INSTRUMENTS AND ACCESS: THE ROLE OF INSTRUMENTS IN MUSIC AND DISABILITY

JACOB HARRISON

INSTRUMENTS AND ACCESS: THE ROLE OF INSTRUMENTS IN MUSIC AND DISABILITY

JACOB HARRISON

Submitted in partial fulfilment of the requirements of the
University of London Degree of Doctor of Philosophy
School of Electronic Engineering and Computer Science
Queen Mary University of London

SUPERVISORS:
Dr Andrew McPherson

April 2020

ABSTRACT

In the past several decades, society's understanding of disability has progressed from an individualised model based on functional limitations, to the identification of disabling barriers in society which are imposed upon people living with physical, cognitive and/or sensory impairments. Alongside this, there is increased interest in new creative technologies which are capable of addressing these barriers. In this thesis, I explore the development of Accessible Digital Musical Instruments (ADMIs) in terms of their ability to address the technical and social barriers that prevent access to music-making.

I begin with a review of relevant literature from the fields of Disability Studies and Digital Musical Instrument (DMI) design. This is followed by interviews with two disabled musicians, who discuss how their approach to music performance and instrumentation relates to their disability identity. I then report three performer studies with purpose built DMIs. The first study explores adapting the bass guitar for one-handed playing, using a prototype mechanical adaptation. The second study continues the theme of preserving the role of the guitar, but asks questions around the role of interaction modality and global form, and how they relate to an instrument's identity. The final study is an ethnographic account of a long-term situated research project with a community of learning-disabled musicians, in which we observe how bespoke guitar-like ADMIs are used alongside unadapted instruments.

This thesis introduces a 'performance-focused' approach to ADMI design, in which sociocultural roles of musical instruments are considered alongside the technical requirements of accessibility. Using theories and methodologies from third-wave HCI, Disability Studies, and DMI design, I aim to interrogate what 'access to musical performance' really means. It is hoped that this thesis can provide a critical counterpoint to existing approaches to accessibility in DMI design, and in doing so, introduce methodologies which are capable of capturing and uplifting the creative potential of disabled people.

ACKNOWLEDGEMENTS

It would be hard to overstate the level of gratitude I feel towards the friends, family and colleagues who have supported me throughout this PhD. It seems strange to call this work 'mine', given that none of it would have been possible without this constant support: from encouraging words, to welcome distractions. I wish to thank everyone who has taken any kind of interest in my work - it's a privilege to have been able to discuss my research with so many people, and every one of those discussions has shaped the way I have done things.

I have been incredibly fortunate to have worked with Dr Andrew McPherson as my supervisor. His constant enthusiasm for the project, generosity with his time and insightful discussion have both supported me to keep going and pushed me to strive towards being the best possible researcher I can be.

I am also very grateful to my advisory panel, Simon Dixon and Elaine Chew, for their constructive feedback during the PhD process, as well as my thesis examiners Rebecca Fiebrink and Tom Mitchell, for a rigorous and insightful viva discussion.

I have been lucky to be part of two incredible communities at Queen Mary: everyone from the Media and Arts Technology PhD programme, and the Augmented Instruments Lab. The MAT group and Augmented Instruments Lab represent the best qualities of research communities: support, enthusiasm, curiosity, and most of all laughter. In particular, I would like to thank Vanessa, Shivani, Astrid and Sophie for having my back at various points throughout the PhD. Thanks also to Robbie for being an excellent collaborator and a joy to work with. Thanks to Adan and Giulio for various Bela-related technical support; to Courtney for her stats wizardry; Giacomo, Jack, Luis and Andrea for assistance with workshops and Strummi Sessions; Lia for organising our lab concerts; Fabio for 'kickstarter-of-the-week' rants, and everyone else who I've had the pleasure of working alongside during these five years. I also want to thank the amazing MAT programme staff: Nick, Jonathan, Geetha and Karen for looking after us so well and keeping this exceptional programme running.

