't much to explore. It would have been better if there were seven notes to play the bass with [a scale, one octave].'
Question 5	'To see how the drums and the bass work together.'
Question 6	'Not around here.'
Question 7	'I already make music, so I will just carry on.'
Question 8	'Yes, it was alright.'
Question 9	'It would have been better with seven notes [a scale, one octave].'
Other Comments	He asked, 'is there anywhere else where I can play with synthesizers in here?'

No. 2 (Questionnaire)

Situation	Woman adult with two children. No queue.
Time Spent in the Sound Circle	2 minutes.
Age	27-40
Question 1	‘I have always been interested in music, but I am interested in how they do it.’
Question 2	9 – ‘Good Instructions.’
Question 3	8 - N/A
Question 4	‘Yes.’
Question 5	‘To explain how sound is formulated and how it works.’
Question 6	‘No.’
Question 7	‘Sound and water elsewhere’ (?)
Question 8	‘Yes - anything that explains surround sound is good.’
Question 9	N/A
Other Comments	N/A

No. 3 (Questionnaire)

Situation	Woman adult with older woman and two children. No queue.
Time Spent in the Sound Circle	3 minutes.
Age	27-40
Question 1	‘Quite high interest. I have just come back from the Beautiful Days festival. I do not make music but I listen to a lot.’
Question 2	10 – ‘It was explained in a simple way. Easy, accessible, and very silly.’
Question 3	10 – ‘Exceptionally entertained. Mum's dancing did it (said one of the children).’
Question 4	‘Yes.’
Question 5	‘To explore the style of drum and bass music and create your own sounds with the rhythm of the drums.’
Question 6	‘Yes - at the festival and at various other events.’
Question 7	‘Yes - I am always looking for new music to listen to. It is good to understand how sounds are made.’
Question 8	N/A
Question 9	‘Really enjoyed the exhibit and I am looking forward to the rest of the museum.’
Other Comments	N/A

No. 4 (Questionnaire)

Situation	Male adult in a group of 5 with one female (wheelchair) and three children. A queue had already formed, involving other groups of people. Left the play button on when leaving.
Time Spent in the Sound Circle	2 minutes 15 seconds.
Age	27-40
Question 1	'I am a musician - I play the bass guitar and drums. I have a pretty in-depth knowledge.'
Question 2	9 – 'It took a couple of seconds to figure it out, but it was not complicated.'
Question 3	10 – 'Great.'
Question 4	'I used everything.'
Question 5	'Tempo - mixing different sounds at different speeds.'
Question 6	'Kind of - I have played around with sounds elsewhere.'
Question 7	'I am already making this sort of music.'
Question 8	'Definitely.'
Question 9	'I really liked it and I hope other people get to use it.'
Other Comments	N/A

No. 5 (Questionnaire)

Situation	One male child and one male adult. The child was in the Sound Circle on his own for most of the time.
Time Spent in the Sound Circle	2 minutes 55 seconds.
Age	0-15.
Question 1	‘I am a drummer and I have used Garage Band at school during lessons, where we start with the drums and the bass before adding a piano.’
Question 2	7.5 - N/A
Question 3	8.5 - N/A
Question 4	‘Yes - it was very fun to press all the buttons.’
Question 5	‘How easy it was to make a rhythm just by pressing a few buttons.’
Question 6	‘I noticed the drums, which were the same as the Garage Band drums.’
Question 7	‘It opened my eyes to the possibility that I could do this.’
Question 8	‘Yes.’
Question 9	N/A
Other Comments	

No. 6 (Questionnaire)

Situation	Male adult, female adult, and three children. They all used it but male answered questions.
Time Spent in the Sound Circle	1 minute 50 seconds.
Age	40-55
Question 1	'My level of interest has improved since coming here.'
Question 2	7 – N/A
Question 3	9 – 'It gives you a lot to do - there are a lot of things going on. It gave us the opportunity to read less and do something more practical.'
Question 4	'Yes.'
Question 5	'How sound is created.'
Question 6	'No.'
Question 7	'I am more intrigued.'
Question 8	'Yes - it gave us more of an insight into how sound is created.'
Question 9	N/A
Other Comments	N/A

No. 7 (Questionnaire)

Situation	Male adult, female adult, one female child.
Time Spent in the Sound Circle	4 minutes.
Age	40-55.
Question 1	'Nothing.'
Question 2	10 – 'Straightforward'
Question 3	8 – 'Good fun.'
Question 4	'Yes.'
Question 5	'How to mix different sounds into each other, and front to back surround sound.'
Question 6	'No.'
Question 7	'No.'
Question 8	'Yes - good.'
Question 9	N/A
Other Comments	N/A

No. 8 (Questionnaire)

Situation	One male child and one female adult. A queue had already formed, involving other groups of people.
Time Spent in the Sound Circle	4 minutes.
Age	0-15.
Question 1	'I listen to a lot of music.'
Question 2	8 – 'You are good at music' [the female said this to male child].
Question 3	9.5 – 'You like the drums and you like the bass' [the female said this to male child].
Question 4	'Yes.'
Question 5	'Learnt how to do beats and stuff.'
Question 6	'No.'
Question 7	'I know a lot about drums, but I want to know more about bass. My brother had a drum kit, and my family listens to a lot of music.'
Question 8	'Yes - it was good.'
Question 9	N/A
Other Comments	N/A

