Digital Musical Instruments, Accessibility, and Facilitated Performance

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Abstract

A range of bespoke devices, ADMIs, and commercially available DMIs are used in inclusive music settings when creating, practising, and performing music. However, the shared knowledge about what makes an existing DMI accessible is limited. This thesis investigates the accessibility of existing DMIs using participatory action research methods to establish more standardised methods for evaluating accessibility. Additionally, this research explores how DMIs are used in inclusive music settings to provide access to music-making activities using the theoretical framework of activity theory.

Improving accessibility in meaningful ways requires the active involvement of disabled people in research. The participatory action elements of this research focused on actively engaging in inclusive music practices with young disabled people. The researcher achieved this active engagement through conducting two field studies within special educational needs and disability (SEND) schools. These field studies allowed the researcher to share disabled musicians' lived experiences of using DMIs and understand the challenges they face because of the technical and social barriers to music-making.

Gaining a deeper understanding of the technical and social barriers disabled musicians face when using DMIs enabled the researcher to systematically evaluate the use and accessibility of DMIs, including how DMIs support access to music creation, what challenges exist when a disabled person uses a DMI, and how DMIs can address an individual's creative and physical needs. Working within inclusive music settings also highlighted the complexity of social structures, and the importance of facilitators, within inclusive music communities.

The outcomes from the field studies introduce the concept of 'facilitated performance' and examine the multiple roles adopted by facilitators in supporting and empowering disabled musicians in their creative processes. This research also proposes five core qualities for evaluating the fundamental accessibility of existing DMIs, while acknowledging that disability is highly individualistic in ways that can impact how a person uses a DMI. These five core qualities are durability, flexibility, practicality, complexity, and compatibility.

This thesis establishes a framework for facilitating access to musical experiences using these qualities. The framework proposes guidelines for achieving accessibility in DMIs and a method for evaluating the accessibility of existing DMIs. By offering a way to evaluate the accessibility of DMIs holistically, this framework aims to assist DMI creators, disabled musicians, and those working in inclusive music settings.

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List of Acronyms

The following acronyms are used within this thesis.

ADMI Accessible Digital Musical Instrument

AI Artificial Intelligence

DAW Digital Audio Workstation

DMI Digital Musical Instrument

GUI Graphical User Interface

HCI Human Computer Interaction

MIDI Musical Instrument Digital Interface

ML Machine Learning

MPE MIDI Polyphonic Expression

NIME International Conference on New Interface for Musical Expression

Contents

List of Tables

List of Figures

Chapter 1

Introduction

> *"Making music is a basic human right, it is a basic human need, because it is a way of expressing who and what we are"* - John Kelly (Human Instruments, 2018)

The research outlined in this thesis is centred on accessibility, Digital Musical Instruments (DMIs), and the potential for technology to provide greater access to music and creativity for disabled people. A range of DMIs are used in inclusive music settings when creating, practising, and performing music. However, the shared knowledge about what makes an existing DMI accessible is limited.

The complexity and diversity of people's lived experiences of disability means that creating a universally 'accessible' DMI for disabled musicians is difficult, even when new technologies provide more accessible features. This thesis seeks to explore this topic in detail and understand how the accessibility of a DMI can be measured, adapted, and potentially improved.

1.1 Motivations

The motivations for proposing this research are a combination of industry, research, and personal interests.

1.1.1 Industry motivations

Disabled people are estimated to make up around twenty percent of the world's population (World Health Organization, 2011). However, access to musical activity for disabled people is low when compared to the general population (House of Lords, Grand Committee, 2014). Contributing to this issue are barriers that are created by the industry through designing music products without inclusion in mind.

In more recent years, the industry has seen accessibility be incorporated into some of the major digital audio workstation (DAW) software. However, this effort tends to focus primarily on visual accessibility and does not include all disabilities. Often, these efforts are driven by communities of disabled users and not by the companies themselves, which results in many solutions being provided as a third-party offering. This can be problematic because any updates to software or hardware can cause synchronisation problems between accessibility solutions and the platform they are built for.

Often work towards disability inclusion is considered a 'nice to have' or a feature to add to products later. However, in 2018, Accenture (2018) produced a research report on 'The Disability Inclusion Advantage', which showed that disability inclusion provides countless benefits for companies. These include up to twenty-eight percent higher revenue, thirty percent better performance in economic profit margins, and being twice as likely to have higher shareholder returns.

Research towards understanding the accessibility requirements of DMIs could help music technology companies evaluate their offerings and move toward being more inclusive for disabled communities.

1.1.2 Research motivations

At the point of writing, the topic of accessibility in music technology and DMIs occupies a niche area of research. Literature is spread across the fields of rehabilitation and medicine, musicology and music therapy, and technology and Human-Computer Interaction.

In the area of Human-Computer Interaction, there are a few communities that have shown a growing interest in the subject, such as the New Interfaces for Musical Expression research community (NIME, 2022). Despite this, there is a severe lack of disabled voices and representation within these communities (Frid, 2019b).

Undertaking further research in this area could help to achieve several goals. First, this research could contribute to improving representation by taking a participatory approach and including disabled people and their voices in the discussion. Second, the research could bring together themes identified across the research fields and help to provide a more unified understanding of the accessibility of DMIs. Third, and finally, the research could positively impact the disabled community in terms of extending the discussion of the importance of access to music and the potential for technology in this space.

1.1.3 Personal motivations

In 2012, on the day following my graduation from my foundation degree in Audio and Recording Technology, I learned that my cousin had been attacked. This attack resulted in a traumatic brain injury. As I continued to my bachelors (BSc), my cousin and his immediate family faced the challenges of adapting to living with the physical and neurological challenges caused by the traumatic brain injury. I would often speak with my mum about his journey and read about rehabilitation and 'recovery' for traumatic brain injuries. In doing so, I encountered some literature about the connections between music and memory. This led to a hyper-fixation on the topic of music and memory and its potential for rehabilitation. Inspired by these ideas of connecting movement, music, and memory, I built a gesture-controlled musical installation using the Microsoft Xbox Kinect controller as my final dissertation project for my BSc.

After graduating, this fixation with music, movement, and memory persisted. I wanted to explore the possibilities offered by technology to provide access to musical experiences. My experience with both audio programming and audio engineering provided me with a knowledge base from which to explore creating new and novel musical interfaces. I proposed this topic for a Ph.D. studentship with the Mixed Reality Laboratory in 2015, and from there began my journey into research.

Almost a decade has passed since my fixation on this topic began. The focus may have shifted, but the desire to explore how technology can remove accessibility barriers for musical experiences remains. Throughout my Ph.D., the goal has been to better understand the barriers for disabled communities in accessing creative musical experiences. Through deepening my knowledge in this area, I aimed to:

1. Explore how accessibility is managed within DMIs.
2. Understand the unique design challenges of making DMIs accessible to disabled musicians.
3. Establish a shared understanding of these challenges between industry, research, and inclusive music communities.

Music and creativity have played a significant role in my life. I recognise that this has been afforded to me through many privileges including (but not limited to) my socioeconomic status and physical abilities as a non-disabled person. It is frustrating to know that many people are excluded from exploring music creatively because there is both stigma about disability and a severe lack of accessibility in the industry (Disability Arts Online, 2021). I hope that through expanding what technology can offer in this space, we can start to improve access to musical experiences for everyone.

1.2 Talking about disability and Digital Musical Instruments

It is impossible to research, discuss, or contemplate accessibility without acknowledging the long history of sociopolitical issues disabled people have faced. Disabled people make up the world's largest minority group (Ladau, 2021), with various statistics citing the number of disabled people to be one-fifth of the world's population (World Health Organization, 2011). There is a responsibility in research to acknowledge that how disability is discussed has 'practical, ethical, and political consequences' (Armagno, 2012). Even the term 'Disability' can have polarised associations (Samuels and Schroeder, 2019).

Many sociopolitical movements have shaped the experiences of music for disabled people, from disability rights movements such as the Disability Arts Movement (Rocco, 2019) to the passing of laws like the 1995 Disability Discrimination Act (DDA) (GovUK, 1995). There are many important lessons to be learned from disability activists that have challenged accessibility in music. One particular lesson, that is the central theme in this thesis, is the importance of inclusion.

Academic research has proved it has the potential to treat communities of people like subjects to be examined. This can be dehumanising, especially so for disabled communities when the research is led by non-disabled people (Ymous et al., 2020). Sadly, it often diminishes the role of disabled people as creators and communicators of knowledge. The goals of this research align with a term that is now widely used in disability activism "Nothing about us without us" (Charlton, 2004). It strives to be inclusive of disabled people, their lived experiences as music creators, and their experiences as users of DMIs.

Being inclusive in research observes everything from the language choices made when discussing disability to meaningful inclusion of disabled people within the research activities. First and foremost, it is important to address the different ways people can talk about disability. There are two main ways of referencing disabled people and disabilities; the first is person-first language, the second is identity-first language.

Person-first language (PFL) puts the word "person" before any reference to disability is made. This form of language intends to acknowledge the person, not just their disability. It is designed on the logic that this is somehow more 'respectful' (Ladau, 2021). Identity-first language (IFL), on the other hand, is about acknowledging disability as part of what makes a person who they are (Ladau, 2021). The way disability is viewed in this use of language is as an identity that connects people to a community, culture, and history. Neither approach is perceived to be wrong (Ladau, 2021), however, often within disabled communities, there will often be a strong preference towards one or the other. Unfortunately, the choice between PFL and IFL can often be questioned by non-disabled people, who can be uncomfortable using terms like 'disabled person' instead of 'person with a disability' which furthers the issue of the word 'disabled' being unnecessarily stigmatised.

A conscious choice has been made to use identity-first language throughout this thesis, except where this is inappropriate because of diagnoses (for example grammatically it does not sound correct to call someone 'muscular dystrophy person' so this is better stated as 'person with muscular dystrophy'). This thesis also opts to use accessible language where possible through the use of 'plain language' (Plain English Campaign, 2022). 'Plain language', or 'plain English' as it is sometimes referred to, is a method of writing that keeps the reader in mind, uses the right tone of voice, and is clear and concise. Using plain language improves readability overall and is more inclusive for people with cognitive disabilities.

1.2.1 Acknowledging my own disability status

In writing this thesis, I must also examine my own disability status. While I have no physical disability, I have recently been diagnosed with predominantly inattentive type Attention Deficit / Hyperactivity Disorder (ADHD). I am learning to navigate a new identity of being neurodivergent and what this means for me personally, professionally, and academically.

1.3 Research questions

The questions that are important to this research focus on the use of DMIs within inclusive music practises.

How are Digital Musical Instruments used to support access to creating music for disabled communities?

This question explores inclusive music practices in particular. It seeks to understand what types of DMI are common in these spaces, who provides them, and how they are introduced into inclusive music sessions. It also examines how DMIs are selected to be used in these practices.

What are the challenges for disabled people when using a Digital Musical Instrument?

The lived experiences of disabled people are extremely important to this research. This question explores the limitations of current DMIs among other challenges. It includes challenges related to physical environments, safety, and individual playing styles.

Can Digital Musical Instruments be used to address individual accessibility needs?

This question is designed to consider what is already known about DMIs compared to their acoustic counterparts. It explores whether technology allows for easier adaptability or better reliability. Additionally, it reviews how current DMIs are used to address individual accessibility requirements.

How might the accessibility of a Digital Musical Instrument be evaluated?

This question focuses on discovering ways in which DMIs might be evaluated for accessibility, including how current assessments are made within inclusive music practices. The goal is to understand what characteristics make a DMI more accessible and the priorities for inclusive music communities.

1.4 Contributions

This research should be considered a starting point for further discussion on how DMIs could be evaluated for accessibility, a currently under-explored area in both industry and research. The following is a summary of the main contributions of this thesis, in the order they appear:

- In Chapter 4 the concept of facilitated performance is introduced.The role of a facilitator in the user experience of a DMI is acknowledged, along with the technical and social implications of their presence. This reveals a context in which some DMIs can be made more accessible through the actions of a facilitator. However, the field study also highlighted many challenges for the social experience of music-making for disabled musicians. These are challenges that could be addressed by improved interaction design.
- In Chapter 5 the core qualities for accessibility in DMIs are introduced.

These qualities were identified through the experience of testing the usability of DMIs with disabled people. The qualities presented some common requirements for improving the accessibility of DMIs. These qualities were identified as fundamental elements required for accessibility, even when further bespoke tailoring may be required to make a DMI fully accessible.

- The summary of these contributions is found within the Facilitating Access to Musical Experiences (FAME) Framework, present in Chapter 7. This pulls together what has been observed during the field studies with considerations from the literature. It proposes a starting point for understanding more about the general accessibility of DMIs. ADMIs could also be holistically evaluated using this framework. However, it is noted that this may not be appropriate for bespoke ADMIs designed for a specific disabled musician. These ADMIs would need to be reviewed against criteria specific to that musician's needs. However, the principles outlined in the framework offer a reminder of the important accessibility qualities for DMIs designed to be used across many contexts, which may be useful for the designers of bespoke ADMIs.

1.5 Thesis overview

This thesis follows the research activities along a timeline from beginning to end. It begins with a literature review that explores the relationships between accessibility, music, and DMIs. Following the literature review is a chapter on the research approach. This chapter discusses the methods chosen to address the proposed research questions, and the ethical implications of this research. After the approach chapter, two chapters focus on the independent studies completed during the research period. The first, Chapter 4, focuses on the Able Orchestra study conducted between February 2016 and February 2017. The second, Chapter 5, discusses the Able Lite study conducted between March and June of 2018. Following these chapters, Chapter 6 presents a framework for evaluating the accessibility of DMIs. This includes information on how the framework was developed and examples of its application. Finally, Chapter 7 concludes this thesis, reflecting upon this research's contributions and identifying future possibilities for research on this subject.

Although it is suggested that the beginning is a very good place to start, this is not a requirement. This thesis has been written to support multiple reading styles and approaches. At the beginning of each chapter is a summary that outlines the connection to the previous work, introduces the aims of that chapter, and provides an overview of the structure.

Chapter 2

Literature Review

This chapter reviews the prominent literature about accessibility and Digital Musical Instruments (DMIs). It outlines the four main topics of research interest and discusses how these topics relate to each other. First, the relationships between music and disability are introduced. Then follows a review of digital musical instruments and their development, including contemporary accessible digital musical instruments. Next, the review turns to Human-Computer Interaction (HCI) and what is known about the implications of performing with technology. Finally, accessibility in technology design is examined, along with existing accessibility frameworks for technology development and what is known for accessible digital musical instrument design. This chapter concludes in summarising six elements of music-making that are impacted by, or have an impact on, accessibility and how these might be considered going forward in this research

2.1 Introduction

There are four main areas of research that inform the work described within this thesis. As highlighted in Figure 2.1, these are music and disability, accessible digital musical instruments, Human-Computer Interaction research focused on performing with technology, and accessibility in technology design.

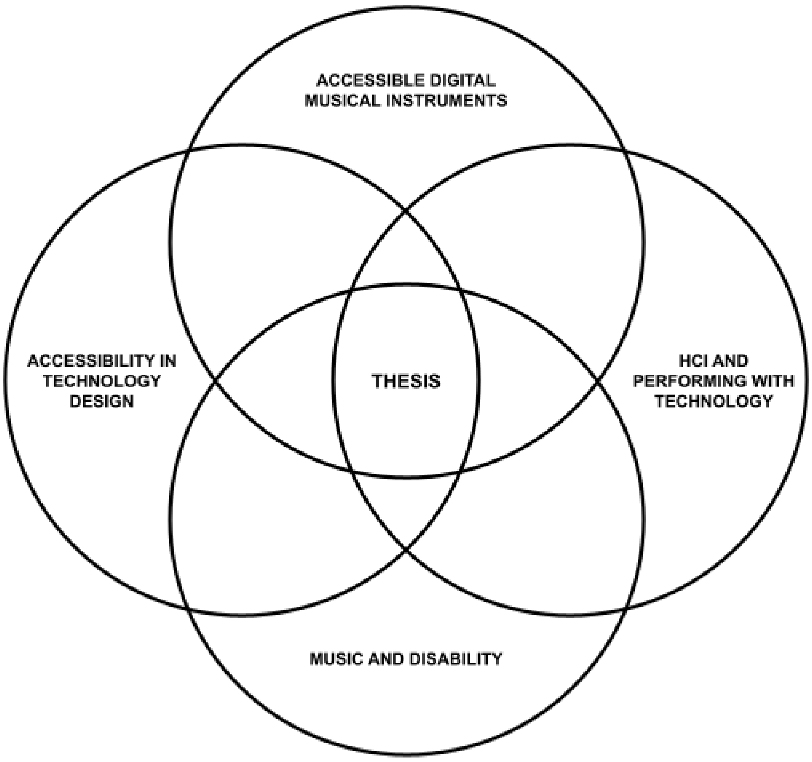

Figure 2.1: *Intersection of research*

It is important to first acknowledge the history of how music and disability are related. This includes discussion of disability rights, political and social activism, and how access to music has been limited for disabled musicians. Critically, it must be noted that the resources and literature used to gain the understanding of this are themselves limited to a very western viewpoint that is mainly centred around the issues of accessibility and music within the United Kingdom. The internationalisation and democratisation of music often discussed in music education (Kwami, 1998; Cain, 2015; Madrid, 2007) is another important barrier to accessibility in music, but it is unfortunately outside the scope of this Thesis.

2.2 Music and disability

In this section, the challenges for disabled people regarding access to playing music are discussed. The continuous work of community music programs and charities in the UK will be acknowledged, along with contemporary research studies in Human-Computer Interaction. The contributions from other research areas such as music therapy will be summarised, as well as those from social studies. Finally, observations will be made about the challenges for bringing accessibility to the forefront of digital musical instrument design and production, along with how research could positively impact this.

The marginalisation of disabled people in the arts and culture of the UK was first challenged through the Disability Arts Movement (DAM), which began in the late 1970s. This was a highly influential movement that brought together a variety of artists, creatives, and activists to campaign for the civil rights of disabled people (Rocco, 2019). The DAM is considered to be a milestone in the history of UK activism and led to both the passing of the Disability Discrimination Act (DDA) in 1995 (GovUK, 1995) and the creation of the National Disability Arts Collection and Archive (NDACA). These events have contributed to changing the viewpoint of disability in the UK, moving away from the medical model, a view of disability as a person-based issue (Ladau, 2021), towards the social model, a view of disability where people are disabled by environments, attitudes, and systems (Ladau, 2021).

Research in Disability Studies and other social fields have acknowledged that despite the change towards the social model, there is still much disparity between disabled artists and the “mainstream” creative arts industries.

Physical, social, and attitudinal barriers continue to exist for disabled people wanting to access music-making (Harrison, 2020). Furthermore, there is still a status quo where the issues of accessibility in the creative arts are ignored mainly by non-disabled people, leaving the work of removing barriers to disabled artists themselves. As stated by Tony Heaton, sculptor and initiator of the NDACA: "if we as disabled people don't make it happen for ourselves then it won't" (Rocco, 2019).

The disparity in access to music-making starting with education has previously been raised by members of the UK Parliament in the House of Lords:

> *"The figures that we have from Ofsted show that between 2008 and 2011, only 6% of students with disabilities were involved in learning a musical instrument, compared to 14% of students without a disability. That is a clear disparity. There was also a consultation by Drake Music in 2012, which revealed that there are still a number of barriers to overcome with regard to effective music education for disabled children."* Lord German, House of Lords debate, July 30 2014 (House of Lords, Grand Committee, 2014).

In the UK, community music programs and charities are bearing a large amount of work to address the issues of access to music-making for disabled people. Just a few examples of these initiatives include organisations like Drake Music (Drake Music, 2022b) [1], Heart n Soul (Heart n Soul, 2022) [2], and Inspire Youth Arts(Inspire Culture, 2022)[3]. Many more organisations supporting disabled musicians can be found through the listings on Disability Arts Online (Disability Arts Online, 2022) [4].

[1]Drake Music is a national arts charity focused on accessibility, music, and technology working across the UK

[2]Heart n Soul is a creative arts company and charity supporting people with learning disabilities based in London

[3]Inspire Youth Arts is part of Inspire, a charitable community benefit society delivering cultural and learning services across Nottinghamshire

[4]Disability Arts online is an online platform for disabled artists to share work, experiences, and their creative processes

While many of these community programs and initiatives successfully provide access to playing music for disabled people, it is difficult to provide up-to-date statistics on the broader context for accessibility in music and music technology. Several reports observe the problem space, such as the Reshape Music report (Mawby et al., 2020) from Youth Music (National Foundation for Youth Music, 2020)[5], but a number of these resources are limited in their scope. This is either due to being centred on a location, an age range, a specific disability group, a specific genre of music, or a specific type of music activity. In terms of the statistical information they present, the focus is often given to music education, along with social and societal barriers. The questions of how music technology and tools themselves pose accessibility barriers are not always addressed, aside from the general observation that specialised or altered equipment is expensive and requires additional funding. The potential of technology to have a great impact in this area was acknowledged by Lord German,

> *"New technologies can make a huge difference in this area. As we know, music breaks down barriers. You can communicate with music even if you do not understand the language, and new technologies in music allow that to happen."* (House of Lords, Grand Committee, 2014)

In more recent years, how technology itself can both create and dismantle these barriers to accessing music-making has been addressed by researchers across many disciplines. Musicology, Music Therapy, Music Education, and Human-Computer Interaction are some fields where discussion of this specific issue can be found.

Music therapy, in particular, has advanced some of the discussions around how using technology can aid access to musical activities for disabled people (Crowe and Rio, 2004). Music therapy uses musical experiences within a

[5]Youth Music is a charity organisation supporting young people aged 0-25 in accessing music in the UK

therapeutic relationship to engage with a person's social, psychological, physical, and spiritual needs (Magee, 2002). However, views towards disability within music therapy can be problematic, as these can assume a medically focused approach linked to rehabilitation or learning (Harrison, 2020). In short, there is an expectation that there will be some form of skills development as a direct result of engaging in musical activities. While there have been many studies that highlight the benefits of musical interventions for a wide range of people (Correa et al., 2009; Kirk et al., 1994; Magee et al., 2011; Cibrian et al., 2017), the concentration on rehabilitation and promoting positive changes in health and well-being has been criticised by the Disability Studies community due to its alignment with the medical model of disability. However, the value of music therapy as a practice is not necessarily denied within the disability community (Lubet, 2011).

Despite the somewhat controversial nature of the relationship between the disability community and music therapy, music therapy as an area of research has sparked growth in the development and use of accessible digital musical instruments (ADMIs). ADMIs are often used in music therapy to provide greater access to music for individuals with complex disabilities caused by traumatic brain injury, stroke, profound and multiple learning disabilities, and neurological disabilities such as autism. Studies have used many technologies to engage in musical practices (Frid, 2019a; Swingler, 1998). Including game controllers and bespoke devices to commercially available ADMIs like the Soundbeam (The Soundbeam Project Ltd., 2022) or Skoog (Skoogmusic, 2022).

The social benefits of music-making activities are frequently discussed in both music therapy research and disability studies. Beilharz (2011) highlighted the importance of self-identity that performing music can provide for disabled people, and there are many other notable factors, including the social impact of performing music together (Beilharz, 2011). Again there is a complex relationship for disabled musicians when discussing the social impacts of engaging in music-making activities. Harrison discusses this complex social landscape in his thesis referencing Firth and Cane (Harrison, 2020), who highlight the social concepts of 'assimilation' and 'affirmation' for disabled musicians — stating that a disabled artist can either choose a path of 'assimilation' through integrating into mainstream arts and culture without making explicit reference to their disability, or a path of 'affirmation' where they seek to uplift and embrace their disabled identity as a performer. This is not necessarily always an active choice that a disabled musician can make, and the availability to take either approach can be dependent on context.

Contemporary researchers in Human-Computer Interaction and the field of Computer Science are also making increasing contributions to the discussion of disabled people's access to music through technology. 'Accessibility of Musical Expression' was the theme for the New Interfaces for Musical Exploration (NIME) conference of 2020 (NIME, 2020), where a number of papers were presented in the proceedings that specifically addressed the topics of accessibility to music for disabled people and ADMIs. Notably, Frid's 2019 review of ADMIs presented at NIME (Frid, 2019a) highlighted that since 2011 the topic of ADMI design and social inclusion in music has been a growing area of interest for both HCI and music technology researchers. Frid's doctoral research (Frid, 2019b) focuses on enabling musical inclusion for under-represented groups, including disabled people.

However, Frid is not alone. Schroeder founded the 'Performance without Barriers' (PwB) research group in 2015, based at the Sonic Arts Research Centre at Queen's University Belfast (Performance without Barriers Research Group, 2022). The research group has been exploring the potential to enhance social inclusion for disabled people through musical practices and the use of digital technologies (Samuels and Schroeder, 2019). Over the years, the group has presented papers on the subject of accessibility in music technology covering topics such as ADMI evaluation (Lucas et al., 2021), longevity of bespoke accessible music technology (Lucas et al., 2020), inclusive music practises (Samuels, 2015), and working with disabled people to design musical instruments in virtual reality (Mills et al., 2021). At the Augmented Instruments Laboratory at Queen Mary University of London, Harrison's doctoral research (2015-2020) was centred around 'performance-focused accessible instruments', resulting in a thesis entitled 'Instruments and access: The role of instruments in music and disability'(Harrison, 2020).

The publications featured at NIME 2020 also highlight research focused on accessibility and music technology at many other institutions. Such as the University of Milan (Davanzo and Avanzini, 2020), The Royal Birmingham Conservatoire (Wright, 2020), Stanford University (Caren et al., 2020; Cavdir and Wang, 2020), Portland Community College (Jarvis Holland et al., 2020), and the University of Art and Design in Austria (Vetter, 2020). Along with collaborative publications between the University of Plymouth and Durham University (Skuse and Knotts, 2020), as well as NYU, Microsoft Research, and the University of Boulder (Payne et al., 2020).

The representation of publications focused on disability and music technology in NIME 2020, shows that there is an ever-growing knowledge base for this field. Even so, there are still areas where research contributions are lacking. Many studies include the use of games controllers and other devices that would not necessarily be considered as an example of a "musical instrument" (Harrison, 2020). There is also a tendency for research to focus on bespoke ADMIs, created for a research project or a specific individual. While these bespoke projects are extremely valuable in terms of providing insight into specific accessibility requirements and technological affordances,an alternative approach would be to evaluate the accessibility of existing DMIs, which addresses a problem that extends beyond research into industry and commercially available devices.

Consequently, much of the existing research does not acknowledge the development processes and constraints for mass-produced technology. The ability to 'productise' bespoke devices is problematic because of two constraints. First, the very nature of these devices is that they are bespoke to a single disabled musician's requirements. Second, bespoke technologies often become an expensive proposition to recreate multiple times. An often-cited problem of creating bespoke adapted instruments is price, as the affordability of an instrument adds another barrier to access.

The lack of existing research into existing commercial DMIs brings into question what we might learn from evaluating commercial DMIs for accessibility. By observing inclusive music practices and the lived experiences of disabled musicians, this research explores how we can better understand accessibility for all DMIs.

2.3 Digital Musical Instruments and accessibility

This section provides an overview of the history of DMIs and the development of contemporary ADMIs. Research related to ADMIs, in particular, is discussed in more detail. This section also examines many considerations and definitions of both DMIs and ADMIs and provides the contextual definition that is observed within this thesis. Additionally, examples are given of commercially available ADMIs and bespoke devices used by contemporary disabled musicians. Finally, it discusses currently available resources to consumers of ADMIs.

2.3.1 The history of Digital Musical Instruments

The history of DMIs can be traced back to electronic musical instruments of the late nineteenth century. At this point, electronic musical instruments were defined as instruments that generated sound using electronic circuitry.

Early examples include the Theremin, Telharmonium, and Trautonium (Collins and d'Escrivan, 2017). However, these devices were often products of scientific experimentation and did not become popularised in culture until much later.

The development of the synthesizer as an instrument from the 1950s onwards was accelerated through the works of engineers across the globe. This included acknowledged pioneer of synthesis Robert Moog, who invented the first commercially available synthesizer released in 1964.

Amongst his works, Moog provided a definition for digital musical instruments that continues to be cited by many researchers (Frid, 2019b; Farrimond et al., 2011). In his description, given at the 1984 Biology of Music conference, Moog considers a DMI to be a modular system consisting of three parts:

> *"first is the sound generator; the second is the interface between the musician and the sound generator; the third is the visual reality of the instrument"*. (Moog, 1988)

In the 1980s, with advances in digital computing, the first computer-based or 'digital' instruments began to appear. The introduction of MIDI (Musical Instrument Digital Interface) as a standardised way to synchronise digital instruments with other computing and studio equipment (Hargreaves and North, 1997) was groundbreaking. In more recent years, the development of new digital musical instruments has moved towards adaptability in physical interfaces, such as the ROLI Seaboard (ROLI, 2022c) or Blocks (ROLI, 2022a) that use a conductive silicone that can interpret more complex gestures via MIDI Polyphonic Expression (MPE). While the development of this protocol has seen a rise in new digital musical instrument interfaces, the exploration of new interaction mediums and musical affordances of digital technologies has largely been limited to research.

It could be said that throughout history, there have been many influential people in the development of electronic music and digital musical instruments. However, the DMIs of today cannot be traced back to one single invention or catalyst. Instead, we must recognise the work of many individuals who pushed forward the boundaries of what an electronic or digital musical instrument could be. As acknowledged by Daphne Oram in her book 'An Individual Note of Music, Sound, and Electronics':

> *"Do not let us fall into the trap of trying to name one man as the 'inventor' of electronic music. As with most inventions, we shall find that as certain changes in circumstances occurred - as certain new facilities became available - many minds were, almost simultaneously, excited into visualising far-reaching possibilities."* (Oram, 1972)

2.3.2 Designing Digital Musical Instruments: novice to virtuoso

As digital technology became more commonplace in music performance, questions were raised regarding achieving virtuosity with digital musical instruments. Virtuosity is a concept within artistic fields that refers to an artist having a high skill level. If a musician is labelled a 'virtuoso', they are considered extremely talented and successful in their artist practice. Virtuosity in acoustic instruments is achieved through practice and working within the constraints of the instrument to provide technically accurate and emotive performances. The lack of these constraints in DMIs often offers an opportunity to shorten the early stages of learning an instrument through simplifying the learning process or lowering the complexity of the interface. However, the impact of making an instrument easier to learn, and in some cases simpler to play, is that this can be seen to 'lower the ceiling' on virtuosity (Harrison, 2020; Wessel and Wright, 2002; McPherson et al., 2019).

Conversly, the flexibility of technology could be used to increase the challenge of instrument learning and continuously adapt in ways to maximise motivation (Pardue, 2017). Achieving a balance between ease of access to learning and managing the complexity of an instrument is an important challenge for DMI design. Overly complex interfaces could frustrate and be demotivating to a novice, but over-simplified instruments could limit the opportunity for artistic expression (Schneiderman, 2007). It is also not uncommon for DMIs designed for musical novices to venture into a playful space (McPherson et al., 2019). In these situations, playfulness must be balanced with learning and skill acquisition; otherwise, there is a risk of the instrument being seen as more of a gimmick or toy instead of an instrument to be used in a performance setting.

In 2001, Jordà observed this relationship between complexity and the appeal of an instrument to both novices and professionals:

> *"Musicians become easily bored with the 'popular' tool, while the casual user may get lost with the sophisticated one."* (Jordà, 2001)

There have been many developments in the two decades since this observation which have introduced many creative new approaches to instrument design, especially for musical novices (McPherson et al., 2019). However, many questions remain about how best to design for the wider spectrum of musicianship from novice to virtuouso). Adaptability and tailoring are recurring themes when discussing potential ways to address this problem in DMI design. Additionally, these themes also apply when considering the accessibility of DMIs (Davanzo and Avanzini, 2020; McPherson et al., 2019; Frid, 2019a).

While it is important to recognise the challenges of complexity management and adaptability, the most important aspect of designing DMIs is translating the performer's intent regardless of their skill level. O'Modhrain quite plainly states this in her Computer Music Journal article entitled 'A Framework for the Evaluation of Digital Musical Instruments':

> *"There is no doubt that the most important stakeholder in the process of designing and building a DMI is the performer. Unless the instrument can successfully translate their musical intent into sound in a reliable way it fundamentally fails as an instrument."* (O'Modhrain, 2011)

The perception of whether an instrument is successful at translating musical intent can be affected by many things. However, it is particularly influenced by a performer's ability to perceive and respond to feedback from the DMI. This causality relationship or "feedback cycle" is extremely important within music performance. Oram also recognised this as the challenge for electronic instruments in 1972, stating:

> *"One of the vital factors about a human being is his (sic) ability to control his (sic) actions according to 'feedback'."*(Oram, 1972)

When a performer plays an acoustic instrument, any action triggers direct feedback. This direct feedback allows the performer to learn and adapt based on the feedback. If a performer plays an instrument and cannot recognize this feedback or how their actions relate to the feedback, the performer may struggle to perceive the object as an instrument.

2.3.3 Classifying contemporary Digital Musical Instruments

In 2022, countless examples of digital musical instruments exist, from bespoke instruments created for an individual artist or research to the many commercial DMIs available to the general public. The developments in technology that accelerated the creation of new DMIs, also diversified what could be considered a musical interface. As acknowledged in the Oxford Handbook of Computer Music (Dean, 2011),

> *"the introduction of computer technology bestowed the instrument designer with the option of complete disjunction between the controller*

and the synthesis engine."

The interface of an instrument was no longer bound by the requirement to generate sound, which is the reality in acoustic instrument design. While this allowed DMIs to become more flexible and offer control of more elements of a performance (Dean, 2011), it also added complexity and additional software requirements. This tension between the control interface and sound generator again called into question which part of the system is considered to bethe instrument.

Another challenge that the gap between physical interface and sound generator introduced is the classification or categorization of DMIs. Classification has been a subject of interest in DMI design research for many years (Paine, 2010). In Organology (the study of musical instruments and their classifications), acoustic instruments are often grouped by the vibrating element within the instrument that produces its sound. For example, 'string', , or 'brass' instruments are well-known subcategories for musical instruments in the western world. However, for DMIs the sound generator is typically a computer-generated synthesiser or virtual instrument (a software-based instrument). In DMIs, it is more common to see categories created from the type of controller or input and not from the way sound is created.

As recognised by Paine, terms used to classify DMIs are freely mixed between technological descriptors and performance methods (Paine, 2010). This causes a problem as a DMI could be classified using such a system in more than one way. The technologies used within DMIs can also fall into several categories that overlap. This makes it more challenging to define categories that separate DMIs into types.

Despite this complexity, several attempts have been made to categorise DMIs in research. Miranda and Wanderley (2006) offer one way to classify DMIs based on their similarities to existing instruments. A system that provides four categories: augmented musical instruments, instrument-like gestural controllers, instrument-inspired gestural controllers, and alternate gestural controllers. However, even the authors acknowledged that this classification is not intended to be in-depth or final.

The type of input or 'mode of interaction' is also a popular method for the classification of DMIs. In the 2011 Youth Music publication entitled 'Engagement With Technology In Special Educational & Disabled Music Settings', Farrimond et al. (2011) offer five categories of musical control interfaces: distance and motion tracking, touchscreen technologies, tangible interfaces, wind controllers, and biometrics. Similarly, in their 2015 paper on 'Adaptive Music Technology: History and Future Perspectives', Graham-Knight and Tzanketakis suggest dividing DMIs into the following: touchless sensor musical instruments, breath pressure sensor musical instruments, biosensor musical instruments, video-based systems, and "other" adaptive musical instruments (Graham-Knight and Tzanetakis, 2015). Frid also takes this approach in both her 2018 and 2019 papers on surveying ADMIs, offering ten categories based on the input method. The categories are 'tangible', 'touchless', 'brain-controlled musical interfaces (BMCIs)', 'adapted musical instruments', 'wearable/prosthetic', 'mouth-operated', 'audio', 'gaze', 'touchscreen', and 'mouse-controlled' (Frid, 2018, 2019a). ADMIs that exemplify some of these categories are shown in Figure 2.2.

Creating categories by input method has the benefit of being more universally understood, as the musician's interface is the part of a DMI that most people are familiar with. Additionally, the playable interface forms most of 'the visual reality of the instrument' if we observe Moog's definition. Audiences significantly benefit from this form of classification, as it is most similar to the western traditions of classifying acoustic instruments. However, the flexibility offered by technology can make it difficult to clearly assign an interface between these categories. It is not uncommon for DMIs to use more

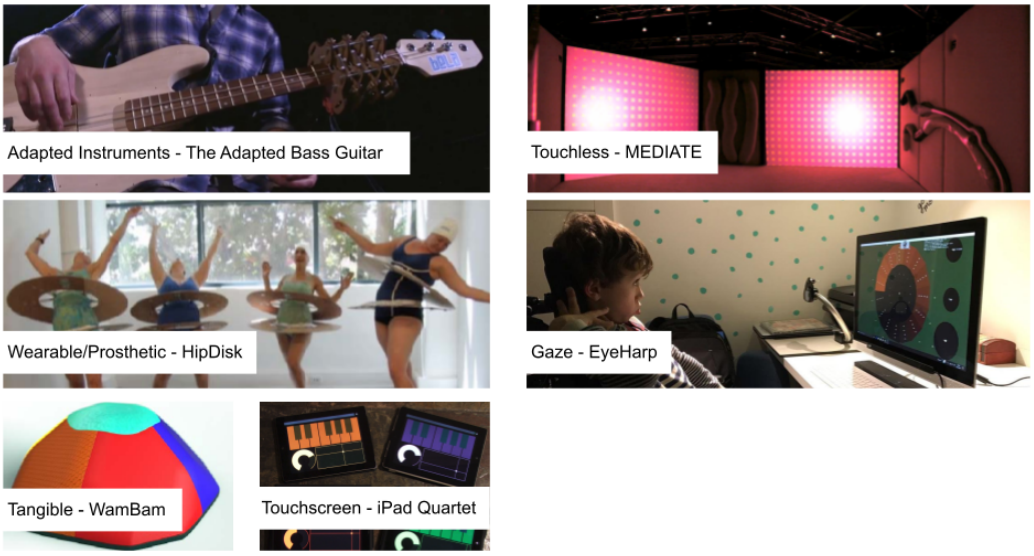

Figure 2.2: *Some example ADMIs from Frid's ten categories. Top row: Left - Adapted Instruments: The Adapted Bass Guitar (Harrison, 2022), Right - Touchless: MEDIATE (Gumtau et al., 2005). Second row: Left - Wearable/Prosthetic: HipDisk (Wilde, 2011), Right, Gaze: EyeHarp (EyeHarp, 2020). Third Row: Left - Tangible: WamBam (Jense and Leeuw, 2015), Right - Touchscreen - iPad Quartet (Favilla and Pedell, 2014).*

than one means of interaction. In these cases, some subjectivity could be introduced based on which mode of interaction is deemed the primary or most important in musical contexts.

Another form of classification used for DMIs is the type of communication protocol/technology used within the device. This can be seen in many commercial settings, where there might be a category of 'MIDI Instruments' with a huge variation on the type of input those MIDI instruments offer. In this method, subcategories are then used to separate the instrument types further. For example, you might see subcategories of 'MIDI Keyboards', 'Drum Pads', or 'MIDI controllers'. Again there is the same issue where devices could meet more than one of these criteria. To take just one example, the Novation Launchkey (shown in Figure 2.3) combines several interface types. The controls include a more traditional keyboard input, as well as both pad and potentiometer inputs that are more typically found on a drum pad or midi controller. As such, this DMI could fall into all three of these aforementioned categories. In this example, the most likely outcome is that this DMI would be classified by the most prominent control input, which is the keyboard. However, the existence of multi-input devices like this one highlights the issue with developing a clearly defined category system for DMIs.

Figure 2.3: *Novation Launchkey (Novation, 2022)*

In ADMIs categorisation by input and technology types is also common, but there has also been movement towards classifying instruments by their purpose. This is specific to ADMIs, where researchers have opted to differentiate ADMIs by use in therapeutic settings or for performance (Harrison, 2020). These categories acknowledge that while an ADMI can be successful in one context (i.e music therapy), it does not necessarily make that same ADMI appropriate for other settings (i.e live performance).

2.3.4 Accessible Digital Musical Instruments

As evidenced in the previous section on Music and Disability, technology has undoubtedly opened up access to musical experiences for disabled people. In the last decade especially, there has been an increase in the development of bespoke assistive music technologies in research (Lucas et al., 2019). However, the increase in the availability of ADMIs is not limited to research (Frid, 2018). Organisations like Human Instruments and Drake Music continue to support individuals and community groups by providing access to music using ADMIs. There are also more options in terms of commercially available ADMIs and DMIs targeting accessibility as a core feature. The Skoog, Skwitch, Arcana Strum, and Jamboxx Pro, shown in Figure 2.4, are just a few examples of this.

Figure 2.4: *Commercially available ADMIs: Left - Arcana Instruments: Strum (Arcana, 2022), Middle - Skoogmusic: Skwitch and Skoog (Skoogmusic, 2022), Right - Jamboxx: Jamboxx Pro (Jamboxx, 2022).*

Frid defines ADMIs as 'accessible musical control interfaces used in electronic music, inclusive music practice, and music therapy settings'. This definition is inclusive of all DMIs used within these settings and not necessarily just those designed to be accessible. However, questions remain regarding the criteria which are used to assess the accessibility of a musical control interface to label it as an ADMI. Frid does elaborate that successful ADMI designs often feature some or all of the following: instrument adaptability and customization, user participation in the design process, iterative prototyping, and interdisciplinary development teams. In research, studies discussing ADMIs often reference bespoke controllers designed to be accessible for a specific person or context. However, some studies into inclusive music practices have also encountered appropriation of other technologies, such as game controllers, which are used as an 'accessible controller' for music creation. Current research does not conclusively answer the questions of whether these appropriated devices are also considered to be ADMIs.

Commercial ADMIs tend to have a broader accessibility approach. These devices do not always target a specific audience but generally have more accessible interfaces that many disabled people could use. However, the industry constraints influence this greatly, as specificity is often lowered to reduce the cost of production and widen the potential audiences for the product. This is reflected in many marketing statements for ADMIs, with many products also targeting non-disabled musical novices.

In recent years resources for buying adapted musical instruments have been created for individuals, parents, teachers, schools, and retailers. The 'Guide to Buying Adaptive Musical Instruments' (Creative United, 2020) created by the Take It Away Consortium (Creative United, 2021)[6] and published by Creative United (Creative United, 2022) [7] is just one example. The guide collates a range of musical instruments from prototypes and bespoke to commercially available, and common accessories. A section dedicated to music technology suggests electronic instruments and music software that could be used in inclusive music practices. The authors acknowledge that the guide is not intended to be an exhaustive list, as new products are continuously being developed.

Harrison's approach of classifying ADMIs by their intended use, as mentioned in Section 2.3.3 of this chapter, could be helpful in separating potential ADMIs between those created for therapeutic and musical goals. However, it must be acknowledged that many examples of DMIs are used within both settings that are not specifically targeting accessibility. These instruments only claim the label of being an ADMI through being used in practice. It is interesting to consider what features of these instruments, in particular, make

[6] The Take It Away Consortium was formed in 2018, it is a partnership between Creative United and leading UK music organisations Drake Music, The OHMI Trust, Open Up Music, and Youth Music. Its purpose is to ensure music-making is inclusive and accessible to all. The group was joined by Music for Youth in 2019 and Technology in Music Education UK (TiME) in 2021.

[7] Creative United is an entrepreneurial community interest company committed to supporting the growth and development of the arts and creative industries

them well suited for these settings without modification. Additionally, it is worth considering what could be learned from these instruments to extend accessibility within all DMIs.

2.3.5 Digital Musical Instruments in this research

Moog's conceptual description of a DMI as a modular system allows us to think about each part of the DMI in isolation and examine how each part might be modified to better suit the needs of a performer (Farrimond et al., 2011).

In this research, DMIs will be considered as "modular devices that produce sound using digital technology". In short, a DMI will be recognised as the combination of its physical interface, the methods through which it produces sounds, and the visual perception of the instrument, as depicted in Figure 2.5.

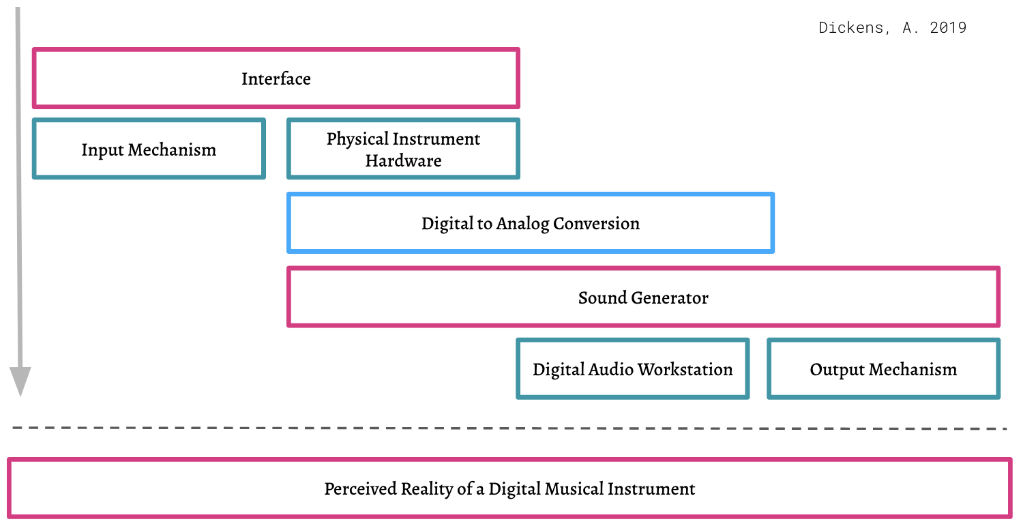

Figure 2.5: *A depiction of the modular system definition observed by this research*

Frid's definition of ADMIs and Harrison's approach to classification between therapeutic ADMIs and performance-focused ADMIs will also be acknowledged. However, this research aims to understand more about what makes DMIs more accessible. Therefore all forms of DMI will be considered without limiting the discussion to only those classified as ADMIs /addin previous research.

2.4 Human-Computer Interaction and performing with technology

This section introduces literature from the field of HCI research that discusses performing music with technology. The challenges of using technology within musical performance will be examined within it. Opportunities provided by new and novel ways of interacting will be explored. Additionally, important stakeholders' perceptions and technology assessment such as the performer and audience will be discussed.