This work has been supported in many ways by three incredible organisations: the OHMI Trust, Heart n Soul and Drake Music. These three charities are doing vital and inspiring work every day to open up access to music-making for disabled people. In particular, I would like to thank Rachel and Stephen from OHMI

for supporting the adapted bass project; Richard, Lizzie and Ugne from Heart n Soul for supporting the Strummi Sessions; also Lizzie, Jenny, Richard, Ned, Ricky, Rosie and Hattie for welcoming me into the DYOT crew; and Tim and Gawain from Drake Music for inviting me into their wonderful community of instrument-makers. I am looking forward to carrying on this work in the future and hope to maintain the connections I have made with these three great organisations.

I am very grateful to those outside Queen Mary who I have worked alongside on this research: Molly Joyce and John Kelly for contributing their time towards the case studies; Alan Chamberlain for collaborating on the Strummi Sessions research and formulating our methods and ideas; Charles Matthews, for the inspiring and challenging conversations we have every time we bump into each other; Alex Lucas, Joe Wright and Emma Frid for collaborating on our NIME workshop (and hopefully more in the future!).

I would like to thank Ben, Sam, Alf, Ollie, Sykes and Rob for being great pals at the times when I needed it most. Thanks and love to the legend that is Zena, not only for her patience and support, but her genuine enthusiasm for what I do - I feel blessed to have been able to waffle on about my work over many pints in the Bank of Friendship. Finally, thanks to the Willingham Crew: Mum, Dad, Theo and Harry. As a family, the last few years have thrown us more than our fair share of challenges, but the seemingly endless reserves of love, patience and resilience that they have shown has been a constant inspiration to keep going.

DECLARATION

I, Jacob Harrison, confirm that the research included within this thesis is my own work or that where it has been carried out in collaboration with, or supported by others, that this is duly acknowledged below and my contribution indicated. Previously published material is also acknowledged below.

I attest that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge break any UK law, infringe any third party's copyright or other Intellectual Property Right, or contain any confidential material.

I accept that the College has the right to use plagiarism detection software to check the electronic version of the thesis.

I confirm that this thesis has not been previously submitted for the award of a degree by this or any other university.

The copyright of this thesis rests with the author and no quotation from it or information derived from it may be published without the prior written consent of the author.

Date: November 6, 2020

Jacob Harrison

PUBLICATIONS

Some ideas and figures have appeared previously in the following publications:

1. Harrison, Jacob, Andrew P. McPherson 2017. "Adapting the Bass Guitar for One-Handed Playing" *Journal of New Music Research, 46(3), pp.270–285*
2. Harrison, Jacob, Andrew P. McPherson 2017. "An Adapted Bass Guitar for One-Handed Playing" *Proceedings of the International Conference on New Interfaces for Musical Expression (NIME)*
3. Harrison, Jacob, Robert H. Jack, Andrew P. McPherson 2018. "When is a Guitar not a Guitar? Cultural Form, Input Modality and Expertise" *Proceedings of the International Conference on New Interfaces for Musical Expression (NIME)*
4. Jack, Robert H., Jacob Harrison, Andrew P. McPherson 2018. "Democratising DMIs: the relationship of expertise and control intimacy" *Proceedings of the International Conference on New Interfaces for Musical Expression(NIME)*
5. McPherson, Andrew P., Fabio Morreale, Jacob Harrison 2018. "Musical Instruments for Novices: Comparing NIME, HCI and Crowdfunding Approaches" *New Directions in Music and HCI.* Springer
6. Harrison, Jacob, Alan Chamberlain, Andrew P. McPherson 2019. "Accessible Instruments in the Wild: Engaging with a Community of Learning-Disabled Musicians" *Proceedings of the International Conference on Human Factors in Computing (CHI)*
7. Jack, Robert H., Jacob Harrison, Andrew P. McPherson 2020. "DMIs as Research Products" *Proceedings of the International Conference on New Interfaces for Musical Expression(NIME)*

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1

INTRODUCTION

This thesis is about the role of musical instruments in music and disability: the role that they play in the lives of disabled musicians, their potential for widening access to musical participation, and conversely the ways that many instruments currently limit access. Active participation in music is an important part of the human experience: it is a means of expression and communication, a way of joining and taking part in a social group, an educational tool, a wellbeing exercise, a way of accessing different career paths and experiences. For disabled people, the opportunities for being actively involved in musical performance are significantly reduced compared with non-disabled people. As we shall examine in this thesis, the reasons for this lack of representation are many and intertwined. Disability activists and scholars discuss this issue in terms of 'barriers to access', and much work has been done in recent years across many disciplines to address and remove these barriers in their many forms.