No. 9 (Questionnaire)

Situation	One male child in a group of 4 with one male adult just observing and one female adult supervising the two children who both used the exhibit - the male child used it the most.
Time Spent in the Sound Circle	5 minutes.
Age	0-15
Question 1	'I am quite interested.'
Question 2	9 – 'Quite easy to just press the buttons.'
Question 3	6 – 'Quite interesting playing the sounds.'
Question 4	'Yes.'
Question 5	'Yes- you can mix sounds together.'
Question 6	'No.'
Question 7	'No.'
Question 8	'Yes - quite fun doing it yourself.'
Question 9	N/A
Other Comments	N/A

No. 10 (Questionnaire)

Situation	One male child in a group of 5, one female adult, one older female adult, two other male children but the third male child used it the most and answered the questions. He was quiet when answering the questions but sounded very musically expressive.
Time Spent in the Sound Circle	8 minutes.
Age	0-15.
Question 1	'I play the guitar.'
Question 2	8 - N/A
Question 3	10 – 'You like making noises' [the female said this to the male child]
Question 4	'Yes.'
Question 5	'Not sure.'
Question 6	'First time.'
Question 7	N/A
Question 8	'Yes.'
Question 9	N/A
Other Comments	N/A

No. 11 (Questionnaire)

Situation	Female adult and Male adult. A queue had already formed, involving other groups of people. They used the exhibit for at least half the time (I looked in). Seemed to be collaborating. Both keen to answer questions.
Time Spent in the Sound Circle	15 minutes.
Age	40-55.
Question 1	Man = 'we are very interested. We love music. I am a musician - I play the guitar and some other instruments.'
Question 2	8 - Man = 'it was confusing that the bass had to be operated one button at a time.' Woman = 'it needed two people to operate it, one on the bass and one on the joystick.'
Question 3	10 - Woman = 'we could have stayed the whole afternoon; it was very fun.'
Question 4	'You used everything there' [the woman said this to the man].
Question 5	Man = 'the exhibit illustrated the interpretational text well, it was about the extra affordances of digital compared to analogue. Just slowing it down was interesting.' Woman = 'did not feel like the exhibit stretched Time and Space because you had to stand still in one place. It would have been better if you could move around and experience the Space better.'
Question 6	Woman = 'we are familiar with drum and bass. We are from that generation.'
Question 7	Man = 'I will try to slow things down when creating music in the future.' Woman = 'I wish there was more resonance in the bass to feel it in your chest like you would experience in a nightclub. A problem with sound management.'
Question 8	Man = 'Yes - what I like about sound is actually doing something with it - it is a primal experience.' Woman = 'Maybe - it is a practical thing you can do. Interactivity in exhibitions is better.'
Question 9	Woman = 'It is the exhibit that they spent the most amount of time with. It felt like we were actually doing something. Because of where the patching exhibit is in the exhibition, it was difficult to feel like you could use it for a long time, but with this exhibit it was your own space and you felt like you could spend longer with it. It would have been better to have more than one drum break, to be able to compare the stretching of Time and Space to something else.'
Other Comments	N/A

No. 12 (Observation and Questionnaire)

Situation	Male adult used the exhibit, whilst a female adult supervised two children using it also: the first to use it was the male child, the second was the female child. Male adult answered questions.
Time Spent in the Sound Circle	2 minutes 30 seconds.
Age	27-40
Question 1	'I have played in bands and have been in choirs.'
Question 2	7 – 'I was unsure what I was supposed to be getting from it.'
Question 3	10 – N/A
Question 4	'Yes'
Question 5	'Blending different sounds and rhythms.'
Question 6	'No.'
Question 7	'I might listen to more synthesizer music.'
Question 8	'Yes - it was interactive. The kids prefer to be hands-on and won't stand and read things.'
Question 9	'Enjoyable, nice experience.'
Other Comments	

No. 13 (Observation and Questionnaire)

Situation	One female adult, two male children.
Time Spent in the Sound Circle	1 minute 33 seconds.
Age	27-40.
Question 1	'I am not into music.'
Question 2	7 – 'Creative, can do what you want with it. Easy.'
Question 3	9 – N/A
Question 4	'Yes.'
Question 5	'How sound works.'
Question 6	'No.'
Question 7	'Maybe.'
Question 8	'Totally, yes.'
Question 9	N/A
Other Comments	N/A

No. 14 (Observation and Questionnaire)

Situation	One teenaged male used it whilst one teenaged female observed.
Time Spent in the Sound Circle	1 minute 45 seconds.
Age	16-26.
Question 1	'I play the piano, guitar and ukulele, and I listen to a lot of music.'
Question 2	6.5 – 'Quite easy. The instructions could have been simpler.'
Question 3	8.5 – 'Enjoyed it.'
Question 4	'Not everything - I was aware that I might be taking up too much time and wanted the kids to go first.'
Question 5	'Different speeds of sounds.'
Question 6	'No.'
Question 7	'It has made me more interested in music mixing.'
Question 8	'Yes - hands on.'
Question 9	N/A
Other Comments	N/A

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