2.4.1 The challenges of using technology in musical performances

As discussed in section 2.3.2, musical performance relies upon an iterative cycle of listening and responding. Audiences of musical performance engage with this cycle, creating an interactive feedback loop. This feedback loop created between the musician and audience supports the holistic experience of musical performance from both perspectives (Spence, 2016). However, technology has somewhat altered this feedback process and the cause-and-effect relationship is not always obvious to an audience when technology is used within a performance.

According to Schloss (2003), the physical 'evidentiality' of musical performances has been dismantled over the past thirty years. Technology has reduced the perceivable causal link between gestures used to play an instrument and the mechanism that produces its sound (O'Modhrain, 2011).

Despite this, DMIs and other technologies have been widely used in musical performance for many years. From major recording artists using technology in their touring performances (Bjork and the Reactable (Reactable

Systems SL, 2022), Imogen Heap and MiMu gloves(MI.MU, 2022a)), to new genres of music performance. 'Algoraves' or 'laptop orchestras' are good examples of music performances created explicitly to showcase music created using technology.

Consequently, laptop orchestras and performances with laptops are classic examples where the causality relationship is not evident to the audience, an issue that is often acknowledged in research (Trueman, 2007; Paine, 2010; Cascone, 2003). Many attempts have been made to resolve this issue. For example, the Princeton Laptop Orchestra (PLOrk) uses multi-channel hemispherical speakers (Trueman et al., 2006) to create localised sound for each laptop instrument. This creates the impression of directional sound from each instrument like an audience would experience with an acoustic orchestra.

Many DMIs struggle with demonstrating the causal relationship to the audience. As O'Modhrain highlights, the issue with DMIs specifically is that there is often no way for an audience to have knowledge of the instrument and how it should be played (O'Modhrain, 2011). In contrast, how acoustic instruments produce their sound has been physically evident to audiences for more than thirty thousand years (Schloss, 2003).

The audience experience of musical performances with technology has been widely researched (Bin et al., 2016; Bin, 2018; Emerson and Egermann, 2016, 2020; Berthaut et al., 2015; Benford et al., 2018). A number of models exist for how audiences make sense of music performance. Huron's Imagination, Tension, Prediction, Reaction, and Appraisal (ITPRA) model, for example, focuses on the emotional response of audiences (Huron, 2008). Huron observes that imagination and tension precede the performance, with prediction, reaction, and appraisal following it. However, as has already been examined in this discussion, it might be difficult to apply such a model to DMI performances where a limited understanding or expectation of the instrument used in performance exists. This is best explained by Bin (2018)

> *"It is precisely a DMIs lack of musical vernacular that prevents the audience from even forming a stable mental model, let alone have one to rely upon for judging musical events as they unfold in real-time."*

Here, the term 'musical vernacular' is used by Bin to describe the aspects of musical conventions such as pitch, rhythm, melody, playing style. This lack of mental model is illustrated by Trueman (2007) in his example of audience reactions, including comments like:

> *"as far as I could tell, they were all just checking their email"*

Unfortunately, this lack of mental model still exists today and could still be expressed by audiences of laptop orchestras or DMI ensembles in 2022. A common way to address this issue is to augment performances with corresponding visual feedback such as computer generated visualisations or responsive stage lighting (Berthaut and Dahl, 2022).

Musical expressiveness, communicating meaning or feelings through music (Fels et al., 2003), is another way in which audiences engage with musical performances and performers. However, expressiveness is also limited for DMIs because there is a lack of familiar musical pieces through which to establish a common emotive language (Dobrian and Koppelman, 2006). As a result, it could be seen to be inaccurate or unfair to try and apply these methods of audience evaluation to a DMI performance because they cannot be directly compared to acoustic instruments. In this situation, an audience of the general public will take reference of their most common source of knowledge, which could be music performance of any kind. In consideration of this, it is easy to align with Tanaka (2012) that the experience of musical performance could be seen as personalised, shaped by an individual's personal knowledge and experiences. As such, there might always exist some juxtaposition between the audience's understanding and enjoyment of a DMI performance. However, as time progresses, the instrument familiarity of DMIs improves, and with it, the action to sound causality relationships and performer agency may become more recognisable to wider audiences. Equally, as technology becomes more common place in our everyday lives, DMIs become more accepted even when the relationship between action and sound is not understood by the audience.

Other challenges that exist for performing with DMIs are related to the physicality of the instruments and of performance spaces. As noted DMIs often do not produce their own sound from the control interface. In live performances and many other contexts, this can create some challenges. Sound generation from DMIs usually requires the amplification of a PA system or series of personal amplifiers. This introduces potential problems in providing a power supply to such equipment and routing cables between the instruments and sound output.

Networking is another commonly cited issue for DMIs in musical performance settings (Trueman et al., 2006). Instability is the biggest issue , with wireless networks being vulnerable to interference of many kinds, including the presence of other networks. Potential resolutions to networking issues have been offered in recent years by providing alternatives to using MIDI over a cabled or wireless network. Systems such as Korg's Wireless Sync-Start Technology (WIST) (KORG, 2011) offer a way to share stop, start, tempo messages between iOS devices over Bluetooth (Martin and Gardner, 2015).

Equally, having some form of "backup plan" for when an element of a DMI fails is required when when using DMIs in liveperformance. Much like a guitarist may carry extra strings in the guitar case, DMI musicians might be required to carry additional equipment to solve issues as they arise. This could stretch as far as having to carry double the equipment in the form of a complete backup should the initial instrument fail (Trueman et al., 2006). Failure in this context can also occur during a performance with a DMI, for example a system or trigger not responding as expected, and this is something the musician has to handle 'in the moment' (Hazzard et al., 2019). Linked with the challenges of failure is the fact that performances can take place in many contexts. Transporting DMIs can be complicated and risks incurring damage to equipment. Therefore the robustness of both the technology used and the physical structure of DMIs is important.

Finally, an issue worth noting is that not all performers that use DMIs have a full technical understanding of the equipment they use to perform. In a similar way to learning acoustic instruments, a musician develops their skill over time. In doing so, the musician becomes more familiar with their instrument and acquires the ability to recognise issues with its performance. Not all pianists would be confident about tuning a piano, but for DMIs, this distance from the inner workings of the instrument can be amplified. In many situations, technicians and instrument builders of DMIs have been known to accompany musicians in performance. This is especially true for novel, bespoke, and technically complex DMIs (Trueman et al., 2006).

2.4.2 Novel interactions in music performance

In terms of HCI research, there are many people exploring the opportunities presented by new technologies for musical performance. The NIME (NIME, 2022) community is a place where many technologies have been explored as potential instruments. From using physiological sensors, such as Electroencephalograms (EEG), to extend the capabilities of the human body as an instrument (Tanaka, 2012) to musical collaborations with artificial intelligence (Kallionpää et al., 2017).

Embodied interaction, an HCI perspective on the relationship between people and systems (Dourish, 2001) is one particular research area that has been used to explore the relationship between music, movement, and technology (Leman et al., 2017; Leman, 2007). While it is true that all experiences with music are embodied in some form (Leman et al., 2017), DMI research tends to focus on embodied movements. From performative gestures and how they are related to sound to the audience's perception of a performer's embodied gestures and exerted energy. A variety of technologies feature in this topic, including computer vision-based sensors, handheld controllers, and biosensors, to name a few. These systems may still be considered a novel experience today, yet movement-based interactive musical systems have actually been developed since the beginning of electronic music (Bevilacqua et al., 2017).

Many challenges have been identified in embodied interaction with DMIs, from documenting a performer's true experience in live performance to understanding common themes in metaphorical representations of music (Wessel and Wright, 2002) and the image schema associated with musical events (Wilkie et al., 2009, 2010). However, it is thought that introducing gestures to DMI performance in a way that mimics what is experienced with acoustic instruments has the potential to improve the audience reception of DMIs and strengthen the authenticity of the musical performance (Paine, 2009).

Another technology that is being introduced to music performance, mostly through research, is the use of artificial intelligence (AI) backed by machine learning (ML). In some cases, this has been used to augment musical performances by having a machine learning-driven ensemble (Martin et al., 2017; Martin and Torresen, 2018). In other cases, AI performers have been created to collaborate with artists or even challenge their human counterparts in a beatbox battle (Kallionpää et al., 2017; Nokia Bell Labs, 2018). Yet these approaches could make it more difficult for audiences to understand the full spectacle of the performance. As acknowledged by Whittam (2015):

> *"By subsuming technological processes within the hidden world of electronics, microchips and computer processors, the spectacular effect of the activation of technology is mostly lost in the digital age. Sound*

> *creation process passes from the visual world (mechanical processes and flailing limbs) to the invisible world (digital processes and button pushing)."*

Machine Learning (ML) is a technology that has also been explored for artist development and used in specialised DMIs to recognise and respond to a musician's practice. The contemporary works of beatboxer Harry Yeff who goes by the artist name Reeps One, examine how an AI can be trained to respond to the voice. The documentary 'We Speak Music', created in collaboration with Nokia Bell Labs, follows Yeff exploring how the voice can be used with technology. In the documentary, Yeff explores creating an AI that he could use to both collaborate with and improve his own practice. Yeff refers to this reflective relationship with technology as an 'augmented intelligence' rather than artificial, embracing technology as "an opponent, a mentor, and a collaborator" (Yeff, 2019). Similarly, in HCI research, Greenhalgh et al. (2015) developed a music recognition system to enable a wide range of musicians to embed musical codes into their performances .

The MiMU gloves (MI.MU, 2022a), a wearable DMI in the form of a glove containing a variety of sensors to capture a musician's gestures, are another example of a DMI employing machine learning techniques. The paired software for the gloves' controllers, Glover (MI.MU, 2022b), allows musicians to train the system using their own gestures and playing styles. The ML element enables musicians to create gestures and assign them to actions in ways that are meaningful to their practice, as opposed to working in the confines of a set of 'accepted' gestures. This is best demonstrated by the musician behind the MiMU gloves, Imogen Heap (Heap, 2013). In offering such a wide range of flexibility for the musician, interfaces like the MiMU gloves continue to add to the debate about mapping movements to musical actions (Brown et al., 2018).

The instruments described in this section, pictured in Figure 2.6, each offer a unique way of engaging with an individual's physical language, which presents opportunities for accessibility.

Figure 2.6: *Novel Interactions: Left - Imogen Heap and the MiMU Gloves (Fairs, 2014), Middle - Reeps One's Second Self AI (AIartists.org, 2021), Right - Maria Kallionpää performing Climb! (FAST IMPACt Project, 2022).*

2.5 Accessibility in technology design

This section explores how accessibility is approached in the wider field of technology design. Challenges that exist across the technology industry will be identified. Evaluation frameworks and design guidelines will be discussed. Additionally, this section will highlight lessons that have the potential to be transferred to the field of DMI design.

2.5.1 Challenges for accessibility in technology design

Accessibility in technology is an extremely broad topic to review. To consider all accessibility challenges for every technology is out of the scope of this review. However, it is possible to look at some common themes for accessibility across different technology guidelines.

The web content accessibility guideline principles (WCAG) (W3C, 2022b) offer a good place to start. The four principles, set by the web standards committee for accessibility, suggest that for web content to be accessible, it must be:

> *"Perceivable - information and user interface components must be presentable to users in a way that they can perceive.*

> *Operable - user interface components and navigation must be operable.*
>
> *Understandable - information and the operation of the user interface must be understandable.*
>
> *Robust - content must be robust enough that it can be interpreted by a wide variety of user agents, including assistive technologies."*

These words are taken verbatim from the WCAG documentation (W3C, 2022c). This documentation is not fully transferable to all technologies, but the top-level principles are. Looking beyond web content, we can ask these questions: Is this technology perceivable by everyone? Is it operable by everyone? Can everyone understand the technology and information it presents? Is it robust?

The meaning of these principles might differ for each context. For example, robustness in physical technologies implies protection against damage, which differs from how the robustness of digital content might be evaluated. Yet the principles still highlight the biggest challenges for most technologies today.

Perceivable invites exploration of the format in which technology is presented. Is it limited to one domain that could exclude certain communities? Visual and tactile interfaces presented without any description or alternative way to understand what they are, exclude people with visual disabilities. Similarly, if a notification within a piece of technology relies on sound alone, it excludes the Deaf community. This highlights the first common challenge in designing accessible technology. Technology must present itself in a way that it is not hidden. The context of the technology and its use will define what extent of exposure is necessary, but as a rule, having a single pathway for feedback to a user will usually be a source of limitation.

Operable offers another common challenge in terms of usability. This term extends to considering the ways in which a technology can be operated. Again this questions whether the technology is limited to being operated by one type of input only. Features related to timing or animations that might limit a person's ability to engage with a technology are also considerations for operability. For example, does a timed window exclude a person with limited mobility who might have slower movements? Or are there types of feedback that can be distracting from the main task or induce seizures?

Task navigation is an element of operability that is particularly exposed to becoming inaccessible. Especially if the equality of the experience is called into question. Simply providing a way to navigate a system does not make it accessible. Designing accessible technology requires understanding a person's trajectory when engaging with that technology. A technology offering a task that takes ten seconds for a non-disabled person but ten minutes for a disabled person using assistive technology cannot be considered accessible (ACM SIGCHI, 2016).

The third principle,understandable, is a concept that goes beyond language use alone. While readability and language use are important in making something accessible, the focus on these alone does not make something 'understandable' to everyone. This is an area that can also be easily confused with other inclusive practices such as internationalisation. In this context, understandable must be considered to be separate from the language a piece of technology uses. For example, readability is a problem that concerns itself with the use of unusual words, abbreviations, and reading levels. These are important to consider regardless of what the spoken or written language of the technology might be. Being understandable is also a concept that extends to predictability, implying that technology should not behave in unexpected ways. For some projects, technology may be intentionally designed to behave unexpectedly. In this circumstance, it must be considered by the creator how this choice could limit accessibility. Providing ways to help people avoid and correct mistakes within a system is also an important accessibility challenge that falls within this concept of being understandable.

Finally the fourth principle, robust, is a term that focuses on the challenges of compatibility, as well as the durability of a technology. While this strongly correlates to the interpretations of robust meaning unbreakable, it acknowledges a number of ways in which technology can 'break' for a person. When considering accessibility, trajectories are again a very important factor of a person's experience when engaging with a technology. In the most obvious sense, technology can physically break, regardless of whether it is a physical or digital interface. Equally, the experience of using the technology can be broken for a person because of many factors. When considering accessibility, experiences are often broken by a technology's poor integration with other assistive devices.

As new technologies are produced, and new ways of interacting are made available, these challenges need to be considered. Embodied interaction for example was highlighted by Dourish (2001) as a way that

> *"computation [is] to be made ever more widely accessible to people without requiring extensive training, and to be more easily integrated into our daily lives by reducing the complexity of those interactions."*

Yet embodied interaction often relies on sensing technologies that have to be trained using machine learning. Unfortunately, there is often a distinct lack of representation of disability and disabled bodies within training data. This often results in such technologies not working for some disabled people (Dickens et al., 2018).

The principles presented here do not speak to the challenges for specific disabled communities or specific genres of technology, nor does this section aim to. What this section does highlight, however, is that there are many accessibility challenges when using technology. These challenges are not limited to the experience of an interface but can appear throughout the interaction trajectory (Benford and Giannachi, 2011) of a person using that technology.

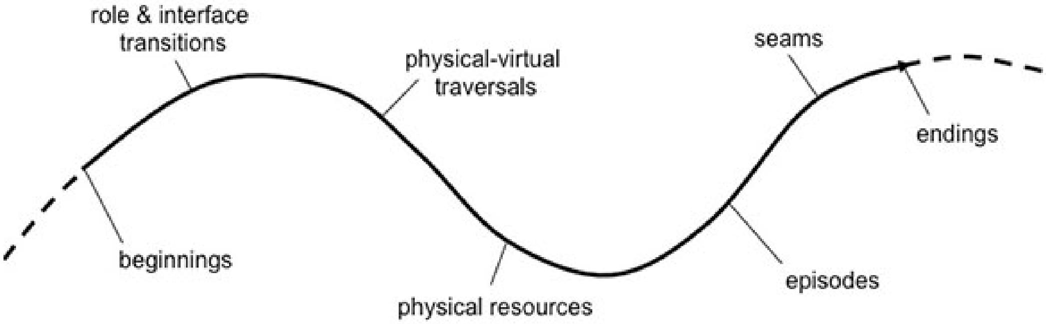

Figure 2.7: *Different kinds of transitions that may be encountered along a trajectory (Benford and Giannachi, 2011).*

Identifying the transition points in a trajectory, as shown in Figure 2.7, that might be limiting to accessibility is another equally important part of the design challenge. The following guidelines and best practices can help to ensure this has been considered. However, to properly identify issues of equivalent experience and other accessibility issues, thorough testing with disabled people is required.

2.5.2 Frameworks for accessible technology design

WCAG is probably one of the most referred to resources when discussing accessibility in technology. However, it is not the only resource, and it is specific to the context of web content. The World Wide Web Consortium (W3C) (W3C, 2022a) produces a number of accessibility-related resources for web technologies. Including guidelines for accessibility in accessible web authoring tools (ATAG) (W3C, 2020b), technical specifications for accessible rich web applications (WAI-ARIA) (W3C, 2020a), real-time communications (RAUR) (W3C, 2021b), and user agents (meaning web browsers, browser extensions, media players, readers, and other applications that render web content) (UAAG) (W3C, 2016).

During the pandemic, W3C have also presented a set of guidelines summarising the considerations for accessibility in remote meetings (W3C, 2021c). Being designed for the context of the web does not necessarily restrict these resources from having uses that transfer to other non-internet connected technologies. Due to the fact that many forms of interactions are now available online, the web consortium has moved towards also producing guidelines for the creators of technical specifications. The editor's draft for the Framework for Accessible Specification of Technologies (FAST) (W3C, 2021a) was released on November 4 2021, which provides advice to those who create technical specifications on how to ensure their technology meets the needs of disabled people.

It is not just the context in which technology is used that can impact the recommendations for how to make it accessible. The type of disability that specifications and frameworks address can also impact the information available to technology creators. It has been acknowledged that a large number of web accessibility frameworks and assessment tools tend to focus on blindness (Bohman and Anderson, 2005) more than any other disability. Similarly, accessibility accommodations in physical spaces often target solutions for physical disabilities.

Web Accessibility in Mind (WebAIM) is a not-for-profit organisation based at the Institute for Disability Research, Policy, and Practice at Utah State University. The organisation produced a conceptual framework for accessibility tools to benefit users with cognitive disabilities, presented at the Cross-Disciplinary Workshop on Web Accessibility in 2005 (Bohman and Anderson, 2005). This framework, in particular, acknowledges some of the bigger challenges for standards that address accessibility. Even where recommendations are made, regardless of context, there can be vagueness and subjectivity which results in different interpretations. The example given by Bohman and Anderson (2005) discusses the interpretation of simplicity:

> *"For example, although few experts dispute the idea that clear and simple text can benefit users with cognitive disabilities, there is no*

> *defining point at which text becomes 'clear and simple', as opposed to 'unclear and complex'."*

This exemplifies that there can be a large amount of subjectivity in the lived experience of accessibility. Even within groups of disabled people with the same diagnosis, there will be variation in how that diagnosis impacts their interactions with technology. Bohman and Anderson (2005) acknowledge this challenge in their writing:

> *"diagnoses mean little or nothing to Web developers because there is not a direct link between the diagnoses and the actions the developer must take to accommodate people with these diagnoses."*

However, they also express that the difficulty of addressing accessibility for cognitive disabilities does not diminish the importance of doing so.

Another set of guidelines for accessibility can be found in the Open Accessibility Framework, created by the Open Accessibility Everywhere: Groundwork, Infrastructure, Standards (AEGIS) project (AEGIS Project, 2013). AEGIS was an international project that ran between 2008 and 2012. The project was aimed at empowering anyone that experiences disadvantages when using internet services, desktop PCs, or mobile devices. AEGIS was a collaborative project with twenty European partners, with Sun Microsystems acting as the coordinator (EPR, 2017). The Open Accessibility Framework (OAF) is a document that highlights the requirements to achieve 'third-generation accessibility', aimed at designers and developers of ICT components and systems (AEGIS Project, 2013). This generational approach to accessibility relates to the development of technology from the 1970s to the present day. More specifically, 'third generation accessibility' refers to the development of accessibility-focused application program interfaces (APIs) across the major operating systems and programming languages. The OAF acknowledges a number of additional frameworks and standards as being influential in its development. These include the W3C standards, commercial standards such as the "Information Technology - Interoperability with Assistive Technology" ISO/IEC 13066 standard (ISO/IEC, 2011), reports related to legal mandates such as the Telecommunications and Electronic and Information Technology Advisory Committee (TEITAC) Report (TEITAC, 2008), and legal mandates themselves, for example, the EU mandate 376 (European Commission, 2005).

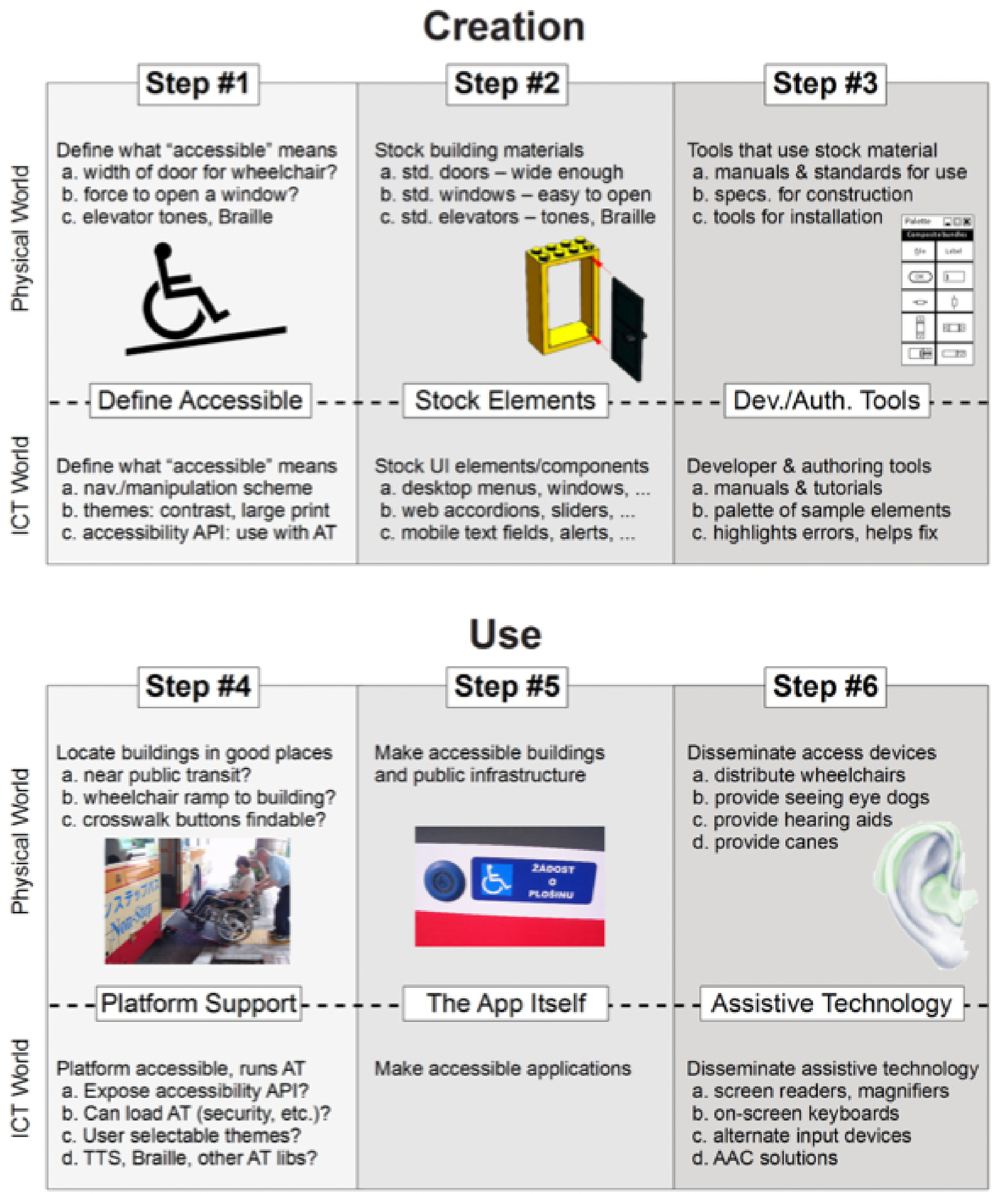

Figure 2.8: *The Open Accessibility Framework Creation and Use steps for building an accessible ICT world (AEGIS Project, 2013)*

The approach of the OAF is to look at how accessibility is managed in the physical world or "built environment" and apply this to the world of information communication technology (ICT), as illustrated in Figure 2.8.

These examples of accessibility frameworks are not exhaustive, nor are they representative of the variety of resources that exist on the topic. However, collectively what can be seen from each document is that there is consensus that there is still more to be understood about the accessibility of technology. Standards and frameworks that exist can vary between being too specific to apply to other domains or being too general in ways that introduce subjectivity.

Another resounding feature of this form of documentation is that in most cases, these standards themselves are inaccessible not necessarily in their presentation and access, but in the language choices of authors. Standards that are closer to legal mandates or initiatives are especially prone to this. Even the seemingly more accessible standards presented within W3C rely on 'how to' guides to help readers make sense of them.

2.5.3 Lessons for accessible Digital Musical Instrument design

When looking for standards about accessibility in the fields of music or music technology, there is not much to be found in terms of documentation. Groups exist that focus on expanding the accessibility of music notation, like the UK Association for Accessible formats Music Subject Area (UKAAF, 2021). Similarly, documents have been produced about expanding accessibility in music education (Lines et al., 2018). However, there is a distinct lack of standards, or guidelines, for creating accessible digital musical instruments (Frid, 2019a; Harrison, 2020).

The core principles presented in W3C's WCAG documentation are a promising starting point for DMI creators. There are many transferable lessons from within these frameworks that could be applied to achieve a basic level of accessibility within DMIs. For example, lessons on the use of colour and contrast.However, the challenge for DMIs is that there can be many contexts in which the DMI is used, and this may subjectively change the accessibility of the experience. For example, an instrument's interface could be perceivable, operable, understandable, and robust in a practice setting but not in a performance setting. As such, the approach of the OAF to look at accessibility in both the creation and use of DMIs could be more beneficial. Though it has been acknowledged that there is still a lot to be understood about DMI use by disabled musicians, as much of the research to date is focused on work with small groups or individuals (Frid, 2018).

As discussed, examining the interaction trajectories (Benford and Giannachi, 2011) of technology could be helpful here. Especially to highlight points where the accessibility of the experience breaks down. DMIs are particularly challenging because of the rich social context in which they are used. A musician is both interacting with the instrument and expressing themselves through the instrument. A DMI must succeed at facilitating both of these interactions. Similarly, both interactions need to be considered when trying to achieve an equivalent accessible experience.

2.6 Conclusions

This chapter has explored the current literature available on the accessibility of DMIs. There are many specialised focus areas that are beyond the scope of this review. Based on the literature considered here, some core observations can be made.

The first observation is that DMIs are complex and often modular systems. The implication is that many breakpoints for accessibility could exist within one DMI. However, it is difficult to assess this implication within the current literature. Additionally many studies focus on bespoke ADMIs, meaningthere is a distinct lack of literature about evaluating the accessibility of commercial DMIs within inclusive music settings, which this research seeks to address.

Thesecond observations is that there are the many stakeholders that need to be considered when evaluating a DMI. This presents a unique challenge for accessibility, as improving the accessibility of an experience from one perspective could have a negative impact on other stakeholders.

The third observation that can be made from the literature is the need to study interactions 'in the wild'. Studying real-world interactions is the best route to understanding both technical and experiential issues related to accessibility.

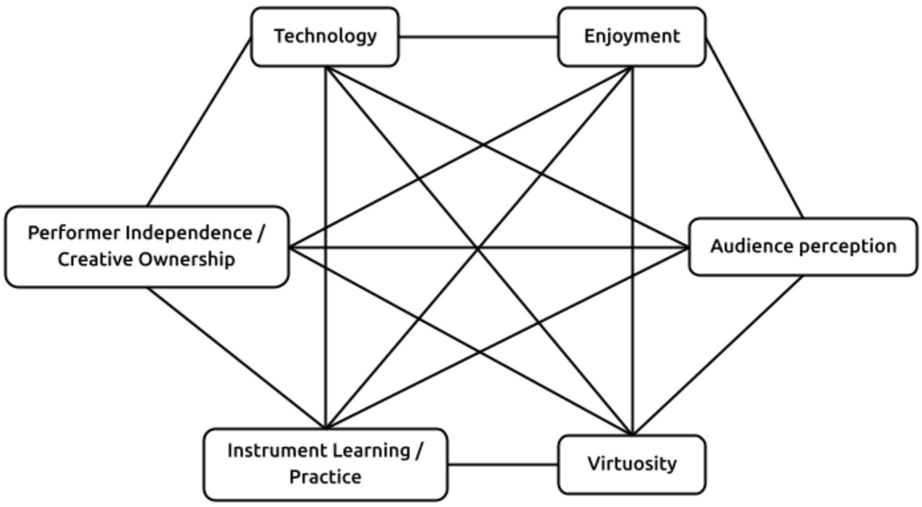

Figure 2.9: *Elements of the user experience that can impact the success of a Digital Musical Instrument*

The fourth observation is that while many standards exist that address issues of accessibility in different technologies, these do not extend to all the nuances of DMIs and music technology. DMIs can have many forms of interface, and their use is embedded in a socially rich activity that is bound by many principles. A number of factors impact the success of a DMI, and the importance of each factor can vary by context. From the literature, it would appear that the core elements of user experience that have the potential to impact a DMIs success are: the technology, the process of instrument learning/practice, the concept of virtuosity, the performer's enjoyment, the performer's sense of independence/creative ownership, and the audience perception of the DMI. Each of these topics are interrelated, as illustrated by Figure 2.9.

The fifth and final observation from the literature is that through a lack of specific guidelines on how to achieve accessibility in DMIs, there is also no guidance on how to evaluate the accessibility of existing DMIs. It could be that there already exist some DMIs that are highly accessible. Currently, without guidelines to assess a DMI against, the only way to evaluate whether that DMI would be accessible to a disabled musician is to physically test it out with them. However, the opportunity to do this can be extremely limited by many factors, from finance to the availability of a DMI. Research projects provide a unique opportunity to connect inclusive music groups with current technologies without responsibility of cost and procurement being put on the community initiative. This opens up the ability to integrate a wider range of DMIs into projects and through this, the relationship between research and inclusive music can become more symbiotic.

Chapter 3

Research Approach

This chapter outlines the methods used during the research process. It introduces a research partnership with Orchestras Live and Inspire Youth Arts, provides an overview of the research activities, and discusses the strengths and limitations of the methodological approach.

3.1 Introduction

This section expands on what was learned from the literature review. It discusses the potential methodological approaches and goals identified by the literature and how these influenced the focus of the research design.

The literature, presented in Chapter 2, exposed some common elements that present challenges for the general user experience of Digital Musical Instruments (DMIs). These elements might help us to understand how successful a DMI is as an instrument. However, only through observation of DMIs in use can the full breadth of requirements for accessibility be understood, appreciated, and explained. Due to this understanding, this research takes an inductive approach that focuses on observing disabled performers and exploring how digital musical instruments feature as an aspect of working practice (Dourish, 2001).

Observation in this manner could be achieved through many means. Initially, it was deemed important to embed the research in a real-world setting and, where possible, conduct research in spaces where accessible music-making activities were already taking place. Taking this approach would allow for a true-to-life observation of the challenges disabled people face when interacting with music technology and digital musical instruments.

Later in the research, however, there was a necessity to take a more designed research approach where the activities were led by the researcher. This allowed for a more structured enquiry into the accessibility barriers posed by specific digital musical instruments.

3.2 Partnership with Orchestras Live and Inspire Culture

This section introduces the research partnership with Orchestras Live and Inspire Culture, two organisations that were involved in accessible music-making activities through a local project called the Able Orchestra. Additionally, this section details the ethical considerations, constraints, and benefits of this partnership from a research perspective.

It was necessary to follow an approach that emphasised being "with and near" (Johnson and McRuer, 2014) the performers throughout their creative processes and production. To achieve this, it was of high importance to the research to form a collaborative relationship with disabled performers, and others involved in providing access to music, to ensure that the focus remained on the perspectives and lived experiences of disabled people (Ymous et al., 2020).

At the beginning of the research period, a relationship was formed with Inspire Youth Arts (Inspire Culture, 2022) through the Fusing Audio and Semantic Technology (FAST) project (FAST IMPACt Project, 2015). The team at Inspire Youth Arts proposed an opportunity for research collaboration with a local community music project called the "Able Orchestra". In this project, disabled students use digital musical instruments and other technologies to create and perform a piece of music with a live orchestra. As this was an annual project, there was a possibility that this collaboration could be repeated and, therefore, would be a good candidate for an iterative research project.

The research collaboration with the Able Orchestra project began in February 2016 and ended in February 2017. This period covered one iteration of the project in full and a number of ad hoc project-related performances, including an appearance at the BBC Proms [1] in the summer of 2016 (BBC, 2016).

The research partnership with Inspire Youth Arts continued beyond the Able Orchestra project. In 2018 another collaboration was made on a project entitled Able Lite. Able Lite, as planned by the team at Inspire Youth Arts, aimed to provide a stripped-down version of the Able Orchestra workshops within a classroom environment. It was offered as an enrichment activity within local special educational needs and disability (SEND) schools. Through this collaboration, the researcher was able to design and lead multiple independent workshops with a SEND school in the Nottinghamshire area.

3.2.1 Ethical and practical considerations for the research partnership

When a research partnership is formed, there are both practical and ethical constraints that are presented upon how the research can be conducted, especially where that partnership involves vulnerable people (Silverman, 2013). In this specific partnership, it is important to acknowledge the challenges of consent, safeguarding, risk assessments, and both environmental and structural restrictions upon the research activities.

3.2.1.1 Informed consent

There are a number of ethical considerations regarding working with vulnerable groups which had to be taken into account throughout this research partnership. Particular issues are noted within the research community about receiving informed consent from individuals within vulnerable groups (Silverman, 2013). This research benefited from being able to work closely with the team at Inspire Youth Arts to ensure participants were sufficiently informed

[1] The BBC proms are an annual classical musical event held at The Royal Concert Hall in London and are televised on the BBC network.

about research activities and use their established practices to obtain consent for the research within each project through parental/individual consent forms. The consent forms and information sheets for each study conducted through this partnership can be found in appendices A and B.

3.2.1.2 Safeguarding

Another ethical consideration in working with both young and disabled people is safeguarding. In some cases, this impacted the ability to collect certain types of data (e.g., video/photography data) due to particularly sensitive safeguarding issues. To ensure that safeguarding practices were upheld, the researcher undertook an enhanced DBS check issued by the Disclosure and Barring Service (DBS) [2] and regularly consulted with the project leaders and SEND school staff. Again working within an established community program such as the Able Orchestra was a benefit to the research, as this process was well established within the Inspire Youth Arts organisation.

3.2.1.3 Risk assessments

Risk assessments were also a practical consideration within the collaborative projects of this research partnership. Such assessments were conducted for each piece of equipment used in the projects and, where necessary, PAT testing was carried out. Further to this, practical health and safety techniques were employed when managing technical equipment in the field.

[2] An enhanced DBS check is suitable for people working in the United Kingdom with children or adults in certain circumstances such as those in receipt of healthcare or personal care. These were previously known as Criminal Records Bureau (CRB) checks.

3.2.1.4 Physical environment challenges

The environmental challenges presented in the research partnership projects often impacted the ability to collect specific types of data. As classrooms, stages, and rehearsal spaces did not always allow for video recordings to be maintained throughout the activities. Access to power, synchronising devices wirelessly, and positioning of research recording equipment were all factors that were limited by changes in the environment. To address some of these challenges, backup devices were arranged by the researcher. Additionally, video data was mostly recorded via handheld devices to capture up-close interactions with individuals while maintaining the least disruptive approach to the contextual settings.

3.2.1.5 Structural challenges

As the research involvement was both facilitated and guided by the partnership with Inspire Youth Arts, there were some limitations on the methods that could be employed to collate data, in addition to those that were posed by the environmental challenges. These "structural" challenges arose from being an external contributor to the projects. This had a negative impact on some communications, management of expectations, and the ability to design optimal ways in which to capture research data. These challenges are reflected upon in the discussion section of this thesis, which can be found in chapter 6.

3.3 Methods

This section details the chosen methods for this research in response to the ethical and practical considerations outlined in Section 3.2.1. The reasoning is provided for choosing an inductive approach and how this is incorporated into each of the research stages. Additionally, activity theory, action research, and participatory design are highlighted as fundamental methods that influenced methodological choices made.

The lack of studies focusing on the accessibility of digital musical instruments, beyond those of novel interfaces designed for the individual or research projects (Frid, 2019a), presents the need to follow an inductive research process. Observing disabled performers using digital musical instruments in their everyday practice forms the first stage of this approach. This stage focuses on qualitative data analysis to identify any common themes in the accessibility barriers of the digital musical instruments observed. The second stage of the research is a second study focusing on understanding the individual experiences and simultaneously reviews the common themes identified in the first study analysis. Finally, the third stage of the research focuses on the synthesis of a conceptual framework for accessibility in digital musical instruments.

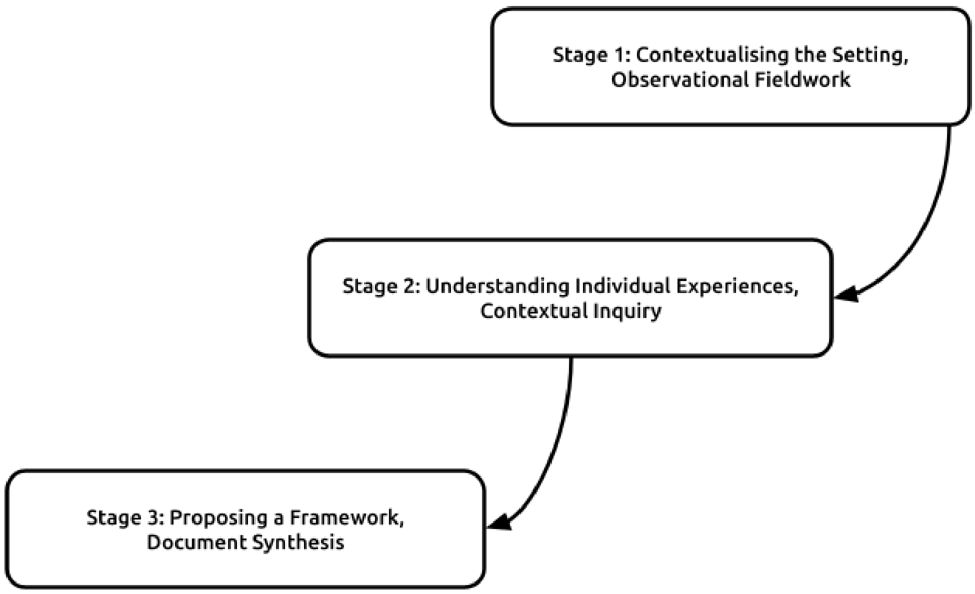

Figure 3.1: *Stages of the Research Process*

The research methods identified to be most appropriate are those associated with activity theory, and participatory action research, as these focus on lived experiences and the importance of activities in context. In particular, this research was guided by the notion outlined by Kaptelinin and Nardi (2006), which states that it is the

> *"doing of the activity in a rich social matrix of people and artefacts that grounds analysis"*

Forming a partnership with Inspire Youth Arts early on in the research process placed a focus on participatory methods. This included participatory design workshops with stakeholders, being an active participant in community music programs for disabled performers, and undertaking naturalistic interviews with other facilitators from these programs.

The research also benefited from the flexibility offered by the cyclical nature of action research. Throughout, focus was given to iterating on planning, acting, developing, and reflecting (Mertler, 2019), as can be seen in Figure 3.2.

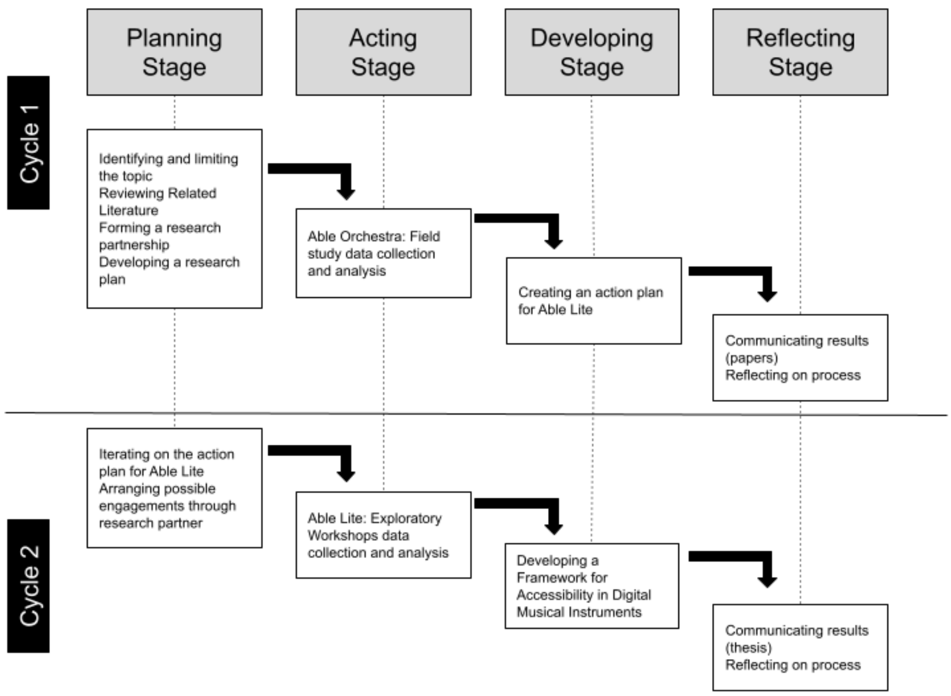

Figure 3.2: *The Action Research Cycle for this Research*

During the "acting" stages of this research, the theoretical framework of activity theory provided a basis from which to observe and analyse the activities of music-making with digital musical instruments by disabled performers. Activity theory posits the relationship between people and tools as a relationship of mediation (Kaptelinin and Nardi, 2006). In the case of this research, digital musical instruments are considered to mediate between the performers and the world. The "triangular" model of activity as a system, developed by Engestrom (Engeström, 2014) as seen in Figure 3.3, is useful for visualising music-making as a system.

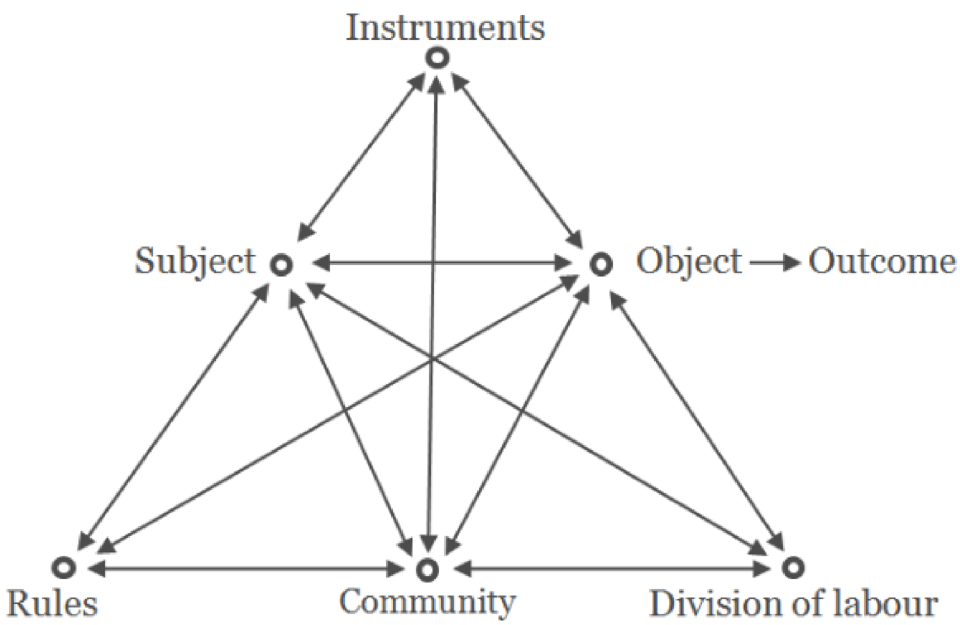

Figure 3.3: *Engeström's activity system model from The Encyclopedia of Human-Computer Interaction, 2nd Edition (Kaptelinin, 2014)*

In addition to providing the key aspects of a described reality (Kaptelinin and Nardi, 2006) this model explores how each aspect influences the outcome of the activity. Through understanding and describing the experiences of disabled performers as a collective of these phenomena, this research can explore how each part of this system influences the accessibility of digital musical instruments. Viewing experiences in this way also aligns with the social model of accessibility, through observing the impact of the environmental conditions and social contexts when considering the accessibility of digital musical instruments, as opposed to only observing the abilities of the individual. Similarly, this research sought to follow an approach akin to Participatory Action Research because this approach encompasses equitable participation with community and a commitment to address action or create social transformation (Benjamin-Thomas et al., 2018). The very nature of this research sits within an issue of social justice and seeks to question the equity of experiences with digital musical instruments. A combined approach taking lessons from activity theory, action research, and participatory action research maintains this focus on the human experience. As best quoted by Kowalski in the SAGE Handbook of action research (Bradbury and Reason, 2006):

> *"It isn't neat, but very human, open to different possibilities and uses time differently. It doesn't end; the impact of action research continues when we are mindful of leaving a legacy, an infrastructure behind."*

The resulting approach included a participatory design workshop, a field study following a community music program, and a series of exploratory workshops with a local special educational needs and disability (SEND) school. Table 3.1 provides the details of these research activities, including methods and data collected.