Increasingly, the domain of Digital Musical Instrument (DMI) research is turning its attention towards the development of new musical instruments which meet the access needs of disabled musicians - which in this thesis we refer to as Accessible Digital Musical Instruments (ADMIs) [Frid, 2019]. This is a promising time for ADMI research and development: the 2012 Paralympic games opening ceremony in London saw a number of disabled musicians performing on a worldwide stage with a range of traditional instruments and novel DMIs, advances in embedded computing equipment are seeing more and more sophisticated, bespoke accessible designs appear, and the 2020 New Interfaces for Musical Expression (NIME) conference has placed issues of accessibility at the centre of its call for participation. Increasingly, we are seeing widespread engagement and interest in the potential of DMIs to open up access to musical participation.

However, while this new interest is encouraging, we should not uncritically assume that new technologies alone can solve the problem of access to music. This is an attitude which appears pervasive throughout much of the discourse on ADMIs: a new technology addresses a particular access need, and so the 'problem' has been solved. While in many cases technology does indeed solve specific problems of access relating to music, current discourse within ADMI research runs the

risk of failing to address the additional factors that can enable/disable musicians, while also failing to acknowledge and uplift the creative potential of disabled musicians. This often leads to a deficit-oriented view of disability that considers only the 'problems' that need to be solved, which can in turn risk further stigmatising and exclusion of disabled people in music, despite the well-meaning intentions of the technologists. In the following chapter, we will consider the 'social' and 'medical' models of disability, explore ways that much current discourse around music and disability remains rooted in the medical model, and consider how the field of ADMI research can begin to more widely adopt the social model.

While primarily rooted in computer science and engineering, both DMI and HCI research have a long tradition of working across disciplines, incorporating theories and methodologies from the social sciences and humanities. I hope to continue this with the work presented in this thesis, through consideration of other disciplines that deal explicitly with music and disability - in particular I aim to look towards Disability Studies as a source of discussion and critique of the way that disability is represented in areas such as music and the arts, and academic research. Besides this, research by music therapists and educators often touches on issues of disability and access, and can provide valuable insights into the wellbeing and educational benefits of music performance.

1.1 MOTIVATION AND AIMS

This research is motivated by a desire to improve access to music for disabled people, through the development of new accessible digital musical instruments. More specifically, this research focuses on guitars as a point of inaccessibility for many disabled people. On the surface, this can be considered primarily as an engineering problem, and the technical challenges to be overcome in developing accessible guitars are many. However, there are other perhaps more subtle points that are less commonly articulated in DMI literature around the socio-cultural role of musical instruments, that might offer insight into ADMI design in a real-world context.

Traditional acoustic string instruments are bound to often-inaccessible designs by the physical properties of their sound-generating mechanics: guitar strings need to be of a certain length and thickness in order to produce the right pitch, and require two dextrous hands for simultaneous fretting and plucking. The ergonomics of DMIs are not so bound by the acoustic properties of physical materi-

als, and so offer opportunities for being reconfigured in order to meet the access needs of disabled musicians.

However, the reconfiguration of an acoustic instrument as a DMI facsimile is not without compromise: acoustic instruments are non-linear systems, and their imperfections and opportunities for exploitation are most often what lends the instruments their 'character' or 'expressivity' (although 'expression' is a fraught term in DMI research [Gurevich and Treviño, 2007]). An often-quoted example of an unexpected flaw being appropriated as an artistic tool is Jimi Hendrix's use of feedback in his electric guitar performances. How to achieve this same level of 'character' in ADMIs is a difficult question: it is a relatively trivial task to design an ADMI that makes guitar-like sounds in a way that is more physically accessible than a traditional guitar - it is a different question altogether to make that instrument as engaging as an electric guitar to both the performer and the audience.

As Bates [2012] points out, instruments are not simply passive noise-producing tools, but possess a socio-cultural load that is at least as equally worthy of consideration as the technical details of the way they can be played. In this research, I aim to further explore this socio-cultural role of musical instruments, and in particular whether or not attempting to harness the pre-existing cultural associations of traditional instruments may provide greater access to existing musical cultures for disabled musicians.