Date	Activity	Description	No. of Participants	Methods	Data Collected
February 2016	Active and Creative Workshop	A pre-activity workshop to evaluate the UX expectations and inform the design of a gesture-controlled musical interface.	3 project stakeholders, 4 researchers	Participatory Design Workshop	Video, Written Questionnaires
February 2016 - February 2017	Able Orchestra Study	A field study following a community music program in which young disabled musicians use technology to create music and collaborate with young acoustic instrumentalists, professional sound and digital artists, and orchestral players.	11 performers, 2 facilitators	Field Study, Technology Probe, User Interviews	Videos, Audio Recordings, Field Notes, Photographs
January 2018 - September 2018	Able Lite workshops	A series of classroom-based workshops introducing digital musical instruments to young disabled people and creating music with them.	8 performers, 5 facilitators	Exploratory Workshops, Contextual Inquiry	Videos, Field Notes, Photographs

Table 3.1: Research activities, methods employed, and data collected

3.4 Contextualising the setting

This section discusses the first stage of the action research cycle. Initial research activities are summarised, along with the chosen methods for each activity. Details are given for approaches to data collection, ethical considerations, and post-activity data analysis, as well as how these choices informed the research approach going forward.

3.4.1 Active and creative workshop

A participatory design workshop, the outcomes of which are discussed in chapter 4, was selected as an initial activity to provoke discussions on the issue of accessibility in digital musical instruments and draw upon the tacit knowledge of the attendees. The workshop was held on January 12 2016 and attended by researchers from the Mixed Reality Laboratory at the University of Nottingham and several stakeholders from Inspire Youth Arts. Ethical approval was granted for the workshop from the University of Nottingham Faculty of Computer Science's ethics committee. Care was taken to ensure that participant data was anonymous and only used in accordance with the consent given by each individual. The consent form and information sheets related to this workshop can be found in appendix A.

Participatory design methods were chosen at this early stage of the research as a way of investigating beyond the individual perspective of the researcher and what could be ascertained from existing literature. A participatory design workshop, in particular, offered a way to understand people's needs and how these might differ by work roles, life stage, physical or cognitive conditions, and their relationship to the task (Muller and Druin, 2012).

The goals of the workshop were to explore the different user experience expectations for digital musical instruments and inform the design of a gesture-controlled musical interface to be used in the upcoming field study with the Able Orchestra. Activities were designed to identify the aspects of DMIs that the facilitators and project coordinators found challenging. Questions were also posed to ascertain the potential application of embodied gestures as a method for interacting with music, in addition to the technologies already used. This approach allowed for a joint exploration of the problem and possible solutions for accessibility in digital musical instruments and, more specifically, in gesture controllers. The workshop lasted for two hours, and data was gathered through individual questionnaires, open group discussions, group sorting activities for design criteria, and an open design activity. The output from the workshop was a mix of qualitative and quantitative data consisting of a two-hour video log of the workshop, images of the final results for the sorting activity, and seven questionnaires as completed by the participants. Post-workshop, the data was reviewed for common themes within the discussions and any commonalities between the participants' survey responses. The collective choices of the group in the design criteria sorting activity were also analysed. Further discussion of the analysis and findings can be found in Chapter 4.

Taking a participatory approach in this workshop was particularly beneficial as it provided an opportunity for the researcher to build empathy with the challenges of the stakeholders in the research partnership before engaging with their project. Additionally, the collaborative activities between stakeholders and researchers from the Mixed Reality Laboratory helped to introduce new perspectives and set expectations.

While the workshop benefited from the diversity of backgrounds held by the participants, none of the participants were disabled. Therefore, they could not speak to the lived experiences of disabled musicians. This limitation was noted by the researcher and was an important influence upon methodological choices going forward in the research.

3.4.2 The Able Orchestra project

Following the participatory design workshop, a field study was conducted with the Able Orchestra community music project. In this project, managed by Inspire Youth Arts, young people with complex disabilities engaged with technology to create and perform music using digital musical instruments. This presented an opportunity to investigate the everyday music-making practices of disabled performers and how digital musical instruments and other technologies are used within them. The full details of the field study, and the outcomes from it, are discussed in chapter 4.

As the participants of this study fall within a group classified as "vulnerable", care was taken when designing the research to consider ethical issues such as exploitation, reinforcement of stereotypes, and the potential to cause distress (Savin-Baden and Howell Major, 2012).

Ethical approval was granted for the field study from the University of Nottingham Faculty of Computer Science's ethics committee. Care was taken to ensure that participants and their parents were fully informed of the research involvement, data was anonymised, and videos/photographs were collected in strict accordance with safeguarding policies and only used in circumstances for which consent was given. The consent forms and information sheets related to the Able Orchestra field study can be found in appendix A.

Fieldwork was selected as a research method that would help to provide a contextual understanding of disabled performers' uses of digital musical instruments through being able to observe and participate in the activities of the Able Orchestra project. Being present in this way meant a rich descriptive background for the research could be established. This approach at first followed the naturalism model of qualitative research in terms of focusing on the factual characteristics of what happens inside a project, such as the Able Orchestra.

As described by Silverman (2013), the process was built around tasks often found in a naturalistic ethnographic research approach, entering the setting, establishing rapport, recording observations, and presenting the findings. However, early in the project, this approach needed to change as a true ethnographic stance could not be adopted (Crabtree et al., 2012).

There were several factors that influenced this change in approach. Firstly, the expectations of the project facilitators were not set on the researcher being in a purely observational role. In a project where the facilitators are facing many time constraints, there was an expectation that another person's presence would result in extra help towards setting up and running activities. While this could have been better established at the beginning of the project, there was a secondary challenge of introducing a technology probe that was developed in response to the participatory design workshop. This meant it was somewhat difficult to create a boundary between setting up and facilitating the use of the technology probe for research, and being an active participant/facilitator in the other project activities. Finally, the pre-existing knowledge that the researcher holds in music technology and audio engineering resulted in being in a position where it was difficult for the other project facilitators to approach the researcher's presence as being 'part of the furniture' of the project (Silverman, 2013). The flexibility of the chosen methodology of action research was important here as this allowed the researcher to adopt a more participatory "hands-on" role within the project.

Fieldwork with the Able Orchestra project commenced in February 2016 with five days of music workshops, followed by three performances in February, May, and July 2016. In preparation for each of the performances, some rehearsals were held to re-engage the participants with the digital musical instrument technologies and adapt the performance piece accordingly. While true ethnographic practices were not applied in this project, techniques for data collection were borrowed from this methodological approach. This includes the use of field notes, along with taking video footage and photographs during sessions as a means of documenting challenges and better understanding the real-world user experience. Furthermore, conducting naturalistic interviews with the facilitators of the community project helped to gain perspectives of the interactions from those who best knew and understood the participants. These were designed to be semi-structured recorded conversations to allow for open discussion from the facilitator's viewpoint.

These naturalistic semi-structured interviews with facilitators often took place during observations, which had the benefit of being able to discuss any points of interest as they occurred. Though this also meant the interviews were both informal and limited by the time constraints of the activity being observed. This was a common limitation of being an active participant-observer throughout the project, as it was not always possible to capture the subtleties of each interaction that was of interest to the research. Data collection was therefore contingent upon what could be collected around the responsibilities of facilitation. How data was collected was also impacted by the project activities and schedule, as data needed to be collected via methods that would be the least disruptive to the project goals. Similarly, because of these project limitations, there was an inability to repeat actions or review activities with a participant due to time constraints.

The goal of adopting fieldwork as a method was to achieve a contextual understanding of what impacts the accessibility of digital musical instruments. However, it was noted by the researcher that this approach lacked repeatability, even in circumstances where the environment and participant group remain constant.

A second method that was employed for this particular project was the use of a technology probe. The technologies in use before this research intervention were primarily iPads and touch-based MIDI control surfaces. The technology probe enabled the use of gesture as a method for controlling digital musical instruments, which was an interaction modality that was not currently used in this project. The use of a technology probe was intended to explore whether a gesture controller would provide a more accessible user experience for the participants. Technology probes are often used in this manner to present new and novel interfaces or interactions to people (Hutchinson et al., 2003). It was considered to be particularly important in this study to present a technology probe that used gesture as a medium for interaction to explore whether specific paradigms or interaction methods afford better accessibility.

The combination of observational field notes, videos, photographs, and facilitator interviews provided a rich data set with which it was possible to describe and contextualise the everyday experiences of disabled performers within community music projects such as this one. Although this data only speaks to the experiences of young disabled people under the age of 19, who are non-professional musicians and novice users of digital musical instruments. Once collected, the data was coded using open and axial encoding (Allen, 2017) and then analysed using thematic analysis as a means of providing insight across the data set. Thematic analysis was chosen to identify commonalities in the experiences documented and subsequently identify which of these commonalities are meaningful and important to the research (Braun and Clarke, 2006). The output of this analysis, as seen in Chapter 4, helped to describe the challenges for designing accessible digital musical instruments. However, it was observed that further focused research was needed to fully understand the needs of individuals and the possible criteria for designing accessible digital musical instruments. This observation played an important role in shaping the methodology for the research going forward.

3.5 Understanding individual experiences

This section discusses the second "acting" stage of the action research cycle as outlined by Figure 3.2. Rationale and research activities are summarised, along with the chosen methods. Details are given for approaches to data collection, ethical considerations, and post-activity data analysis.

The second stage of the research aimed to understand the challenges faced by individuals. On reflection of the fieldwork with the Able Orchestra project, it was observed that there was a need to observe similar activities where research was the primary focus. This would allow for further exploration of the technology and present an opportunity for the researcher to shape the activities to meet the research objectives. In consultation with the research partner, a study was designed in which the researcher would lead music-based activity workshops that mimicked the Able Orchestra project workshops but without the extended time constraints and pressures of working toward a public performance. These workshops became known as the "Able Lite"[3] workshops.

3.5.1 Able Lite workshops

A total of six Able Lite workshops were held over three days in March and April 2018 at a SEND school in the Nottinghamshire area. Each workshop was scheduled over three hours which included one hour of setup and a thirty-minute break. During the workshops, participants were introduced to different digital musical instruments and given time to explore, create, and play music together with the other participants. The workshops were delivered by the researcher, supported by one external facilitator. Participants were young disabled students between the ages of nine to nineteen, and the workshops were offered as an extracurricular activity during the school day.

[3]The title for these workshops is a wordplay on Ableton Live Lite which is the 'lightweight' free version of a DAW technology called Ableton Live that is used within the Able Orchestra project

As with the first research study, this participant group was classified as “vulnerable” and care was taken in designing the research workshops to ensure that the participants were sufficiently safeguarded against common issues when working with vulnerable people. Ethical approval was granted for the workshops from the University of Nottingham Faculty of Computer Science’s ethics committee. Participants and their parents were fully informed of the research involvement, data was made anonymous, and videos/photographs were collected in strict accordance with safeguarding policies and only used in circumstances for which consent was given. The consent forms and information sheets related to the Able Lite workshops can be found in appendix B.

A workshop plan with activities designed to be flexible around the abilities of the participant group was created prior to the research engagement, and this can be found in appendix B. The digital musical instruments selected for the workshops were grouped into four categories based on their interaction method. The four categories used were tangible, gesture, virtual, and wearable. Throughout the workshop, participants were given the opportunity to interact with different digital musical instruments that were best suited to their abilities. The sessions were designed to allow for points where the participants and their facilitators could provide feedback on the experience.

A contextual inquiry was a prominent method that informed the design of the Able Lite workshops, as to truly understand the requirements for designing accessible digital musical instruments, it was necessary to conduct an active inquiry (Holtzblatt and Beyer, 2014) into how they are used by disabled performers. In the context of the Able Lite workshops, the “work-practice” is centred on learning, playing, and performing with digital musical instruments. While working with digital musical instruments was not necessarily a daily work-practice of the participants, the workshops were designed to understand who the participants are and how they interact with technology in a way where the researcher could lead activities and inquire into the participants’ actions as they occurred. Understanding the participants' work practice and setting in this manner was extremely important for this research. It is known that useful design data can often be hidden in everyday details; therefore, using this method could help discover best practices for designing accessible digital musical instruments that would be both accepted and valued.

Following a cycle of inquiry and reflection centred in action research was beneficial throughout this stage of the research process. Action research, in particular, has been found to be effective in similar research where the goals are aligned with bringing about change, improving participant outcomes, and enabling empowerment (Manfra, 2019).

Similarly, the exploration of the interaction experience for disabled performers as part of this research aligns with addressing inequity and social injustice, which often forms the basis of participatory action research. While it cannot be said that each of the central tenets of this methodology can be found within this research, the social practices of participatory action research were influential in designing the Able Lite workshops. Involving the stakeholders from the research partnership in framing the research problem, involving community members in conducting the study, and practicing reflexivity (Benjamin-Thomas et al., 2018) are a few of the participatory action research practices that were applied.

Adhering to these practices required being flexible, ensuring that each stakeholder involved in the Able Lite project was accommodated and that planned research activities were not disruptive to the ongoing work of both the research partner, community facilitators, and participating SEND schools. This considered approach resulted in a longer timeline than initially anticipated, with workshops being first discussed and planned in consultation with the research partner in October 2017 and execution of the workshops taking place between March and April 2018.

Data collected during the workshops included field notes, images, and video footage of the workshops. Post-workshop, this data was used for comparative analysis against the findings from the previous study with the Able Orchestra. Any new emergent issues related to the accessibility of the technologies used within the workshops were also noted in the analysis process. The full discussion of the post-workshop analysis and findings can be found in Chapter 5.

3.6 Proposing a framework for evaluating Digital Musical Instruments

This section discusses the second "development" stage of the action research cycle as outlined in Figure 3.2. It provides a summary of the rationale in choosing a framework for presenting the research outcomes, along with the processes for its development.

3.6.1 Why a framework?

Proposing a framework for evaluating the accessibility of digital musical instruments was considered the best method for sharing the research outcomes in a way that they could be easily understood across the digital musical instrument industry and communities that share an interest in the accessibility of digital musical instruments. Particularly, a framework allows for the flexibility of revision and can be considered a living document, open to discussion, reflection, and critique. This is most appropriate for documentation regarding technology, where contemporary information often creates the need for updating prior documented knowledge. Choosing an evaluation framework, in particular, helps to outline the key findings from the research for the ways in which DMIs can be evaluated for accessibility. Such a framework enables multiple stakeholders to gain a shared understanding of the problem space, process for evaluation, and ways to identify potential improvements for accessibility.

3.6.2 Reviewing existing documentation

Reviewing existing documentation helped to position what is already known about the accessibility of digital musical instruments, as well as identify current best practices. Documents reviewed included technology frameworks, guidelines, technical standards and specifications, reports, and product/performance reviews.

Contemporary papers about accessible digital musical instruments were also reviewed. As acknowledged in Chapter 2, much of the literature produced on accessible digital musical instruments comes from the field of music therapy. As such, the ways in which ADMIs are evaluated in this context largely focused on the therapeutic and medical outcomes an instrument can provide. While this can be a valuable source of reference, this is not the primary concern of this research. Therefore more weight has been given to the studies of contemporary academics who have discussed ADMIs in the broader context of usability and in line with the social model of disability.

3.6.3 Use of action research principles

For this research, it was of both ethical and moral importance to ensure the lived experiences and opinions of disabled musicians remained the primary focus. Care was taken throughout the development of the FAME framework to consider all stages of the action research cycle as proposed in Figure 3.2.

The findings of the Able Orchestra and Able Lite workshops were particularly valuable in providing context for the use of ADMIs in practice. Additionally, staying an active member of the disabled music-making community throughout the development of the framework was crucial in ensuring that any recommendations made reflected the experiences of the community. Disabled musicians were considered as co-researchers throughout this process, meaning that each person's ideas were considered equally significant in creating categories for evaluating the accessibility of DMIs.

Critically it must be noted that while this attitude of co-research was employed, two-way communication of ideas was not always possible during the full research period. Especially outside of the practical engagements with the community. As a result, it is acknowledged that the framework developed within this research period is a document that acts as a support for ongoing discussion among collaborators, rather than a final conclusion of fact (Winter, 1996). Employing core action research principles such as reflexive critique ensure that, what Winter (1996) describes as

> *"the interpretations, biases, assumptions and concerns upon which judgments are made"*

were addressed during the development of the framework.

3.7 Summary

This chapter provides a description and rationale for the methodological choices made within this research, including the approach to use action research as the core methodology throughout the research process. It outlines the three stages of the research process and how the two studies that were conducted during the research period sit within these. It also acknowledges the critical considerations for the ethical and practical challenges of engaging in a research partnership and working with a 'vulnerable' population. Finally, it identifies some of the limitations to the data gathering techniques and how the research was designed to be flexible around these.

In addition to this chapter detailing the approach, chapters 4 and 5 more fully explore the data gathering techniques and tools used for each study. The following chapter, Chapter 4, provides the full details for the Able Orchestra study, including the use of a gestural technology probe created to be used within the project. Chapter 5 outlines the details of the Able Lite workshops and how they were designed to explore DMI evaluation in inclusive music settings.

Chapter 4

The Able Orchestra Project

This chapter introduces the first study of this Ph.D. research with the Able Orchestra, a community music project managed by Inspire Youth Arts. It discusses the ethical considerations, details of the study, including participants and technology used, and the research observations from the data collected.

4.1 Introduction

The Able Orchestra project (Orchestras Live, 2022), as introduced in Chapter 3, is a community music project in which disabled young people use technology to create and perform music with a live orchestra and other professional musicians. The project was started by Inspire Youth Arts (formerly County Youth Arts) as an action research project for the organisation in 2013 (MEHEM, 2021). In 2015 the project grew to include Orchestras Live, who partnered with Inspire Youth Arts to produce the first orchestral collaboration between the Able Orchestra and the BBC Concert orchestra. Since 2015 the Able Orchestra has become an annual project with multiple live performances occurring each year. The project goal each year is to build a creative ensemble that includes local Special Educational Needs and Disability (SEND) schools, public school communities, professional orchestral groups, and contemporary artists.

The project workshops are held during school hours, usually over a period of a few weeks. The technologies used before research intervention were primarily iPads and touch-based MIDI control surfaces. The focus of research involvement was to understand the difficulties for disabled performers when using Digital Musical Instruments (DMIs). In addition to this, a gesture-controlled DMI was introduced to the project as a "technology probe" to investigate the possible uses of gesture as a way for disabled performers to interact with DMIs.

Research with the Able Orchestra began in February 2016, and the collaboration continued until February 2017. This period covered one iteration of the project in full, which included attending workshop sessions, rehearsals, and a number of performances. The most notable performance was at the BBC Proms in the summer of 2016 (BBC, 2016). A detailed timeline of the research activities can be found in Table 4.1.

Date	Activity	Description	Participants	Data Collected
February 8 - 12 2016	Able Orchestra Workshop Sessions	Five days of collaborative workshop sessions within a SEND school setting focused on the BBC Ten Pieces initiative.	9 disabled performers, 4 facilitators from Inspire Youth Arts, 6 SEND facilitators	Field notes, Video footage, Images, Audio recordings of interviews with facilitators
February 23 2016	Live Performance at the Royal Concert Hall Nottingham	A live performance as part of the Inspire Youth Arts Showcase event	9 disabled performers, 4 on-stage facilitators	Images
May 9 2016	Live Performance at Mansfield Palace Theatre	Collaborative live performance with the Hallé Orchestra and students from Outwood Academy Portland	12 disabled performers, 7 facilitators, 16 school orchestra members, 2 music teachers, 15 members of the Hallé orchestra	Video footage, Images
July 23 - 24 2016	Live Performances in Prom 10 and Prom 12 of the BBC Proms at the Royal Albert Hall London	Collaborative live performances with the BBC Philharmonic Orchestra, Members of the Hallé Orchestra, and students from Outwood Academy Portland	12 disabled performers, 6 on-stage facilitators, 14 school orchestra members, 2 members of the Hallé Orchestra, Full BBC Symphony Orchestra	Video footage, Field notes, Images, Video footage of interviews with participants and facilitators

Table 4.1: Able Orchestra Study: Research Activity

4.2 Ethics and data collection

4.2.1 Ethics and consent

Ethical considerations were made regarding the research partnership ahead of the engagement, as observed in Chapter 3. The core ethical issues to be considered for the Able Orchestra project were obtaining informed consent from the participants, safeguarding queries related to working with young people under the age of 18 years old, and various structural and environmental challenges of working within a SEND school setting. Each of these issues was acknowledged and presented to the School of Computer Science research ethics committee for consideration prior to the project commencement.

Consent for this research was gained through the Inspire Youth Arts parental consent forms. An insert was added to each of these forms explaining the research involvement with the Able Orchestra project, which provided the opportunity for research consent to be given. Consent was obtained from eleven of the disabled performers involved in the project and from two of the classroom facilitators with whom interviews were conducted. A DBS (Disclosure and Barring Service) check was carried out on the researcher (previously known as a CRB or Criminal Records Bureau check) for safeguarding purposes, and to meet the legal requirements for working with children under the age of 18 in the United Kingdom.

Copies of the information sheets and consent forms for this research period can be found in Appendix A.

4.2.2 Data collection

Various methods were used for data collection throughout this project. Video and audio recordings were the primary sources of data for the workshops and performances. This was necessary due to the researcher's active engagement in the sessions and them being viewed as an additional facilitator within the project. This active participation was beneficial to understanding the contextual problems, but it limited the availability of additional data collection methods throughout the project. Therefore supplementary data types such as field notes were only collected when there was availability to do so.

During the workshop sessions held in February 2016, a total of twelve videos were captured, transcribed, and analysed. Additionally, two audio recordings of interviews with classroom facilitators were captured, transcribed, and analysed. Field notes were taken for each of the workshop days and during one rehearsal prior to the performance in May 2016. Further to this, several videos were collected during the rehearsals and performances for the BBC Proms at the Royal Albert Hall in July 2016.

The data collected from each activity was analysed post engagement using thematic analysis, the process of analysis and results are discussed in section 4.7.

4.3 Participatory design workshop

4.3.1 Workshop aims

A participatory design workshop was held on January 12 2016, to identify potential uses for gesture sensing technologies within the Able Orchestra project. Initial research and reviews of literature had identified that gesture sensing technologies had high potential for therapeutic musical interventions for disabled people (Crowe and Rio, 2004; Magee et al., 2011). Positive responses to the Soundbeam (The Soundbeam Project Ltd., 2022) in particular opened up questions as to whether more complex gesture sensing devices could improve options for accessibility and musical expression.

The goal of the workshop was to understand three key points:

- Are gesture controllers currently used within the project and, if so, how?
- Could gesture controllers provide greater access to the Able Orchestra participants?
- What would form an ideal gesture controller for the context of accessible music performance?

4.3.2 Workshop participants

The design workshop was attended by seven people, including researchers and stakeholders from the Able Orchestra project. The attendees were asked to disclose information about themselves, including age, gender, occupation, and their own experience with musical instruments. As part of the research consent process, participants were asked to confirm if this personal information could be used within the research, and all seven participants consented. Copies of the information sheet for the workshop and consent forms given to participants can be found in Appendix A.

From the information provided, the following is known about the participant group:

- Five participants identified as male, and two participants identified as female.
- The age range of participants was between 25 and 52 years old.
- Four of the participants were researchers, and three worked within Inspire Youth Arts.
- Six out of seven participants had some experience with acoustic musical instruments.
- The musical experience of participants ranged from 2 years to 40 years.

4.3.3 Workshop activities

The workshop schedule included an individual questionnaire for each participant to complete, an open discussion of the group's responses to this questionnaire, a demonstration of a possible gesture controller for use with DMIs, a hierarchical card sorting activity, and an open design activity.

The goal of these activities was to understand the participants' individual associations between sounds, music, and gesture. Then explore in group discussion whether any consensus existed amongst the participants on how sound and gesture should be linked.

Starting the workshop with the questionnaire activity was intentional so that individual responses could be captured before they were influenced by any group discussion. The questionnaire consisted of eight questions about controlling sound with movement, including questions related to feedback mechanisms and the possible relationships between certain gestures and sounds. A copy of this questionnaire can be found in Appendix A.

For the card sorting activity, the group was provided with a total of 27 cards containing statements about potential features of a fictional digital musical instrument. The group collectively had to classify which statements they would assign to the following groups:

- Core: essential or required for the instrument to function
- Expected: not essential to functionality but expected based on interactions with other instruments
- Desirable: not essential to functionality but considered to be nice additions to the instrument

The results from this activity can be found in Appendix A.

Finally, for the open design activity, each participant was given a blank piece of paper and pens. The task required the participants to sketch out or describe what an ideal gesture control might feature for this context. For guidance, some examples of current gesture sensing technologies were given at the beginning of the 30-minute activity, but the instruction was extremely open to the participants' own interpretations.

4.3.4 Data collection and analysis

The resulting data collected from the participatory design workshop included:

- Seven written questionnaires
- Two hours of video footage of the workshop
- Images of the results from the hierarchical card sorting activity

The responses from the questionnaire and card sorting activities were collated into a database for comparison. The video footage was transcribed and analysed for common themes in the group discussions, along with any notable points of disagreement or consensus.

4.3.5 Workshop findings

4.3.5.1 Importance of visual feedback

The participants were split on the importance of visual feedback when using movements to control sound output. Three participants felt that visual feedback was important to help a person understand aspects of the control mechanism, such as the amount of control used/needed or understanding the effects of their own actions. One participant felt that visual feedback could provide additional information that sound feedback could not.

One participant commented that the need for visual feedback is dependent on the context and that it had the potential to provide supporting feedback to audio output. The three remaining participants felt that visual feedback was not important, auditory feedback was enough, and in some cases may create a better understanding of what the controller is affecting if sound is the only output.

Later in the card sorting activity, the group assigned cards relating to visual feedback outside of the 'core' group. Card 24 "User can see a visual response to their movement" was assigned to the 'expected' category, and card 23 "Area that sensor can 'see' is made visual to user" was assigned to the 'desirable' category. This reflects that as a group, there was some consensus that this feature of visual feedback might be expected or desired but is not essential to the functionality of a gesture-controlled DMI.

The split verdict on the importance of visual feedback influenced the decision not to make this a focal point of the technology probe design going forward into the Able Orchestra workshop sessions. This allowed for other features and functionality to be made a higher priority in the limited time for additional development between the participatory design workshop in January 2016 and the Able Orchestra workshop sessions in February 2016.

4.3.5.2 Gesture sensing and involuntary movements

Involuntary movement and the ability to have prolonged control of one's movement was a subject of discussion amongst the participants when considering gesture as a control mechanism. In the individual questionnaires, this issue was highlighted by three of the participants when asked about whether the speed of movement should impact the resulting sound output. Collectively they stated that consistent control or altering the speed of movement might be difficult depending on a person's disability. One participant suggested that perhaps this could be a feature that could be switched off for those who could not easily control their movements in this manner.

Despite this, the general consensus was that speed of movement should have an impact on the resulting sound output, with the majority of participants feeling that this would aid expressiveness in a musical performance.

4.3.5.3 Tailoring interactions for individuals with different abilities

The possible solutions to the barriers that might arise from a person having involuntary or limited movement were focused largely on providing a tailored control/interface. This exact suggestion was offered by a participant during the group discussion of the questionnaire, commenting that a solution would almost *need* to be tailored. Later in the discussion, the concept of tailoring was reiterated as an ideal to aim for by another participant who stated:

> *"it is about collaboration with the person you are working with and what their movement vocabulary is and tailoring it around that to make it work for them and the piece of work that they are trying to create. That's the key thing I think - if we were able to do that, it would be great."*

This concept of being able to reflect and cater to a range of abilities through one interface was of particular interest to the participants who were stakeholders within the Able Orchestra project. This was influenced by their experiences of the previous iterations of the project and their work with young disabled musicians. Tailoring, in particular, was quoted as something that:

> *"allows lots of people to be involved in one piece because they all work at different levels. So some people with more, you know, less of a disability, or certain aspects could actually manipulate more of it but somebody with less could still contribute, but in their own way. So it's having something that can reflect a range of abilities and disabilities, isn't it?"*

As this received a lot of attention during the participatory workshop discussions, finding a way of tailoring or adapting the gesture-controlled technology probe was prioritised in the next stages of development. Consequently, a rudimentary solution was employed where the range of movements from a person using the controller could be measured at the start of an interaction and used to set some parameters about the minimum and maximum movement that would control the corresponding output.

4.3.5.4 Choosing gestures for musical interactions

Another area that generated a good amount of discussion amongst the workshop participants was the choices one might make for control gestures. One participant acknowledged that there was a bias in their own relationships between movement and sound, commenting that someone with a restricted range of movement may not view specific movements in the same way as them. A case of what feels "natural" to one person may be perceived differently by a disabled person that experiences limited ranges of movement.

The idea of bias was also acknowledged by a second participant who stated:

> *"it's hard to not be constrained by the movement you already know"*

This is a point that has been raised in previous research about musical gestures in DMIs (Bevilacqua et al., 2017), there is an almost universal expectation to pair certain sounds with certain actions. This is particularly common in western music, where mimetic gestures have been used throughout time to make references to certain instruments.

In the discussion of how this might be interpreted within the Able Orchestra project, the participants who were project stakeholders reiterated the challenges of controlling movements and being able to repeat gestures with the same accuracy. They questioned what might happen if a gesture was performed at a different speed or not in exactly the same space or in the same manner as its initial performance.

Considering the conversations held within the workshop, a decision was made to ensure that the control of the technology probe could be simplified to a vertical movement in a single plane. Additionally, this movement would be paired with the ability to scale the output from a tailored range of movement. Together, these features allowed for a controlled movement that was repeatable and did not rely upon the gesture being performed at exactly the same point each time.

4.3.5.5 Outcomes for the Able Orchestra research

Each of the activities and the group discussions provided some additional insight into the potential requirements for a gesture-controlled DMI. Most notably, the prioritisation of features such as visual feedback and tailor-ability influenced the technology choices for the gesture-controlled technology probe that was put into use within the study.

The need to have explicitly clear feedback (in any form) from a gesture-controlled DMI was taken into consideration as a point to observe within the workshop sessions. Including how different types of feedback might be perceived by the Able Orchestra participants. The questions that arose about feedback methods during the participatory design workshop were relative to context. There were concerns that while the relationship between interaction and output might be clear when being used solo by a participant, this relationship might get lost in a collaborative activity, such as a performance in an ensemble. Again the suggestion that there should be multiple ways of receiving feedback was taken into account.

This notion of contextual dependency was also raised during the hierarchical card sorting activity. The workshop participants felt that the desirability of features could be impacted greatly by the context in which a DMI was to be used. A further note was made to observe the changes in usability and accessibility of the DMIs in use throughout the project sessions, taking care to observe each DMI's performance when changing contexts between creating a musical piece, practising with others, and performing on-stage.

4.4 Technology

The DMIs in use within the Able Orchestra project consisted mostly of iPad devices using a number of different applications. These iPad "instruments" were then connected (both wired and wirelessly) to a central computer (MacBook Pro) running a digital audio workstation (DAW) software called Ableton Live (Ableton, 2022). An audio interface was used to output the sound from the DAW to a large speaker so that it could be heard by everyone in the workshop session.

The main application in use on the iPads in the 2016 project was an application called ThumbJam (Sonosaurus, 2017). ThumbJam is a touch-based application that allows a person to choose from a number of preset graphical user interfaces (GUIs) and synthesised instrument voices. ThumbJam also offers control of virtual instruments within the DAW using MIDI (Musical Interface Digital Interface) control data. The application has multiple options for the GUI layout and controls that can be modified, including the ability to assign a specific musical scale or note range. These options for control and customisation make the application popular in settings like the Able Orchestra project, as the same application can be used for a number of disabled performers and adapted to suit their abilities.

In addition to ThumbJam, an app called Bloom (GenerativeMusic.com, 2017) was used during the project for one participant. Bloom is another touch-based application, but it has a much simpler GUI. On launch, it displays only a plain background until a person touches a point on the screen. At the point of touch, a small dot appears, and a corresponding sound is played. The dot then grows, spreading outwards like a ripple, and after a length of time, it fades away. The dot created continues to repeat a cycle of appearing, growing, and disappearing until the screen is manually reset. This occurs every time the screen is touched by a person. The soundscape, length of repetition cycle, and some visual aspects of the display can be customised through changing presets. However, Bloom cannot be adjusted in as many ways as ThumbJam. This application has been noted as being specifically engaging for Autistic people and this, along with the creative freedom offered by the simple GUI, are some of the reasons it was chosen for the Able Orchestra project.

Other technologies previously used within the project prior to research collaboration were hardware-based MIDI control interfaces such as the Novation Launchpad. These controllers work by sending MIDI control messages to the DAW, which links them to a virtual instrument to produce sound output. Hardware devices were less common within the project due to the limitations created of having a fixed interface that could not be customised as easily as an application on an iPad.

4.4.1 Introducing a gesture-controlled technology probe

A gesture controller was introduced to the Able Orchestra workshops as part of the research collaboration. The idea behind introducing gesture as a control mechanism was to use this as a form of "technology probe"(Hutchinson et al., 2003) to explore whether gestural controllers could be used within this context. This was adopted into the workshops and became part of the technology used in the live performances.

The gesture controller technology probe, developed by the researcher and dubbed 'LeapMusic', consisted of a Leap Motion device (Ultraleap, 2022) connected to a MacBook Pro. The data from the Leap Motion was ingested into a Max patch (Cycling74, 2022) [1] via an application called OSCMotion (Senabre, 2015), and the patch outputted MIDI control information that was shared to the

[1] Max is a visual programming language for music and multimedia developed and maintained by San Francisco-based software company Cycling74.

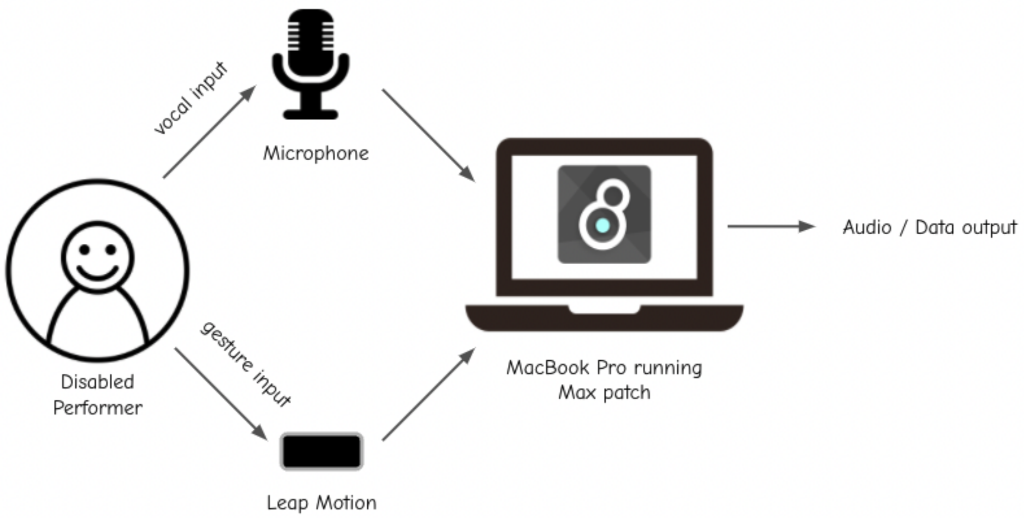

Figure 4.1: *Diagram of the LeapMusic Technology Probe System*

DAW (Ableton Live). The MIDI control information could then be assigned within Ableton Live to control a variety of sound outputs. A representation of this system is shown in Figure 4.1.

The Max patch, as shown in 4.2, offers three modes for controlling audio using the leap motion sensor.

The first mode is a vocoder, which operates by taking a microphone input and uses the data output of the leap motion sensor to select a set of notes that are controlling a vocoder effect on the audio input from the microphone. Figure4.3displays the sub-patch that runs the process for this.

The second mode is pitch selection, which uses the data output of the leap motion sensor to control the pitch of a sine wave output. This could also be used just to send MIDI note values to any object within Max or to any external software accepting MIDI notes as an input. Figure4.4displays the sub-patch that runs the process for the pitch selection.

The third mode is low pass filter mode, which uses the data output of the leap motion sensor to control the cut off frequency of a low pass filter that can be applied to any input source, for example a pre-loaded track or live microphone input. Figure4.5displays the sub-patch that runs the process for the low pass

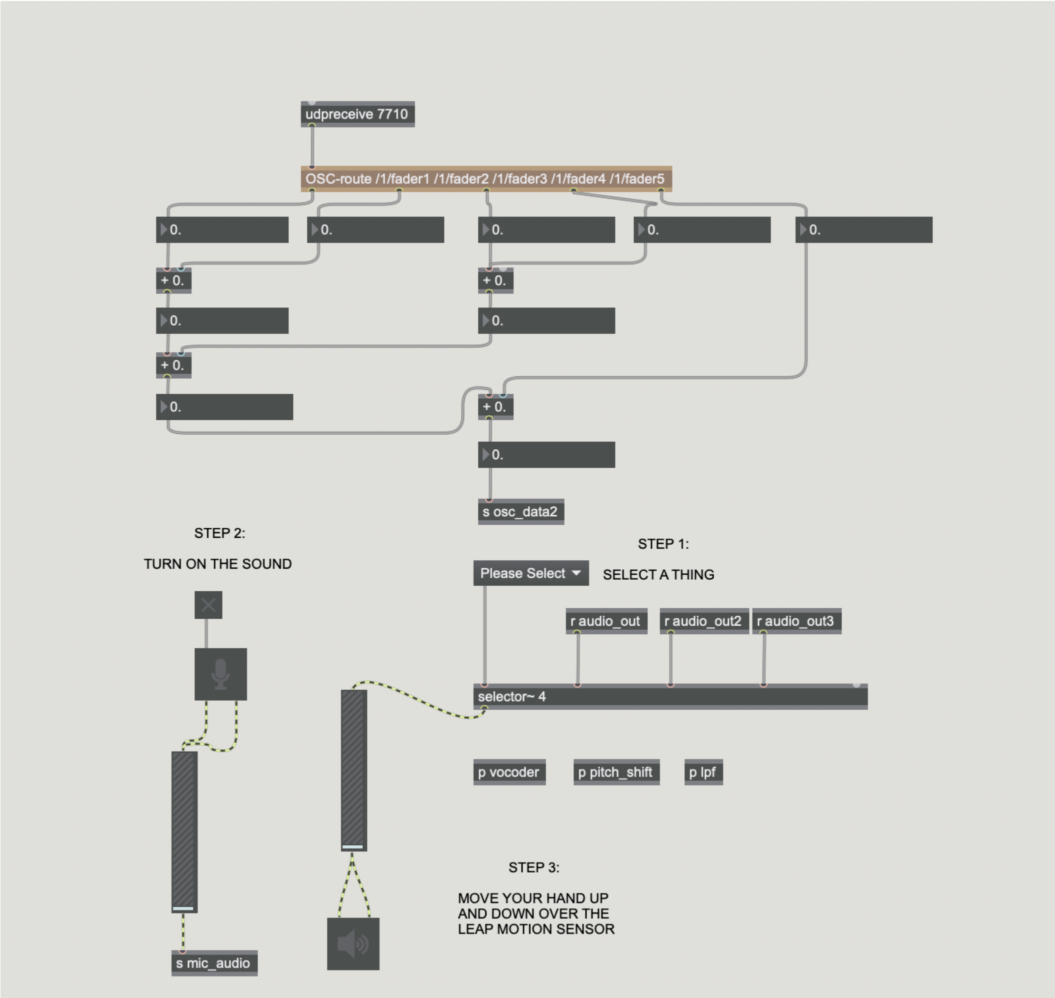

Figure 4.2: *The LeapMusic Max Patch*

filter.

A simplified interface, shown in Figure 4.6was created for people to set up the LeapMusic device. This was a 'presentation view' of the Max patch that provided three instructions: 1. Chose what mode the device would use, 2. Turn on the audio, 3. Move your hand up and down over the leap motion sensor.

During the participatory design workshop, discussed in section 4.3, potential areas to improve the initial prototype gesture control were identified. Throughout the research study, the technology probe was adapted to better suit the needs of the performers interacting with it.

The technology probe was used throughout the Able Orchestra project. Initially it was used by all participants in their exploration of different digital

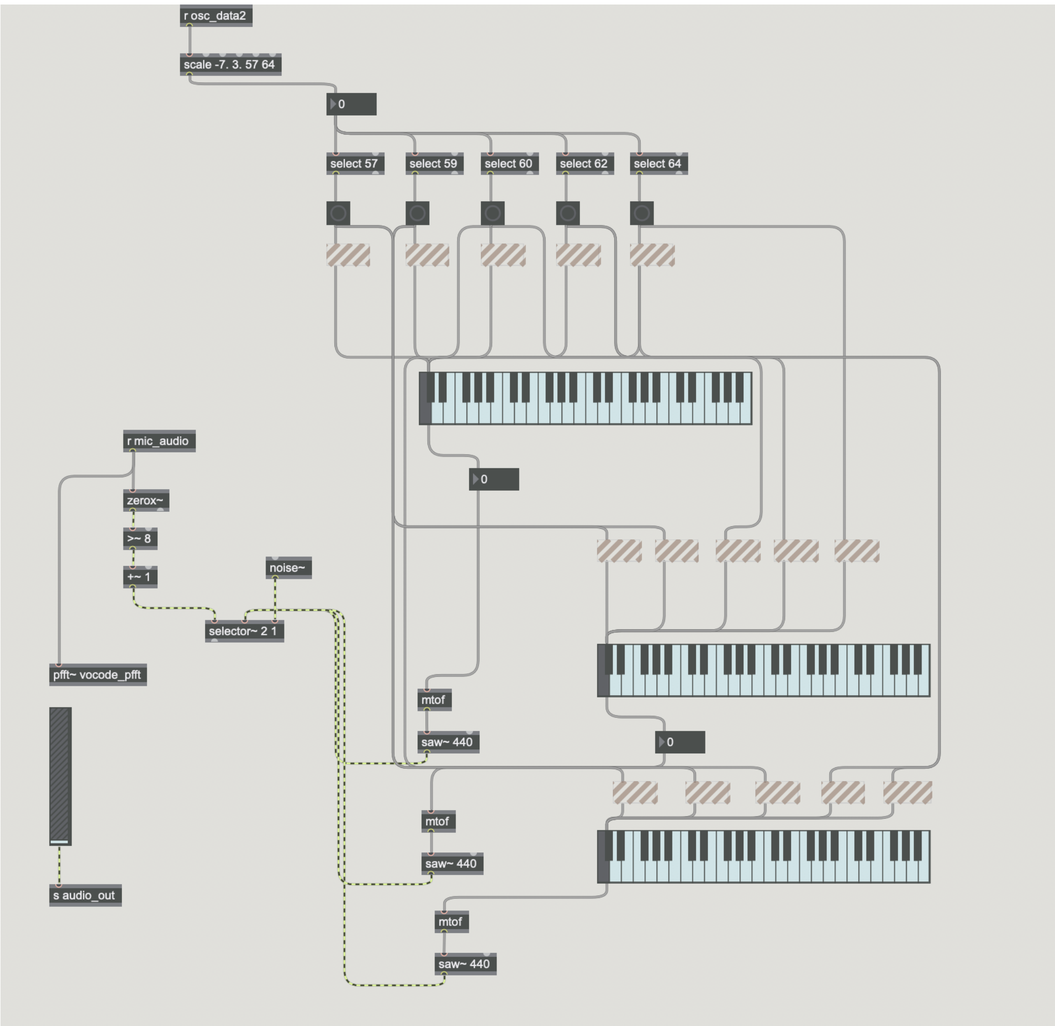

Figure 4.3: *The Vocoder sub-patch from LeapMusic*

musical instruments. It was also used during the creative development to record the voices of the participants through using the vocoder mode. Finally, it was used by one participant in the live performances in the low pass filter mode where the filter was being applied to a selection of tracks within Ableton Live.

4.5 Participants

Eleven out of fourteen participants in the Able Orchestra project in 2016 consented to take part in the research study. The participants were a group of young people (aged nineteen and under) with complex conditions such as Cerebral Palsy, Schizencephaly, Muscular Atrophy, and Muscular Dystrophy. They all attended a local SEND school that was partnered with the Able

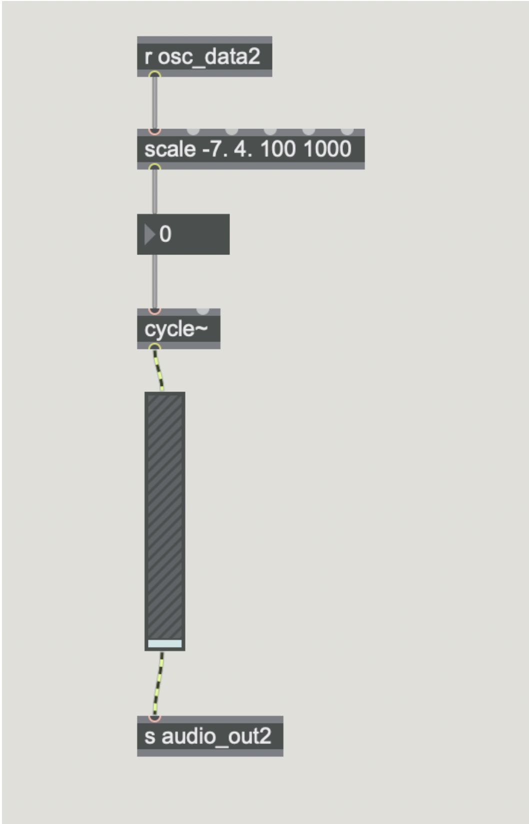

Figure 4.4: *The Pitch Selection sub-patch from LeapMusic*

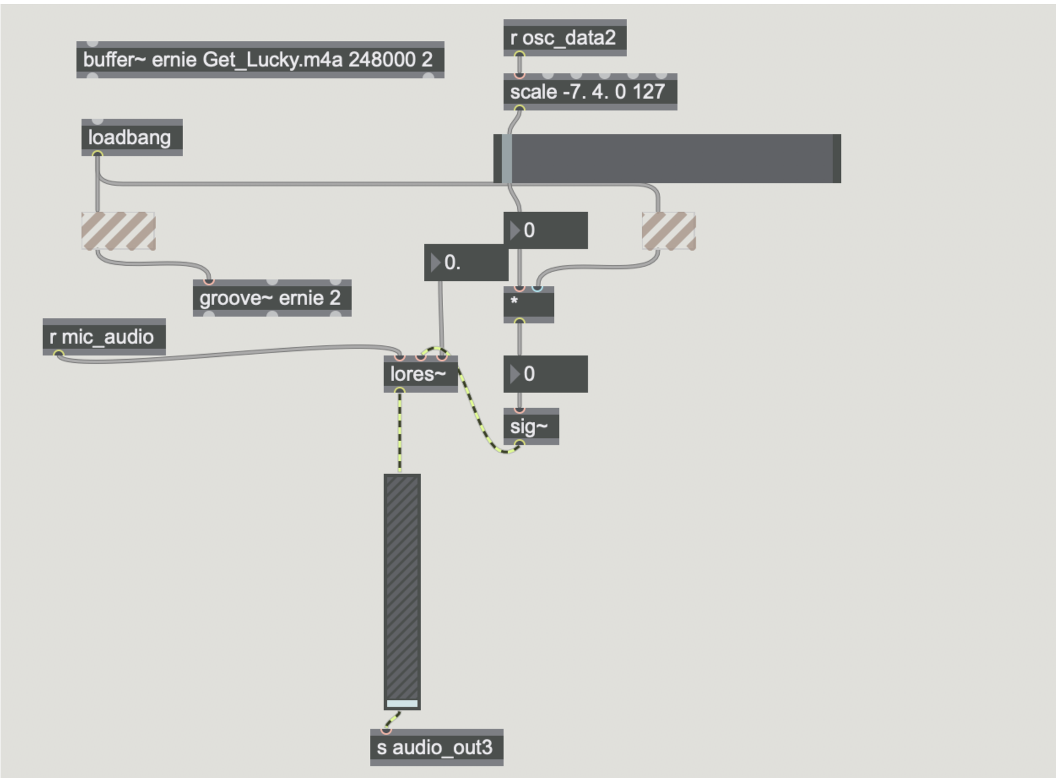

Figure 4.5: *The Low Pass Filter sub-patch from LeapMusic*

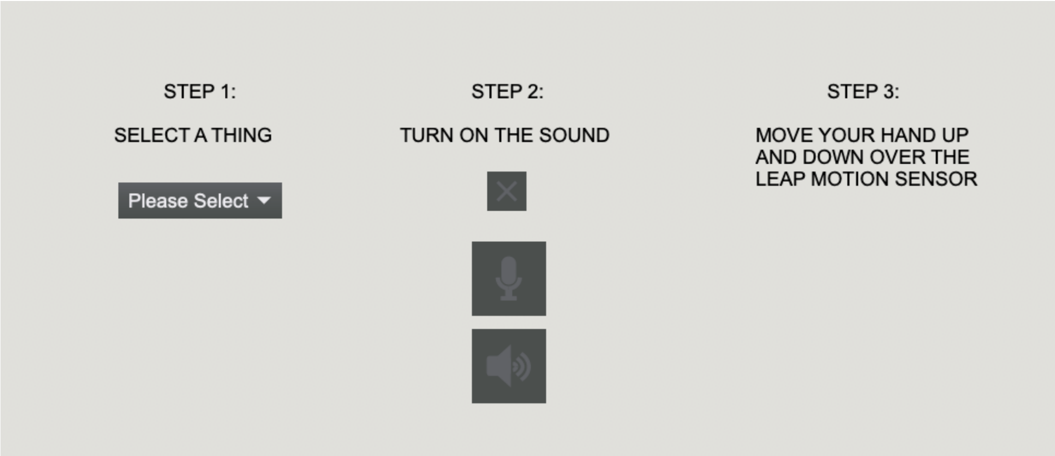

Figure 4.6: *The Simplified User Interface for LeapMusic*

Orchestra project.

Some of the participants had previously taken part in the Able Orchestra project once before. For others, the 2016 workshops and performances were their first experience with a project of this nature. This group of young people had a range of accessibility requirements when interacting with technology. For example, some participants had difficulties interacting with a touch screen due to a lack of fine motor control of arm and hand movements. Other participants struggled more with large movements and preferred to use a touch screen that could be more responsive to smaller hand movements/gestures.

Table 4.2 provides the disability information for each of the participants, along with the DMI they used within the project. Please note the participant names have been replaced with gender-neutral pseudonyms.

Participant	Disability Information	DMI
Alex	Spinal Muscular Atrophy	ThumbJam
Blair	Cerebral Palsy Quadriplegia	ThumbJam
Charlie	Worster-Drought Syndrome, epilepsy, developmental delay including significant communication difficulties and motor coordination difficulties (dyspraxia)	Bloom
Devon	Cerebral Palsy	ThumbJam (using two iPads)
Ellis	Athetoid Cerebral Palsy	Assigned to visual controls
Finley	Duchenne's Muscular Dystrophy	Assigned to visual controls
Gene	Prader Willi	ThumbJam
Harley	Cerebral Palsy	ThumbJam
Indigo	Schizencephaly	ThumbJam
Jesse	Ehlers Danlos	Assigned to visual controls
Kieran	Left-side Hemiplegic Cerebral Palsy	Gesture Controlled Technology Probe

Table 4.2: Able Orchestra Participants: Disability Information

4.6 Able Orchestra sessions and performances

The Able Orchestra project sessions took place between February and July 2016. This section provides details for the sessions that took place during this period.

4.6.1 February 2016 workshop sessions

The goal of the initial workshop sessions held between February 8 and February 12 2016, was to create a piece of music to be performed as part of the BBC Ten Pieces initiative (BBC, 2022), a national project by BBC Teach designed to help teachers engage young people with classical music. Groups across the country were invited to create their own versions of the songs provided on the BBC Ten Pieces website and record their performances of these.

The workshop sessions were held at a local SEND school, each starting at 10:00 and finishing at 15:00. All eleven research participants were present for the workshops. During the workshops, the researcher was required to adopt an active role as a facilitator, assisting the creative team in setup, troubleshooting technical issues, and taking down/packing away equipment at the end of each session.

Table 4.3 outlines the activities that took place on each of the sessions throughout the week.

Workshop Date	Activities
Day 1: February 8 2016	Introduction to facilitators, Explanation of project to participants, Listening to BBC Ten Pieces music, Discussion with participants about Ten Pieces music
Day 2: February 9 2016	Introduction to Technology, Discussion of the potential piece, Experimenting with sounds and selecting sounds for the piece, Creation of visuals, Recording chords and found sounds
Day 3: February 10 2016	Deciding on elements of piece with participants, Gesture technology probe introduced as part of the piece, Testing interfaces with participants to select the best instrument for each individual
Day 4: February 11 2016	Putting together the full piece, Creating solo parts for participants to perform, Practising the full piece together
Day 5: February 12 2016	Completing the arrangement, Practising the full piece, Pairing the audio-visuals with the music, Rehearsing full performance, Technical testing and preparations, Assembly performance

Table 4.3: Able Orchestra Workshops: Session Activities

4.6.2 February 2016 performance at Inspire Youth Arts Showcase event

The first public performance of the Ten Pieces-inspired musical piece took place on February 23 2016 at the Nottingham Royal Concert Hall. Prior to the performance, there was a rehearsal at the SEND school and a technical check at the venue. Table 4.4 contains information on the locations, times, and activities of these sessions.

Session	Time	Activities
Rehearsal at SEND school	13:00 to 15:00	Practice run of piece for the live performance, Check participants are happy with their roles and remind them of all details for performance (times, wardrobe, etc.), Label and prepare all tech ready for transport to venue
Technical check at Royal Concert Hall	17:00 to 19:00	Load into venue, Check stage access and adjust line up, Tech setup and test, On-stage practice session
Performance at Royal Concert Hall	20:00	Live performance on-stage, Management of tech during performance, Assist performers on and off stage, Pack down of technical equipment

Table 4.4: Inspire Youth Arts Showcase: Session Information

4.6.3 March - May 2016 additional sessions

Between March and May, the Able Orchestra and Hallé Orchestra extended their collaboration to include a local school orchestra in the run-up to a much-anticipated performance at the BBC Proms in July 2016. The collaboration required additional composition to incorporate all the performers into a 15-minute performance. This called for additional rehearsal sessions and workshops with the additional school orchestra to create a working performance piece.

Table 4.5 includes the dates and information for these additional sessions. During these sessions, the researcher retained an active role as a facilitator within the project and continued to offer support to the Able Orchestra and creative team from Inspire Youth Arts.

Date	Session Information
March 11 2016	Creative team meeting, Workshop with local school orchestra
March 14 2016	Workshop at SEND school
March 21 2016	Workshop at SEND school, Workshop with local school orchestra
April 18 2016	Workshop at SEND school, Workshop with local school orchestra
April 25 2016	Workshop at SEND school, Joint rehearsal of school orchestra and SEND performers at SEND school

Table 4.5: Able Orchestra: Additional Sessions

4.6.4 May 2016 performance with the Hallé Orchestra

On May 9 2016, a public concert was held to showcase the collaboration between the Hallé, Able, and local school orchestras. This was staged at the Mansfield Palace Theatre in Nottinghamshire. In this performance, the ensemble included twelve disabled performers from the SEND (eleven of whom were participants in the research study), seven facilitators from the Able Orchestra project (including the researcher), seventeen members of the local school orchestra, and fifteen members of the Hallé orchestra.

During the performance, the researcher was in an active facilitation role, providing support to the performer that was using both the gesture-controlled technology probe and ThumbJam on an iPad (Kieran), as well as another participant using the ThumbJam application on an iPad (Blair).

The performance began with an original piece composed by the students of the SEND school. This was followed by two classical pieces by the Hallé (Grieg - Morning from Peer Gynt and Bach - Toccata and Fugue). After which came an original piece performed by the local school orchestra, which again was followed by three classical pieces performed by the Hallé (Debussy - En Bateau, Bizet - Habanera and Toreadors, and Shostakovich - Symphony No. 10). The performance culminated in the original collaborative piece with all performers playing together.

Throughout the duration of these individual performances, every performer and facilitator remained on-stage. This is somewhat unique for showcase performances. This decision was made because of the environment lacking the space to safely and swiftly move each of the performing groups off stage, especially with the consideration of many of the SEND performers using motorised wheelchairs. The environment was mostly accessible to people using wheelchairs but not amply prepared for multiple people using motorised wheelchairs in one performance.

The technical running order of this performance is outlined in Table 4.6.

Time	Activity
13:00	Load In
15:00 - 16:15	Rehearsal of Hallé items
16:15 - 16:30	Hallé Orchestra Break, School Orchestra setup
16:30 - 17:00	Rehearsal of School Orchestra piece
17:15 - 17:30	SEND school performers setup
17:30 - 18:00	Combined rehearsal with all performers
18:00 - 18:30	Rehearsal of SEND performers' piece
19:00 - 20:00	Concert
21:00	Load out

Table 4.6: Performance with the Hallé Orchestra: Technical Run of Show

4.6.5 July 2016 BBC Proms performances

In July 2016, the collaborative performance group, including the Able Orchestra, local school orchestra, and the Hallé, were invited to perform in the BBC Ten Pieces Prom at the Royal Albert Hall in London. This was to include the original collaborative piece between the three performance groups, which was entitled "Supersonic" and based on Prokofiev's concerto for turntables.

The researcher returned to document the experience and take an active facilitation role in supporting participants throughout the process, including on-stage. The Ten Pieces prom was featured twice in the BBC Proms programming, on July 23 and July 24 2016. In the lead-up to this performance, there was a technical rehearsal for the creative team at the Royal Albert Hall, a musical rehearsal for all performers at the SEND school, and a full dress rehearsal at the Royal Albert Hall. The schedule for the rehearsals and performances can be found in Table 4.7.

Date and Time	Activity	Attendees
July 18 2016, 09:30 - 12:30	Tech Rehearsal at Royal Albert Hall	Creative/Technical Team from Inspire Youth Arts (including researcher)
July 20 2016, 10:00 - 15:00	Pre-Proms Rehearsal at SEND school	All performers and facilitators
July 22 2016 10:00 - 13:00	Rehearsals at Royal Albert Hall	All performers and facilitators
July 23 2016 10:00 - 13:00	Performance 1 at Royal Albert Hall	All performers and facilitators
July 24 2016 15:00 - 18:00	Performance 2 at Royal Albert Hall	All performers and facilitators

Table 4.7: BBC Proms: Rehearsal and Performance Schedule

4.7 Initial findings

Following the initial Able Orchestra workshops and the first live performance in February 2016 the data captured was analysed. A thematic analysis was conducted through reviewing images, audio transcripts of recorded interviews with two classroom assistants, video footage, and field notes for any recurring observations or common themes among the data. This led to some initial findings on the use of DMIs in the context of an accessible music program like the Able Orchestra. These findings centered on themes of DMI technology requirements for the context of accessible music-making, facilitators and their roles, and common accessibility barriers.

4.7.1 DMI requirements in the context of accessible music-making

From the very beginning of the workshop sessions with the Able Orchestra, it was evident that there were a number of contextual limitations in place that meant the choice of technology was extremely important when working with DMIs in a program like this.

Firstly there are limitations of the environment, a classroom-style setting in a SEND school. The technical setup for working with a large number of DMIs can require connecting and powering a number of different interfaces. Having access to enough power sockets, space to setup larger equipment, and safe routes for multiple cables, are just a few of the considerations for the preparation of the physical space.

While a SEND school environment affords some positives in the accessibility provisions such as wider doorways, clear pathways in corridors and classrooms, and more power access points, there were still some common issues once the technical setup was in place. These issues were mostly about cables and connectivity. Options to limit the number of cables and use remote/wireless connections to network some of the interfaces faced the barriers of unreliable networks.

Time was a secondary factor that was governed by the context of working within a SEND school. Access prior to sessions to complete any technical setup and check the status of equipment was extremely limited, as was time after sessions to complete the packing away of technical equipment used in the sessions. These limitations resulted in the need for technology being brought into the sessions to have a very quick setup time and simple connectivity options. "Plug-in and play" was the goal for much of the technology in use within the Able Orchestra.

Another requirement for DMIs in this context was the ability to alter the interface to suit a performer's ability. This seemed to be the principal cause for iPads being selected for use within these sessions, as many applications could be altered easily or swapped for a different application when they were not best suited for a performer's ability.

Altering hardware interfaces is more challenging and, most importantly, more time-consuming than customising the GUI on an application. ThumbJam, as the example of the most popular DMI application used within the project, has a number of options for tailoring the GUI, that can be seen in Figure 4.7, and each of these settings can be altered to suit the needs of a performer.

Time restrictions also have an impact on the technology chosen through how long it may take to learn a DMIs interface either for the performer or facilitator who is assisting the performer or setting up the technology. Anything with a steep learning curve or unusual interface for interaction will struggle to be adopted in projects such as these due to the need to move quickly from learning to creating.

This was a particularly interesting consideration for incorporating the

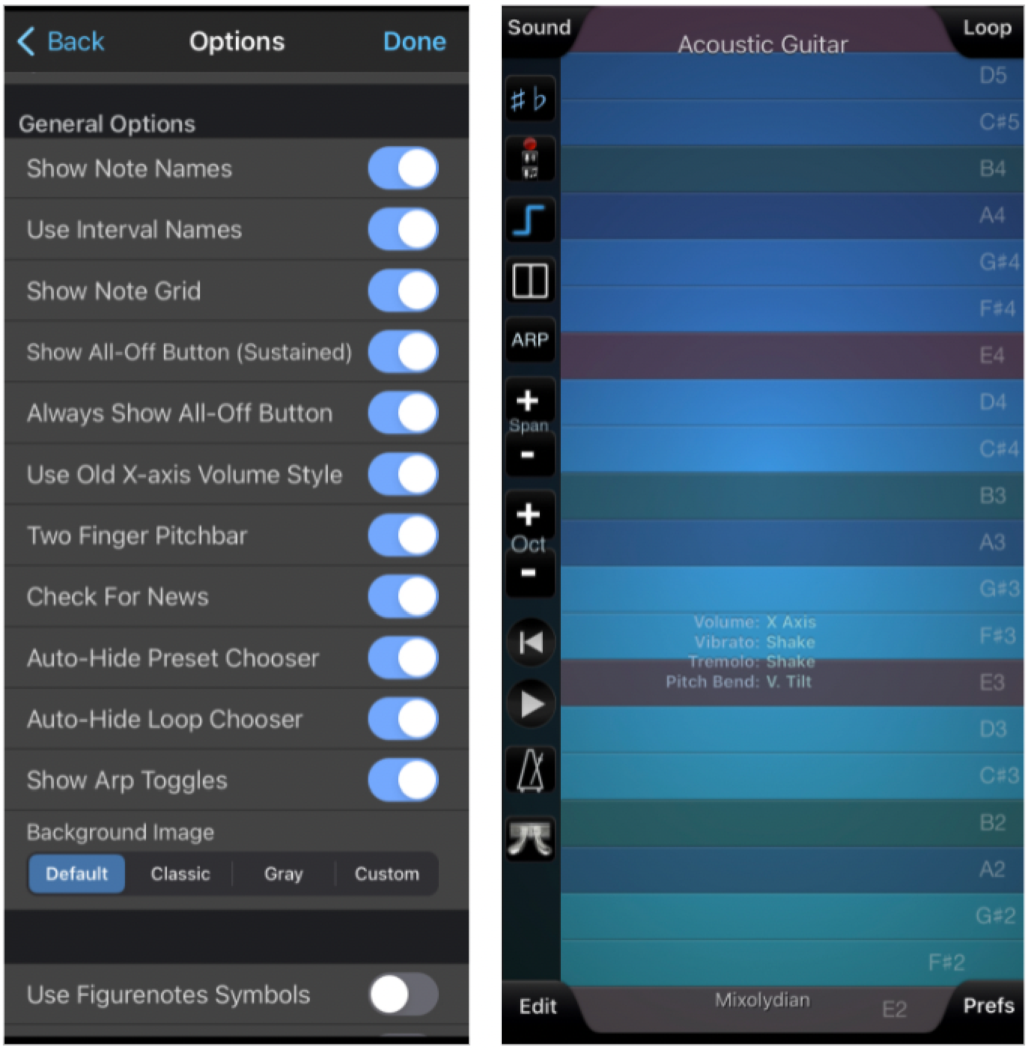

Figure 4.7: *Screenshots of the Thumbjam GUI: Left - the preferences menu showing options for altering the GUI, Right - The default GUI with an Acoustic Guitar instrument selected*

gesture controller technology probe into the Able Orchestra sessions. After experiencing the workshops first hand, a conscious choice was made to keep the interaction simple through capturing motion on the vertical axis only and linking this to an obvious effect upon the sound output to avoid a lengthy period of learning nuanced gestures or controls.

4.7.2 Facilitators and facilitator roles

Another initial observation was that there were many roles adopted by facilitators within the setting. In some interactions, the facilitators would become a conduit to the interaction with technology for the performers. This could be through customising the interface under the performer's direction, being a physical part of the interaction through guiding or supporting the movement, or even becoming a physical 'instrument stand'.

The roles that were observed in the initial sessions included technical support, physical support, interaction support, and musical direction. Figure 4.8 shows some examples of facilitator roles as observed in performances.

Figure 4.8: *Facilitator Roles in Performance: Top - facilitator physically assists participant by supporting his arm while using an iPad, Bottom Left - facilitator prompts participant by mimicking the action she needs to perform, Bottom Right - facilitator provides a musical count in front of the ensemble*

The most important factor for the facilitator in adopting any of these roles was to ensure that, in doing so, there was no removal of agency from the performer. This was extremely well-managed by the Able Orchestra's creative team, who were working alongside the SEND classroom assistants. There was an extremely strong interaction feedback loop between the facilitators and the participants that ensured the focus remained on the participants' creative choices as performers.

4.7.3 Common accessibility barriers

The final theme for the initial observations from the workshop sessions and first performance was around accessibility barriers, which mirrored some of the conversations held in the participatory design workshop.

Feedback mechanisms were particularly challenging for participants during the workshops and performance. This was noted during an interview with one of the classroom assistants when referring to poorly contrasted visual feedback on one of the iPad applications

> *"like the key on the iPads, unless they are looking at it constantly and it goes light blue or red for a second, it's not very easy for them to see."*

Figure 4.9 shows an image of the ThumbJam GUI in use that demonstrates poorly contrasted visual feedback. This reinforced the comments from the participatory design workshop that feedback mechanisms for a DMI need to be clear to the performer, regardless of the form they take.

Similarly, there were some challenges with sound being the only form of perceivable feedback for some performers. Especially during the collaborative parts of the music where the sound could become lost in the ensemble for some performers, and this would break their ability to perceive the cause and effect of their actions. This was particularly challenging for the gesture-controlled technology probe and, at points, a decision was made to make the GUI of the OSCMotion application available to the performers during the sessions. The GUI displayed a representation of the performer's hand movements via coloured dots on a depth grid, see Figure 4.10. This was made available on a laptop screen so that a performer could view when the sensor could 'see' their hand movements.

Figure 4.9: *ThumbJam GUI in use: demonstration of poor contrast, active note under the participants thumb is highlighted by a light blue colour*

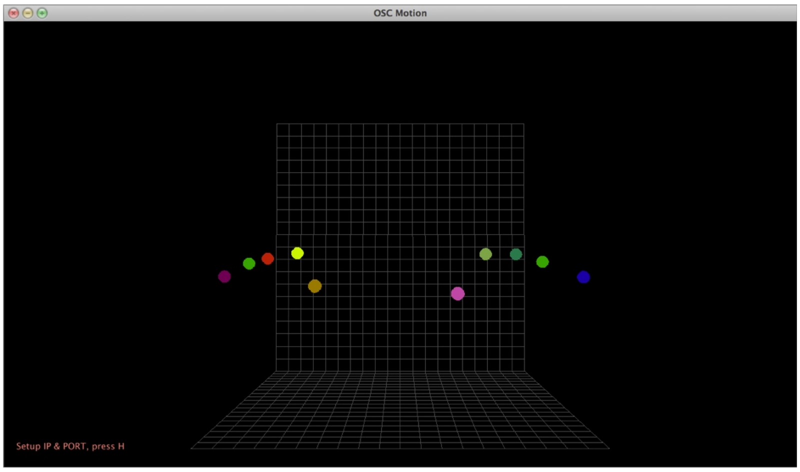

Figure 4.10: *OSCMotion application: screenshot of GUI*

Another feedback issue observed within the sessions and live performances was related to touch. For many of the performers, it was not always possible for them to accurately see a touch target or be able to perceive where on the iPad screen they had touched. This was especially prevalent in changing contexts, for example, from the classroom workshops to the live performance on-stage. Environmental factors like stage lighting and differences in the spatial layout had the ability to introduce more difficulties for a performer.

These were not the only environmental factors that could be perceived as accessibility barriers for the technology and performer. Again, cables and connectivity could be problematic here, for example routing cables in a manner where a performer might knock or pull out the wiring by accident. Sometimes choices were limited as to how this could be achieved.

The need for stands or mounts could also be problematic when working with disabled performers. Often the stands were either not robust enough or did not provide enough flexibility in how they could be arranged around a performer's other assistive devices such as a motorised wheelchair. Often this would result in improvised solutions or workarounds to be able to provide a more comfortable arrangement.

The concept of robustness was another common accessibility barrier. DMIs and all the other technology in use needed to be able to withstand the changing conditions between creative sessions, rehearsals, and performances. This was not just a consideration for the physicality of the devices used but also the battery life they could retain, the length of time they could persist without overheating or becoming unresponsive, and the ability to maintain a strong connection to the other equipment when required. Backup devices were required in order to be prepared for these potential issues and maintain the experience for the performers with limited interruption.

While these initial observations were not novel in terms of what has been observed in similar studies, the extent to which they could impact the adoption of technology was interesting to observe. The challenge in a project like the Able Orchestra is not only to provide an accessible interface that a performer can use, but also to offer a DMI that can perform across contexts with little impact on the experience for the performer.

4.8 Discussion

After the research period was completed, the data from the initial workshop sessions and performances, along with the new data collected during the following rehearsals and performances between February and July 2016, was reviewed. Although the active role of the researcher incurred some limitations on the breadth of data collected, common themes were established that were of high interest to the research project.

Facilitation and the nuanced ways in which facilitators interacted with performers throughout the project was an unexpected but important observation. Coinciding with this were the different ways in which instruments were adapted to meet the needs of an individual performer. Additionally, the strengths and limitations of each DMI used was particularly interesting to this research, especially for understanding the criteria for the adoption of a DMI into projects like the Able Orchestra.

Furthermore, the observations of the technology probe provided some insight into the possible use of gesture as a control mechanism in this context and the challenges that might arise for gesture-controlled DMIs. Finally, the challenges of context-switching added complexity in assessing a DMIs usability within the project. The management of technical information of the DMIs in use between these context switches was also interesting to observe.

4.8.1 Limitations of data collection

As noted, the researcher adopted an active role and was viewed by the creative team as a facilitator/assistant to the project. It should be acknowledged that it was not always possible to collect certain types of data. Live or 'in the moment' field notes were difficult to write because of the requirement to be on hand assisting in interactions. Also, time limitations and space constraints meant that setting up recording devices such as cameras and audio recorders was not always possible for every session.

A pragmatic approach was taken to manage these issues. Field notes were created retrospectively at the end of sessions to capture any notable moments of interest for the research. Recordings of interactions that were identified as useful for the research were captured in an ad hoc manner using a handheld recorder or mobile phone. Additionally, images and videos of the performances (with full image consent) were provided by the Inspire Youth Arts team, which were added to the body of data for review.

4.8.2 Facilitated performance

During the collaboration, the term 'facilitated performance' was adopted by the researcher as a means of describing the contextual setting of the Able Orchestra workshops and live performances. The term is used to describe when a disabled performer is supported by another person in the act of musical performance. Following the review of data, the roles of facilitators in this context was still an ever-present theme.

Upon review, it would appear that the roles of facilitators could be grouped into a set of actions. These actions classified the type of assistance being provided. In the context of the Able Orchestra project, the types of assistance being provided by facilitators could be classified into one of three categories: musical, technical, and physical.

Musical assistance included activities enacted to support a person's musical performance. This could mean tasks such as helping the performer with timing, a crucial element of musical performance. Alternatively, providing musical direction, for example, signaling to an individual performer or conducting performers within an ensemble, as shown in Figure 4.11. Other activities related to music assistance included providing assistance with creative choices like instrument sounds, providing reminders of melodies and sections, and helping a performer with scoring or notating their parts.

Figure 4.11: *Musical Facilitation: A facilitator uses a sign to inform the ensemble of the change to musical section during a performance*

Technical assistance relates to all the activities for providing access to a technology/DMI, for example, setting up equipment, adapting the GUI or other elements of a DMI to better suit the performer, and working with the performers to route cables and manipulate stands for comfort when performing, as shown in Figure 4.12.

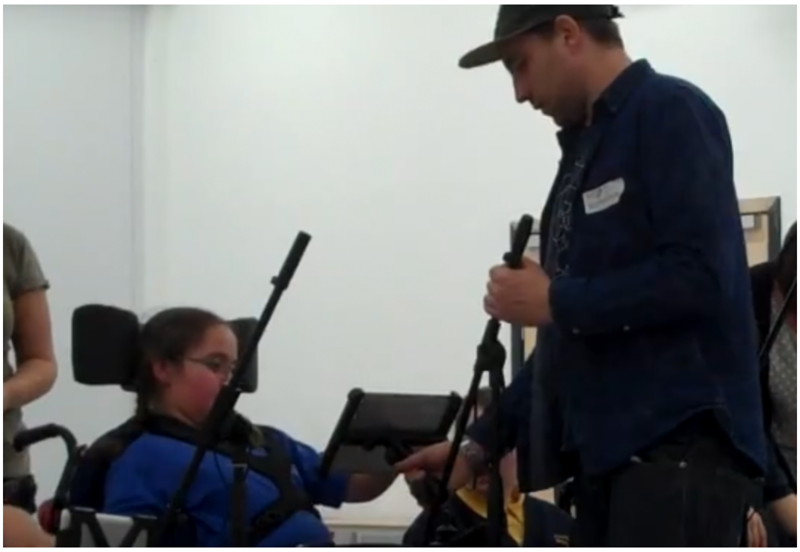

Figure 4.12: *Technical Facilitation: A facilitator adjusts an iPad device on a stand for a participant during a workshop*

Physical assistance could include many activities, but for the focus of this research, it relates to any physical support provided in the context of music-making. Some examples of activities related to physical facilitation include: assisting a performer on and off stage for rehearsals and performances, supporting movements to interact with a DMI's interface, or even being the physical replacement for an instrument stand, as shown in Figure 4.13.

Figure 4.13: *Physical Facilitation: A facilitator becomes an instrument stand for a participant during a performance, as the stand has failed and is being fixed by another facilitator*

At some points during the sessions and performances, certain roles were adopted by a specific facilitator. For example, the musical direction of the ensemble would be led by one facilitator, and the other facilitators present would be following their cues to provide additional support where necessary. In general, it was seen that facilitators would move between roles throughout the project, even when their primary role was designed to fall within one of these categories. Knowledge would be shared amongst the facilitators to enable this level of flexibility and ensure sessions could keep moving at a pace suitable to the project requirements.

Despite this, it was evident that each facilitator held different knowledge that made them more suitable to certain role types over others. For example, the technical aspects and musical facilitation was led by the Inspire Youth Arts facilitators, but the roles of physical support mostly remained with the SEND classroom assistants. When a role overlapped or intertwined with other actions, it could be taken on by either group of facilitators.

There were also some elements of facilitation that were a collaborative effort between the facilitators and their collective knowledge, for example, the initial assessment of a performer's ability and pairing a technology that best suited their needs. Additionally, finding a way to adapt the delivery of important information for performance, such as individual/section cues, is something that would be discussed amongst the facilitators and performers to find the best solutions.

Perhaps the most interesting part of facilitated performance is the facilitator's primary objective is to go unnoticed. To only be a conduit to the disabled performer's creative expression and to not remove or take focus away from their agency and performance. While this was not always the reality, the efforts to preserve this 'invisibility' were most notable during performances. During workshop sessions and rehearsals, a facilitator could move about the space more freely and jump between performers when assistance was needed. In performances, this was not often possible, and the roles of the facilitators were rehearsed with the same attention to detail as the musical contributions from the performers.

4.8.3 Adapting DMIs for accessible music-making

There are many ways in which the DMIs used within the Able Orchestra project were adapted. Some of these adaptations were made for the individual needs of the performers, and others were choices to aid the musical synchronicity of the project. Some features were also employed to avoid technical issues during the workshops and performances.

As mentioned, the primary technology in use throughout the project were iPads with a variety of music-based applications. One of the accessibility features of an iPad is a mode called 'Guided Access'. This was employed during the project once the interface was correctly setup for the performer. Guided access was used to limit the areas of the touch screen that could be interacted with. This was used when interface elements like buttons, that would normally exit the application or change the view to a context menu, could not be removed and had the potential to be accidentally triggered by the performer.

Another feature offered by some of the musical applications used was the ability to 'key lock' the output to a specific musical scale. This is a feature offered for musical synchronisation, as the interface is limited to how many notes can be provided on the GUI. A 'key lock' refers to setting the notes available to a specific musical scale, which is useful in an ensemble performance using a variety of DMIs. For the Able Orchestra project, where this feature was offered, the musical key/scale was set to C major (relative A minor). This enabled some performers (who experienced difficulties in performing articulated parts) to free play across their instrument without having to repeat the exact same gestures or notes played due to the instrument being set to a key which meant any notes would harmonically work within the piece.

For applications such as ThumbJam, the adaptation of the instrument could be taken much further. The GUI can be set to emulate a specific instrument, for example, piano keys or guitar strings. The number of keys/strings/touchable points can also be increased or decreased, which also allows for making touch targets larger or smaller depending on the needs of a performer. Other features for control can also be toggled on or off, for example, a control can be assigned to the horizontal or vertical tilt or even to respond to shaking the device. ThumbJam also allows for the creation of custom instruments which allows a facilitator to create an entirely custom interaction for a performer.

The other ways in which DMIs might be adapted were related to the physicality of a device. While not much can be altered about the physicality of an iPad, items such as hard-wearing cases can be added to make them more robust. Additionally, peripheral equipment such as instrument stands and mounts can be ‘hacked’ for easier access. In one example from the Able Orchestra project, a performer was struggling to access the devices using a standard mount or stand. A facilitator created a makeshift surface using a lap tray and used sticky tack to affix the two iPad devices the performer was using so they stayed in place, shown in Figure 4.14. This enabled the performer to comfortably use the two devices without having to navigate two sets of stands.

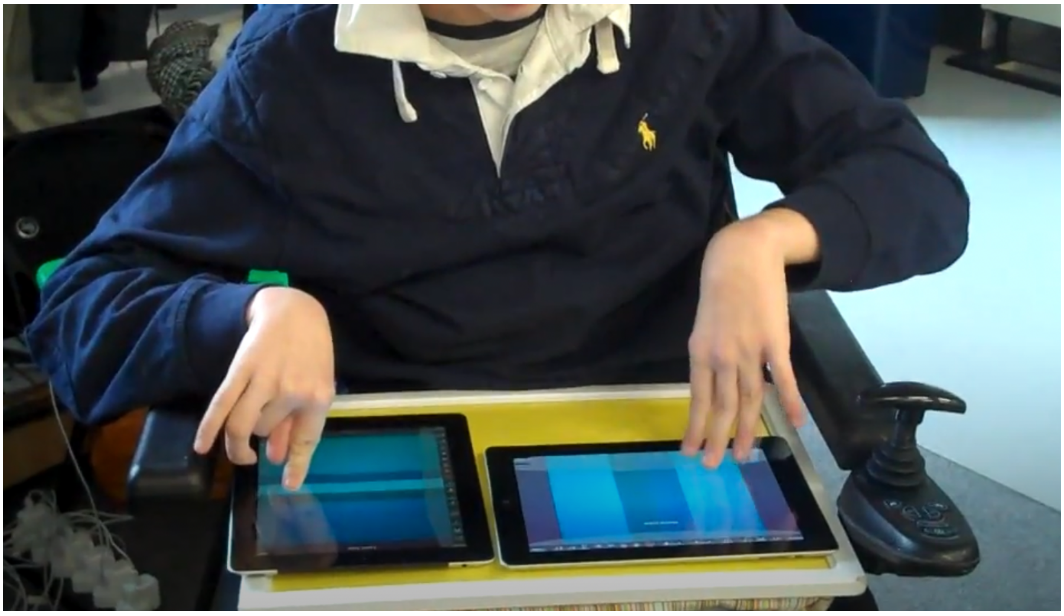

Figure 4.14: *An example of an accessibility workaround: The iPad tray*

4.8.4 Assessing DMIs for accessible music-making

Throughout the project, it was observed that there were certain features that were more desirable for DMIs within the context of accessible music-making. As mentioned in the initial findings, the contextual limitations such as time constraints and spatial limitations required that any technology introduced to the project be quick to learn and ideally adopt as close to a ‘plug in and play’ experience as possible. Flexibility was also a desirable feature due to the changing environments from the SEND classroom workshops to on-stage performances.

This flexibility was especially important when considering how devices connected with one another and the main system controlling the sound output. Trailing multiple cables over long distances becomes more complex in on-stage setups. Additionally, time restraints on live performances and changeover times for stage shows make it difficult for a completely wired setup to be cleared with the efficiency demanded from a live performance schedule.

Robustness of technology was also a major consideration of DMIs before they could be adopted into a project such as the Able Orchestra. A bespoke controller, for example, is more difficult to replace than an iPad if accidentally broken. Additionally, the technology needs to be able to function at a high capacity for long periods of time and in different contexts. That is another reason why it is more reliable to use common devices that have been well tested for common usability issues.

The familiarity of an interface also made it easier for a device to be adopted into this setting. Using commonplace devices like iPads was something each performer could easily get accustomed to due to experiencing these within everyday use. Novel or specialist music technology can introduce the extra requirement of having to learn the interface before being able to interact with it in a creative manner.

In terms of barriers to introducing new technology, the success of integrating a new DMI often hinged on there being a facilitator present who could understand, demonstrate and teach others how to use the instrument. Anything that required the facilitators to also have to learn about it before being able to put it into use would struggle to be considered because of the time constraints of the project. Furthermore, anything that required extra software, bespoke connectors, or additional technical overhead likely would not be considered because of the intricacies of the technical setup. Adding new devices or new ways of connecting devices adds another layer for facilitators to consider when troubleshooting any technical issues. The goal, especially for the live performances, was to limit the stress points in order to minimise any technical issues.

4.8.5 Observations from the gesture-controlled technology probe

The successful integration of the gesture-controlled technology probe into the Able Orchestra was extremely reliant on the presence of the researcher to act as a facilitator for the interaction. It was clear that had this been deployed without this facilitation, it would not have been used within the project and performances. However, the fact that it was able to be integrated and used throughout the project helped in understanding what the applications and limitations for gesture-controlled DMIs would be in this context.

The positive reaction to the device implemented by the researcher was initially aided by the ability to react responsively to usability challenges. Having the researcher present and working with individual performers when using the device allowed for the flexibility of adapting the interface 'on the fly' to suit a performer's abilities. This meant that the device could be tailored to an individual performer and adapted throughout the project, which was a positive feature for a DMI in this context.

The use of gesture as a control mechanism was observed to have both positive and negative traits. In the positive view, simple gestures that were easily recognised and performed lessened the learning curve for the performer. Many of the participants were able to interact with the device easily. However, a negative trait of using in-air gestures was that this appeared to induce fatigue more quickly than some of the other DMIs in use. This was challenging for the performer when using the technology over long periods of time, for example, during rehearsal sessions.

The technology probe received a mixed perception from observers. For some, it appeared to be clear what the performer was controlling in terms of

Figure 4.15: *Technology Probe in use: Top Left - participant uses the technology probe during a workshop, Top Right - participant uses the technology probe on-stage with the Hallé Orchestra, Bottom Left and Right - participant uses the technology probe on-stage at The Royal Concert Hall, Nottingham*

the sound output with their hand gestures, and for others, it wasn't obvious. However, the general consensus was that it was enjoyable to experience the novelty of this type of interaction and was easier to relate to the sound output than some of the other devices in use. Figure 4.15 shows the gesture-controlled technology probe in use during the sessions and in the performances.

The biggest challenges for the technology probe were faced at two points. During the initial introductory sessions to the instruments and project, it became evident that the Leap Motion sensor struggled to detect the fingertip points for those with closed hand syndromes. This is likely to be a failure of diversity in the model upon which the sensor is trained. However, this is just speculation as to what could be the cause for this lack of recognition. Fortunately, there were ways around this, and the response from performers was not negative towards the technology probe.

The second challenge was faced during the final performances at the BBC

Proms, where there was a failure in network connectivity between the devices on-stage, including the technology probe. This was due to the presence of the audience (and all their devices) causing an interruption to the network created for the on-stage equipment. Luckily the facilitators present were able to troubleshoot and resolve this technical issue before the second Proms performance, shown in Figure 4.16.

Figure 4.16: *The Able Orchestra at the BBC Proms: July 24 2016 (c) Guy Levy*

Using the technology probe during this study allowed for exploration of gesture as an instrument control method for disabled musicians. While this provided some helpful insights, it was evident that there are many existing commercial devices that can be used successfully in inclusive music practice and many of these are yet to be evaluated for accessibility. A decision was made to stop iteration on the gesture control at the end of this study in favour of reviewing the accessibility of commercially available products.

4.8.6 Context-switching and the impact upon DMIs

The impact of switching contexts has been mentioned throughout this section, and it is one of the bigger challenges for projects like the Able Orchestra. It was observed projects like this could be broken down into four phases that form a complete cycle. These are referred to in this research as the 'discover/create' phase, the 'practice' phase, the 'perform' phase, and the 'reflect' phase.

In the 'discover/create' phase, performers and facilitators engage in activities of creative exploration. Choosing instruments, experimenting with different technologies, playing with melody and soundscapes would all be activities commonly seen in this phase. The 'practice' phase follows, during which performers will perfect upon what has been created and become more accustomed to their instruments and roles to play in the performance. The next phase is the 'perform' phase, where performers and facilitators engage in the act of live performance to an audience. Finally, the 'reflect' phase, where all stakeholders of a project can reflect upon the previous phases and provide or receive feedback. This last stage has some variations, as it depends on the project. In some projects, time is given to all participants to engage in some form of reflection, and this can also be done collaboratively or independently.

Depending on the project length and the activities scheduled, this cycle of discover/create, practice, perform, and reflect may occur more than once. In the 2016 iteration of the Able Orchestra project, there were three iterations of this cycle.

The first cycle included the workshops and the first live performance at the Nottingham Royal Concert Hall, through which the original 'Ten Pieces' musical piece was created. The second cycle followed the adaptation of this to include both the Hallé and school orchestras and the resulting collaborative concert in May 2016 at Mansfield Palace Theatre. The third and final cycle occurred from

May to July 2016, culminating in the live performances at the Royal Albert Hall in London for the BBC Proms.

For each of the phases within a cycle, there can be many changes to navigate, from changing roles or parts in the performance to changing locations and having to adapt to new environments. Each can contribute their own set of challenges for both the creative team operating the project and the technology being used within it.

Moving equipment, for example, is just one small part of the challenge posed by changing environments. Managing the DMIs used across the different contexts involves many tasks. For example, recalling application settings for each performer, ensuring that enough charge is available and that devices are returned to charge stations when not in use, and networking or routing cables to each device. Furthermore, some equipment can be compromised because of changes to the environment. Stage lighting can interfere with reflective screens and, therefore, the usability for some performers. Lighting can also interfere with sensors and the ability of technology that uses them to perform in the same manner.

As discussed with the issues experienced with the technology probe, networking and connectivity is another complex challenge for DMIs when moving between environments. The ability to connect devices without wires, for example, can be impacted by the availability and usage of wireless networks within a venue. This is especially challenging when operating from larger venues and with larger audience sizes, as there is much more opportunity for interference to occur.

Similarly, the arrangement of a venue or space for practice or performance can make routing cables particularly challenging. This can be amplified by there being restrictions on which areas of a space are accessible to the performers. Sometimes the space for technical equipment could be far enough removed from the accessible stage/floor space to make this particularly challenging.

For each phase in the cycle and for every venue change, the challenges for both the performers and the technical setup would need to be addressed. This could result in changing out DMIs that no longer worked well enough to be reliable.

4.9 Outcomes

Working with the Able Orchestra throughout 2016 and across the many different sessions and performances provided a very comprehensive introduction to accessible music-making projects. It also highlighted the key requirements for technology to be adopted and work successfully in this context.

The challenges of this project are not unique; there are many similar initiatives where activities like this take place, and technology plays an equally important part in their success. However, it was made evident during this research study that there is a lack of centralised information about DMIs and accessibility that could benefit projects just like the Able Orchestra. Much of the knowledge within the project is held by the members of the creative team involved and expanded on throughout the project iterations.

Time limitations and reliance on facilitator knowledge makes adopting new technologies difficult, as there is no quick way to assess how well DMIs are suited to this type of project without engaging in the process of trial and error testing with a performer. Similarly, the knowledge being held predominantly by the project team means that it is difficult to offer meaningful ways of continuing to engage with DMIs after the project is over.

At the end of the research study, it was evident that having a way to assess accessibility in DMIs would be beneficial. Not only for community programs like this one, but also for disabled people interested in using DMIs and facilitators who work within disabled communities, such as SEND schools or music engagement programs.

It was decided that the research would focus on moving toward providing a way to meaningfully assess DMIs for accessibility. In order to do so, it was recognised that a wider range of DMIs needed to be observed in a more controlled environment where data collection could be better managed. This was then set as the criteria for the next study discussed in Chapter 5.

Chapter 5

The Able Lite Workshops

This chapter discusses the second study of this Ph.D. research, including the ethical considerations, details of the study including participants and technology used, and the research observations from the data collected.

Date	Participants	Data Collected
March 21 2018	4 participants, 1 Inspire Youth Arts facilitator, 3 SEND facilitators	Video footage, Audio Recording of output from DAW session, Field Notes
March 28 2018	5 participants, 2 Inspire Youth Arts facilitators, 3 SEND facilitators	Video footage, Audio Recording of output from DAW session, Field Notes
April 25 2018	6 participants, 2 Inspire Youth Arts facilitators, 4 SEND facilitators	Video footage, Audio Recording of output from DAW session, Field Notes

Table 5.1: Able Lite Workshop Dates: Participants and Data Collection

5.1 Introduction

This study features a series of music interaction workshops that were held at Special Educational Needs and Disability (SEND) schools in the Nottinghamshire area in partnership with Inspire Youth Arts (previously County Youth Arts). The workshops focused on engaging disabled students in music creation activities with DMIs.

The workshops were designed with the research partner to create a similar experience to a workshop series that happened earlier in the academic year (from September to October 2017). In total, six workshops were held over three dates in March and April 2018. Each workshop was two and a half hours long and held during school hours.

Table 5.1 outlines the workshop dates, number of participants, and types of data collected during each workshop.

The focus for these workshops was to gain further insight into the accessibility of DMIs in a more controlled setting than the previous study with the Able Orchestra. As the workshops were designed specifically to incorporate research, a greater variety of DMIs could be chosen for evaluation and be used within the workshop setting.

5.2 Ethics and data collection

5.2.1 Ethics and consent

As with the Able Orchestra project, the ethical considerations regarding the research partnership with Inspire Youth Arts are observed in Chapter 3. The core ethical issues to be considered for the Able Lite workshops were obtaining informed consent from the participants, safeguarding queries related to working with young people under the age of 18 years old, and the various structural and environmental challenges of working within a SEND school setting. These issues were acknowledged and presented to the School of Computer Science research ethics committee for consideration.

Consent for this research was gained through the Inspire Youth Arts parental consent forms. Across the six workshops, full research consent was obtained for eight of the participants and six of the facilitators. Additionally, an updated DBS (Disclosure and Barring Service) check was obtained for the researcher to meet the legal requirements for working with children under the age of 18 in the United Kingdom. Copies of the information sheets and consent forms for this research period can be found in Appendix B.

5.2.2 Data collection

Video recordings were the primary source of data for the Able Lite workshops. This was necessary due to the researcher's active engagement in leading the sessions. Again active participation limited the availability of additional data collection methods. Supplementary data types, such as field notes, were only collected when there was availability to do so. During each session, a short recording of the Digital Audio Workstation (DAW) output was also captured for use in reflection activities.

For each workshop, video footage of the entire workshop was captured, transcribed, and analysed, along with a number of images that captured elements of the workshop environment and some participant interactions with the DMIs. For each workshop session, minimal field notes were taken. These included a rough sketch of the workshop layout, which outlined the location of each participant in the workshop space and which DMI they used within the session.