The aim of this research is to widen understanding about the role of musical instruments in the performance contexts of disabled musicians, and to provide a pathway towards more and better ADMI designs in the future. It is motivated both by the potential of ADMIs to improve access to music, and the need for deeper and wider discourse around issues related to access within the ADMI community.

1.2 RESEARCH QUESTIONS

The research questions I ask in this thesis are as follows:

RQ1: How can we design ADMIs which fulfil the role of existing musical instruments - in particular the bass guitar and the guitar?

Specifically:

A. What role does interaction technique play in an instrument's identity?

B. How does interaction technique interact with prior experience of that instrument?
C. What role does the global form of an instrument play in an instrument's identity?
D. How does global form interact with prior experience?
E. What are the requirements of an ADMI designed with music performance in mind; are they different from those of an instrument designed for music therapy, and if so, how?

RQ2: What can instrument designers and researchers learn from existing disability arts and community music practices?

Specifically:

A. What tools and techniques do practicing disabled musicians use in their music performance?
B. What roles do ADMIs and unadapted musical instruments play in community music settings?
C. What theories and concepts can we take from disability studies that apply to the design of ADMIs?

1.3 METHODS

The work done in this thesis involved a variety of methods inspired by prior work in HCI and DMI research. This involved developing a number of research artefacts and deploying them in different research environments for evaluation and reflection. The terms *prototype*, *technology probe* [Hutchinson et al., 2003], and *research product* [Odom et al., 2016] are all used to describe the kinds of research artefacts developed in this research, and the subsequent chapters detail a development from the former to the latter in the way these instruments were conceptualised.

This research also saw a move from lab-based studies in Chapters 4 and 5, to a long-term and situated research activity inspired by ethnographic and 'in-the-wild' methods in Chapter 6. This final study was done in collaboration with *Heart n Soul*, a creative arts charity who work with learning-disabled young people and adults. This collaboration took the form of a year-long engagement, wherein I regularly volunteered at and contributed to their activities and introduced them to the Strummi instruments which are described in Chapters 5 and 6.

1.4 STATEMENT OF CONTRIBUTION

The main contribution of this thesis is the exploration of the technical, social and musical roles of ADMIs in music and disability, with a view to informing the direction of new research on ADMIs and signposting areas that are currently underexplored, such as the application of theories from Disability Studies, and the roles of interaction modality and global form in ADMI design. The following is a summary of the contributions of this thesis, in the order they appear:

- In Chapter 4, I describe a method of mechanically adapting the electric bass guitar for MIDI-controlled note selection. This prototype system showed potential as a method of adapting an existing bass without making major modifications, using relatively low-cost and reproducible parts.
- The adapted bass study in Chapter 4 highlighted the non-obvious roles of the fretting and plucking hands in bass guitar performance, suggesting additional design considerations when attempting to adapt the bass guitar (or other plucked string instruments). This study also showed us that bass players were able to adapt their existing technique to accommodate the limitations of adapted bass, in order to deliver a convincing bass guitar performance without the use of one hand.
- Chapters 5 and 6 introduce the Strummi: a new guitar-based DMI using acoustic-excitation and string-modelling techniques. Based on previous work such as the Kalichord [Schlessinger and Smith, 2009] and BladeAxe [Michon and Smith, 2014], the Strummi represents a further development through the use of physical guitar strings to preserve the interaction modality of strumming and plucking. Although the Strummi was not developed with specific access requirements in mind, it presents a potential method of making plucked string instruments accessible, through the removal of the requirement for note selection via fretting strings.
- The comparative study design using the *technology probes* approach in Chapter 5 describes an investigation into the effects of instrument form versus interaction modality in DMI design. Using variations of the Strummi instruments, we explored the ways that the interaction modality of strumming strings influenced participants' appraisals of 'guitar-likeness', when compared with the global form of the guitar.

- Chapter 5 also describes an investigation into the effects of richness of interaction in DMIs and how it relates to expertise and prior instrumental experience.
- The field study in Chapter 6 highlighted the roles of instrumentation and environmental factors in access to music, through utilising a *research products* methodology.
- Chapter 6 also provides an ethnographic account of an *in-the-wild* research activity with a learning-disabled community music group.