The data collected from each workshop was analysed at the end of the research period. A thematic analysis approach was used and compared with the themes found in the previous study. More specifically, the analysis focused on identifying accessibility barriers for each of the DMIs used within the workshop. The process of analysis and results are discussed in section 5.6 of this chapter.

5.3 Technology

A range of DMIs were chosen to be used within the Able Lite sessions. There wasn't always an opportunity to use all the technologies on this list in each workshop. Table 5.2 provides the details for each DMI and indicates which of the sessions the DMI was used within. DMIs that do not have any sessions against them in Table 5.2 were tested with participants during each of the sessions but not selected for use based on the participants' needs.

Instrument Name	Description	Interaction Method	Used in Session
BopPad	An expressive electronic drum pad	Touch - an object or finger presses on silicone membrane	
Mogees Pro Sensor	A sensor that transforms vibrations into sound	Vibrotactile - any form of impact on surface that device is attached to	
Skoog	A tactile cube interface made from conductive foam	Touch - conductive foam that can be squeezed or pressed	March 21 2018, March 28 2018
SeaBoard Rise	An expressive silicone waved keyboard	Touch - a silicone surface that can interpret several touch gestures	April 25 2018
ThumbJam	An iOS app with numerous sounds and GUI layouts, uses samples, live recordings or can a MIDI controller	Touch - via the touch screen of an iOS device	March 21 2018, March 28 2018, April 25 2018
Bloom	A generative audio app for iOS	Touch - via the touch screen of an iOS device	March 21 2018, March 28 2018, April 25 2018
Thicket	A generative audio app for iOS	Touch - via the touch screen of an iOS device	
Impaktor	An iOS app that turns vibration into sounds	Vibrotactile - any impact to the iOS device or surface it is placed on	March 21 2018, April 25 2018
GyroSynth	An iOS app that turns accelerometer data into sounds	Movement - any movement of the device	
Playground	An iOS app with preset musical ‘playgrounds’ that present various GUIs	Touch - via the touch screen of an iOS device	March 28 2018
PhaseRings	An iOS app with ring based GUI, uses various sounds and scales	Touch - via the touch screen of an iOS device	March 21 2018, March 28 2018

Table 5.2: Able Lite Workshops: Technology used in the workshop sessions

These DMIs were chosen as they showcased a range of interaction methods. Some were included as a result of their successful use within the Able Orchestra project. Others were chosen because they had not been explored in the previous study and offered different features or interaction methods.

5.4 Participants

The participants for this study were SEND school students between the ages of eight and eighteen years old. Eight out of fifteen workshop participants provided full consent to be included in this research. The participants had varying disabilities, including visual, hearing, motor, speech, and cognitive disabilities. The participants' previous experiences with music technology and DMIs were unknown.

Additionally, consent was obtained from six SEND facilitators who were involved in supporting the workshops within their roles as teaching assistants or support workers. Each workshop had between four and six facilitators including up to two workshop facilitators from Inspire Youth Arts and up to four school based assistants. These facilitators adopted many of the roles that were observed in the Able Orchestra study outlined in Chapter 4.

The workshops were an extension of a trial program by Inspire Youth Arts to recreate experiences similar to the Able Orchestra project workshops. For many of the students and facilitators involved, the workshops were a first-time experience in using DMIs within school activities.

Table 5.3 outlines the accessibility requirements of the eight participants and which DMIs they used during the sessions. The disability descriptors provided in this table are those as specified on the Inspire Youth Arts consent form. Please note the participant names have been replaced with gender-neutral pseudonyms.

Participant	Disability Information	DMI used
Leigh	Learning difficulty, sight impairment, physical impairment	Did not actively participate due to illness
Morgan	Learning difficulty, physical impairment	Bloom
Nico	Learning difficulty, sight impairment, physical impairment	ThumbJam
Payton	Learning difficulty, hearing impairment, physical impairment	ThumbJam, Bloom
Quinn	Learning difficulty, sight impairment, hearing impairment, physical impairment, other/hidden impairment	ThumbJam
Riley	Learning difficulty, hearing impairment, physical impairment	Impaktor, Skoog
Sidney	Learning difficulty, sight impairment, physical impairment, other/hidden impairment	Phase Rings
Toni	Learning difficulty, sight impairment, physical impairment	Seaboard RISE, Impaktor, ThumbJam

Table 5.3: Able Lite Workshops: Participant Information

5.5 Able Lite workshop sessions

This section provides details of the Able Lite workshop sessions, including information on planning the research activity, technical setup, and session activities.

5.5.1 Planning the workshop sessions

A plan was created ahead of the Able Lite workshop sessions that outlined the aims, timeline, and potential activities. Each workshop required one hour of preparation time in which to setup the equipment and sound check.

The workshops then followed a pattern of four phases, mirroring the phases found in Chapter 4, over a period of two and a half hours. These phases were discover/create, practice, perform, and reflect. The phases were designed to allow the participants to experience each of these musical activities. The time taken to progress between these phases could vary between workshop sessions.

A number of external factors impacted a session's progression. For example, participants needing to leave for personal care or additional students joining the sessions after they had started. The schedule, as outlined in Table 5.4, acted more as a rough guideline for how long to spend on each activity, when to gather feedback, and when to take breaks.

A copy of the full workshop plan can be found in Appendix B, which outlines the aims and objectives, equipment to be used, and activities to try when engaging with participants in each phase. From the experiences gained through the Able Orchestra study, it was noted that the most suitable activity in each phase could depend on the individual participant. The workshop plan acknowledged this by providing a number of suggested activities based on an individual's abilities and support needs.

5.5.2 Technical setup and arrangement

The workshops used a stripped-back technical setup, compared to the Able Orchestra field study. The sound output was centralised through a PA system, which was connected to an audio interface and a MacBook Pro running

Time	Section	Activity
-01:00	Preparation	Load in
-00:30	Preparation	Setup
-00:15	Preparation	Sound check
00:00	Part One	Discover/Create Phase
00:30	Part Two	Feedback
00:45	Break	
01:00	Part Three	Practice Phase
01:30	Part Four	Perform Phase
01:45	Part Five	Feedback
02:00	Part Six	Reflect Phase
02:15	Break	Final Comments
02:30	End of Workshop	

Table 5.4: Able Lite Workshops: Schedule of Activity

Ableton Live. Each DMI used within the session was connected to the main sound output using an audio cable output from the DMI to the audio interface or via a Bluetooth connection to the MacBook Pro. Figure 5.1 displays a system diagram for the workshop session's setup.

For each workshop, a room layout diagram was documented in the field notes, which captured the arrangement of the participants in the room relative to the sound output. The diagram was updated following session breaks or at any point when the arrangement of the participants altered for any reason. An example of a digitised diagram from the first workshop sessions is shown in Figure 5.2.

5.5.3 Session Activities

The activities conducted in each session varied based on the requirements of the group. For the 'discover/create' phase, the common approach between the six sessions was to use a method of trying out the different DMIs in turn.

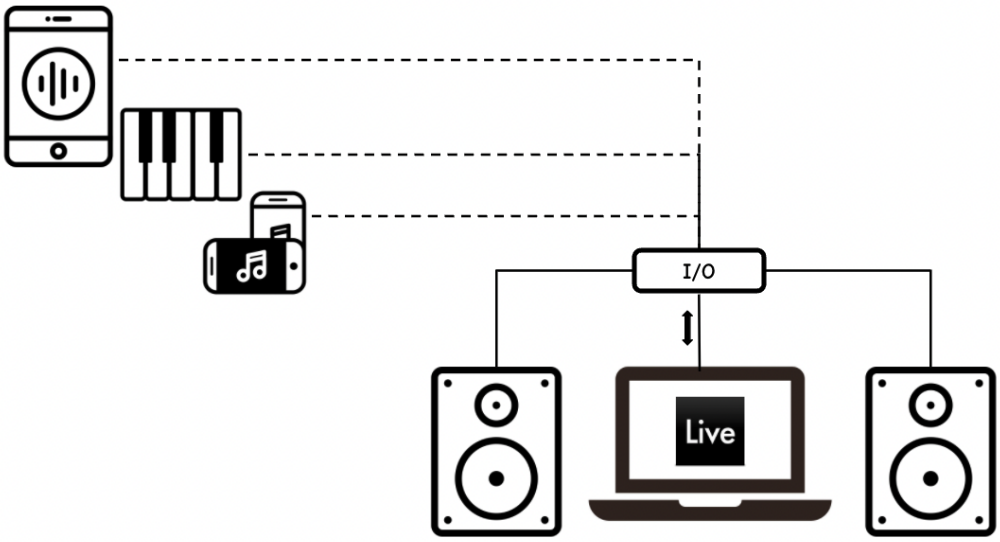

Figure 5.1: *System diagram of the setup for the Able Lite workshops.*

This would sometimes involve adding another DMI so a few participants could be trying out different DMIs at the same time. In the workshop plan, this activity is referred to as 'pass it on' or 'pass it on +1' in the instance where there is more than one DMI involved.

This approach was chosen at the time of the workshop for a few reasons. First, the session group sizes were small enough to allow for this dedicated time for individual exploration of the DMIs. Second, the support requirements of all six groups were better suited to this approach. Finally, in some instances, there was a lot to be learned about the interaction methods and DMI suitability for specific participants. Therefore it was beneficial to be able to try multiple DMIs with each person.

The activities for the 'practice' phase often adopted something closer to a further exploration rather than following any of the activities in the workshop plan. Following the initial 'discover/create' phase, a suitable DMI would be selected for each participant. The participants would then continue to explore and make noise with their instruments together. Again, because of the small group size and the mixture of support requirements within the groups, this approach was better than trying to follow the suggested activities from the

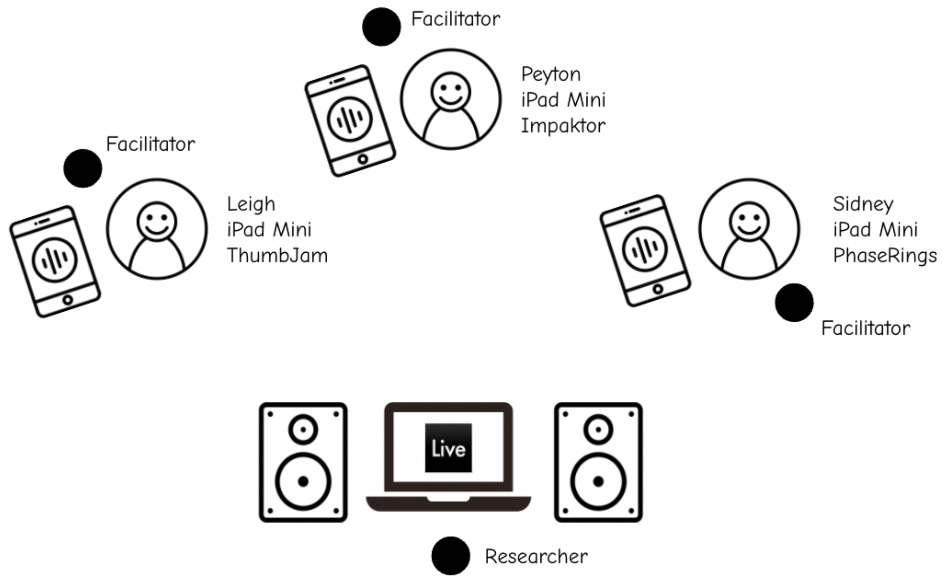

Figure 5.2: *Digitised version of session diagram from the first Able Lite workshop.*

workshop plan, which pushed for more controlled actions involving direction, turn-taking, or playing along with a backing track.

For the 'perform' phase of the six workshop sessions, the most suitable activity was a group listening exercise. To achieve this, a few minutes of audio was captured during each workshop. At the end of the sessions, this recording was played back to the participants and facilitators. This activity merged with the 'reflect' phase as it resembled more of a reflective listening section to each workshop rather than a specific performance-led element. During the session activities, it was made apparent that any form of live performing was optimistic within the time frame given to these workshops.

Activities were chosen based on the diversity of the participant's requirements in each workshop and to ensure that the sessions remained inclusive throughout. This approach was upheld to align with the participatory stance of the research. Instead of following a strict structure and activities that would be of the highest research interest, the sessions were intentionally led by the participants' needs and wants.

5.6 Initial findings

Following each of the Able Lite workshops, the data captured was analysed. As with the Able Orchestra study, a thematic analysis was conducted through reviewing images, video footage, and field notes for any recurring observations or common themes.

Some of the initial findings reinforced the observations made within the Able Orchestra studies, for example, findings related to the environmental limitations of working within a classroom setting. As discussed in Chapter 4, the DMIs selected for use in projects like the Able Orchestra project were carefully chosen to work well within these environmental constraints. Additionally, the importance of facilitation was another theme that repeated throughout the Able Lite sessions. Especially how these relationships helped the performers to maintain agency and independence in their exploration of the DMIs.

For the Able Lite workshops, one of the goals was to explore a number of technologies and their suitability for this setting. Again, concerns about the physical space were centred around having access to enough power sockets, enough space to setup larger equipment, and safe routes for multiple cables. These were common issues that persisted throughout the data collected for the Able Lite workshop sessions, though some classrooms were found to be more suited than others. For example, some classrooms within the school included a sensory space and, as a result, were more suitable for the workshop activities. The data collected from each workshop day also identified some of the features of DMIs that were more accessible to disabled performers.

5.6.1 Workshop day 1: March 21 2018

During a review of the first two workshops, the increased flexibility of the different instrument types was positively noted. This provided opportunities for each participant to try out different interaction methods and interfaces. The flexibility of some of the DMIs used was also very positively responded to by the SEND facilitators. For some participants being able to adjust sensitivity settings, change the graphical user interface (GUI), or alter the touch targets made a significant difference in the ability to interact with a DMI.

One participant, Sidney, specifically benefited from this ability to tailor the GUI of the DMI PhaseRings. PhaseRings is an iOS application with a GUI that represents several rings on the screen arranged like a target, as shown in Figure 5.3. Each ring represents a different pitch. The touch gestures used are taps or 'swirls', which create combinations of long and short notes. The application provides seven "sound schemes" that feature synthesised instrument sounds like marimba and singing bowls, as well as more typical synth sounds like a phase or string synthesis. The target touch areas and visual size of the rings can be increased or decreased using a plus and minus control at the bottom of the screen. The visual labels on the GUI can also be removed to create a more minimal interface if that is preferred.

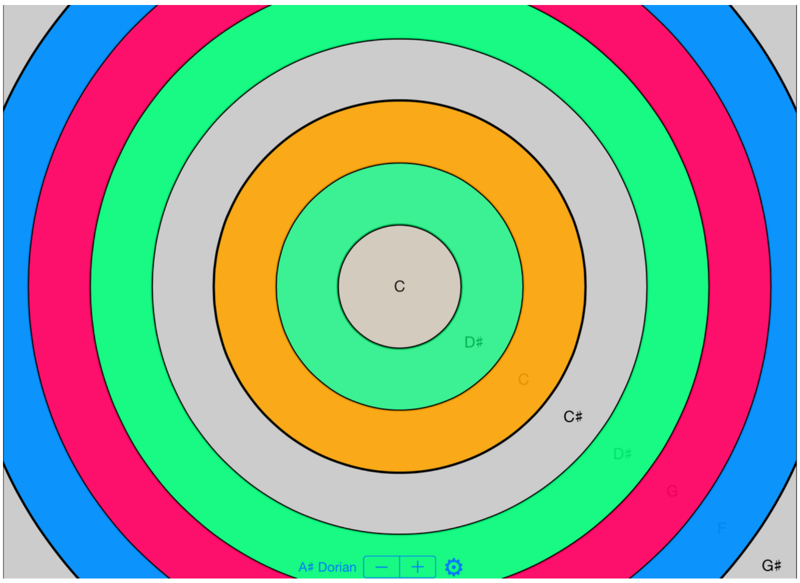

Figure 5.3: *Screenshot of the PhaseRings Application GUI*

For Sidney, who has limited arm movements, the ability to alter PhaseRings to have larger touch targets that could be triggered with slight gestures provided an interaction method that enabled them to have increased participation in the workshops. The visual change to the GUI was not as important for Sidney as the change to the touch size area. This is because Sidney's disability means that their field of vision does not extend to include the arm and hand they use to interact with a device. Sidney's facilitator worked around this by using a mirror to show the GUI to them so they could have some visual feedback as well as auditory. The relationship held between facilitator and musician here was extremely important in helping Sidney to quickly find a comfortable setup that allowed her to start creating music sooner.Figure 5.4 shows the setup used by Sidney during the workshop session.

Figure 5.4: *PhaseRings in use: setup used by participant to interact with the PhaseRings application on an iPad*

Tailoring the GUI continued to be a theme as the first workshop progressed. However, this was not always achieved through a DMI's settings. In some cases tailoring a DMIs interface was achieved through the accessibility features of an operating system. This was most common for iOS applications.

For example, ThumbJam was the DMI paired with Quinn, which has a good amount of features that can be customised, including being able to alter the GUI. However, the interaction area still includes buttons that link to menus and other controls, and these can be easily triggered unintentionally. This can be a great source of frustration for disabled performers who have limited motor control or sometimes experience involuntary movement. An iOS accessibility feature exists that can help in these situations called 'Guided Access'. 'Guided Access' allows a person to select areas of the touch screen that they wish to exclude from the interaction area. For Quinn, this proved to be the best way to tailor ThumbJam so that they could avoid the accidental triggering of menus or closing the application.

The method of using accessibility features to support interactions was used for more than one participant during this workshop session, which highlighted the importance of DMIs being compatible with such features.

5.6.2 Workshop day 2: March 28 2018

On the second day of Able Lite workshops, another theme observed in Chapter 4 repeated itself. This was the theme of cause and effect and how this impacted the participants' perception of a DMI.

For some participants, the sound choice appeared to be extremely important in creating and maintaining the cause and effect relationship. For example, for DMIs such as the Skoog, the perception of cause and effect appeared to be stronger when using more percussive or short sounds. This was due to the common gestures the participants used being quick, poke or jab-like presses, or short squeezes of the Skoog's malleable surface, pictured in Figure 5.5.

This requirement to have well-matched instrument sounds to the type of interaction was particularly important for DMIs that offered only auditory feedback. For some participants, however, there was still a requirement to have an additional form of feedback as well as the sound created by interacting with a DMI. During the workshop, this was mostly achieved by providing participants with a DMI that also offered some form of visual feedback either through a GUI or an LED indicator on a physical device. It was also noted by facilitators that more sensory or ambient feedback could also enhance the experience for the participants, especially when someone's field of vision might be restricted.

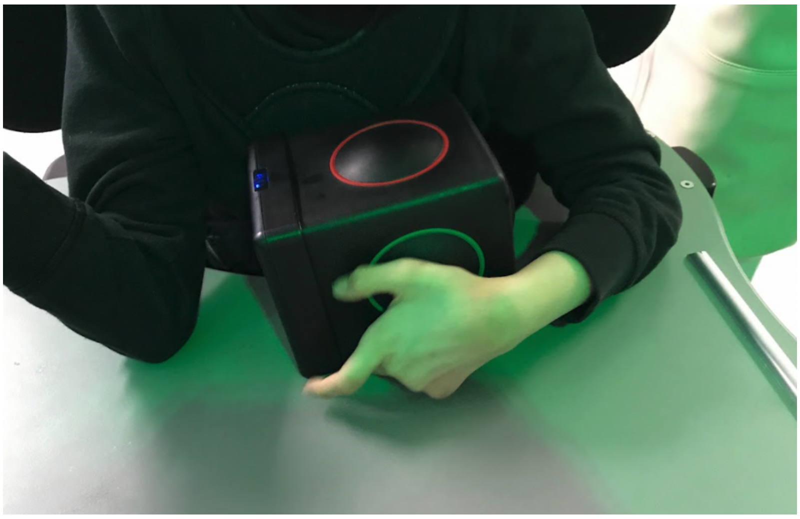

Figure 5.5: *Skoog in use: participant squeezes one side of the DMI which rests on a table that is attached to their wheelchair*

Another interesting initial finding from this workshop was that in some cases, the complexity of iOS applications and their GUIs could cause confusion when using an iPad as a DMI. Tablet devices, such as iPads, are commonly used within accessibility settings as assistive devices and teaching aids. While adding another use to a familiar device was part of the confusion for some, for others, it was the change of familiar gestures or the drastically different GUIs encountered when using DMI applications.

'Playground' is a good example of a DMI that caused some confusion. As an app, it is designed to be simple to learn through inviting exploration. There is no wrong or right way to interact with each display, and people are encouraged to discover what happens when they interact with the different objects on the screen. An example of a Playground GUI can be seen in Figure 5.6. This caused some confusion and hesitancy for the participants when using this as a DMI.

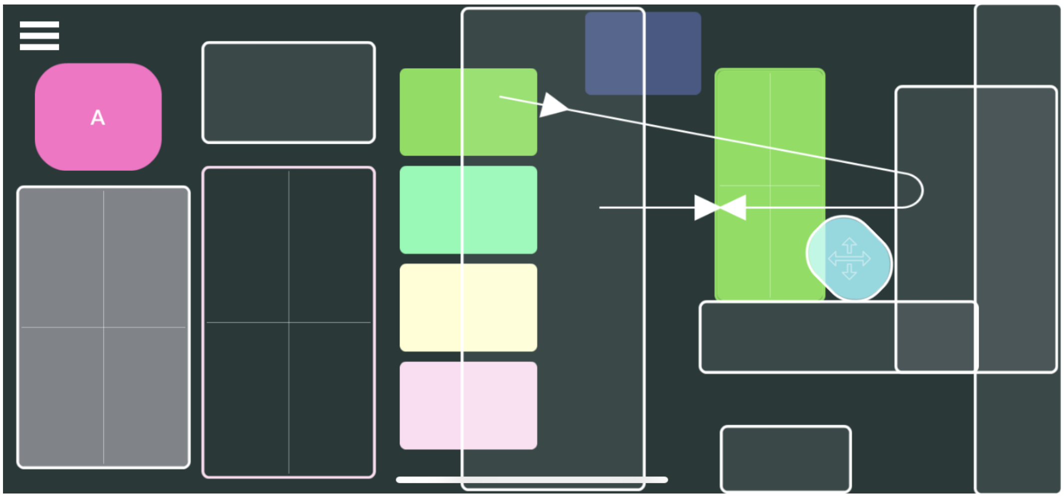

Figure 5.6: *A screenshot of the playground application's GUI*

5.6.3 Workshop day 3: April 25 2018

On the third day of Able Lite workshops, the themes of causality, complexity, and tailoring all reappeared in the observations. This workshop had more time dedicated to instrument discovery than the previous two, which enabled more detailed observations over the suitability and challenges faced when a participant was exploring a new DMI for the first time. However, due to consent, only one participant, Toni, could be included in the research from this workshop session.

Toni used the Seaboard RISE, Impaktor, and ThumbJam DMI options during the workshop. Again, being able to adjust the sensitivity of a DMI was important for Toni due to them having difficulty applying pressure in their gestures. This was somewhat achievable with the Seaboard RISE, but this did not reliably capture the softness of Toni's gestures even at its highest level of sensitivity. Due to the silicone surface of the Seaboard RISE requiring some pressure, it was mostly unusable for Toni, and they could only really achieve the lightest touch by resting their hands upon the surface without applying pressure. Figure 5.7 shows Toni interacting with the Seaboard RISE.

When exploring Impaktor, the issues were similar. However, the sensitivity could be adjusted in a way that allowed Toni to create more sound output than

Figure 5.7: *Participant explores the Seaboard RISE*

with the Seaboard RISE. Impaktor is an iOS application that takes input from the environment through capturing vibrations and audio from the iPad's inbuilt microphone. This allows a person to trigger sound from the application using vibrations or sounds instead of touching the screen. It can be particularly accessible for those who might struggle to interact with a screen. Whole surfaces, such as a table the device is placed on, can become the interaction area for generating sounds.

The sound selections of Impaktor are well suited to this 'impact' and response method of interaction that the application uses. Toni responded positively to this, and it was clear the causality relationship for them was strong. It was highlighted by the facilitators that Toni is highly reliant on sound feedback due to the nature of their visual impairment.

Finally, when using ThumbJam, the GUI was simplified to remove any visual grid elements and create a large open interaction area for Toni. Guided access was used once again to avoid accidental triggering of the non-musical elements on the screen. As experienced in the first workshop, the minimal sensitivity required to interact with an iPad touch screen allowed Toni to easily interact with ThumbJam and actively take part in the music creation.

5.7 Discussion

Following the completion of the Able Lite workshops, the data from each workshop was reviewed. The active role of the researcher was once again acknowledged to have some limitations upon the data collection. Other limitations included the size of the workshop sessions and the small number of consenting participants.

Initially, the hope had been to run up to ten Able Lite workshops, which would have increased the number of participants and opportunities for more data collection. However, this was limited by external factors, such as uptake in the program from the local schools, staffing issues meaning the timing was not convenient for some interested schools, and more generally the time of year being in the final term of the academic year when there was already a number of planned activities and examinations to consider.

The workshops themselves also experienced some limitations on attendance that reduced the participation levels and data collection. Illness and medical appointments were two of the main factors that impacted participation. In some cases, safeguarding issues also meant students could not actively participate in the research.

Despite these limitations on the data collection, some common issues for using DMIs in this setting were evident. Also, additional insight was gained into how DMIs worked for specific needs, as well as the qualities of a DMI that had the greatest impact on accessibility.

5.7.1 The strengths and limitations of DMIs in accessible music-making

The themes identified in the chapter 4 regarding the strengths and limitations of DMIs when used in accessible music-making were reiterated in this study. Time constraints and spatial limitations once again highlighted the importance of flexibility in DMIs. In many of the DMIs used, the flexibility offered was an important factor for their success in this setting, especially when considering the difference in experience between the flexibility of an acoustic instrument and DMIs. However, the addition of various cables and connections, which is not experienced with acoustic instruments, does add risk to both the accessibility of the space and increases the potential for accidental damage.

The use of multiple cables is often counteracted by having a 'wireless' mode or some wireless capabilities, but the reliability of such things in DMIs is not always guaranteed. A good example of this within the Able Lite workshops relates to the use of the Skoog. While this DMI was acknowledged to have some very accessible features, the connectivity issues experienced between the software and hardware resulted in the Skoog only being able to be used consistently during one workshop session. In the first session, the connectivity was lost and could not be resolved before the end of the session time. In the third session, the Skoog could not establish a connection at all. These issues of connectivity and reliability relate directly to the concepts of flexibility and robustness identified in chapter 4.

Similarly, the observations around familiarity of interfaces were continued within the Able Lite study data. It was apparent that when using iPads, participants were quicker to interact with the touch screen due to this being an interface that was familiar to them. When exploring other technologies that were more novel, such as the silicone-based interface of the Seaboard RISE, it was often seen that it took longer to establish the connection between actions and sound output. However, this hesitancy was also experienced with some DMIs that were iPad applications. In these circumstances, interaction hesitancy appeared to be consistent with applications that differentiated from the typical touch screen gestures of tapping and swiping, for example, Playground's use of gesture combinations that follow shapes with a long press/swipe gesture. This extra requirement to learn new gestures or interfaces added a level of complexity that relied on increased facilitation and time to explore the DMI. While the additional time required was not an issue within the Able Lite workshops, the delay between starting to use a DMI and producing any musical sound from that DMI increases the potential for the device to become frustrating to use

5.7.2 Pairing DMIs with disabled performers based on accessibility requirements

Overall, the majority of DMIs used within the Able Lite sessions appeared to offer many benefits in terms of access to creativity. The workshop phases allowed for more exploration of the different DMI features, which in turn resulted in a more tailored approach when 'matching' instruments to individual participants. However, it was quickly acknowledged that there was no singular feature of a DMI that made it more suitable for a specific disability or accessibility requirement. On some occasions, two participants with similar access requirements could have vastly different responses to the same DMI. Therefore it is impossible to suggest a particular DMI meets the accessibility requirements for a specific disability or group of disabilities. The inability to make suggestions like this is what makes it difficult to assess which DMIs are the most 'accessible' because the concept of 'accessible' changes based on individual requirements.

Sometimes the DMIs that worked best for participants were unexpected, in that on paper, they may not seem to be at all suitable for the person's creative or access needs. These unexpected pairings only occur through a process of trial and error that allows a participant to explore all the options available, which suggests that assessing DMIs based on suitability for specific disabilities or requirements might not produce a consistent outcome.The speed of this process is also dependent on the musician-facilitator relationship, those with a more familiar relationship might work through options more quickly. A potentially better solution for assessing accessibility would be to observe the qualities that make DMIs more suitable to a wide range of disabled people. This concept does not necessarily mean taking a generalist approach to the accessibility of DMIs, as the data reinforces the notion that lived experiences of disability are vastly different for each individual. If, for example, a way of assessing core qualities like the "flexibility" of a DMI existed, this could provide useful insight into the accessibility and suitability of the DMI for both facilitators and disabled musicians.

5.7.3 Qualities of DMIs that impact accessibility

A number of potential qualities that could be considered fundamental for the accessibility of DMIs were discovered upon reviewing the data with this consideration in mind. Some of these qualities were already highlighted within the Able Orchestra study discussed in chapter 4.

The first recurring quality was the stability or robustness of a DMI. In the Able Orchestra study, 'robustness' was highlighted in terms of the comparison between novel or bespoke technologies and commercially available devices like iPads. Arguably it is easier to replace commercially available devices if they were to be broken accidentally. Equally, a bespoke device is more likely to be in a prototype form factor and more susceptible to damage. Yet, this quality speaks to much more than how replaceable or easy to damage an item is. Robustness also applies to the reliability of a DMI and the consistency of behaviour even when in constant use over a number of hours. Minimising the risk of accidental damage through reducing the number of wired connections also relates to the robustness of a DMI. However, 'robustness' as a term could be open to multiple interpretations and, at the same time, could be considered to be limited to the physicality of a DMI. After reviewing the data from both studies and finding more examples of this quality that include both physical and digital considerations, it was decided that the term 'durability' would serve as a better descriptor. This term encapsulates all the potential issues that can impact the durability of a DMI and is a core quality for the accessibility of a DMI.

The second recurring quality centred around the customisation or tailoring of a DMI. Being able to adjust many different elements of a DMI, such as the input sensitivity, touch target size, or the layout of a GUI, was beneficial for accessibility in both studies. Additionally, it was found in the data from the Able Lite workshops that being able to use a DMI as a MIDI controller could also make a big difference for cognitive accessibility. The relationship between cause and effect could be managed by the facilitators by changing the sound set to be more suited to the interaction style of a participant. This way, a sound could be selected that made the cause and effect relationship more obvious to a participant. Again neither customisation nor tailoring offers an unambiguous description of a quality that a DMI should possess to be more accessible. After reviewing the data and related issues that customisation or tailoring helped resolve, it was decided that the term 'flexibility' best described what was meant by these terms.

It was observed in the Able Lite workshops that the cause and effect relationship is not only impacted by the flexibility of a DMI or the ability to alter the sound to suit an interaction style. The complexity of an interface or interaction also impacted the perception of this relationship. This quality of a DMI also describes the level of complexity of an interaction. For example, where unexpected gestures were used in interfaces, this added to the perceived complexity of that DMI and increased the exploration time required for a participant to fully understand the interaction. This was amplified if controls of a similar design did not perform in the same way. Providing feedback on top of the sound output of a DMI was also experienced to reduce complexity in both the Able Lite workshops and the Able Orchestra project. Finally, another overlapping area for flexibility and complexity was recognised in the ability to change the user interface of a DMI to remove elements that could be distracting. A good example of this appeared in the Able Lite workshop with the PhaseRings application, where the labels for the rings displayed on the GUI could be removed to simplify the interface.

The fourth quality that was evidenced in both studies relates to the setup times of DMIs. In accessible music-making settings such as the Able Lite workshops or Able Orchestra project, it is more desirable to have devices that are as close to a 'plug in and play' experience as possible. Requiring proprietary software, cables, or anything additional to start making music with a DMI increases the time it takes to get everything setup and reduces the amount of time that can be dedicated to exploring instruments and making music. Similarly, having the ability to store and load previously used settings on a DMI could reduce setup times, especially when the DMI was in use over long periods of time or multiple sessions, like in the Able Orchestra project. Even the act of being able to place a DMI on a stand makes a big difference in making the setup process more accessible and efficient for disabled performers. However, many of these features are relevant at all times, not just the period of setting up a DMI. Using a term like 'setup' doesn't sufficiently describe how these features are related or the issues they can cause for accessibility. It was decided to use the term 'practicality' to describe this quality, as the issues relate to how practical or impractical a DMI could be to integrate into accessible music-making settings.

The fifth and final quality identified from the recurring themes in the data relates to how DMIs operate with existing assistive technologies. Assistive technology (AT) is a blanket term used to describe products or systems that support and assist people with disabilities. AT can be a number of things, from low-tech printed communication boards to computer hardware and software, like screen readers or physical switches. In the Able Orchestra project some participants required a DMI to work around some of their physical aids, such as arm support slings that attached to a wheelchair. Similarly, during the Able Lite workshops, it was necessary to consider mounting DMIs to a participant's wheelchair or using tray tables to provide a surface for a DMI to rest on. Other considerations also occurred around the sound choices used in sessions and how they might interact with cochlear implants and hearing aids. The term chosen to describe this quality was 'compatibility', as this best describes the issues related to DMIs and how they might work with a person's assistive technology.

5.8 Outcomes

The main goal of the Able Lite workshops was to gain a better understanding of the accessibility barriers experienced by disabled people when using DMIs, building on what was previously observed and learned during the Able Orchestra project field study in 2016.

The five qualities identified in the discussion provide a basis that could potentially be used to assess the accessibility of DMIs. These are not exhaustive in terms of capturing all accessibility issues, especially those that are related to specific scenarios or individual experiences. Instead, these qualities look at features that are fundamental for improving accessibility and cover a broad range of accessibility issues. The descriptors that were chosen also move towards creating single statements about the accessibility of DMIs that are easier to understand. For example, "to be accessible, a DMI should be durable". It is not expected that such statements could be fully understood without an accompanying description. However, the ability to form such sentences helps to create more memorable and meaningful principles that can be used to review accessibility.

These outcomes move the research focus towards how the qualities observed in the research studies might be used to evaluate the accessibility of DMIs. In order to examine ways in which this could be achieved, it is necessary to revisit the literature and review the findings of both studies. This is the focus of the next chapter, Chapter 6, which considers the research findings against the literature and research areas proposed at the beginning of this thesis.

Chapter 6

Discussion

This chapter explores the findings of both research studies in more depth. First, ‘facilitated performance’ as a concept will be discussed, including how this relates to Human-Computer Interaction (HCI) and the potential impact for digital musical instruments (DMIs) designers. Then the chapter follows a more detailed discussion of tailoring DMIs in response to a disabled performer’s creative and physical needs. This discussion considers whether certain technologies provide greater accessibility or if there are any common themes when it comes to adapting DMIs. Finally, the chapter concludes with an expansion of the discussion found in Chapter 5, continuing the exploration of evaluating DMIs for accessibility. This discussion concludes by proposing a framework, provided in Chapter 7, based on qualities that could improve the fundamental accessibility of DMIs.

6.1 Introduction

The questions set out at the beginning of the research period highlighted the important focus areas for discussing the use of DMIs within inclusive music practices. These questions follow a structure that first investigates current practices and progresses to question how it might be possible to grow and share understanding about the accessibility of DMIs. To reiterate these questions: how are digital musical instruments used to support access to creating music for disabled communities? What are the challenges for disabled people when using a digital musical instrument? How can digital musical instruments be used to address individual accessibility needs? How might the accessibility of a digital musical instrument be evaluated?

Early in the research, the researcher acknowledged that the best way of investigating questions about inclusive music practice was to take an active role in the inclusive music community and focus on observing the lived experiences of disabled people using DMIs. The two field studies conducted were centred on participatory action research methods, with the researcher taking an active role within the studies as a facilitator and workshop leader. In this role, the researcher was able to share in the experience of inclusive music practices and better understand the challenges that exist.

The first study with the Able Orchestra project addressed the first two research questions. Through being a facilitator in this project, it was possible to observe how DMIs are currently used within inclusive music projects and understand some of the challenges presented for the disabled performers when using DMIs. Perhaps the most important lesson taken from the Able Orchestra project focuses on the social complexity of inclusive music-making. Including the roles of facilitators and the concept of 'facilitated performance'. Section 6.2 of this chapter will focus on this concept and the implications for HCI.

The Able Lite workshops, discussed in Chapter 5, explored the second two research questions in more detail. In the role of the workshop leader, the researcher was able to design the sessions to include activities that were of high interest to the research. Through this, the researcher gained deeper insight into tailoring DMIs to meet specific performer needs and ways in which the general accessibility of DMIs could be evaluated and potentially improved. Section 6.3 and 6.4, will cover these topics in more detail.

6.2 Facilitated performance and Human Computer Interaction

Facilitated performance is a concept introduced in this research to describe when another person supports a disabled performer in the act of musical performance. From an HCI standpoint, this introduces an idea of a facilitator being a secondary user of technology such as a DMI, which also introduces the notion of a 'secondary user experience' that is more indirect but equally as important. However, a facilitator's use of a DMI may not be constant in these settings, even when a facilitator is ever-present. Facilitators' roles in inclusive music settings cover many activities and serve different purposes. The types of assistance noted within the Able Orchestra study, discussed in Chapter 4, fell into three distinct categories, musical assistance, technical assistance, and physical assistance. Although technical assistance may be the most relevant type of facilitation when considering HCI and DMIs, each category relates to part of the user experience. Musical assistance, for example, could relate to assisting someone in choosing a specific instrument sound which would involve the facilitator also interacting with the DMI. Equally, physical assistance could involve a facilitator becoming a physical replacement for an instrument stand, which requires some knowledge of how a DMI works to best present it to the performer. Table 6.1 presents the roles observed within the two studies, including the related category for each role.

Category	Role	Description
Musical	Producer	Leads the production throughout the stages of a project, works with the performer(s) to make creative decisions.
	Director	Directs and provides prompts for a performer or group of performers.
	Teacher	Introduces concepts, teaches technique, demonstrates musical tasks.
Technical	DAW Operator	Manages session material within the Digital Audio Workstation software, including all metadata needed (track names, sound samples, sections) and records material when required.
	Audio Visual Technician	Routes and manages all audio visual signals, includes setting up audio cables, interfaces and live sound output devices.
	Equipment Technician	Sets up and monitors all equipment including microphone stands, power supplies and cables, as well as any DMIs in use.
	Technical Lead	Coordinates all technology, records necessary information about sessions about technical requirements. Directs other technicians.
Physical	Individual Support	Provides one to one support for a performer or more focused support to a few performers. Includes managing assistive equipment, as well as helping guide and monitor interactions.

Table 6.1: The roles of facilitated performance

The impact of using a DMI in facilitated performance is that there could be many people who 'use' the DMI, but the information that each individual requires from the DMI could be very different. The disabled performer, as the primary user, might need a tailored visual interface that offers lower complexity. A facilitator or secondary user might want to have a 'quick access' view that provides more detailed technical information.

In HCI, several conceptual frameworks could be 'interrupted' by the presence of a facilitator as a secondary user. The interaction trajectory (Benford and Giannachi, 2011) of a disabled performer, for example, could be interrupted at points where a facilitator is required. This transition in the trajectory, labelled by Benford and Giannachi (2011) as a form of role or interface transition, could lead to a break in the performer's experience of using a DMI or even a loss of agency. Often, the facilitator considers how to manage these transitions; nonetheless, it is an element of DMIs that interaction design could improve.

When enacting some roles, facilitators are performers in their own right. Especially if we consider transactional models of performance, like those presented by Schechner (1968). Schechner proposes that there is little separation between performers and technicians in theatrical performance, to the extent where technicians form part of the 'performing group'.

Facilitators are comparable to performing technicians, but different fields can also view them through many other lenses. For example, in assistive technology, facilitators might be considered a 'soft' assistive technology. The terms hard and soft are used for assistive technology to distinguish between tangible components that people can purchase and the human areas of decision making, training, strategy development, and concept formation (Gray, 2017). For example, by this definition, assistance from a teacher or therapist is a form of soft assistive technology. Figures 6.1, 6.2, and 6.3, feature diagrams that display how some conceptual HCI frameworks could view the role of facilitators. These conceptual views of a facilitator can help creators of DMIs to consider how to design for the context of facilitated performance. This might include trying to reduce potential touchpoints in the interaction trajectory by providing features that lower the requirement for facilitation or introducing features that can make the act of facilitation less visible to an audience.

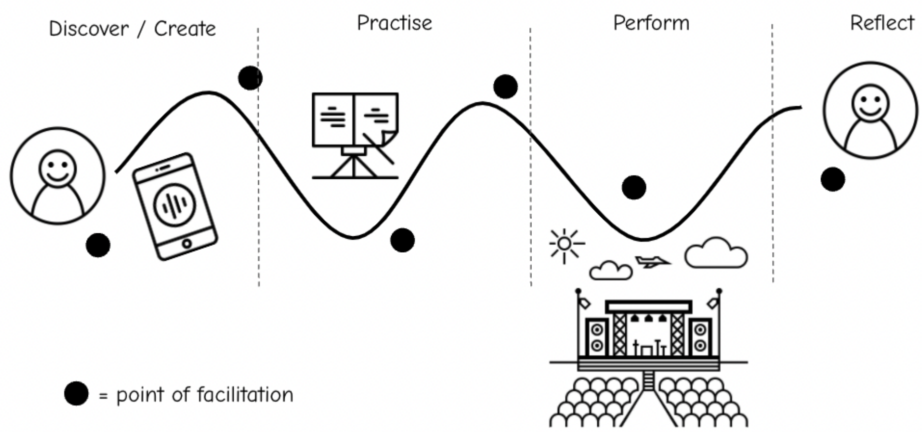

Figure 6.1: *An example interaction trajectory through the four phases of facilitated performance, showing where facilitation could create transition points.*

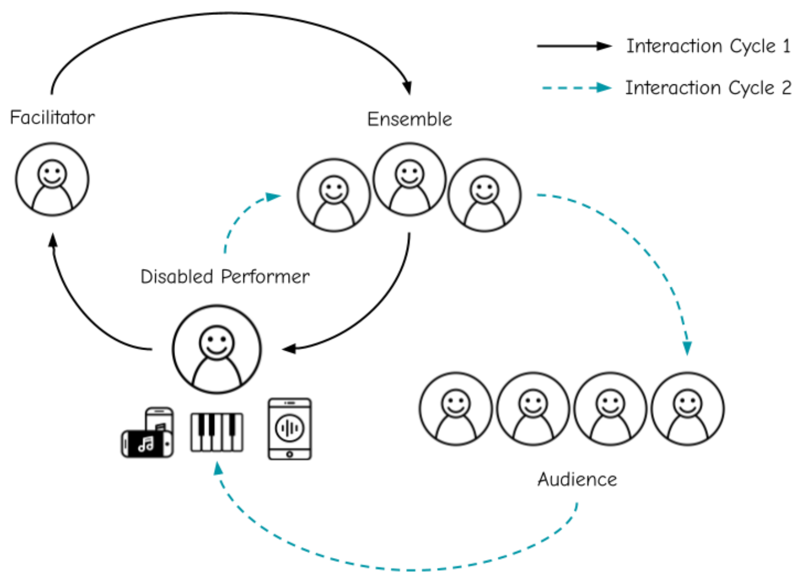

Figure 6.2: *Facilitated Performance Interaction Cycles: based on Schechner (1968) transactional models of performance.*

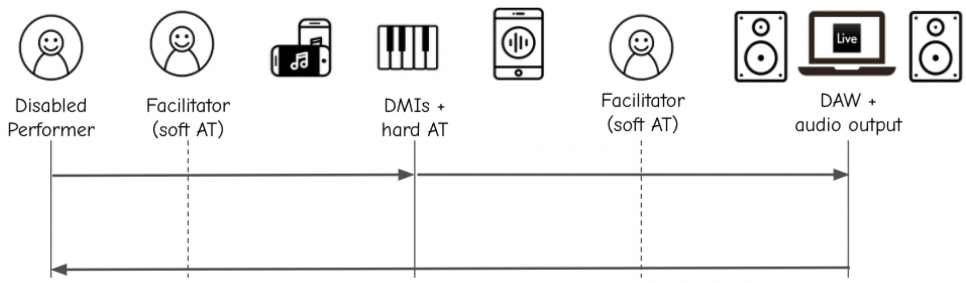

Figure 6.3: *Facilitators as 'soft' Assistive Technology (AT): A system diagram showing the interactions between the hard and soft elements of assistive technology in facilitated performance.*

6.2.1 Design recommendations for supporting facilitators as secondary users

As displayed in Table 6.1, facilitators might adopt roles that are musical, technical, or physical. However, not all facilitators can perform all roles. For example, prior knowledge may be required for some technical roles, meaning that only facilitators who possess this knowledge can perform them. Similarly, only facilitators with certain certifications can perform some of the physical support roles due to safeguarding or health and safety regulations. While there might be some facilitators that can switch between different types of roles easily, it is rare to find an individual facilitator that can perform all of the roles listed in Table 6.1. It is important for designers of DMIs to carefully consider any expectations of prerequisite knowledge and assess what challenges facilitators might face when using a DMI in each of these roles.

The diversity of knowledge required for each of the facilitation roles is notable. Knowledge about DMIs specifically and how they operate is most prevalent in technical roles. However, even those enacting physical support roles will need to familiarise themselves with the interface, regardless of their technical knowledge or abilities. Being able to recognise when there are issues, or perform 'quick fix' tasks, can be extremely helpful to keep inclusive music sessions on track. Complex and unfamiliar interfaces or interaction methods can make it harder for a facilitator to feel comfortable and confident performing these tasks.

The design of some DMIs considers that people using them may range from novice to expert musicians. Yet, there may be some assumption of knowledge of musical controls or features, even when this is the case. This tacit knowledge is something that some facilitators in inclusive music settings may not possess (Lucas et al., 2021; Dickens et al., 2018). When using DMIs in these settings, there is a need to consider this knowledge gap. Often this leads to a preference for using familiar devices, like tablets, and choosing DMIs that use familiar interface paradigms, such as a keyboard.

New and novel controllers can require time to learn the interface, which is not always available and can detract from the user experience by removing the immediacy of making music with a DMI. The introduction of new or novel DMIs into inclusive music settings is usually a result of one of two things. First, the DMI is a prototype built by a facilitator that they are testing in practice, or second, the device has accessibility benefits and is easy to demonstrate/learn. In both circumstances, concerns of troubleshooting and learning time decrease due to the creator/facilitator's support.

The majority of knowledge management occurs through a communication exchange between the types of facilitators. For example, a facilitator with musical and technical knowledge may support other facilitators acting in a physical support role and help them understand the DMIs in use. Alternatively, a facilitator with the physical support knowledge may advise a musical or technical facilitator on the placement of DMIs in line with a disabled performer's assistive technology (if they cannot do so themselves). However, some of this knowledge management could be improved through DMIs having more accessible interfaces. For example, store and recall settings would lessen the requirement to know the full interface to setup a DMI for a performer. Though as acknowledged in the literature (O'Modhrain, 2011), any changes that may improve the experience for additional users should not alter the experience for the most important stakeholder, the performer.

Another important consideration for designing or evaluating a DMI for use within inclusive music sessions is the different creative activities and 'phases' of facilitated performance. The data gathered during the Able Orchestra project regarding using the 'LeapMusic' gesture-controlled technology probe showed that how a device interacts with the environment could alter its accessibility. This research identified four phases of facilitated performance: discover/create, practice, perform, and reflect. Each of these can present challenges for the accessibility of a DMI. In some cases, the transition between phases could drastically change accessibility. This change was most common when moving from practice to performance because of moving between environments. The literature review, provided in Chapter 2, highlights such challenges. Including issues with the relocation of sound sources in performance (Trueman et al., 2006; Trueman, 2007; Paine, 2010; Cascone, 2003), networking and instability issues (Hazzard et al., 2019; Trueman et al., 2006), and environmental elements that can alter functionality (Dickens et al., 2018).

The final challenge that the concept of facilitated performance appears to contribute to is the way DMIs address the musical concept of virtuosity. Circling back to the idea of making an instrument easier to learn and, in some cases, simpler to play can be seen to 'lower the ceiling' on virtuosity (Harrison, 2020; Wessel and Wright, 2002; McPherson et al., 2019). A facilitator's presence and assistance could also affect virtuosity or the perception of virtuosity from an audience perspective.

Performer agency is a crucial element towards this goal of virtuosity. In particular, there has to exist the ability to make mistakes to be able to learn and improve from them. As discovered in the Able Orchestra study, a facilitator adopting any role in an inclusive music session should be conscious of maintaining the performer's agency. This social navigation of agency may seem unrelated to the design or accessibility of a DMI, yet how technology presents and operates can mitigate it. For example, having clear visual feedback and auditory feedback can provide a way for a facilitator to problem solve 'at a glance' rather than having to 'use' the DMI to access settings or check the current state of the DMI. This additional feedback can be significant in performance settings, as the audience may misinterpret a facilitator's actions of stepping in to alter or 'fix' settings as some level of active performance participation. Additionally, having a DMI that interacts well with assistive technology can result in less reliance on a facilitator's presence. Which can increase agency for the performer, giving them more time and space with a DMI to learn and explore.

6.3 Tailoring technology

One of the activities related to facilitated performance is the act of tailoring DMIs to suit the creative and physical needs of disabled performers. Adapting or tailoring DMIs was a common activity experienced within both research studies. This could be achieved through adapting the musical, technical, or physical elements of a DMI. Musical elements that can be tailored include the instrument sound, the harmonic key or scale the DMI is set to, and the step value between the available notes on the interface. Whereas the technical tailoring of DMIs includes actions like increasing interaction targets or changing colour profiles. Finally, physical tailoring might include changing elements of a hardware device to be more usable, switching out physical controls for different form factors, or creating custom-built housing/stands/supports for an existing DMI.

Tailoring or adapting DMIs is a theme that occurs in the literature mostly when discussing bespoke DMIs or ADMIS (Frid, 2018, 2019a,b; Harrison, 2020; McPherson et al., 2019). However, there are some studies that look at adapting commercially available DMIs for disabled people (Lucas et al., 2019). As research studies are often iterative, the time given to the exploration and review of adaptations is not always representative of a real-world context in which a DMI might need to be adapted quickly. Additionally, the adaptations made for a device, bespoke or commercial, can be difficult to replicate without specialist equipment.

In this research, the concept of 'tailoring' explores the existing features of DMIs and how these can be used to adapt a device to better suit a disabled performer's needs. Some features that were identified as offering the potential to tailor a DMI include the ability to adjust the input sensitivity of an interface, offering colour profiles or choices for LEDs or graphical user interfaces (GUIs), being able to use the DMI as a MIDI controller, offering ways to change the size of touch targets, and the ability to reduce the number of elements on a GUI. These features listed are not exhaustive, nor are they common to every DMI. However, it was observed that the number of options to customise a DMI offer far more flexibility when compared to traditional acoustic instruments (Harrison, 2020).

Through exploring the existing features of DMIs and how these could be used to customise or tailor an instrument for a disabled performer, some commonly used features were discovered. These features offered a means of improving the accessibility of a DMI and also increased the DMI's potential usability for inclusive music-making settings. The first of these common features is the ability to use a device as a MIDI controller. MIDI is a communication protocol that allows a DMI to interface with other devices and MIDI modes or settings are available on both hardware and software devices. Sometimes this is achieved wirelessly, which is an additional benefit from an accessibility viewpoint, but that is not always the case. Having MIDI available as a feature on a DMI improves the potential accessibility through offering a way to customise or 'map' the controls (Dickens et al., 2018; Frid, 2019a), and through widening the range of instrument voices that can be used.

The second common feature is the ability to change the colour profile of a DMI. This feature does not apply to all DMIs, as some fixed hardware devices cannot offer this option. However, offering colour customisation was recognised as a common feature that a lot of DMIs can offer, even if they currently do not. For software-based DMIs changing colours, most importantly contrast levels between colours as acknowledged in the Web Content Accessibility Guidelines (W3C, 2022b), can be extremely beneficial for the visually impaired community, especially for people with a colour vision deficiency. In hardware, being able to change the colour of LED indicators, or the colour of any back-lit controls, can be extremely helpful for providing custom visual indicators that better suit a performer's needs.

A third example of a common tailoring feature that supports accessibility is the ability to adapt a DMI to use a set musical scale. In the research studies, this was referred to by facilitators as 'key locking' a device. This feature could be controversial to some, as it relates back to the ideas of virtuosity and 'simplification' of a DMI. In reality, it offers a method of standardising the ensemble to the same musical scale, much like an orchestra might collectively tune to a 'concert A' before a performance. This musical tailoring helps with accessibility as it can provide a way to reduce the complexity of an instrument's interface, as well as limit the impact of accidentally triggering a control through involuntary movement. In inclusive music projects, like those discussed in the study chapters, time dedicated to practice and learning can be minimal. The musical 'key lock' feature can be extremely important for preserving the user experience and reducing concerns about 'getting it wrong' (Dickens et al., 2018).

Tailoring the interface of a DMI was another commonly used feature observed within the studies. Again this is not always possible for physical hardware devices, but a number of software and hardware devices do allow for interface customisation. Software-based DMIs can offer many ways to change the GUI, not just through colour choices, as already mentioned, but through changing touch target sizes, removing labels, and even deactivating or removing certain controls from the interface. In hardware devices changing the visual representation of the interface is less common, yet some still provide an option to customise the mapping of controls, and this can include making some controls inactive. Hardware can also offer ways to increase the size of controls through having removable faders, rotary potentiometers, and other button/switch type controls. These types of hardware control can then be switched out for customised elements or larger commercially available controls. In both circumstances, this can extend the accessibility of the DMI to be tailored to better suit the needs of a wider range of performers (Lucas et al., 2019).

The fifth and final example of a common feature that allows for the tailoring of a DMI to better suit accessibility requirements relates to the input methods offered by a DMI. Often instruments are limited to only one form of input, for example, touch, but through the availability of sensing technologies, some DMIs can offer multiple types of input. Again, software-based DMIs have the most flexibility here, as they can rely on the other inbuilt sensors of the devices that run the software. Though less common, it is not impossible to find hardware-based DMIs that also offer multiple types of input, for example, both touch and motion-activated controls. Offering multiple input methods in this way expands the accessibility of a DMI to more people.

A DMI offering a single one of these customisation options is not going to instantly become more accessible to everyone. However, having tailoring options can change the fundamental accessibility of a DMI. The flexibility of technology makes it easier to adapt or tailor DMIs; as already acknowledged for traditional acoustic instruments, this level of customisation is difficult to achieve within projects. The cost of doing so is also much greater and requires longer consultation processes with an individual because the form factor or body of an instrument might need to be completely reimagined and reproduced (Harrison, 2020). Adapting acoustic instruments in this way also creates products that are bespoke to a single performer, which is important for disabled musicians who need an instrument for their individual practice but lowers the possibility of using that instrument with multiple performers in an inclusive music session. Technology in these circumstances triumphs because of re-usability. This is especially true for software-based DMIs on familiar interfaces like tablets. It is rare that adapting a software instrument will change the physical features of a device, and all changes that are made can easily be reset to the defaults.

From observing the flexibility that technology can offer in these settings, it is easy to understand why the use of DMIs in inclusive music settings is increasing, with communities being created to support growth (Lucas et al., 2020). Yet there are still challenges to be faced in tailoring DMI technologies to suit individual needs; as represented by Lucas et al. (2021) in Figure 6.4 there exists a series of trade-offs that have to be made in order for this process to be successful.

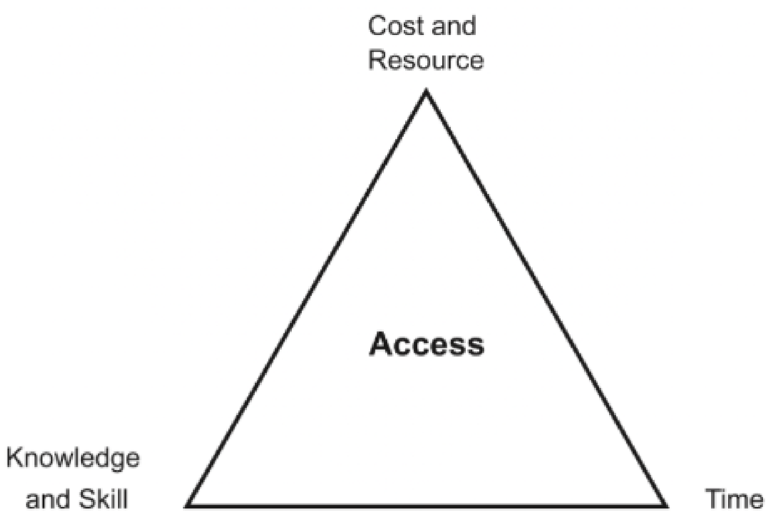

Figure 6.4: *The dependency mode of accessing music through technology represents a series of trade-offs. A shortage of one factor can be compensated by the presence of another.(Lucas et al., 2021)*

Improving some of the fundamental accessibility issues of commercial DMIs could lead to a reduction in both knowledge/skill and time dependencies. However, this proposition leads to two questions:

1. What are the fundamental accessibility issues for a DMI?
2. How can DMIs be evaluated for fundamental accessibility issues?

6.4 Evaluating accessibility in Digital Musical Instruments

Evaluating the accessibility of DMIs has been acknowledged as a challenging task that is yet to be addressed fully within research (Frid, 2019b; Lucas et al., 2019; Davanzo and Avanzini, 2020). The reason that evaluation of the accessibility of a DMI is recognised as challenging is largely due to the recognition that disability is a unique experience based on the individual. A generalised accessibility review from a user perspective would be difficult to achieve even with a large user group. Equally, the evaluation criteria for accessibility in DMIs can be dependent on the context in which the DMI is being used.

The method through which accessibility should be measured has also been brought into question, as both quantitative and qualitative methods could provide value. The vast differences in what a DMI can be and how DMIs are classified, as discussed in Chapter 2, also add to the complexity.

While some public resources exist for buying accessible instruments (Creative United, 2021), these don't always specify how the instruments were selected or identified as 'accessible'. Research has attempted to propose some dimensions for evaluating accessibility (Davanzo and Avanzini, 2020), but some of the dimensions proposed, such as 'Adaptability' or 'Simplification' can rely on a value judgement that could easily be open to subjectivity and bias based on who is evaluating the DMI.

Equally, in (Davanzo and Avanzini, 2020), the relationship posed between disability and musical abilities leans into a more medical than social model of exploring this problem space. For a true social model approach to accessibility in DMIs, it is more beneficial to consider how the DMI poses barriers to disabled people. Even if it is identified that a type of DMI is inaccessible to people with a specific disability, the question should be *"what about this DMI limits the experience for people with this disability?"* and not *"how does this disability impact ability to interact with this DMI?"*

It is important when proposing an evaluation tool of any kind that the tool does not perpetuate a bias or stereotype of what can be achieved by disabled musicians. Therefore, it feels necessary to provide information that is focused on the technical features of a DMI first and only relates these to disability through an explanation of how a DMI's features can create barriers to access. While it is sometimes beneficial to assess a DMI against a performer's disability, leading with this approach can risk stepping into evaluating a person's competency instead of an instrument's accessibility.

Web standards (W3C, 2022b, 2016, 2020b) are perhaps the best example of accessibility documentation that balances the acknowledgement of technology imposing barriers with offering solutions that address different accessibility requirements. This is achieved through a set of success criteria that address different levels of accessibility, classified by an A, AA, and AAA system. As developers address the success criteria for each level, the websites that are created become more accessible to more people.

To achieve this for DMIs, the understanding of accessibility has to start at a fundamental level with identifying common barriers that exist across multiple DMI formats. The studies conducted in this research have allowed some of these commonalities to be identified. More specifically, the qualities of durability, flexibility, complexity, practicality, and compatibility, identified in Chapter 5, provide a set of fundamental themes on which to form guidance about accessibility in DMIs.

How to evaluate each of these fundamental themes presents a different challenge. As noted, literature in this field has discussed both qualitative and quantitative methods for analysing accessibility in ADMIs (Lucas et al., 2019; Frid, 2019a; Davanzo and Avanzini, 2020). This research has taken a qualitative approach to gain insight and understanding of the accessibility challenges for DMIs in inclusive music settings. From this approach, it was observed that some DMI features could be evaluated by a method of closed questioning. For example, questions such as *"Can this DMI be used as a MIDI controller?"* could be given a binary yes or no answer and would provide more insight into the flexibility of that DMI.

Using closed questions in this manner could reduce the subjectivity that may be introduced by other methods of evaluation, such as the aforementioned dimension space evaluation (Davanzo and Avanzini, 2020). However, it was noted that using closed questions in this manner could not be extended to all features of DMIs that are important for accessibility. Therefore, an evaluation tool or framework using this approach alone would not be fully representative of all the issues related to DMI accessibility.

Proposing a set of closed questions as an evaluation tool could be helpful to several people, including those looking for more accessible DMIs. Even so, this would need to be paired with some open questions to gain a deeper understanding of all the potential accessibility issues of a DMI. For example, *"How many steps are there from turning the DMI on to making music with it?"*, questions like this cannot be answered with a binary answer. It could be proposed that providing a range of options for such a question would work for evaluation. In this case, someone might choose between options such as *"none"*, *"under five"*, *"six or more"*. However, these options, in reality, are arbitrary, and the relationship between increased steps and increased complexity can be subjective to the individual. Using open questions about this element instead provokes discussion and reflection on a feature of a DMI that has the potential to add complexity.

These open questions are especially important for people outside of inclusive music-making communities. As Chapter 4 highlights, a number of accessibility barriers only become apparent in use. Additionally, some features of DMIs that present challenges for accessibility only occur in certain environments. Using open questions that prompt consideration of environments and use contexts can help to build an awareness of these challenges.

Additionally, an evaluation resource for looking at the accessibility of DMIs should also look to help people build empathy and gain a better understanding of accessible music-making. Much like web standards, (W3C, 2022b, 2016, 2020b) and the Aegis Open Accessibility Framework (AEGIS Project, 2013) provide additional information to contextualise why they are needed and how they should be used. From the observations in Chapters 4 and 5, it could be concluded that providing insight into facilitated performance, as well as the roles and activities of facilitators, could be very helpful in providing additional context.

Combining an evaluation tool with these resources on facilitated performance would be best encapsulated in a framework document. It could offer both the knowledge sharing that has been lacking within the inclusive music community (Samuels and Schroeder, 2019; Dickens et al., 2018) and a method of gaining more understanding about the accessibility of specific DMIs. Yet, there are some important considerations for how to compile such a document, for example, the language it uses and the audience that has access to it.

Here it is important to emphasize the statement from disability movements,

"Nothing about us, without us" (Charlton, 2004).

Proposing a framework for evaluating the accessibility of DMIs must acknowledge this. Furthermore, it must provide a way for disabled musicians and those who are part of inclusive music-making communities to both access and contribute to the document. Therefore a document written in an academic manner and only shared in an academic forum would be limited as to the impact and adoption it could have within both community and industry.

Chapter 7 proposes a framework written with a general audience in mind and tries to use accessible language throughout. This framework is shared on a publicly accessible website [1] and actively invites critique and contributions from the community.

[1]www.accessibleinstruments.org

Chapter 7

Facilitating Access to Musical Experiences (FAME) Framework

This chapter explores the development of the facilitating access to musical experiences (FAME) framework. It outlines what is meant by musical experiences and how accessibility can be related to digital musical instruments (DMIs). It considers the scope, audience, and aims of such a framework. After which, it introduces the framework composed from the research activities. A section is then dedicated to putting the framework to work', in which example reviews are completed and discussed. Finally, it outlines the potential for community engagement and the possible impact of the framework for inclusive music.

7.1 Introduction

As acknowledged in the two study chapters, Chapter 4 and Chapter 5, a lot of time is spent within the accessible music community testing DMIs for different requirements. Including sometimes even “hacking” or adapting the technologies to better suit an individual and their abilities. This activity of “trial and error” with DMIs is often repeated by different community groups with the same outcomes.

The discussion in Chapter 6 evidenced that while there is much enthusiasm within the community to engage in knowledge sharing, there is a distinct lack of time and resources to achieve it. The lack of a canonical source of information about inclusive music-making and the accessibility of DMIs is one of the issues here. Creating a shared knowledge base enables communities to support each other through sharing their experiences of working with DMIs, which could result in saving time in accessible music projects. A shared knowledge base could also help to establish a public and more extensive list of DMIs that can be used successfully in inclusive music settings. This could also benefit DMI creators to better understand the requirements for accessibility and how to build these into their own designs through feedback from the community.

The Facilitating Access to Musical Experiences framework aims to encourage people to consider accessibility at the foundation of DMIs and related music technology. Through sharing knowledge about inclusive music-making and providing guidance on accessibility requirements, the framework encourages DMI creators to adopt best practices for accessibility. The audience for the framework includes but is not limited to DMI creators, inclusive music communities, and researchers in relevant fields. For DMI creators the framework can help to support and inform design choices in the development of new or existing DMIs, for inclusive music communities the framework can help community members evaluate DMIs before including them in their practice, and for research it offers a starting point for continued discussion of evaluating the accessibility of DMIs.

The language choice of 'facilitating access to musical experiences' was made to emphasise that the framework is not aimed at a specific context or accessibility requirement. It has potential to be useful to both individuals and communities. Equally, it could be useful for assessing DMIs for use in many contexts, from learning how to play a DMI to engaging with music for therapeutic purposes. The framework however,does not take a generalised approach to accessibility and acknowledges that there is no such thing as a 'one size fits all' approach.

7.2 Developing the framework

There are four sources of information that contributed to the development of the FAME framework:

1. The lessons learned during active observation of inclusive music-making practices, as outlined in Chapters 4 and 5.
2. Common themes for accessibility and music within the literature, as highlighted in Chapter 2.
3. Reviews of accessibility documentation and standards for technology, also discussed in Chapter 2.
4. Professional experiences of the author, as a web accessibility specialist and accessibility consultant.

The following four sections discuss each of these sources and how they have contributed to the development of the framework in more detail. Following this is a section that outlines some additional considerations that were made when developing the framework.

7.2.1 Observational studies

The findings from observing how DMIs were used in inclusive music practice, as discussed in Chapters 4 and 5, were particularly helpful when creating the formal principles of the framework. This included findings related to observing specific activities such as musical exploration, structured practice, rehearsals, and live performances. Observing disabled musicians in each of these contexts was extremely valuable in exposing some of the accessibility requirements for DMIs. More specifically, findings from both the Able Orchestra project and Able Lite workshops helped to identify the features of DMIs that made them more suitable and successful for disabled musicians.

These features were analysed and broken down into five core qualities, as outlined in 5.7.3: durability, flexibility, practicality, complexity, and compatibility. The contextual definition for each of these is given within the framework, outlined in section 7.3 of this chapter. The choice to use these words specifically was made so that each could be put into a single sentence about accessibility in DMIs that could be easily understood. For example, "to be accessible, a DMI must be durable". The framework offers some guidelines for each of these five qualities, which helps the reader to understand them in more detail.

Additionally, the observational studies informed much of the contextual information for the "Guide to Facilitated Performance". This is an additional section within the framework that aims to help those unfamiliar with inclusive music settings. It explains the activities, roles, and other elements of facilitated performance. This section is intended to help DMI creators and designers in particular in understanding the contextual challenges of inclusive music practices.

7.2.2 Themes from the literature

As emphasised in Chapter 2, there are a number of themes related to accessibility and DMIs that occur throughout the literature. In examining these, it became clear that the FAME framework needs to cover all the features of a DMI which might be used to evaluate it. Figure 7.1, included in Chapter 2 and repeated below, shows the elements of a DMI that may be questioned when evaluating its success as an instrument. However, it is important to note that these elements do not equally contribute to evaluating the accessibility of a DMI. Yet, the five core qualities identified within the framework could potentially have a large impact when evaluating these elements and may contribute heavily to the success or failure of evaluating a DMI against them. For example, complexity relates directly to instrument learning and practice, and flexibility can impact performer independence and creative ownership, and so on.

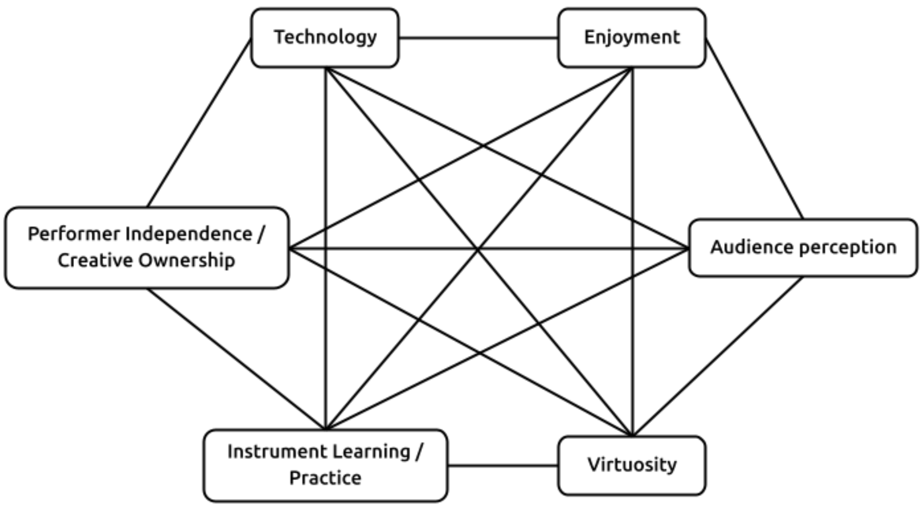

Figure 7.1: *Elements of the user experience that can impact the success of a Digital Musical Instrument*

The framework addresses the fundamental qualities that impact accessibility, which is in some ways prerequisite to being able to evaluate a DMI for success/failure as an instrument. As explained by O'Modhrain (2011), if an instrument is unable to communicate the intent of a performer to an audience, it fundamentally fails as an instrument. The accessibility of a DMI is a prerequisite to evaluating how the instrument communicates performer intent to an audience.

The literature also exposed that there is a lack of standards, or guidelines, for creating accessible DMIs (Frid, 2019a; Harrison, 2020). This framework does not speak to creating accessible DMIs specifically, but it addresses one of these issues by providing guidelines on the qualities that can improve accessibility in DMIs. It does not intend to address the entire problem space here. In reality, this can only come from a much bigger community effort to provide more insight into individual experiences. However, it is a starting point and can evolve over time as new technologies and accessibility challenges are discovered.

7.2.3 Evaluating accessibility frameworks

At the time of writing, several guidelines exist for accessibility. As outlined in Chapter 2, these can range from being domain-specific to more general technology guidelines. Additionally, the resources for technology that can be easily discovered in the public domain are mainly focused on online access and information presented on a screen.

While much of the documentation mentioned can provide a general overview of the best practices, it is difficult to apply these best practices to the technologies used in creating DMIs without specialist knowledge of accessibility. A goal of the FAME framework is to bridge the gap between general accessibility guidelines and guidance that is specific to the domain of DMIs and related music technology.

7.2.4 Professional experiences

The FAME framework also has been heavily influenced by the researcher's previous professional work as a Certified Professional in Web Accessibility (CPWA) and current role as an accessibility consultant for the music technology industry. This includes experiences within companies in the music technology industry, as well as training and certification in accessibility core competencies from the International Association of Accessibility Professionals.

These experiences have impacted the way in which the researcher thinks about and refers to accessibility and disability. An important consideration when creating the framework was the use of accessible language in order to be inclusive. One of the difficulties encountered in many guidelines and standards for accessibility is that the language used can be inaccessible, which can be exclusive to any reader with a cognitive disability. Equally, the way in which these documents are visually and structurally presented is often a barrier for many. As observed in Chapter 2, many existing resources include a quick reference or 'how to' document as an addendum because of these issues.

The FAME framework aims to make no assumptions about a reader's prior knowledge or experience of accessibility. Accessible language is prioritised throughout, with the exception of using specific technical terms related to music, music performance, or DMIs. A familiarity with DMIs and common features of their interfaces is anticipated.

7.2.5 Additional considerations when developing the framework

There were a number of additional considerations in developing the framework that shaped the final version; these are summarised in this section.

7.2.5.1 DMIs used in developing the framework

The DMIs evaluated in developing the framework are considered to be consumer products and are available to purchase at the time of writing. This was an intentional consideration. It is important to note that FAME does not explicitly discuss requirements for novel or emerging technologies. However, guidance provided within the framework may be applied to such technologies.

Consequently as technology evolves, new questions will arise regarding accessibility recommendations. For this reason, there will be an interactive process whereby future versions of the framework may be updated to address new information. Therefore the version discussed in this chapter should only be considered to reflect readily available technologies at the time of publication.

7.2.5.2 Additional content created for the framework

Three additional pieces of content were created to accompany the framework document. A guide to facilitated performance, a set of facilitator personas, and a data log for use in inclusive music settings.

Guide to facilitated performance

The guide to facilitated performance was developed from both the observational studies and examples of inclusive music practice provided in the literature. This additional guide is designed to help readers gain an understanding of the challenges within inclusive music settings. Inclusive music-making is a sociologically rich setting, and it is useful to contextually understand the characteristics of this, especially when considering the design and accessibility of DMIs. The guide provides insight into the phases of music creation when using DMIs in inclusive music workshops while also outlining some of the activities, roles, and responsibilities of facilitators. However, it is not designed to capture every detail about the social experience of facilitated performance. The guide acts as an introduction to the expectations and limitations for technology introduced to these settings.

Facilitator personas

Another resource created alongside the framework document is a list of facilitator personas. This was developed from professional experience and observational studies. Including such a list within the framework was considered important because of the potential to consider a facilitator as an additional 'user' of a DMI.

Testing with musicians can be common within some DMI production processes, but testing in this way cannot always be easily completed due to associated costs. In such a position where a company may not be able to engage with testers because of lack of funding or time constraints, personas like these can be a useful resource. For example, personas can be used within creative teams to conceptually walk through how the hypothetical character may respond to a product.

The observational studies helped to create personas that were representative of real-world facilitators in inclusive music settings.

The FAME Data Log

The observational studies also highlighted the common challenge of data collection for facilitated performance and inclusive music practises. Often in these settings, a multitude of devices would be used, with many settings altered to fit the requirements of the performer or piece of music. On many occasions, it was observed that a device would be given a specific setup for a specific musician and then labelled with the name of the musician. Once a device was labelled, it was a common understanding amongst facilitators and others that this device should not be altered or used by anyone else. Should a device labelled in this way fail, it was then up to the memory of a facilitator to recall the previous setup chosen for the musician to whom the device was assigned.

Memorising this level of metadata is challenging, even in small groups. Notes would be taken, but these could be very sporadic and not always shared in a centralised way where anyone could assist with the task.

Adding a log template for this data as an additional resource within the framework is intended to help facilitators with the collection of metadata about instruments. The data log provides a way to store this information and presents it in a way that can be understood by others if required. It also offers insight for DMI creators about the types of information collected by facilitators in these environments.

7.3 Facilitating Access to Musical Experiences (FAME): A framework for understanding the accessibility of Digital Musical Instruments

This section contains a copy of the FAME framework. The format aligns with other technical standards and is intentionally similar to the web standards formatting (W3C, 2022a). This format includes the document status and information related to scope and audience, followed by the core qualities and guidelines. It also includes additional resources for understanding facilitated performance.

7.3.1 Contents

7.3.2 Document status

Version: 1.0 [draft]

Author: A Dickens

Last Edited: February 9 2022

7.3.3 Introduction

This framework addresses the accessibility requirements for Digital Musical Instruments (DMIs) It aims to help DMI creators understand the needs of disabled performers and facilitators, including ways to include accessibility in product design .

The following documents are included in the framework:

- A how to guide on reviewing Digital Musical Instruments using the FAME framework
- An introduction to facilitated performance
- A list of facilitator personas
- A data log template designed to allow facilitators and disabled performers to capture additional data for music-making sessions

The approach taken by this framework is not to provide a way to 'score' the accessibility of a DMI. Instead, the goal of this framework is to help DMI creators understand potential accessibility barriers for DMIs and reflect upon these.

Accessibility is not a one time fix. This framework should be used repeatedly throughout the production life-cycle of DMIs, including reviewing products at release or when a new version is being produced.

7.3.4 Who is the framework for?

The following groups of people may find this framework useful:

Digital Musical Instrument Creators - This includes all people who may be involved in the process of creating digital musical instruments. For example, developers, designers, product managers, and manufacturers.

Accessible Music-Making Communities - Including facilitators, teachers, independent musicians, program managers, and people who purchase DMIs for community programs.

Researchers - Any person who is conducting research in the following areas: digital musical instruments, accessible or inclusive music-making, accessible technologies, and accessibility standards.

7.3.5 Important terminology

Digital Musical Instrument

A Digital Musical Instrument (DMI) is a device that produces sound using digital technology. They can come in many forms, including some that mimic the look and feel of traditional acoustic instruments.

Accessible or Inclusive Music

These two terms are used interchangeably. The terms refer to music activities that are inclusive of disabled performers and/or specifically aimed at engaging groups of disabled musicians.

Facilitated Performance

Facilitated Performance is a term used to describe the practice in which a musician or performer is supported by another person (a facilitator). Facilitators can offer musical, technical, or physical support for a person depending on their needs.

7.3.6 The framework

7.3.6.1 Understanding the accessibility of a Digital Musical Instrument

To understand a DMIs level of accessibility, this framework examines five core qualities of digital musical instruments:

Durability

Durability questions how robust the instrument is.

A DMI must be able to work reliably within many different contexts, from practice to performance.

This quality measures the strength of the physical or virtual elements of a DMI.

Flexibility

Flexibility examines how adaptable an instrument is.

The more flexible a DMI is, the more it can be adjusted to a musician's style or needs.

This quality measures the level of flexibility afforded by the physical or virtual elements of a DMI.

Practicality

Practicality observes how quickly an instrument can be setup.

This is an important quality for a DMI to succeed in inclusive music settings and live performance.

This quality measures the speed of setting up the physical or virtual elements of a DMI.

Complexity

Complexity explores how complex the user interface of an instrument is.

This quality measures the level of complexity introduced by the physical or virtual elements of a DMI.

Compatibility

Compatibility looks at how well an instrument integrates with a musician's existing setup. This includes whether the DMI supports any form of assistive technology.

This quality measures the level of compatibility offered by the physical or virtual elements of a DMI.

7.3.6.2 FAME guidelines

These guidelines offer ways to improve the accessibility of an instrument based on each of the five qualities.

1. Durability: A DMI should be able to withstand the physical demands of practising and performing.
   - 1.1 Provide alternatives to physical connections.
   - 1.2 Safeguard against accidental damage.
   - 1.3 Provide stable operation for long periods of time.
2. Flexibility: A DMI should accommodate many musical and playing styles.
   - 2.1 Offer more than one way of interacting with the DMI.
   - 2.2 Allow the musician to alter the interaction settings.
   - 2.3 Provide the ability to adapt the musician's interface.
3. Practicality: A DMI should be easy to introduce to a musician's setup.
   - 3.1 Aim for 'plug in and play'.
   - 3.2 Provide any specialist adaptors that may be required.
   - 3.3 Enable the ability to recall settings or musician profiles.

4. Complexity: A DMI should be simple enough for all levels of musicians to understand.

    4.1 Provide options to minimise the detail of an interface.

    4.2 Ensure the interface can be understood in many contexts.

    4.3 Provide clear feedback in response to actions.

5. Compatibility: A DMI should be compatible with a musician's setup, including hardware, software, and assistive technologies.

    5.1 Expose the interface to assistive technologies.

    5.2 Offer multiple ways to mount the instrument.

    5.3 Allow open communication with the instrument.

7.3.6.3 Reviewing Digital Musical Instruments using the FAME framework

A series of questions have been developed that address each of the five core qualities outlined in the FAME framework.

The first part of reviewing the accessibility of a DMI involves answering 20 closed questions that can only be answered with either 'yes' or 'no'. The answers to these questions help to build an accessibility profile of a DMI related to the five core qualities outlined in the framework. Any of these areas where a DMI could have accessibility issues will be highlighted in the profile of the DMI. This will be signified by either +, !, or !!, which indicate a 'low', 'medium', or 'high' chance of there being accessibility barriers for the DMI.

These questions are accompanied by a set of 10 open questions, found in part two. These open questions invite a more reflective look at an instrument's potential barriers to accessibility.

The FAME review questions: Part One

1. **Can the instrument be used as a MIDI controller? YES / NO**

   This means the instrument can communicate with other software and hardware using the most up to date MIDI protocols (either wired or wirelessly).

   Using a DMI as a MIDI controller can provide a more accessible way for disabled musicians to interact with other music software and hardware.

   Related guideline: *Flexibility*

2. **Does the instrument require additional setting up before first-time use? YES / NO**

   'Setting up' is a term that can include product authorisation, downloading paired applications or software, altering user preferences, etc.

   DMIs that have setup processes containing many steps can be problematic for disabled musicians. The more steps involved, the more likely it is that one of those steps is inaccessible. If a step is inaccessible, it can take much longer to start using the instrument or prevent it from being used.

   Related guideline: *Practicality*

3. **Does the instrument only work with preset sounds? YES / NO**

   This means an instrument only has a limited selection of sounds and cannot be used with other software or hardware that might extend this.

   Using a list of preset or 'built-in' sounds could limit an instrument's use for disabled musicians. For example, a person with a sensory disability may not be able to find a suitable sound within the limited choice.

   Related guideline: *Flexibility*

4. **Can the instrument be used wirelessly? YES / NO**

Wireless in this context is inclusive of all connections, including power and audio cables.

An instrument connected to multiple cables can be hazardous in some situations, especially for disabled musicians with sudden involuntary movements.

Related guideline: *Durability*

5. **Can the instrument produce sound independently? YES / NO**

   This means the DMI can produce sound without being connected to any other hardware or software, apart from headphones or an amplifier.

   Requiring additional software or hardware to produce sound increases the possibility of part of this system being inaccessible in some way. It also adds to the complexity of the instrument. This can make it difficult for disabled musicians to integrate the DMI into their current setup and practices.

   Related guideline: *Compatibility*

6. **Can the instrument be mounted on a stand? YES / NO**

   This could be using a general or specialist stand attachment.

   Being able to mount a DMI on a stand can be helpful for disabled musicians who use a wheelchair, as well as musicians with disabilities that impact their dexterity or ability to grip and hold an item.

   Related guideline: *Practicality*

7. **Can the input sensitivity of the instrument interface be adjusted? YES / NO**

   Being able to adjust an instrument's sensitivity to input can be very important for a musician's playing style and ability.

   A disabled musician with limited movement may want to adjust the input so that the output can be scaled from a smaller range of movement.

Related guideline: *Flexibility*

8. **Can a musician store and load custom settings? YES / NO**

   The ability to load an instrument's previously used settings or setup a custom profile and preferences is useful.

   This can reduce the time disabled musicians may spend navigating potentially inaccessible settings and preference menus.

   Related guideline: *Practicality*

9. **Can the instrument interface be adapted? YES / NO**

   This refers to the ability to change the physical controllers on hardware or adjust the visual interface of software-based instruments.

   For many disabled musicians, this can reduce the complexity of an interface. It can also provide a way of creating an interface that is easier to physically interact with.

   Related guideline: *Complexity*

10. **Can a musician adjust the colours used in the instrument's interface? YES / NO**

    Colour can be present in many visual interfaces; this includes LED lights on hardware controllers.

    For musicians with a visual disability, changing the colour can be extremely important and, in some cases, make or break the interaction.

    Related guideline: *Flexibility*

11. **Does the instrument interface support high contrast? YES / NO**

    High contrast allows a musician to invert foreground and background colours. For software-based DMIs high contrast can be supported as an accessibility feature or through colour profiles. For hardware-based DMIs, this can mean offering a secondary version of a product with the colours inverted.

Musicians with visual disabilities may require a high contrast interface to be able to use it comfortably.

Related guideline: *Compatibility*

12. **Does the instrument interface work with screen reading technology? YES / NO**

    Screen reading technologies can be present in both hardware and software instruments.

    Disabled musicians who use a screen reader may not be able to use equipment that does not provide speech output.

    Related guideline: Compatibility

13. **If the instrument were to be accidentally knocked to the floor (from a 1-meter height or more), would it still function in the same way? YES / NO**

    It can be of benefit if an instrument can withstand reasonable damage and remain functional. For software instruments, the physical device used to access them should be considered.

    Disabled musicians that have sudden involuntary movements are more likely to accidentally drop or knock an instrument unintentionally.

    Related guideline: *Durability*

14. **Can the instrument operate consistently for longer than 2 hours? YES / NO**

    This refers to an instrument being able to continuously operate for long periods of time with minimal risk of processing or buffer issues that may impact performance.

    In inclusive music settings, creative and practice sessions can take much longer than anticipated. Technology that needs to be recharged or that becomes temperamental during long sessions can be restrictive.

Related guideline: *Durability*

15. **Are protective accessories for transport available for the instrument? YES / NO**

    Protective accessories refer to all types of accessories designed to protect the physicality of the instrument. This could include cases, silicone covers, cloth protectors, etc.

    Having additional protective accessories can minimise the 'wear and tear' of an instrument, especially in some contexts, like inclusive music sessions, where the likelihood of accidental damage is high.

    Related guideline: *Durability*

16. **Are proprietary adaptors and/or cables required to use the instrument with live sound equipment? YES / NO**

    Live sound equipment refers to PA systems, DI boxes, audio interfaces, etc.

    Having to remember to always carry and connect additional adaptors for equipment can be tricky for musicians with a range of disabilities.

    Related guideline: *Practicality*

17. **Does the instrument operate the same in practice and performance? YES / NO**

    Performance environments can be challenging for some instruments. Changes in lighting, for example, can impact the ability to see the instrument interface, and this may require adjustment.

    The need to switch between a practice and performance mode or setting can be difficult for some disabled musicians.

    Related guideline: *Complexity*

18. **Is feedback from a musician's action presented in more than one way? YES / NO**

A musician's action can result in many forms of feedback. Sound output is not always present as there are many actions that relate to other instrument functions, like changing the type of sound or mode.

If these actions are only communicated by one type of feedback, for example, visually by an LED, the result can be 'invisible' to musicians with a visual disability.

Related guideline: *Complexity*

19. **Can a musician pause, stop, hide or control elements of an instrument that may be distracting? YES / NO**

    Moving, blinking, or auto-updates to an interface can be distracting. A musician should be able to remove any distracting actions apart from those that may be considered essential, for example, a blinking LED indicating tempo.

    Musicians with certain types of cognitive disabilities can struggle to use interfaces with lots of distracting elements such as lights or animations.

    Related guideline: *Complexity*

20. **Do instrument controls of the same type behave in the same way? YES / NO**

    Controls that behave the same way create consistency. Any controls that appear similar but behave differently can add complexity and cause confusion, for example a hardware control that can be pressed and turned on a DMI that features other controls that appear the same but these can only be turned.

    This can be an issue for musicians with cognitive disabilities and for musicians with physical disabilities. Creating a mental model for similar controls that behave differently is more difficult, equally changing the movement used to interact with a control when the control form factor remains the same can be uncomfortable.

Related guideline: *Complexity*

The output of these questions alone will not provide a complete overview of the accessibility issues for a DMI. To complete the review, please also complete part two of the FAME review questions.

The FAME review questions: Part Two

The following open-ended questions explore the accessibility of a DMI as a whole 'system'.

1. **How does the musician interact with the DMI?**

   Think about every step of making music with the instrument. Consider the level of strength or dexterity an action may require. Note how each of the controls is operated. Try to explore if there are any situations in which the DMI would not respond to a musician's input.

2. **What genres of music can the DMI be used in?**

   Consider the type of interface the DMI has, what are the genres of music where it might be more commonly understood. If an instrument can be used across a wide range of genres, think about the styles of music where it might be difficult to use. Challenges could include the interface not offering a playing style that is required to achieve a certain sound or musical technique.

3. **Does the environment change the way a DMI works?**

   Evaluate whether anything in the environment could impact the use of the instrument. Changes in lighting are common between practice and performance spaces. In some live performance scenarios, water might even be a risk factor. Think about how these environmental factors could make the interface harder to navigate.

4. **Would a disabled musician require some form of support to use this DMI?**

In using an instrument, a disabled musician may require some support throughout the process. Consider what kind of support, how much, and when the assistance might be required for the DMI. Think about whether a disabled musician could engage with all parts of the setting up process, navigating instrument preferences, authorisation. If support is required to use the DMIs, consider whether this is likely to be only at certain times or necessary throughout.

5. **Are the action and output sound paired in a way that is obvious to an audience?**

   Audience perception of an instrument is an important part of music performance. Think about how a musician interacts with the instrument. A DMI should aim to make the relationship between a musician's actions and the instrument output clear to an audience. Consider if any adaptations made to the instrument or changes to the way it is used for a disabled musician could impact this. If this connection between action and output relies on the type of sound choice, think about whether any guidance is provided for the musician.

6. **What elements of the DMI can be altered to suit a musician's style or needs?**

   Think about the structure of the instrument and how fixed it is. Consider how it might be adapted for different needs; this could be through changing parts of the physical interface or settings that make it more or less responsive. For a graphical user interface, this could include changing the size of interaction areas on the screen or altering a colour profile. Create a list of the potential ways the DMI could be adapted.

7. **What are the required actions from switching on the DMI to making sound with it?**

   Create a list of all the actions involved in "setting up" the DMI for a music-making session. Consider whether there is additional equipment needed for the instrument to produce sound or extra software or updates that might need to be downloaded. If this is the case, note whether actions like downloading, authenticating, or pairing with other equipment are a one-time action on the first use or will need to occur with each use.

8. **How could the DMI be damaged?**

   Consider the instrument and where it has the potential to be easily damaged. Wired only connections can be problematic for causing tripping hazards on-stage, for example. Is there a requirement to charge the instrument regularly, and as a result, could it fail in long periods of use? The physicality of the DMI is also important here. Think about whether there are any elements to the physical device that could be damaged beyond repair. For software instruments, think about the device used to interact with the software. Also, consider the technology used to build the software and ways in which this could be fragile.

9. **Does the DMI rely on a single method of feedback?**

   Think about how the musician receives feedback from their actions when using the instrument. List the ways in which the DMI presents feedback to the musician. Feedback can be auditory, tactile (haptic), or visual. If the instrument uses a graphical user interface of any kind, note whether the feedback presented visually on the screen is presented in any other form.

10. **How does the DMI work with Assistive Technology?**

    Some examples of assistive technology include screen readers, magnification tools, colour overlays, guided access (available on iOS to limit the interaction areas of a screen), text enlargement, etc. When used with assistive technology, make a note of how the instrument behaves. Go through the whole experience of the instrument using assistive technology. Find any points where this differs from the experience without it.

7.3.7 Additional resources

7.3.7.1 A guide to facilitated performance

Facilitated Performance is a term used to describe the practice in which a musician or performer is supported by another person (a facilitator) in the activities of musical performance. Facilitators can offer musical, technical, or physical support for an individual depending on their needs. It is important to recognise that not all disabled musicians require support.

Facilitated performance is common within community-based accessible music-making programs. Often these programs introduce new technologies over a short period of time, which does not allow for an individual to become familiar with an instrument in a way that they can confidently use it independently (regardless of disability).

It is important to consider the activities that facilitators undertake and the roles they can adopt in order to understand how facilitated performance can impact both the adoption and use of a DMI.

The activities of facilitated performance

The activities of facilitated performance can be placed into four groups that reflect different phases of music-making. These are:

1. Discover/Create
2. Practice
3. Perform
4. Reflect.

Phase 1: Discover/Create

The 'discover/create' phase of the music-making life-cycle is focused on discovery. Facilitator activities related to the 'discover/create' phase are described in Table 7.1.

Activity	Description
Introducing Tasks	Introducing any project briefs, providing demonstrations of musical styles, soundscapes of instruments that will be used, including performers in project decisions.
Setting up equipment	Setting up any technology, putting up stands for microphones and other devices, running cables for the technical setup, moving furniture and setting up the space, giving directions to other facilitators.
Pairing musicians with DMIs	Working with individual performers, and testing out different DMIs. Using trial and error methods to find an instrument that suits the performer's abilities.
Adjusting technology to suit musician's needs/skill	Changing the sound of a DMI, altering the user input (e.g. sensitivity), making adjustments to the user interface, creating 'hacks' or workarounds to make an instrument work better for an individual.
Recording metadata	Taking notes about each session, including all the metadata from instrument settings.

Table 7.1: The activities of facilitated performance: phase one 'discover/create'

Phase 2: Practice

The 'practice' phase of the music-making life-cycle is focused on mastering the instruments and practising elements of a musical piece. Facilitator activities that are specific to the practice phase are described in Table 7.2.

Activity	Description
Recalling setup	Recalling the settings of technology used, positioning of stands and all other elements required for practice.
Directing	Usually musical direction, including providing cues for musicians, keeping time, or prompting performers one to one.
Assisting	Providing physical or musical support to an individual musician.
Observing	Watching the performer or group of performers as a spectator and making notes for improvements.
Giving Feedback	Delivering constructive feedback on progress throughout.

Table 7.2: The activities of facilitated performance: phase two 'practice'

Phase 3: Perform

The 'perform' phase of the music-making life-cycle is about sharing work through performance. Facilitator activities that are specific to the 'perform' phase are described in Table 7.3.

Activity	Description
Setting up for performance	Setting up the stage environment and equipment, including all technology settings and testing live sound levels with the front of house engineers.
Performing 'comfort checks'	Checking with each individual performer that they are happy with their technical and physical setup. Dealing with any concerns about the setup.
On-stage directing	Providing direction for a group or individual performer while on-stage. Working alongside conductors/musical directors. This can include being visibly on-stage with the performer(s).
On-stage assisting	Assisting a performer one on one while on-stage. This includes being visible on-stage with the performer during the performance.

Table 7.3: The activities of facilitated performance: phase three 'perform'

Phase 4: Reflect

The 'reflect' phase of the music-making life-cycle is about evaluating progress. Facilitator activities that are specific to the 'reflect' phase are described in Table 7.4.

Activity	Description
Reviewing	Watching or listening to recorded material from a performance. Leading discussions about the experience with the performer(s) and other facilitators.
Observing	Recording notes of the performer(s) reflections during review sessions.
Providing feedback	Delivering feedback and responding to performer reflections.

Table 7.4: The activities of facilitated performance: phase four 'reflect'

The Roles of a Facilitator

Some facilitators can be multi-skilled and take on a number of roles during the activities of facilitated performance. However, other facilitators may have a specific skill-set and will only take on a specific role or set of roles.

The roles of a facilitator can be grouped into three categories: musical, technical, and physical.

Musical Roles

Musical roles include Producer, Director, and Teacher, described in Table 7.5.

Role	Description
Producer	Leads the production throughout the phases of a project, works with the performer(s) to make creative decisions.
Director	Directs and provides prompts for a performer or group of performers.
Teacher	Introduces concepts, teaches technique, demonstrates musical tasks.

Table 7.5: The roles of facilitators: musical roles

Technical Roles

Technical roles include Digital Audio Workstation (DAW) Operator, Audio Visual (AV) Technician, Equipment Technician, and Technical lead, described in Table 7.6.

Role	Description
DAW Operator	Manages session material within the Digital Audio Workstation software, including all metadata needed (track names, sound samples, sections) and records material when required.
AV Technician	Routes and manages all audio visual signals, includes setting up audio cables, interfaces and live sound output devices.
Equipment Technician	Sets up and monitors all equipment including microphone stands, power supplies and cables, as well as any DMIs in use.
Technical Lead	Coordinates all technology, records necessary information about sessions about technical requirements. Directs other technicians.

Table 7.6: The roles of facilitators: technical roles

Physical Roles

Physical roles include providing individual support or assistance as required, described in Table 7.7.

Role	Description
Individual Support	Provides one to one support for a performer or more focused support to a few performers. Includes managing assistive equipment, as well as helping guide and monitor interactions.

Table 7.7: The roles of facilitators: physical roles

7.3.7.2 Facilitator personas

When designing DMIs that could be used in facilitated performance, it is important to consider facilitators as another user of a DMI alongside the musician. It is also worth noting that not all facilitators possess the same knowledge and skill-set.

Provided are some facilitator personas that can be used in the development processes of DMIs. Each of these personas exhibits a facilitator skill-set that has been developed from real-world observations. These provide close to real-life examples of people that work within accessible music-making.

For a perspective of how a DMI might be used in a facilitated performance environment, consider how each of these personas may experience the instrument. Think about what personal challenges they might face in using the DMI and in assisting a performer with it.

Persona 1: Technical and Musical Facilitator

Name: Jamie

Age: 31

Job: DJ

Roles in inclusive music workshops: Producer and DAW Operator

About:

- Tech savvy but would not label themselves an expert
- Works with industry-standard software daily
- Has their own hacks for working around equipment failure
- Owns all the technical kit needed to run a workshop
- Limited on time outside of workshops
- Spends fifty percent of their career DJ-ing the other fifty percent on community workshops and programs
- Has worked in inclusive music-making for five years
- Has tendencies to work to their own rhythm and sometimes does not communicate very well
- Not great at sharing knowledge, "I had to learn it on my own, so should you."

Persona 2: Musical and Physical Facilitator

Name: Alex

Age: 45

Job: Teacher

Roles in inclusive music workshops: Individual Support and Teacher

About:

- Music Teacher at a school
- Happy to assist in any form
- Not very technical - finds it hard to use technology they are not familiar with
- Really wants to improve access to music
- Great at following directions in workshops
- Always asking questions and trying to make the most of opportunities
- Limited by school technology offerings and budgets

Persona 3: Technical and Musical Facilitator

Name: Charlie

Age: 28

Job: Musician

Roles in inclusive music workshops: Director and Equipment Technician

About:

- Trained musician in three instruments
- Provides lessons for young disabled musicians
- Happy to support in all roles and switches between them easily
- Often focused on prompting and directing, or one to one support
- Has a very soft nature, great at encouraging musical behaviour
- Sometimes needs reminders of how some audio equipment works and support with solving technical issues

Persona 4: Technical and Musical Facilitator

Name: Dylan

Age: 49

Job: Community Program Manager

Roles in inclusive music workshops: Technical Lead, Director, and Audio Visual Technician

About:

- Worked in community music programs for 15 years
- Plays an instrument to a high standard
- Performs in a band but more as a hobby
- Spends a lot of time and energy planning accessible music workshops
- Is responsible for sourcing equipment, as well as testing and maintaining current equipment
- Values flexibility of technology, willing to invest in something if it can be used in many settings

7.3.7.3 FAME data log

The data log template on the next page is an example that could be used to collect metadata related to DMIs during inclusive music sessions. The suggested headings capture common information that might be required to recall a past session.

This includes the type of instrument used, sound choices, any custom settings, any assistive technology that the instrument paired with, how it was physically presented, whether it was used with or without any wires, and a space for any additional notes. This could be digitised and extended to include other data points that are useful to collect, or it can be printed as a physical copy and used as-is.

Performer	DMI	Sound Used	Custom Settings	Assistive Tech	Stand/Mount and Orientation	Wired / Wireless	Notes
Ellie	*Skoog (as MIDI controller in Ableton Live)*	*vibraphone (Ableton Live software instrument)*	*sensitivity adjusted to be half way between mid and high*	*none*	*using wheelchair mount*	*wireless*	*must be mounted to the left side of Ellie's wheelchair for comfort*

Performer	DMI	Sound Used	Custom Settings	Assistive Tech	Stand/Mount and Orientation	Wired / Wireless	Notes

7.4 Understanding and using the FAME framework

This section offers more detailed explanations and guidance for using the FAME framework, as well as details its potential applications. The discussion highlights four areas in which the FAME framework could be helpful: DMI design, inclusive music projects, evaluating the accessibility of DMIs, and helping disabled musicians discover instruments. This section then features some example evaluations of DMIs using the FAME evaluation questions. Finally, it provides some reflections on using the evaluation tool, including limitations, areas for improvement, and potential for future developments.

7.4.1 Developing the FAME framework evaluation questions

The five core qualities outlined in the framework form the foundation for the DMI evaluation questions. The questions assigned to each of these qualities were developed based on the most common accessibility barriers or issues experienced in both the research studies and the researcher's professional practice. For part one of the evaluation, four questions were created for each quality as a starting point, with the intention that over time, and with more input from the community, more questions can be added.

Durability is the first quality highlighted by the framework. For this quality the questions reflect the common points where damage might occur that impacts the experience of using the DMI. Power cables and any other connecting wires to a DMI creating tripping hazards, issues for mobility aids such as wheelchairs, and can create a physical weak point in terms of where the inputs are placed on the DMI and how the cables connect. Questioning a DMIs ability to withstand reasonable damage and remain operable comes directly from experience with DMIs in both studies being accidentally knocked to the ground, this becomes increasingly likely if the DMI is mounted on a free-standing stand (as opposed to being mounted onto a wheelchair). Transportation issues were also experienced across the board, in one particular workshop the equipment had to be loaded into the venue using a shopping trolley, protective cases become extremely important in circumstances like these. Finally, the questions around operation time relate to issues experienced in rehearsals where some DMIs would run out of battery and others had the potential to overheat.

Flexibility is the second quality highlighted by the framework. Barriers to flexibility experienced in the studies mostly were related to being able to adapt and instrument to suit a performer's needs. Sensitivity and user interface adjustments, such as being able to customise colours, were extremely helpful in this process of tailoring a DMI to a specific performer and so the initial questions were shaped around this. Other common issues that reduced the flexibility of a DMI in practice were being 'locked in' to a specific sound set, which can limit the DMI to a specific genre or musical role within an ensemble. DMIs that offer the ability to edit the sounds they produce or interface with a DAW via MIDI to extend the sounds they can control offer more flexibility in this sense.

Practicality is the third quality highlighted by the framework. Initial observations in the studies showed that a DMIs ease of use was heavily impacted by how quickly and effectively the DMI could be put into action. Requiring adaptors, additional software or hardware, and not being able to store presets were all barriers for practicality. Being able to place an instrument onto a stand was also important for this quality, especially where no specialist adaptors or additional equipment was required to make it compatible with a standard instrument/microphone stand. In community music programs, and as experienced in the Able Orchestra study, carrying additional equipment for a single instrument can become impractical very quickly.

Complexity is the fourth quality highlighted by the framework. In the studies there were a couple of common issues related to complexity. First, the changing contexts of using a DMI could introduce changes in how easy a DMI was to interact with. For example, managing the glare on iPad screens under stage lighting was an element that had to be considered in all the performances within the able orchestra study. The feedback provided to the performer also could have a positive or negative effect on the perceived complexity of a DMI. Having consistent, multi-sensory feedback that can be altered by the performer makes a DMI much more usable in the context of inclusive music practices.

Compatibility is the fifth and final quality highlighted by the framework. This mostly refers to how the DMI interacts with assistive technologies. During the studies some instruments were unusable for some performers because the DMI was not compatible with certain mobility aids or other assistive devices. Examples of less common assistive technologies experienced within the studies included specialist arm-supports that attach to wheelchairs and cochlear implants. Each of these have an impact on the ability to use a DMI, arm-supports introduce space constraints and cochlear implants can alter how sounds might be perceived. In the researcher's professional practice compatibility has been shown to be one of the most important considerations. Musicians with assistive technology need to understand how a DMI will interact with their devices to know if it is worth investing in. Assistive technology is often tailored to meet a person's needs and can be extremely expensive, so it is unlikely a musician would alter their assistive technology setup in order to use a specific DMI.

The open questions that form part two of the DMI evaluation are influenced mostly by the researcher's professional practice. When working with individual performers, there is often an opportunity to ask these more holistic questions as a means of discovering more about the individual and their requirements for a DMI. Featuring questions of this style alongside more explicit closed questions allows the evaluator to go a little deeper into the experience of using a DMI. These particular questions were designed as follow up to the closed questions, for example asking does context change how a DMI operates might tell us whether an instrument behaves differently in different conditions but not how exactly it changes. Pairing the open ended questions with the closed questions in this manner is more akin to how facilitators work in practice with a disabled musician to find a suitable DMI.

7.4.2 Guidance for using the framework

The framework format is designed to be simple and begins with a short introduction, followed by a glossary of terms, followed immediately by the core qualities and their related guidelines. The following section addresses how these qualities can be used to assess the accessibility of a DMI.

The FAME framework has a number of proposed use cases, which could vary depending on context. The potential applications that have been considered are: using the framework in DMI design processes, using the framework in inclusive music-making projects, using the framework to assess DMIs, using the framework to help disabled musicians discover suitable instruments. Each of these applications are explained in Sections 7.4.2.1, 7.4.2.2, 7.4.2.3, and 7.4.2.4.

7.4.2.1 Using the FAME framework in the DMI design process

There is potential for the framework to be introduced at many points during the design process for new DMIs. In the beginning stages of a product's development, the framework could be used within the ideation processes. This could be through using the core qualities and guidelines as a sort of conceptual scaffolding from which to generate ideas or question the accessibility of ideas that have already been generated. Later in the development process, the questions for reviewing accessibility provided by the framework could be used to evaluate prototypes or devices that are in testing processes.

The fundamental approach of starting the design and development processes with the framework is the most desirable option here. However, it is acknowledged that the reality of such processes often means this is not always possible, and retrospective analysis of accessibility is sometimes the only possibility.

Consequently, using the FAME framework to question accessibility in the design process may provide an opportunity to identify any accessibility issues before a product is released. This allows designers and developers to consider solutions and propose alternatives to the original design ahead of a product release.

7.4.2.2 Using the FAME framework in inclusive music projects

In inclusive music projects, the FAME framework can assist those in charge of purchasing DMIs to be used within community workshops or other inclusive music settings. The qualities and guidelines provided by the framework are a helpful conceptual scaffold to apply as direct questions when learning about new DMIs. For example, when examining a new DMI, a buyer can ask, "How flexible is this?" They can then examine the specifications for indications of flexibility, such as a confirmation that it can be used without wires or that the DMI also acts as a MIDI input device.

The framework can also be used by those managing inclusive music programs. For example, to help curate an equipment list. DMIs can be added or removed based on the level of accessibility they offer and how this meets the needs of the disabled musicians that will be engaging with that specific program.

During workshops or events, facilitators may also use the framework questions to consider the levels of accessibility of the DMIs they have available.

Then use this information to make decisions on which musician would be best suited to which instrument.

7.4.2.3 Using the FAME framework to assess the accessibility of DMIs

Evaluating the accessibility of existing DMIs is potentially the most obvious of the use cases for the FAME framework as it provides a section for this. However, as explained in the framework, this is not something that will provide an accessibility 'score' or prescribe something to have good or bad accessibility. The review questions are included as a way to better understand the current accessibility status of a DMI and identify the potential areas for improvement.

In practice, it is expected that anyone should be able to use these questions and answer them with only the standard information provided with a DMI. However, it might be easier for someone that has more familiarity with a DMI, be that someone who has used the instrument for an extended period of time or a person who was involved in the development of the DMI.

7.4.2.4 Using the FAME framework to help disabled musicians discover instruments

The final example use case is using the framework to help disabled musicians discover instruments that might be well suited to their abilities. This use case is less clear, as the way in which the framework might be helpful could depend on the musician's requirements.

However, a couple of approaches could be considered. Firstly a facilitator or the musician could use the review questions to evaluate a number of DMIs and pick from these which is best suited for their requirements. Alternatively, the musician or facilitator could consider the core qualities and guidelines in terms of which are the most important for them and their needs. These could then be used to tailor the review questions in a way that only those qualities are being assessed.

7.4.3 Evaluating Digital Musical Instruments using the FAME framework

This section tests the application of the FAME framework through evaluating some of the DMIs used within the two studies detailed in Chapters 4 and 5.

Instruments were chosen based on the interaction method they offered in order to provide some diversity in the selection. From the selection of DMIs used within the observational studies, the following devices were chosen: ThumbJam, ROLI Seaboard, Keith McMillan BopPad, Skoog, Bloom.

The 'LeapMusic' gesture-control technology probe created for and used within the Able Orchestra observational study was also reviewed using the framework.

7.4.3.1 Evaluation 1: ThumbJam (iOS application by Sonosaurus)

ThumbJam is an iOS application that can be used on iPhones and iPads, shown in Figure 7.2. It uses the touch screen displays of these devices as a means of input. It also incorporates tilt and shake gestures, to add effects to the sounds it produces.

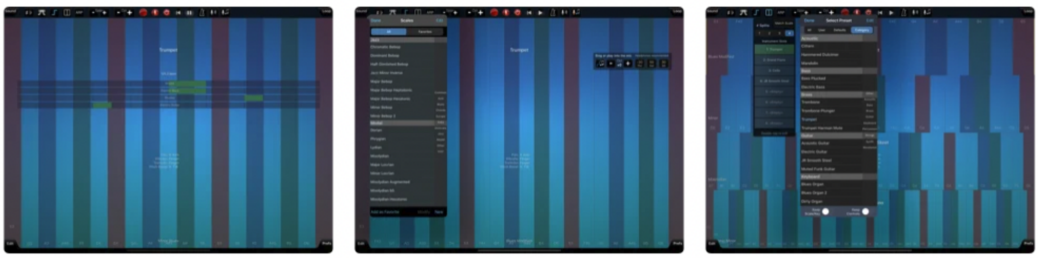

Figure 7.2: *Screenshots of ThumbJam on iPad from the App Store (Apple, 2022c)*

When evaluating ThumbJam using part one of the review questions provided in the framework, the application performed well in terms of durability, flexibility, practicality, and complexity. The only area where the application stumbled was compatibility, more specifically related to high contrast. None of the current colour profiles offers a high enough contrast ratio within the application. This includes when paired with the high contrast accessibility options offered by the device settings.

In total, nineteen out of twenty questions provided positive answers for accessibility.

For part two of the review process provided in the framework, the ten open-ended questions provided some insight into the areas where there might be some ambiguity about the accessibility of ThumbJam.

Firstly, as with all applications, the physical traits of the DMI are reliant upon the device that hosts the software. In this case, this could be an iPhone or an iPad. ThumbJam behaves a little differently on each, which introduces potential issues for accessibility, as having options that differ between devices can cause confusion and has the potential to increase complexity.

The accessibility features of iPhones and iPads are well developed when compared to other mobile devices, and so in some ways, ThumbJam benefits from these. In terms of the interaction modes, sensitivity can be changed at a device level, and ThumbJam offers some customisation over the controls within its 'Preferences' menu. While touch is the primary way of interacting with the app; there are also controls that can be assigned to tilt and shake. The control menus for these are depicted in Figure 7.3.

ThumbJam is flexible in terms of the music genre it could be used within. There is a large number of built-in voices to choose from that feature realistic synthesised sounds. The app can also be paired with other software, which offers even more options.

The requirement for assistance and perception from an audience viewpoint are areas where ThumbJam appears to perform less well in terms of accessibility. The settings of the application are not easy to navigate and require some level of

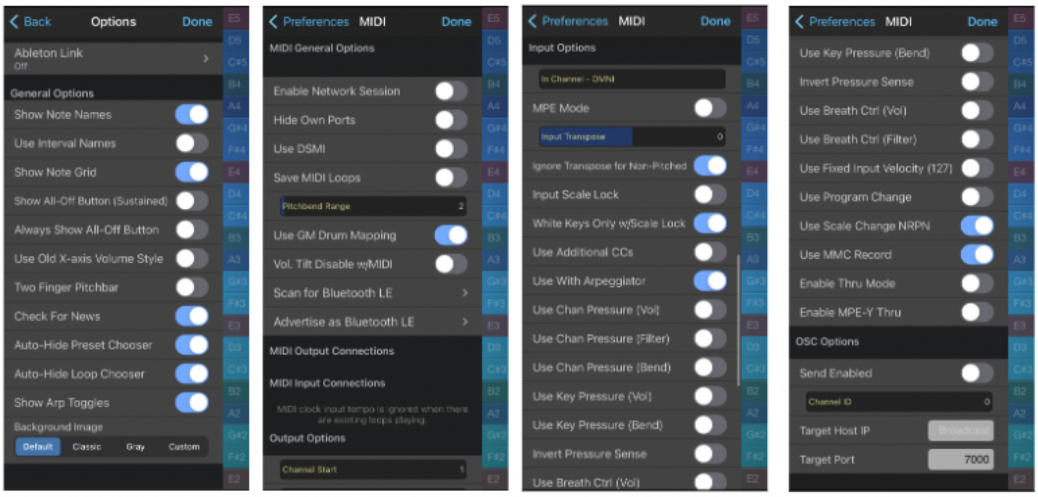

Figure 7.3: *Screenshots of ThumbJam on iPhone displaying preference menus with the different options for GUI customisation and controlling the application*

experience with the app or time investment in learning these. The high number of options available for customisation make this an excellent choice for flexibility, but it does increase the complexity in terms of having many choices to make and remember.

However, the ability to save presets once these choices are made makes it slightly more practical than other applications. In terms of audience perception, the use of commonly known mobile devices that offer a number of functions creates ambiguity for spectators. Similar to using laptops in performance, audiences may see no difference between the musical interaction and viewing messages or emails (Trueman et al., 2006). Unless gestures are exaggerated by the performer, or the display somehow is made visible to the audience, the causal link between a performer's actions and a sound output can be obscured.

The graphical user interface (GUI) of the application can be altered to better suit a musician's style or needs. Again, there is potentially more flexibility on the iPad version as this has more layouts available. On both devices, the touch areas can be increased using a zoom level, though this can impact the practicality by reducing the number of notes available on the screen.

Accidental triggering of the menus around the edge of the screen could be possible, but some menus can be hidden as an application setting, and guided access can also be used to reduce the risk of this. In terms of customisation, the colour contrast of the profiles is somewhat lacking, as highlighted by the review questions in part one. This was raised as an issue in Chapter 4, where one of the facilitators recognised that the change of colour when interacting with an area of the screen was not highly contrasted enough for all participants to recognise it.

The final few questions of part two of the review process discuss the speed of setup, the potential for damage, feedback methods, and compatibility with assistive technologies. ThumbJam, once downloaded, is instantly playable. However, to get to a “suitable” setup for each individual may take some customisation which increases the time from starting up the app to making music. Using this as a MIDI controller may also increase the time it takes to get started, as pairing devices can be impacted by connectivity issues.

Regarding damage, ThumbJam relies heavily on the physicality of the devices it is used on. Consequently, a number of protective cases, stands, and additional accessories are widely available for iPads or iPhones, which can significantly reduce the risk of damage.

When considering feedback methods, ThumbJam provides instant sound response to interaction and visual response in the form of a colour change in the GUI. It also works with Voiceover on both devices so text to speech output from the control areas of the device can be activated. The MIDI options offered by the application also include MIDI input, so alternative controllers could be used.

Overall, ThumbJam could be seen to suit many requirements for a DMI in inclusive music settings. There is a high potential for adapting the application to suit specific needs. However, there are also some limitations.

While the interface itself is not overly complex and can be adjusted, doing so requires interacting with many different menus and options that are somewhat overwhelming. There are also many caveats regarding how durable and practical the app is.

This is because the physical characteristics rely on the device. This can introduce many responses to questions that may include the phrase "it depends". For example, considering durability and accidental damage very much depends on the accessories being used with the device. Even considering the device dependency here, the outcome of the review would suggest that ThumbJam is a good choice for inclusive music settings.

7.4.3.2 Evaluation 2: Seaboard RISE 25 (hardware device by ROLI)

The Seaboard RISE 25 is a new generation of MIDI controller based upon the piano keyboard. A soft, continuous, touch-responsive surface replaces the keys of a traditional keyboard. This surface is made from a conductive silicone material that allows a musician to play a number of gestures using MIDI Polyphonic Expression (MPE) technology. The Seaboard comes in a number of sizes, and the RISE 25 refers to the size of the instrument as it features 25 "key waves", as can be seen in Figure 7.4.

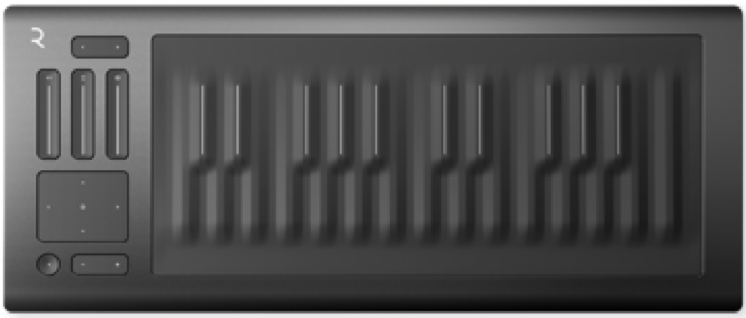

Figure 7.4: *Seaboard RISE 25 by ROLI (ROLI, 2022c)*

When reviewing the Seaboard RISE 25 using the part one questions provided in the framework, the instrument performed well in terms of durability. However, it performed less well against the qualities of flexibility, practicality, and complexity. Furthermore, it failed for questions based on compatibility. As experienced with ThumbJam, high contrast support was lacking, something that is harder to achieve on a physical hardware device.

Other challenges for the Seaboard hardware include an inability to adapt the interface and not having any screen reader support for the keyboard interactions. Altogether, this means that the Seaboard is unlikely to be compatible with setups that rely heavily on assistive technology. It also might be challenging to incorporate this instrument into inclusive music practices if customising the interface is of high importance.

The battery life, wireless capability, and robustness all suggest that this would be a good instrument in terms of durability. However, the additional downloads, authentication, and pairing with software before being able to start using the product make it less practical than other DMIs. Consequently, the Seaboard offers a high level of flexibility on being able to adjust the sounds, the sensitivity, and be used as a MIDI controller. It lacks the ability to change the colour profile of the instrument, and the accessibility is limited by following a familiar aesthetic within the music industry of a sleek, black, minimalist finish. Although ROLI has provided a number of ways to interact using their 5D touch system (ROLI, 2018), the feedback from touch is through sound alone.

It could be argued here that, like with acoustic instruments, there is some physical haptic feedback happening in the resistance of the silicone interface. Nevertheless, without there being an accompanying vibration of a sound generator, this resistance does not provide information about the qualities of the sound being produced. In general, the 5D touch system also increases the complexity of the instrument significantly.

Some solutions to these initial accessibility barriers can be resolved through the software that accompanies the physical hardware of the Seaboard, especially in providing additional visual feedback. Although, the ability to use such feedback would be very dependent on the context, and as shown in Figure 7.5, the software that is provided with the device is visually complex.

Figure 7.5: *Equator2 MPE Synthesizer software by ROLI (ROLI, 2022b)*

In the second part of the review process outlined by the framework, the Seaboard offers some positive points for accessibility. The ability to adjust sensitivity and use multiple gesture types to interact with the interface makes it flexible for many movement types. Again this instrument is not bound to a specific genre, and there are many examples of the Seaboard being used across multiple musical subcultures. The look and feel of the instrument are not subject to change when moving between the contexts of practice and performance. Additionally, the form factor adhering to a familiar instrument, the piano keyboard, offers a way for the audience to better understand the device. It should be noted that the choice of sound, gesture, and the visibility of a musician's actions could all impact the audience's perception of this DMI.

Unfortunately for the Seaboard, more barriers are identified through the open questions. It is doubtful that this device could be used unsupported, though it could be possible depending on the needs of the musician and the accessibility of the authentication processes and paired software.

The setup process is not the most practical either, as it is not just a case of 'plug in and play'. Furthermore, despite the interface being well made, it is known that specific types of damage to the silicone parts of the interface, for exmaple punctures in the silicone membrane, can render the whole instrument unplayable.

Overall, the Seaboard offers some promising features for accessibility in terms of sensitivity adjustments and multi-gesture input. However, the complexity and poor compatibility could make it difficult to use in inclusive music settings. Especially in shorter programs or workshops where the setting up time for each individual could make this impractical.

7.4.3.3 Evaluation 3: BopPad (hardware device by Keith McMillen)

The BopPad is an expressive electronic drum pad. The playing surface is divided into four separate quadrants, where a musician can strike the instrument to create sounds. The BopPad also uses MPE technology via a tuned elastomer surface that covers a ten-inch circle of Keith McMillen's patented Smart Fabric Sensor Technology (Keith McMillen Instruments, 2020), which can be seen in Figure 7.6.

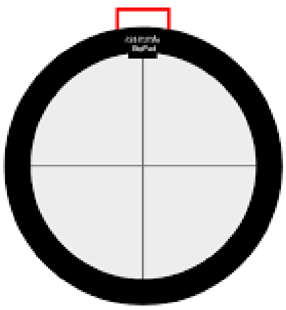

Figure 7.6: *BopPad by Keith McMillen Instruments (Keith McMillen Instruments, 2020)*

When evaluating the BopPad using part one of the review process outlined in the framework, the qualities that it performed well against were flexibility, complexity, and practicality. The only setback for flexibility is the inability to change the colour profile of the device.

Similarly, the inability to hide potentially distracting controls, in this case, the blinking LED light that displays the connection status and interactivity, was an issue for the complexity of the device. The practicality was impacted by the requirement to download software before using the BopPad, as this reduces the 'plug in and play' aspect of a DMI.

The BopPad performed less well when being evaluated against durability, which is surprising, as there is a featured video on the BopPad product page that shows the device being driven over by a car and still functioning (Keith McMillen Instruments, 2017). This lack of protective accessories for transport and the inability to use the device without a cable is considered to reduce durability for inclusive music settings. Though based on the rugged design demonstrated in the product videos, the lack of protective accessories might not be problematic.

Similar to the Seaboard, the biggest problem for accessibility of the BopPad is compatibility. There appears to be no way to achieve inverting the device's colours or adapting the physicality of the device, which could be problematic for some musicians. The lack of screen reader support could also make it tricky to include in a setup where a musician is reliant on assistive technology.

Finally, the inability to produce sound without being connected to other devices makes it more challenging to incorporate into some inclusive music settings.

In the second part of the review process, the BopPad shows some promise for accessibility. The wide range of genres it could be used within, many ways it can be interacted with, adjustable sensitivity, and consistency between practice and performance environments are all excellent features for accessibility.

Additionally, the resemblance between the BopPad and a drum, combined with the action of striking the BopPad like a drum to interact with it, provides an obvious and understandable relationship from the audience's viewpoint.

Despite the evaluation of durability from the questions in part one, it is evident that there are very few ways in which this DMI can be damaged. The design is very robust, and there is only one port that uses a standard cable (a mini USB), which could be considered to be the only weak point on the device.

However, the BopPad does fall short when it comes to working with assistive devices, performer independence, and interaction feedback. Even though there is more than one method for providing action related feedback to a musician, the visual element is a small LED that will colour change from green/red to orange depending on the connection type. This could be problematic for those with Deuteranopia (red/green colour vision deficiency) and in on-stage environments where that feedback could be made less visible by factors such as lighting.

Furthermore, there is a risk of potentially inaccessible stages to setting up the instrument for an individual performer. Although the software interface for the BopPad Editor, as pictured in figure 7.7, is more visually accessible than some software in this space, many musicians could struggle to use this independently.

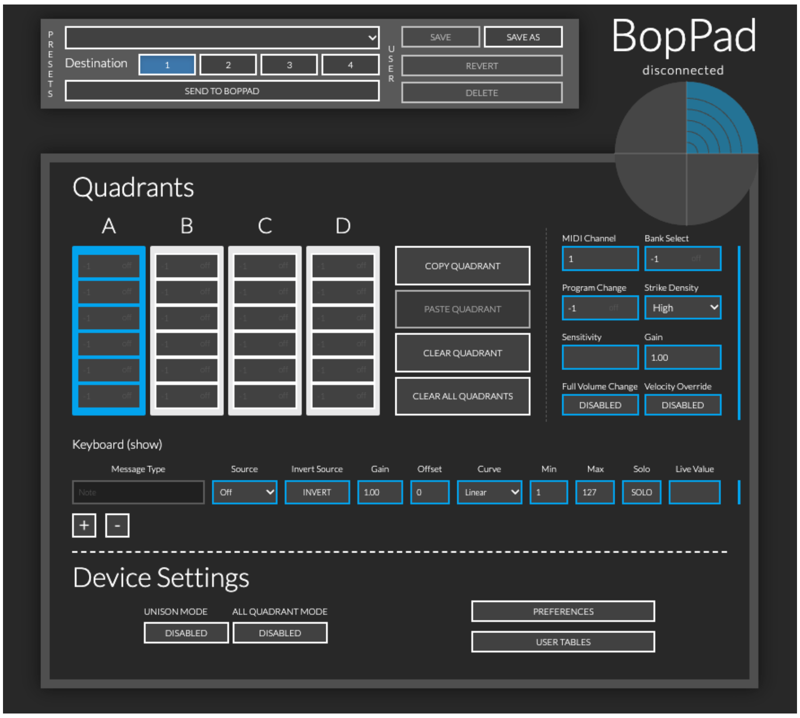

Figure 7.7: *BopPad Editor by Keith McMillen Instruments (Keith McMillen Instruments, 2022)*

The review of the BopPad showed the importance of reviewing a DMI against both parts of the process provided within the framework. The outcome following the open-ended questions provides a more optimistic view of how this instrument could be used in inclusive music practice. However, as with the Seaboard, the potential setting up times for each individual could make this more impractical than other DMIs.

7.4.3.4 Evaluation 4: Skoog (hardware device by Skoogmusic)

The Skoog, pictured in Figure 7.8, is a tactile musical instrument made from conductive foam. There are five sides on a Skoog, each featuring a coloured accent, red, blue, yellow, green and orange. Each side plays a different note. As well as pressing within the coloured circles, the Skoog can be squeezed anywhere on its sides, edges and corners. It can be played with any part of the body.

Figure 7.8: *Skoog by Skoogmusic as displayed on the Apple store (Apple, 2022b)*

The initial review of the Skoog, using part one of the process outlined in the framework, showed that the Skoog performed well in terms of durability and flexibility. It performed less well against the qualities of practicality and complexity. The practicality of the Skoog was impacted by the requirement for additional setup in terms of downloading software and a lack of being able to store presets within the paired application.

Furthermore, complexity suffered because the sound is the only means of feedback from the physical device. As with other instruments discussed, this could be altered by using additional visual feedback from applications or software. However, this becomes a challenge to use throughout different contexts. For example, it might be possible to provide a view to this in practice but not possible when performing on-stage. Similar to the other hardware devices, it performed the least well when reviewed against the compatibility quality. The issues here link to the form factor being fixed, and there is no high contrast or inverted colour version of the physical interface. Additionally, the Skoog's inability to produce sound independently and lack of compatibility with assistive technology such as screen readers could limit its use for some disabled performers.

The Skoog performed similarly across the second part of the review using the open questions provided in the framework. In terms of interaction, the ability to change the sensitivity is a bonus for accessibility, and as stated on the website, it can be played with any part of the body (Skoogmusic, 2022).

However, the action of squeezing or pressing the surface of the Skoog still invites questions as to whether a lighter touch or stroking action would be compatible. This could pose problems for those who are not able to apply force or squeeze the device. While the Skoog performs well in durability and can handle many environmental changes, there is still potential for a disabled musician to require support in pairing the device and setting up the preferences.

Unlike some of the other hardware that has been reviewed, the Skoog also presents a visual form that to an audience is not familiar, and this could impact the ability for an audience to recognise a musician's intent and actions as having an impact on the sound output. The form is also fixed, so the interface cannot be tailored beyond changing the sensitivity.

Other challenges include the single method of feedback, the requirement to have paired software, and the lack of assistive technology support. Providing additional feedback could be achieved through presenting the paired application or some form of visual from other software. The usability of the device without a stand or mount is also interesting to note. Without physically holding the device, pressing firmly on any of the sides of the Skoog can result in it falling over. Holding the device to prevent this can trigger the device mistakenly. Some form of stand or mount would be required to avoid this, neither of which are provided and come at an additional cost.

Overall, some of the positive factors for accessibility make the Skoog well suited for inclusive music-making, particularly for disabled people with specific needs. However, it still appears to have some of the issues with compatibility and practicality that other hardware has shown in these reviews.

7.4.3.5 Evaluation 5: Bloom (iOS application by Brian Eno and Peter Chilvers)

Bloom is a generative audio iOS application. Sounds are triggered by tapping on the touch screen surface of an iOS device. The sounds are looped on a delay with an accompanying visual of bubble-like objects that start small and swell until they fade away, shown in Figure 7.9. Bloom requires no musical knowledge/experience.

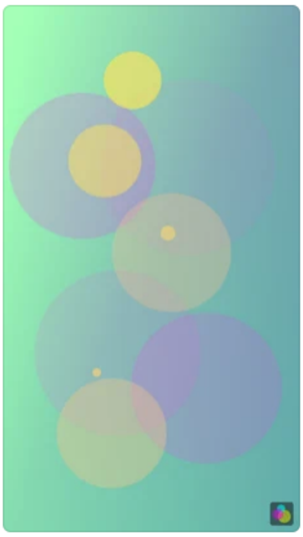

Figure 7.9: *Screenshot of Bloom GUI on iPhone as displayed on the Apple app store (Apple, 2022a)*

When evaluating Bloom against the questions featured in the first part of the framework, it performed well. Durability, practicality, complexity, and compatibility were all qualities that were shown within the application. The only quality that Bloom did not perform well against was Flexibility. This was due to a lack of being able to adjust the sensitivity, though this could be remedied through using some of the iOS accessibility settings. Additionally, the flexibility was limited by the lack of MIDI communication and the application only using predetermined sounds. The lack of these features reduces the musical flexibility of Bloom as a DMI.

For the second part of the review process outlined in the framework, Bloom is seen to benefit from many of the accessibility features provided by the iOS device. Although the interaction is entirely touch-based, it can be triggered by light touch and appears to be triggered by any skin to device contact, so technically could be triggered by a palm or a nose even. The only challenge worth mentioning here is that if an open palm is pressed against the touch surface, this will cause multiple triggers within the app.

In terms of musical genres, the musical flexibility of Bloom as a DMI is more limited than others discussed in this section. This is due to the fact that it only allows the choice of a preset number of sounds, all of which fall within a similar category. It is hard to imagine that this would translate well in all genres, as Bloom's soft aesthetic might feel out of place within certain types of instrumentation and musical styles.

Other issues for Bloom are related to the audience perception, lack of screen reader compatibility, and limited choices for adapting the instrument. As with many other software-based instruments that operate on multipurpose devices, the audience perception of what a musician is actually triggering from their actions can be minimal. Again, this is a problem that was highlighted earlier in this section when discussing ThumbJam. This type of disconnect between the audience and musician has the potential to decrease feelings of agency for the musician.

The screen reader compatibility is also an issue, especially as the app offers some integration with VoiceOver (the iOS screen reader) on the start menu but not on the interaction area once the 'create' mode has been entered.

Finally, the ability to adapt the interface is present but limited to presets, which involve a 'mood' choice that impacts the colour of the GUI and sounds produced, the point at which a sound is generated and how it behaves, and the speed of the delay. The changes between the moods are incredibly subtle, and the delay control has a slider from one extreme to the other but no label to indicate which is faster or slower. There are some additional settings in another menu accompanied by a switch for each to turn them off or on again. However, some of these suffer from a lack of description and could be confusing for some musicians.

As the intention of Bloom is more towards creating generative art and sounds, it might be unfair to compare it against other devices that were designed with the intention of being a DMI. However, Bloom has been used as a DMI within many community music projects for disabled musicians, including the Able Orchestra project discussed in Chapter 4. The application is particularly engaging for Autistic musicians, so it was of interest to examine what features of the application's design make it more accessible in this way.

7.4.3.6 Evaluation 6: 'LeapMusic' research gesture-controlled technology probe

The final review in this section is a review of 'LeapMusic', a gesture-controlled technology probe used within the Able Orchestra study. First, before discussing the review, it must be noted that this is a prototype and not a finished product. Therefore, some of the issues raised about the LeapMusic controller are directly related to the unfinished form of this device.

The LeapMusic device is a technology probe used within this research. It is a system that uses a Leap Motion controller to detect a musician's hand movements. This is connected to a MacBook Pro computer that uses OSCMotion (Senabre, 2015) to take the positional values of a musician's fingertips from the motion sensor and process these within a max patch.

There are a number of output choices from the max patch. First, the data can be paired with a mic input of a voice to control the output of a vocoder effect on that voice. Second, it can be used to transform the data to a MIDI output that can be used to control any device, virtual instrument or effect that accepts MIDI input. Finally, it can be used as a virtual instrument, with the Leap Motion data being used to control sound being produced within the max patch.

The LeapMusic technology probe performed the poorest out of the devices reviewed when evaluated against part one of the framework. Durability, complexity, and compatibility were the areas where it was most lacking. Durability was inevitably going to be low because of the nature of the LeapMusic system being in a basic "hacked together" form.

Similarly, compatibility was reduced by the musician's visual reality of the instrument being a single leap motion sensor, which offers no form of visual feedback and cannot be adapted. The controller could be augmented to create a more responsive visual experience, but this was beyond the scope of what could be achieved within the research period.

Complexity was a quality that was also limited because of the lack of additional feedback other than the sound output. Moreover, complexity was impacted by the Leap Motion sensor, as to perform on-stage, the device often required an alteration of settings (due to additional infrared lights being detected in the sensor's field of view).

In terms of flexibility and practicality, however, the LeapMusic technology probe performed well. When considering the open questions in part two of the review process outlined in the framework, some issues for the LeapMusic technology probe were highlighted that were also discovered in the Able Orchestra study, as discussed in Chapter 4.

Regarding interaction, it was noted that while there are some benefits to being able to use free 'in-air' gestures, this form of interaction can quickly cause fatigue for musicians, especially for some disabled musicians who can experience fatigue much sooner. There were also some situations in which the sensor was unable to recognise a disabled musician's movements.

The discovery that the environment had a significant impact on the sensor's response is also an issue that is a barrier for both practicality and complexity. This requires a technical understanding of the sensor's operation, which a musician should not be expected to have. Similarly, the level of support required is high because of LeapMusic being an unfinished system. The operation of the system relies upon a technical facilitator to setup the instrument to a point where the musician can interact with it. There is also a high risk of accidental damage because of the LeapMusic system being in a more fragile prototype state.

Finally, it was further acknowledged that the lack of additional feedback is problematic for accessibility. There would also need to be further consideration given to how a device like this might interact with assistive technologies and be adapted for different musicians' needs.

Overall, the expectation was that the LeapMusic controller would perform poorly in this review, and this is also the reality. However, the example is helpful as it highlights that even where an interaction medium, such as gesture, has the potential to increase accessibility, it is the entire system that has to be considered in a holistic way to gain a clear perspective on accessibility for DMIs.

7.4.4 Reflections on putting the framework to work

Completing these example reviews using the process outlined in the framework provided an opportunity to also evaluate both the review process and framework. The goal of the FAME framework is holistically evaluate the overall accessibility of DMIs.

While it provides some guidelines, these are at most illustrative of the core qualities that a DMI should possess and should not be considered to be the same as success criteria found in technical standards. The FAME framework aims to encourage a more thoughtful and reflective approach. This is achieved through the two-part process, where part one explores how a DMI measures against the qualities identified to be essential for accessibility and part two asks questions that encourage reflection upon these areas in more detail.

Considering accessibility as a binary state does not reflect the complexity of what it means to be accessible and inclusive. In some cases, there are technical or physical features that either exist or don't, but the majority of accessibility is more aligned with a sliding scale. There is not one element alone that makes these scales move from terrible to fantastic. The whole experience must be considered in order to understand and if necessary, toimprove.

The framework review process appears to successfully engage this reflective approach. However, there were some elements of the process that could be improved. For example, in the first part of the process, a few of the questions posed are not always applicable or could be open to ambiguity. This could be an issue if it was a singular process, but whenever this was encountered in the example reviews, the open questions of the second part presented an opportunity to address the ambiguity and potential accessibility issues.

In some cases, the ambiguity is caused by DMIs that have multiple elements to them. For example, a hardware device that has a paired iOS application. In these circumstances, it can be difficult to answer some questions directly because of a 'technicality' that the iOS application provides some of the features that the physical interface does not.

In developing the framework, it was acknowledged that the document would require regular review to ensure that it is inclusive of new technologies and future knowledge of inclusive music practices. The best way in which to achieve this is to engage with existing communities by providing the framework in an open-source manner and inviting feedback.

As previously acknowledged, one of the existing issues in inclusive music communities is the lack of knowledge sharing and centralised sources of information. One of the aims of making the FAME framework available in this manner is to help towards resolving this issue. The framework, evaluation tool, and other resources can be found at www.accessibleinstruments.org.

7.5 Potential for community impact

As with many technologies, there is a misunderstanding within the music technology industry about the need for accessibility in products. This is often caused by the misconception that because no disabled customers are using a product, this means that disabled people are not interested in using such products.

In some circumstances, people will also comment that "improved accessibility" has never been requested by anyone. When working as a consultant, often the reminder has to be given that the lack of accessibility is the reason why there are no disabled customers asking for accessibility support or feature requests. Feedback on accessibility cannot be provided if a product is entirely inaccessible to begin with.

This is why proposing a framework to help people understand accessibility requirements for DMIs was initially intended to engage DMI creators in the discourse around accessibility. However, as the FAME framework was developed, it became clear that the output of reviewing the accessibility of DMIs could also benefit the inclusive music community. Through providing access to the output of reviews in a public space online, disabled musicians could see the potential barriers of a DMI and more easily assess a DMI for their own needs before buying it. Equally, those purchasing equipment for inclusive music activities could also use this information to understand what DMIs might be suitable for the projects they are working on. An online space could also open up a collaborative effort to review more DMIs for accessibility. Visitors to the online space could potentially add their own reviews of DMIs and, as a result, contribute to the library of reviewed DMIs.

At the time of writing, nothing like this currently exists for disabled musicians or DMI creators. Yet, sharing knowledge in this way is desired by many in the inclusive music community. Consequently, efforts are already being made to create more shared resources like this by charity organisations such as Drake Music, who are currently working on a project to create an accessible instrument collection (Drake Music, 2022a). This shows that there is potential for the FAME framework to become a much more collaborative effort between industry, charitable organisations, academia and disabled artists.

Chapter 8

Conclusions

This concluding chapter revisits the research questions posed in Chapter 1. It also reflects on the research conducted, including the methodologies used, and how the findings of the two studies detailed in Chapters 4 and 5 relate back to these research questions. This is followed by a discussion of the limitations of the research and potential future directions for research related to accessibility, DMIs, and facilitated performance.

8.1 Introduction

At the beginning of this thesis, in Chapter 2, the growth of research interest in the topic of accessibility and digital musical instruments was acknowledged. There is a much larger body of related literature in 2022 than was available in 2015 when this research began. During this period, communities have also developed, and initiatives have been started that are focused on accessibility and digital musical instruments, such as the 'Accessible Musical Instrument Collection' at Drake Music (Drake Music, 2022a,b).

While the increase in literature, activism, and community collaboration is promising for accessibility in DMIs; this research addresses questions that still remain about the use of DMIs in inclusive music practice and fundamental qualities that can improve a DMI's accessibility.

8.2 Digital Musical Instruments and inclusive music communities

The first of the research questions posed in Chapter 1 focuses on the current use of DMIs within disabled communities and inclusive music practices:

> **How are digital musical instruments used to support access to creating music for disabled communities?**

The field study with the Able Orchestra, discussed in Chapter 4, provides the majority of the insight for this question. From observing and taking an active role in an inclusive music project, the researcher was able to document how DMIs were incorporated into such projects. This included how they could be used to support access to creating music for disabled performers.

In summary, it was found that DMIs played an integral role in the Able

Orchestra project and many other inclusive music projects. However, there are a number of factors that impact what DMIs can be easily adopted into projects like these. The familiarity of commercial tablet devices, like the iPad, creates a lower barrier to entry for using software-based DMIs in these contexts, as such, software-based DMIs were more commonly used than hardware devices. In practice, software-based DMIs offered the participants a wide range of creative agency, starting with the ability to select soundscapes through to changing the arrangement of the graphical user interface (GUI). In some cases, this even led to a participant recording 'found sounds' that they enjoyed and then using a DMI to control these as samples.

Other influential factors on DMI selection relate directly to the constraints of inclusive music projects, the most prominent being time and environment. There is a distinct lack of time in projects that are working towards an educational or creative outcome in the space of a few weeks. This lack of time reduces the ability to explore more complex DMIs that have a steeper learning curve for the performer and potentially for facilitators. Equally, environmental constraints can restrict the ability to introduce DMIs that require certain types of connection or those that are powered through an adaptor as opposed to being battery operated.

As a result of the experience with the Able Orchestra project, the research direction moved towards understanding what makes a DMI successful in inclusive music settings. This included exploring whether there are any commonalities between the DMIs that are easily adopted into inclusive music projects and trying to understand the relationship between DMI features and what makes them more 'accessible' for this context.

8.3 Digital Musical Instruments and accessibility

The second research question, outlined in Chapter 1, moves the focus to the accessibility barriers that DMIs can pose for disabled musicians:

> **What are the challenges for disabled people when using a digital musical instrument?**

A combination of the findings from the Able Orchestra study, detailed in Chapter 4, and findings from the second study with the Able Lite workshops, detailed in Chapter 5, identified a number of potential accessibility barriers that could be encountered when using DMIs. Similarly, a number of features that improved the accessibility of some DMIs were also identified within these studies.

It was found that fixed interfaces, devices with singular feedback mechanisms, and unfamiliar interface designs all risk creating an accessibility barrier or diminishing the user experience for a disabled musician. Conversely, some examples of features that had the potential to improve the accessibility experience included providing options to alter the interface, being able to use an instrument wirelessly, and having multiple streams of feedback when performing with a DMI (e.g., visual feedback and audio feedback).

Upon reviewing the findings from both studies, a set of themes or core qualities were identified that highlight the fundamental areas that can impact the accessibility of a DMI. As introduced in Chapter 5 and revisited in the discussion in Chapter 6, these core qualities are durability, flexibility, complexity, practicality, and compatibility.

These core qualities address the fundamental accessibility of DMIs and will not necessarily address all accessibility requirements. However, this research acknowledges the limitations of more general approaches to accessibility and reiterates throughout that a 'one size fits all' approach to accessibility is not sufficient. The proposed core qualities are intended to provide a base-level indication of the accessibility of a DMI rather than provide a comprehensive commentary on how accessible a DMI is for specific disabilities.

Following more bespoke approaches has been acknowledged as the most comprehensive way to address individual accessibility barriers to using DMIs (Harrison, 2020; Frid, 2019b; Vahakn Matossian, 2015). However, the core quality of 'flexibility' does observe whether a DMI offers options to improve the accessibility through tailoring or adapting the DMI to better suit the specific creative and physical needs of a disabled musician.

8.4 Tailoring Digital Musical Instruments

The 'tailoring' of a DMI is a subject that is addressed through the third research question posed in Chapter 1:

> **Can digital musical instruments be used to address individual accessibility needs?**

This is mostly addressed within Chapter 5 in the findings of the Able Lite Workshops. Unfortunately, there is no short answer to this question, and the findings generally indicate that it depends on the specific DMI being assessed.

Relating back to the core quality of 'flexibility', some DMIs offer more 'flexibility' and can be adapted more easily than others. Yet, this does not mean that DMIs with a high level of 'flexibility' will offer tailoring that suits all possible accessibility requirements. In most cases, facilitators play an important part in the process of adapting DMIs to meet the creative and physical needs of a disabled musician. Facilitators achieve this by working alongside the musician to establish the right setup or customisation of a DMI.

Additionally, tailoring or customising a DMI in this manner does not always provide greater accessibility throughout the user experience. In some circumstances, a customised DMI leaves disabled musicians with less agency as they might rely heavily on a facilitator to navigate inaccessible menus to achieve the customisation. For this reason, bespoke devices that can be created for a disabled musician's use are often preferred over heavily tailored commercial DMIs, as they can be designed to be accessible throughout the user experience, without the need for facilitation or any technical assistance.

Through this, it can be seen that an evaluation of the accessibility of DMIs should not be limited to considering whether a disabled musician can play the instrument. A true evaluation should also extend to consider all other aspects of using the DMI, such as the ability to tailor the DMI and the autonomy of use.

8.5 Evaluating the accessibility of a Digital Musical Instrument

The final research question, outlined in Chapter 1, brings the discussion to the outcomes of this research:

> **How might the accessibility of a digital musical instrument be evaluated?**

The consideration of this question forms a large part of the discussion in Chapter 6. Both qualitative and quantitative methods for evaluating accessibility in DMIs have been explored in the literature (Lucas et al., 2019; Davanzo and Avanzini, 2020). Though qualitative methods are more commonly employed for accessibility as these prioritise the lived experiences of disabled people above statistical information.

A challenge with evaluating accessibility is that it can be difficult to remove subjectivity from the evaluation process. Disability is unique to the individual and can be impacted by the context or environment, so the consideration of what is ‘accessible’ can change dramatically. This thesis proposes a method of evaluation that combines closed and open questions to assess the accessibility of DMIs, using the five core qualities to form the basis of this evaluation.

This evaluation method is integrated into the Facilitating Access to Musical Experiences (FAME) framework, established in Chapter 7. The framework is the main contribution of this thesis towards ongoing research in this area. The framework’s evaluation tool does not seek to provide an accessibility rating or score but instead presents a way to gain more understanding of the accessibility of DMIs in a holistic manner. This is emphasised through the design of closed questions that address the existence or lack of accessibility features, being paired with open questions that invite a more reflective and detailed look at specific accessibility barriers a DMI may present.

Similar to other standards, specifications, or frameworks, it is hoped that community engagement will offer ways to maintain and evolve the FAME framework evolve beyond this initial version.

8.6 Reflections on the research

The partnership between Inspire Youth Arts, the Fusing Audio and Semantic Technology impact project, and the Mixed Reality Laboratory has been hugely beneficial throughout this research. For the researcher, this provided an opportunity to fully engage in an active role in more than one inclusive music project. This active engagement in real-world projects provided closer access to the lived experience of disabled musicians could not have been achieved through lab-based studies. However, it did not come without its limitations on the research process.

First, the study sizes were smaller than anticipated. In some cases, this made it difficult to differentiate common experiences from individual experiences. Similar research studies have experienced this, especially when working within inclusive music communities (Samuels and Schroeder, 2019; Frid, 2018, 2019a).

Second, the ability to fully engage with a specific methodology or approach to data collection was often interrupted. There was a consistent need to be flexible or reactive to what was happening within the project at any point in time. As an independent researcher within a non-controlled environment, it was not always possible to have contingency plans for collecting data around these interruptions.

Third, taking on an active role within an existing project for the first study resulted in some confusion around the researcher's presence and responsibilities within the workshops. On the other hand, it was only through assuming this active role that the researcher was able to build close relationships within the inclusive music community. These relationships have continued to have a positive impact on the research.

8.7 Future work

The main contribution of this research, the FAME framework, proposes a starting point for future discussions and versions of such a document. It is hoped that through publishing the framework and evaluation tool in an accessible format via a public website, there will be opportunities to engage the wider community in this discussion of what makes a DMI more or less accessible.

A community-driven standard or framework achieved through consensus could have a huge impact on the music technology industry, much like web standards have an impact upon web technologies.

A movement towards standards that include disabled people and disabled voices could be significant in improving the awareness of and responses to the accessibility of DMIs going forward.

Equally, in research, future studies related to this work could examine the evaluation process suggested within the framework. It would be ideal to review the evaluation process through a study with larger numbers of participants than was possible to achieve during this research period.

In conclusion, this research supports the notion that digital musical instruments and other music technologies can enable better inclusion in music (Frid, 2019b; Harrison, 2020). While there is still a long way to go to address the societal barriers to accessibility and inclusion in music, there is hope that providing resources that help DMI designers, developers, and creators to understand accessibility barriers will encourage more empathy and understanding throughout the industry.

Building a community around improving accessibility in DMIs has the potential not only to improve the experience for future generations of disabled musicians but also to put the voices of disabled musicians at the forefront of establishing accessibility guidelines for the music technology industry.

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Appendix A

Documents relating to the Able Orchestra Study 2016 - 2017

A.1 Active and Creative Participatory Workshop

A.1.1 Consent Form

Active & Creative: Gesture Controlled Sound – A Design Workshop

This workshop aims to explore the potential uses of gesture controlled sound in relation to community music programs, music performance and music therapy.

The design workshop will ask participants to observe a demonstration of gesture controlled sound and discuss the potential design issues or needs in using gesture controlled sound in music programs, performance and therapy.

Participants have been invited based on their background knowledge and involvement in these areas. Collaborative design activities will then take place to come up with new and desirable uses for gesture controlled sound.

The workshop aims to inform design of interactive controls for music that could benefit people within the Special Education Needs and Disability (SEND) and Acquired Brain Injury communities. Any data collected during the design workshop will be used to assist in the design and development of these interactive controls.

All data collected will be held in a secure and safe manner in accordance with the Data Protection Act 1998.

Participants are free to withdraw at any time and their personal data will be erased from our records. Requests to withdraw from this study can be made in writing by email to:

Amy Dickens – psxad2@nottingham.ac.uk

This research is conducted by Amy Dickens, Mixed Reality Laboratory, School of Computer Science, The University of Nottingham and is funded by the Engineering and Physical Sciences Research Council (EPSRC). All research has been approved the School of Computer Science's Ethics Committee in accordance to the University Code of Research Conduct and Research Ethics.

Active & Creative: Gesture Controlled Sound - Design Workshop Consent Form

This is to confirm that I have agreed to take part in a research design workshop; I have read the information sheet provided and I understand what is involved.

As part of this workshop, I understand audio and video recordings will be taken and this data will be analysed for research purposes.

I understand that I can withdraw at any time, by sending an email to Amy Dickens and that if I do so, all data collected from my involvement in this workshop will be removed from the research project records. However, I understand that scientific publications – which may include anonymous data – cannot be changed after publication.

- I confirm I am over the age of 18.

- I give permission for anonymous quotations to be used in scientific publications and presentations.

- I give permission for the data collected to be used in subsequent associated research.

- I also give permission to researchers directly involved in the research to use my non-anoymised data (i.e. pictures taken from recorded videos) for scientific publication and presentation. **– Optional please only tick this box if you are happy for your image to be used.**

Signed ……………………………………..

Name …………………………..…………….

Contact Tel No: ………………………………

Email: …………………………………………...

A.1.2 Questionnaire

ACTIVE & CREATIVE DESIGN WORKSHOP – ACTIVITY 1
MUSIC & MOVEMENT – INDIVIDUAL QUESTIONNAIRE

CANDIDATE No:

The responses gathered in this questionnaire will help to inform the design of a sensor base gesture controlled musical interface. It is important to note that there are no correct or incorrect responses and the responses given should be that of the individual.

1. Using sensors to detect movement allows a user to control sound using their body movement freely within the space that the sensor can detect.
Considering this please use the scales below to state to what degree you either agree or disagree with each of the following statements:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
(a) Freedom of movement makes the technology more accessible					
(b) Freedom of movement makes the technology difficult to use					
(c) Freedom of movement allows for greater creativity					
(d) Freedom of movement gives a more natural feel to the technology					
(e) Freedom of movement could frustrate a user					
(f) Freedom of movement is challenging in a positive way					

2.
(a) Do you feel it is important to have visual feedback when using movement to control sound? *Please circle your answer.*

YES NO

(b) Why do you feel this way?

3.
(a) Do you think that the speed at which a movement is made should affect the sound triggered from this? *Please circle your answer*.

YES NO

(b) Why do you feel this way?

4.

Figure A Figure B Figure C Figure D Figure E

Considering the above diagrams please answer the following questions:

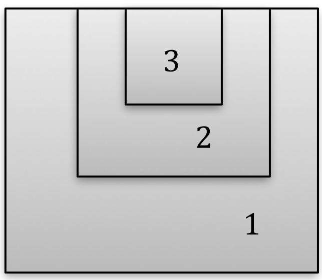
(a) What sound event would you associate with a vertical upward motion as represented by the Figure B?

____

(b) What sound event would you associate with a vertical downward motion as represented by Figure D?

____

5.



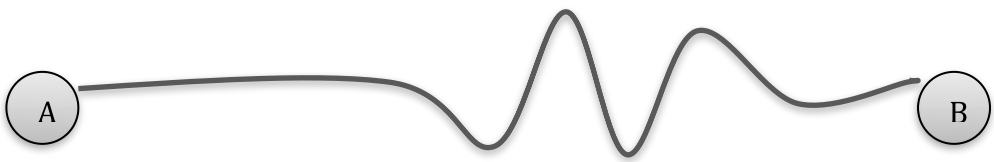
Imagine the above diagram as a set of three boxes each contained within the other.
Considering this please order each set of words below with the numbers 1, 2 & 3 to correspond to the boxes as displayed on the diagram:

(a) Song = Melody = Chorus =

(b) Song = Note = Key =

(c) Melody = Note = Chorus =

6.



The above diagram shows a line connecting two points, imagine this as a path between point A and point B. Now imagine that A and B represent musical or sound events, please answer the following:

(a) What musical event are you imagining point A to be?

____

(b) What musical event are you imagining point B to be?

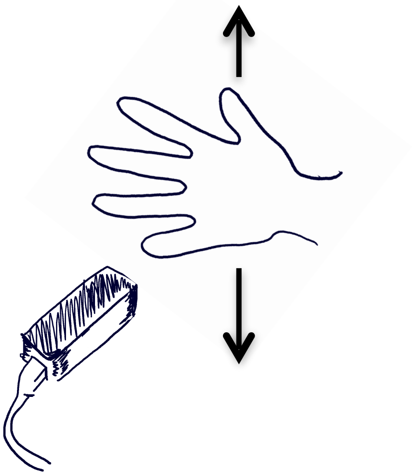
____

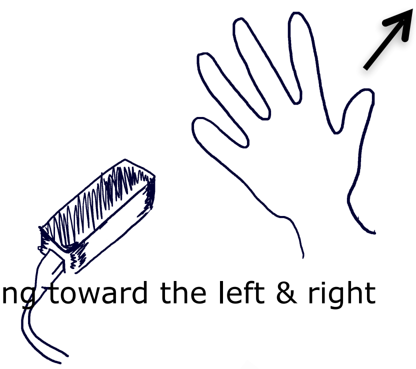
(c) What happens to the sound/musical events as you move along the path from point A to point B?

____

7. Consider each of the diagrams below, using the space provided please write what sound you would expect to hear from the motion being made in the diagram.

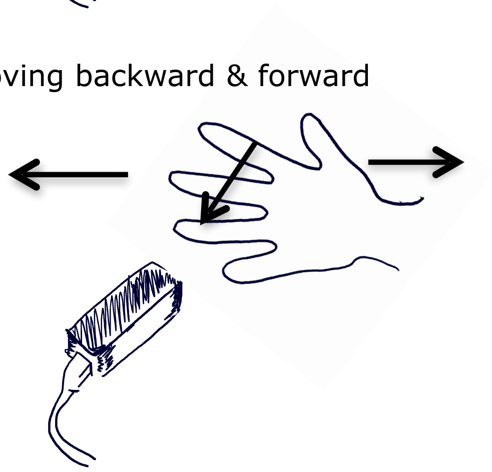
(a) Moving upward & downward





(b) Moving toward the left & right

(c) Moving backward & forward



8.

(a) If you could use any motion to control a sound event what motion would that be?

____

(b) How would it control the sound event?

____

(c) Why would you choose this?

____

Please feel free to provide a diagram in the space below to represent your answers to the above questions (optional).

Finally, please could you provide some information about yourself so that your previous response can be put into context.

What is your age?		YEARS	
What is your gender?	MALE	FEMALE	PREFER NOT TO SAY
What is your occupation?			
Have you previously played or do you still play a musical intrustment? **If you answer yes to this question** please also confirm for how long you have been playing/played?			

☐ Please tick this box if you are happy for this information to be included in the research data alongside your answers to this questionnaire.

A.1.3 Results from Hierarchy Activity

CORE/REQUIRED		
Card no.	Card Statement	Adjustments
*04	Device is Robust	
*25	Device can interact with other software (DAW)	
*27	Device is easily portable	
*26	Changes in sound are obvious to the user	
*14	Device has a reset mode (button)	Button - need for this was questioned
*22	Interaction can be tailored by a third party (therapist)	
*20	Sound is responsive in realtime (no delay)	
*02	Device is stand alone does not need laptop or other device to be used	
*17	Tailoring is simple to complete and needs little instruction	
*11	Device can be connected to an amplifier	
*16	Device can be switched on and off	
*01	Device can be used intuitively (without instruction - plug and play)	Basic instruction once configured
*18	Device requires no prior musical knowledge	
*03	Device can be used with headphones	
EXPECTED		
Card no.	Card Statement	Adjustments
*15	Device has memory of users (shows development)	
*19	Interaction can be tailored by the user	
*07	Device needs to be aesthetically pleasing	
*21	Device can be used with multiple sensors (adaptive)	
*12	Device can record the interaction for playback later	
*10	Device features a volume control	
*24	User can see a visual response to their movement	
AUGMENTED		
Card no.	Card Statement	Adjustments
*23	Area that sensor can see is made visual to user	
*05	Device has option to have a monitor for visual feedback	
*08	Setup instructions are provided from the device	
*13	Device can be personalised visually	
*09	Device can be hacked to add functionality	
*06	Device has inbuilt speaker	

A.2 Able Orchestra Project

A.2.1 Consent Form - Participants

Nottinghamshire County Council

Children, Families and Cultural Services
Arts and Sports for Children and Young People
General Consent
(Projects/Events/Visits)

To be completed in respect of all young people aged under 18 years by their Parent/Guardian.
To be completed by young people aged18 years and above themselves.

Please complete the following form to enrol in the **event** and bring it with you to the **event**. If you have any questions or need any help filling in the enrolment form please contact us on the telephone number at the end of this form

DETAILS OF PROJECT / **EVENT** / VISIT ______________________________

DATE(S______________________________

1. PERSONAL DETAILS of Participant

First name: ____________________ Surname: ____________________

Address: ______________________________

____________________ Postcode: ____________________

School: ____________________ Email: ____________________

Home Tel No: ____________________ Mobile: ____________________

Date of Birth: ____________________ Gender: MALE / FEMALE

Emergency Contact Name: ____________________ Tel: ____________________

Relationship to young person: ______________________________

I am not available on the following date(s): ______________________________

2. ADDITIONAL SUPPORT

We require the following information to assess whether we are able to provide any extra support, for example, childcare expenses, etc. **Any information that you give is strictly confidential and will not affect your enrolment**.

Is there anything that would stop you taking part or make it difficult for you to take part in the project/event?

☐Yes ☐No

If Yes, how can we make it easier for you to take part? ______________________________

____

Do you have a support worker? i.e. youth worker, probation officer, etc If so please give their contact details:

Name: ______________________________ Tel no: ____________________

3. IMAGE CONSENT

Nottinghamshire County Council may take you/your child's photographs to use in its publicity. These pictures may be sent out to the media with a press release, used for our publications, on County Council promotional videos, CD ROMs or on either website (Please note that websites can be seen throughout the world, and not just in the United Kingdom, where the UK law applies.)

- To help us comply with the Data Protection Act 1998, we'd like your permission before we take your photo.
- Photos will be stored in a secure location and only authorised staff will have access to them.
- Addresses will not be disclosed in detail, but we may state, for example, 'John Smith from Newark'.
- We will not use the images taken, or any other information you provide, for any other purpose.
- We will not include personal email or postal addresses, or telephone or fax numbers on video or in other printed publications.

Conditions of use: The image consent form is valid for three years from the date you sign it. The image will be destroyed by the County Council when the 3 years has lapsed. All images will be stored securely and used by those who are authorised to do so.

I have read and understood the information above and the conditions. I agree to my / my child's image being used by Nottinghamshire County Council.

Parent/Guardian signature: ________________________________ Date: _______________________________
(If under 18 years)

Your signature: ____ Date: _______________________________
(If 18 or over)

4. SOCIAL NETWORKING CONSENT

To be completed in respect of all young people aged under 18 years by their Parent/Guardian. To be completed by young people aged 18 years and above themselves.

As part of the accreditation and evaluation work that participants will undertake during the course they are encouraged to use various social networking tools to record and share their experiences. They can use their own facebook and blogs however it is their own responsibility to ensure that the content is appropriate as we can take no responsibility for this. However, when using the County Youth Arts/Old Library pages and blogs they will be monitored and any inappropriate content will be dealt with and removed.

I have read and understood the information above and the conditions. I agree to my son / daughter / myself using County Youth Arts/The Old Library *facebook/*tumblr. I acknowledge the need for responsible behaviour on his/her/my part. * please delete as applicable.

Parent/Guardian signature: ________________________________ Date: _______________________________
(If under 18 years)

Your signature: ____ Date: _______________________________
(If 18 or over)

5. RESEARCH CONSENT

To be completed in respect of all young people aged under 18 years by their Parent/Guardian. To be completed by young people aged 18 years and above themselves.

A researcher (Amy Dickens of the Mixed Reality Laboratory, The University of Nottingham) will be assisting during this project. During the course of the project the researcher may document participant's experiences through hand written field notes, motion capture data, images and short video or audio recordings. The research aims to build knowledge for creating more accessible technologies for music creation.

- To help us comply with the Data Protection Act 1998, we'd like your permission for your information to be included in this research.
- Any data collected will be securely managed and only accessed by the researcher and authorised individuals.
- Photos will be stored in a secure location and only authorised individuals will have access to them.
- Addresses or personal information (including names of participants), will not be disclosed.
- We will not use the images taken, or any other information you provide, for any other purpose.

Conditions of use: The research consent form is valid for seven years from the date you sign it. Images, recordings and any identifying (non-anonymous) data collected will be destroyed by the researcher when seven years has lapsed. All images will be stored securely and used by those who are authorised to do so.

I have read and understood the information above and the conditions. I agree to anonymous data collected regarding my / my child's experiences being used in the research publications of Amy Dickens of Mixed Reality Laboratory at The University of Nottingham.

Parent/Guardian signature: ______________________________ Date: ______________________________
(If under 18 years)

Your signature: ____ Date: ______________________________
(If 18 or over)

Further to this I agree to my / my child's image being used in the research publications of Amy Dickens, Mixed Reality Laboratory, The University of Nottingham.

Parent/Guardian signature: ______________________________ Date: ______________________________
(If under 18 years)

Your signature: ____ Date: ______________________________
(If 18 or over)

6. GENERAL CONSENT

To be completed in respect of all young people aged under 18 years by their Parent/Guardian. To be completed by young people aged18 years and above themselves.

1. I agree to my son / daughter / myself taking part in the **event** as detailed above. I acknowledge the need for responsible behaviour on his/her/my part.

2. INFORMATION

a. Does your son / daughter / yourself suffer from any condition requiring medical treatment, including medication?
YES / NO

If YES, please give brief details

b. To the best of your knowledge, has your son / daughter / yourself been in contact with any contagious diseases or suffered from anything in the last four weeks that may be or become contagious or infectious?
YES / NO

If YES, please give brief details

c. Is your son /daughter / yourself allergic to any medication / substances e.g. Wasp stings
YES / NO

If YES, please specify

d. Has your son / daughter / yourself received a tetanus injection in the last five years?
YES / NO

e. Please outline any special dietary requirements of your child / yourself

f. I agree to my son/daughter being left unsupervised in periods of free time
YES / NO

g. I agree my son / daughter consuming alcohol in a controlled social education environment e.g. with a meal – but NOT at any other time
YES / NO

3. DECLARATION

I agree to my son / daughter / myself receiving emergency medical treatment, including anaesthetic, as considered necessary by the medical authorities present.

I may be contacted by telephoning the following numbers:

Work: .... Times: ....

Home: .... Times: ....

Mobile: ....

Please tick the first contact number in event of an emergency

My home address is: ....

....

....

If not available at any of the above telephone numbers please nominate additional contact person

Name: ....

Relationship: ....

Emergency Tel. No. ....

Address: ....

Name, address and telephone number of family doctor:

Signed: ____________________________________(Parent / Guardian /or by the young person if if over 18 years) Date: _________________ Name ____

7. DISABILITY INFO

Any information that you give is strictly confidential and will not affect your enrolment

Would you consider yourself as having any disabilities?

☐Yes ☐No

If Yes, how would you describe these?

☐ Learning Difficulty ☐ Sight Impairment ☐ Hearing Impairment

☐ Physical Impairment ☐ Other/Hidden Impairment

(e.g. Asthma, Diabetes, Mental Health, Allergies etc.) Describe here:

8. ETHNICITY INFO

Any information that you give is strictly confidential and will not affect your enrolment
I would describe my ethnic origin as:

Ethnicity	White British		White Irish		White Other	
	W/B Caribbean		W/B African		W/B Asian	
	Other Mixed Background		Black Caribbean		Black African	
	Black Other		Indian		Pakistani	
	Bangladeshi		Other Asian Background		Chinese	
	Other		Afghani		Iranian	
	Iraqi Kurd		Turkish		Turkish Kurd	
	Traveller of Irish Heritage		Gypsy/Roma		Prefer not to say	

Please send the enrolment form to:
County Youth Arts
The Old Library Venue and Media Centre
Leeming Street
Mansfield
Notts NG18 1NG
Tel: 01623 644377 / Email: countyyoutharts@nottscc.gov.uk

This form should returned to the Unit and a copy taken by the leader on the activity.

IMPORTANT – Pre-printed briefing sheets / parental consent forms are available from County Youth Arts, The Old Library Venue & Media Centre. Please obtain sufficient copies of the forms from the Admin Office.

A.2.2 Consent Form - Facilitators

Able Orchestra Participant Interviews

Active & Creative is a research project which aims to explore the potential uses of gesture controlled sound in relation to community music programs, music performance and music therapy.

This interview will ask participants to provide information regarding their experiences and discuss the potential design issues or needs in using gesture controlled sound in music programs such as the Able Orchestra project.

Participants have been invited based on their involvement in this project and will be verbally presented with a series of questions relative to their experience during the Able Orchestra activities at Fountaindale School during February 2016.

Any information provided will help to inform further development of interactive controls for music that could benefit people within the Special Education Needs and Disability (SEND) and Acquired Brain Injury communities. Any data collected during the interview will be used to analyse the implementation of these interactive controls within the Able Orchestra Project at Fountaindale School during February 2016.

All data collected will be held in a safe and secure manner in accordance with the Data Protection Act 1998.

Participants are free to withdraw at any time and their personal data will be erased from our records. Requests to withdraw from this study can be made in writing by email to:

Amy Dickens – psxad2@nottingham.ac.uk

This research is conducted by Amy Dickens, Mixed Reality Laboratory, School of Computer Science, The University of Nottingham and is funded by the Engineering and Physical Sciences Research Council (EPSRC). All research has been approved the School of Computer Science's Ethics Committee in accordance to the University Code of Research Conduct and Research Ethics.

Able Orchestra Participant Interviews

I confirm that I have agreed to take part in an interview that will assist with the research of Amy Dickens, Mixed Reality Laboratory, School of Computer Science, The University of Nottingham.

I understand audio and video recordings of this interview will be taken and this data will be analysed for research purposes.

I understand that I can withdraw at any time, by sending an email to Amy Dickens and that if I do so, all data collected from my involvement in this interview will be removed from the research project records. However, I understand that scientific publications – which may include anonymous data – cannot be changed after publication.

- I confirm I am over the age of 18.

- I give permission for anonymous quotations to be used in scientific publications and presentations.

- I give permission for the data collected to be used in subsequent associated research.

- I also give permission to researchers directly involved in the research to use my non-anoymised data (i.e. pictures taken from recorded videos) for scientific publication and presentation. **– Optional please only tick this box if you are happy for your image to be used.**

Signed …………………………………………..

Name ……………………………..…………….

Contact Tel No: …………………………………

Email: …………………………………………...

Appendix B

Documents relating to the Able Lite Workshops 2018

B.1 Plan for the Workshops

Workshop Plan : Able Lite

SECTION 1: AIMS & OBJECTIVES

Aims (Participants)
- Explore making music through the use of a digital musical instrument
- Create a short piece (individually or together as a group) of music using the DMI
- Practice this short piece using the DMI and reflect upon this
- Perform the piece of music in front of a group of peers

Objectives (Researchers)
- To collect data in the form of field notes, video recordings and feedback sheets from participants
- To observe DMIs in use by users with complex disabilities
- To identify any parts of DMI design that are blockers for accessibility
- To identify any parts of DMI design that are useful for accessibility
- To evaluate the Facilitating Access to Musical Experiences framework using data from the workshops

SECTION 2: EQUIPMENT

The Equipment to be used in the workshops will feature Digital Musical Instruments as grouped by these four categories-

1. Tangible
2. Gesture
3. Application-based
4. Wearable

Tangible instruments refer to hardware devices that are built for purpose and use touch as their medium for interaction.

Gesture instruments refer to hardware and software through which the user can interact using body movement in the air, without touch.

Virtual instruments refer to software available on a tablet (namely iPads will be used in this study) that can be used for music generation/control.

Wearable instruments refer to wearable technology that can be used as controllers for musical software. Body motion will be the medium of input here.

There are some instances of DMIs that may feature elements of more than one category. In this case they will be grouped with the category with which they most strongly align and marked with an asterisk to indicate that they could be perceived differently.

1. TANGIBLE
    - ROLI Blocks
    - BopPad
    - Mogees Pro
    - Skoog
2. GESTURE
    - Leap Motion Technology Probe
3. VIRTUAL
    - Playground
    - ThumbJam

Bloom
Thicket
Impaktor

4. WEARABLE
   Myo Armband
   Specdrums
   MiMu Gloves

SECTION 3: ACTIVITIES

For each of the workshops there will be four phases **DISCOVER/CREATE, PRACTISE, PERFORM, and REFLECT.**

The activities are designed to be flexible depending on the abilities of the group and a suggestion is made for each phase for low, mid and high functioning groups.

For the purpose of these workshops the definition of these groups are as follows:

Low support groups are observed as having verbal ability, good academic skills and ability to address their own personal care needs.

High support groups are observed as having limited or no verbal ability, limited academic skills, and require support to address their personal care needs.

Mid support groups may contain a mixture of individuals with both high and low support needs.

The lead facilitator will decide which activities are best suited to the participant group.

Please note - these descriptors are used to identify physical support requirements only. Which informs the potential equipment choices for that workshop group. These terms should not be used to comment on an individual's ability to take part in the activity nor should they be used as descriptors for that person or their skillset.

It is important to remember that an individual can have low or high support needs and still possess high cognitive processing, social skills and emotional balance.

Please take care when using labels, descriptors or discussing any of the participants personal diagnosis..

ACTIVITY - DISCOVERY

H *Pass It On*
This activity will be guided by the lead facilitator who will engage the group in a discovery experience trying the equipment in turns.

M *Pass It On + 1*
This activity is as before, but a second or third DMI can be introduced amongst the group. Where possible turn taking should be upheld.

L *Make Some Noise*
In this activity each participant will be provided with a DMI to explore. A time window will be allocated, during which participants such be

encouraged to just explore the equipment without being guided.

ACTIVITY - DISCOVER/CREATE

H *Show me what you got*
In this activity each participant will get an opportunity to play along with a backing track controlled by the lead facilitator. This will be done one by one like in the discovery activity. The lead facilitator may also take the opportunity to record this.

M *Follow My Lead*
In this activity the facilitator with the participant will lead the performer in a repeat after me pattern. Again this is done one by one and the lead facilitator will control a backing track for the user to perform with. The lead facilitator may take the opportunity to record these.

L *Play along with this*
In this activity the group will be given a backing track and encouraged to play along with it together. Facilitators will listen out to what the group is doing and make recommendations to the performers about patterns that sound good.

ACTIVITY - PRACTISE

L/M/H *Play that again*
In this activity the facilitators will support the group in repeating and refining the parts they have played and discovered in the creation activity. As this happens the lead facilitator will take the opportunity to record the parts being played and add in effects etc.

ACTIVITY - PERFORM

H *Group Listening*
In this activity the group will listen back to what they've created and facilitators, support staff and others will be invited to listen and experience this also.

M *Group Performance*
In this activity the group will do a live performance together as group. This will be very informal and others may or may not be invited into the space to be an audience.

L *Perform to Peers*
In this activity the group will undertake a more structured performance. Where possible moving spaces should be avoided. An audience will be invited in - from peer class groups to teaching staff and parents/friends.
The lead facilitator will record this performance.

SECTION 4: SCHEDULE

Every workshop will require 1 hour of preparation and 2.5 hours of activities (inclusive of 30 minutes break).

TIME	SECTION	ACTIVITY
-01:00	Preparation	Load in
-00:30	Preparation	Set up
-00:15	Preparation	Sound Check
00:00	PART I	Discovery
00:30	PART II	Feedback I
00:45	PART II	Break
01:00	PART III	Creation
01:30	PART IV	Practise
01:45	PART IV	Feedback II
02:00	PART V	Perform
02:15	PART V	Break & Final Comments
02:30	End of Activity	

PREPARATION

All workshop facilitators should attend the location a minimum of 1 hour prior to the workshop start time to begin with preparation.

Load in:

There is a lot of equipment that will need loading into the location.
Including - PA system, interfaces, digital instruments, cables, stands, tablet devices, cameras and other recording devices, and laptops.

Set up:

Under the instruction of the workshop lead, the facilitators will set up the equipment ready for the workshop use. This will include (but won't be limited to)
-
PA system hook up, powering devices, assembling stands, opening applications and setting options for these, cable management and setting up the DAW (Digital Audio Workstation).

The facilitators will also need to assist with the setup of recording equipment to capture the workshop interactions.

Sound Check:

At the beginning of each session prior to the arrival of the participants each of the DMIs will need to be sound checked through the desk and a base and max level for the PA system should be set.
The recording equipment should also be checked to ensure sound is captured without distortion and new memory cards placed into the devices to ensure there is enough space on the disk.

Once sound check is completed, all devices should be switched into their interaction states. The facilitators will need to check for guided access settings on tablet devices, playback modes on MIDI devices and sound settings on some of the other DMIs, depending on what is in use during this session. Facilitators should also take note of any participant requirements on arrival, i.e. the use of ear defenders for sound sensitivity or other assistive equipment that might need to be used (arm supports) etc.

FEEDBACK SESSIONS

Time has been placed in the schedule for feedback to take place during the workshop.

BREAKS

Breaks have been allocated on the schedule, however participants may need to take additional time at any point for comfort or personal care breaks.

Facilitators should do everything they can to support the participant experience. If time is taken for personal care, a note should be taken to ensure that the participant has the opportunity to take part in any missed activity upon their return.

FINAL COMMENTS & ENDING THE ACTIVITY

During the final break there is an opportunity to ask the participants for any final comments about their experience.

Facilitators also should ensure that ALL forms have been collected regarding the participants' involvement. Additionally it should be ensured that all participants have been given an information sheet to keep.At this point the lead facilitator will also ask any staff members/audience if they would be happy to give feedback. This will be done in session time where possible - but may also include feedback at a later date.

At the end of the session the participants should be thanked for their time. The lead facilitator will inform participants that a recording of the final output will be made available. This will be shared to the staff for distribution to the participants.
If staff have taken any images/recorded any parts of the performance the usage of this material should be discussed, and where possible collection of that data should be organised so that it can be included in the study.

PACK DOWN

After the workshop has ended and collection of all feedback material, participant forms etc. has happened, all the equipment will need to be packed down.

This will require resetting applications, dismantling stands, disconnecting the PA system and interfaces, and returning any equipment to their boxes for transport and storage.

The lead facilitator should ensure that any recordings captured are stored onto a disk and correctly named. They should also collect all data disks from recording equipment and notes from facilitators. All equipment should be loaded out and the space returned to how it was before the workshop.

CONTACT INFORMATION

Lead Facilitator: Amy Dickens
They/Them
amy.dickens@nottingham.ac.uk
07807 056 961
Supporting Facilitator: Elle Williams
She/Her

B.2 Consent Form - Participants

Nottinghamshire County Council

Children, Families and Cultural Services
Arts and Sports for Children and Young People
General Consent
(Projects/Events/Visits)

To be completed in respect of all young people aged under 18 years by their Parent/Guardian.
To be completed by young people aged18 years and above themselves.

Please complete the following form to enrol in the **project** and bring it with you to the **project session**. If you have any questions or need any help filling in the enrolment form please contact Amy Dickens on the telephone number or email at the end of this form.

DETAILS OF **PROJECT** / EVENT / VISIT ____________________

DATE(S____________________

1. PERSONAL DETAILS of Participant

First name: ____________________ Surname: ____________________

Address: ____________________

____________________ Postcode: ____________________

School: ____________________ Email: ____________________

Home Tel No: ____________________ Mobile: ____________________

Date of Birth: ____________________ Gender: MALE / FEMALE

Emergency Contact Name: ____________________ Tel: ____________________

Relationship to young person: ____________________

I am not available on the following date(s): ____________________

2. ADDITIONAL SUPPORT

We require the following information to assess whether we are able to provide any extra support, for example, childcare expenses, etc. **Any information that you give is strictly confidential and will not affect your enrolment**.

Is there anything that would stop you taking part or make it difficult for you to take part in the project/event?

☐Yes ☐No

If Yes, how can we make it easier for you to take part? ____________________

____

Do you have a support worker? i.e. youth worker, probation officer, etc If so please give their contact details:

Name: ____________________ Tel no: ____________________

3. IMAGE CONSENT

Nottinghamshire County Council may take you/your child's photographs to use in its publicity. These pictures may be sent out to the media with a press release, used for our publications, on County Council promotional videos, CD ROMs or on either website (Please note that websites can be seen throughout the world, and not just in the United Kingdom, where the UK law applies.)

- To help us comply with the Data Protection Act 1998, we'd like your permission before we take your photo.
- Photos will be stored in a secure location and only authorised staff will have access to them.
- Addresses will not be disclosed in detail, but we may state, for example, 'John Smith from Newark'.
- We will not use the images taken, or any other information you provide, for any other purpose.
- We will not include personal email or postal addresses, or telephone or fax numbers on video or in other printed publications.

Conditions of use: The image consent form is valid for three years from the date you sign it. The image will be destroyed by the County Council when the 3 years has lapsed. All images will be stored securely and used by those who are authorised to do so.

I have read and understood the information above and the conditions. I agree to my / my child's image being used by Nottinghamshire County Council.

Parent/Guardian signature: ________________________________ Date: _______________________________
(If under 18 years)

Your signature: ____ Date: _______________________________
(If 18 or over)

4. SOCIAL NETWORKING CONSENT

To be completed in respect of all young people aged under 18 years by their Parent/Guardian. To be completed by young people aged 18 years and above themselves.

As part of the accreditation and evaluation work that participants will undertake during the course they are encouraged to use various social networking tools to record and share their experiences. They can use their own facebook and blogs however it is their own responsibility to ensure that the content is appropriate as we can take no responsibility for this. However, when using the County Youth Arts/Old Library pages and blogs they will be monitored and any inappropriate content will be dealt with and removed.

I have read and understood the information above and the conditions. I agree to my son / daughter / myself using County Youth Arts/The Old Library *facebook/*tumblr. I acknowledge the need for responsible behaviour on his/her/my part. * please delete as applicable.

Parent/Guardian signature: ________________________________ Date: _______________________________
(If under 18 years)

Your signature: ____ Date: _______________________________
(If 18 or over)

5. RESEARCH CONSENT

To be completed in respect of all young people aged under 18 years by their Parent/Guardian. To be completed by young people aged 18 years and above themselves.

A researcher (Amy Dickens of the Mixed Reality Laboratory, The University of Nottingham) will be leading this project. During the course of the project the researcher may document your / your child's experiences through hand written field notes, images and video or audio recordings. This data is collected for an ongoing research project that aims to support designers and builders in creating more accessible music technologies.

- To help us comply with the Data Protection Act 1998, we'd like your permission for your information to be included in this research.
- Any data collected will be securely managed and only accessed by the researcher and authorised individuals.
- Photos will be stored in a secure location and only authorised individuals will have access to them.
- Addresses or personal information (including names of participants), will not be disclosed.
- We will not use the images taken, or any other information you provide, for any other purpose.

Conditions of use: The research consent form is valid for seven years from the date you sign it. Images, recordings and any identifying (non-anonymous) data collected will be destroyed by the researcher when seven years has lapsed. All images will be stored securely and used by those who are authorised to do so.

I have read and understood the information above and the conditions. I agree to anonymous data collected regarding my / my child's experiences being used in the research publications of Amy Dickens of Mixed Reality Laboratory at The University of Nottingham.

Parent/Guardian signature: ______________________________ Date: ______________________________
(If under 18 years)

Your signature: ____ Date: ______________________________
(If 18 or over)

Further to this I agree to my / my child's image being used in the research publications of Amy Dickens, Mixed Reality Laboratory, The University of Nottingham.

Parent/Guardian signature: ______________________________ Date: ______________________________
(If under 18 years)

Your signature: ____ Date: ______________________________
(If 18 or over)

6. GENERAL CONSENT

To be completed in respect of all young people aged under 18 years by their Parent/Guardian. To be completed by young people aged18 years and above themselves.

I agree to my son / daughter / myself taking part in the **project** as detailed above. I acknowledge the need for responsible behaviour on his/her/my part.

Signed: ___________________________________(Parent / Guardian /or by the young person if if over 18 years) Date: ________________ Name

____

7. DISABILITY INFO

Any information that you give is strictly confidential and will not affect your enrolment

Would you consider yourself as having any disabilities?

☐Yes ☐No

If Yes, how would you describe these?

☐ Learning Difficulty ☐ Sight Impairment ☐ Hearing Impairment

☐ Physical Impairment ☐ Other/Hidden Impairment

(e.g. Asthma, Diabetes, Mental Health, Allergies etc.) Describe here:

8. ETHNICITY INFO

Any information that you give is strictly confidential and will not affect your enrolment
I would describe my ethnic origin as:

Ethnicity	White British		White Irish		White Other	
	W/B Caribbean		W/B African		W/B Asian	
	Other Mixed Background		Black Caribbean		Black African	
	Black Other		Indian		Pakistani	
	Bangladeshi		Other Asian Background		Chinese	
	Other		Afghani		Iranian	
	Iraqi Kurd		Turkish		Turkish Kurd	
	Traveller of Irish Heritage		Gypsy/Roma		Prefer not to say	

Please complete the enrolment form and bring it to the workshop for the activity leader (Amy Dickens) to collect in person.

If you have any questions about this form or the activity please contact Amy Dickens at:

The Mixed Reality Laboratory
School of Computer Science
The University of Nottingham
Jubilee Campus
Wollaton Road
NG8 1BB
Tel: +44(0)7807056961
Email: amy.dickens@nottingham.ac.uk

B.3 Consent Form - Facilitators

Able LITE Workshops 2018 - Facilitating Access to Musical Experiences Research

What are the Able LITE workshops?

The Able LITE workshops are part of research project which aims to explore the potential uses of digital musical instruments in relation to community music programs and music performance for people with complex disabilities.

Why have I been asked to sign this?

As part of the research being conducted there are several recording devices within the space, as a result data that represents you (audio recordings or video recordings) may be collected. You have been asked to sign this consent form to give permission to the researcher (Amy Dickens) to use this data in the activities of the research.

Any data collected will help to inform further development of interactive controls for music that could benefit people within the Special Education Needs and Disability (SEND) communities.

What will you use my data for?

Amy will use this data to analyse the use of digital musical instruments within the Able LITE workshops.

Representations of you will not be shared without explicit permission from you. This includes both anonymised and non-anonymised representations.

All data collected will be held in a safe and secure manner in accordance with the Data Protection Act 1998.

You are free to withdraw at any time and your personal data will be erased from our records.

Requests to withdraw from this study can be made in writing by email to:

Amy Dickens :: amy.dickens@nottingham.ac.uk

This research is conducted by Amy Dickens, Mixed Reality Laboratory, School of Computer Science, The University of Nottingham and is funded by the Engineering and Physical Sciences Research Council (EPSRC). All research has been approved the School of Computer Science's Ethics Committee in accordance to the University Code of Research Conduct and Research Ethics.

Able LITE Workshops 2018 - Facilitating Access to Musical Experiences Research

I confirm that I have read and understood the video information sheet regarding the research of Amy Dickens, Mixed Reality Laboratory, School of Computer Science, The University of Nottingham.

I understand video and audio recordings of this session (workshop and/or performance) will be taken and this data will be analysed for research purposes.

I understand that I can change the type of consent I have given at any time, by sending an email to Amy Dickens. However, I understand that scientific publications - which may include anonymous data - cannot be changed after publication.

Please place your **INITIAL** inside each **BOX** below to confirm the following.

☐ I confirm I am over the age of 18.

☐ I give permission for the data collected to be used in subsequent associated research.

☐ I also give permission to researchers directly involved in the research to use my non-anonymised data* (i.e. pictures taken from recorded videos) for scientific publication and presentation ***Optional please initial this box if you are happy for your image to be used.**

Signed ....

Name ....

Contact Tel No ....

Email ....