1.5 STRUCTURE OF THIS THESIS

The structure of this thesis is as follows:

Chapter 2 is a review of the literature related to the topic of ADMI design. It is split into three sections: music and disability, instrument design, and accessible instruments. 'Music and disability' provides an introduction to key concepts and terminology from disability studies, as well as an overview of academic fields in which the interaction between music and disability are considered, for example music therapy. 'Instrument design' provides an overview of topics related to the design of new musical instruments. This primarily comes from discourse around DMI research, but also involves organology and ethnomusicology. Finally, 'accessible instruments' first provides a review of the state-of-the-art of both ADMIs and accessible acoustic instruments. At the end of this chapter, I introduce the concept of 'performance-focused' instruments, as a means of problematising the field of ADMI design and considering how music performance as distinct from music therapy might influence new ADMI designs.

Chapter 3 provides case studies of two practicing disabled musicians: John Kelly and Molly Joyce. Here, I interview both musicians in order to gain insight into their approach to their musical practice, how it relates to their disability identity, and the role that their choice of instruments play.

Chapter 4 is an account of the first performer study undertaken as part of this research. In this chapter, I document the development of a prototype system for adapting the bass guitar for one-handed playing. We conducted a survey of bass guitarists in order to find out the most important aspects of bass guitar playing, and found that much of the role of the bass guitar, for example rhythmic elements such as timing and dynamics, is enmeshed with plucking hand techniques. We developed an attachment to the bass guitar fretboard which mechanically frets the

strings, and is controlled via a MIDI controller. A performer study highlighted the extent to which the fretting hand can be feasibly replaced through mechanical means. Reflecting on this study lead us to consider the role of the overall aesthetic properties of the bass guitar, and how they contribute to the preservation of the instrument's identity, versus the importance of the plucked string interaction modality.

Inspired by the previous study, Chapter 5 describes a study conducted in collaboration with Robert Jack, on the subject of 'global form vs. interaction modality' in guitar-like DMIs. We looked to the *technology probe* methodology [Hutchinson et al., 2003] and designed a comparative user study which saw participants play one of two pairs of guitar-based DMIs. The instrument pairings were designed as a 'congruent' pairing, which comprised a guitar-like body with real guitar strings and a tabletop design with a touch sensor, and an 'incongruent' pairing, where the guitar-like body featured a touch sensor, and the tabletop instrument had strings. We also recruited two sets of participants: experienced guitarists and non-musicians, in order to discover whether prior experience with the guitar would affect the outcome of the study. Our goal was to ask the question: 'when emulating a guitar as a DMI, which is more important: global form, or interaction modality?'. An additional component of the study was based on my co-researchers work, which saw participants use the stringed instruments in two settings which varied the overall richness of interaction.

Chapter 6 describes an 'in-the-wild' study with a community of learning-disabled musicians and other key stakeholders from the *Heart n Soul* creative arts organisation. In this chapter, I explore how environmental and contextual factors contributed to access to music, and the role that instruments have to play, in the context of regular community music sessions with a mixed-ability group. Specifically, I introduce the guitar-like DMIs developed in the previous chapter and consider how they are received within this group, compared with existing instruments already in use during the music sessions. This chapter marks a key moment in this research: where ideas around global form, interaction, and the cultural role of musical instruments, are explored in a real-world context rather in lab-based studies. I looked to prior HCI works which employ ethnographic techniques as a methodological foundation for this work. This chapter also reframes the instruments developed in Chapter 5 as *research products* [Odom et al., 2016], which were also christened the *Strummi* at this stage of development.

Finally, in Chapter 7, I expand on the conclusions drawn from the final study and look back at the findings from the two prior studies, literature review and case studies, and how they relate to the original research questions, and the key concepts from Disability Studies that are relevant to ADMI design. This is followed by a discussion of potential future directions for research on the topic of ADMIs, and the wider themes of technology, instruments and access to music.

2

BACKGROUND

A discussion of the themes around accessible instruments necessarily requires an understanding of how music and disability relate, as well as the theories, methods and tools used in designing and researching Digital Musical Instruments (DMIs). In this chapter, I provide an overview of these topics, and attempt to bring together the relatively disparate fields of Disability Studies and DMI design. I then review the state of the art of Accessible Digital Musical Instruments (ADMIs), and set out a definition for 'performance-focused' ADMIs.

2.1 MUSIC AND DISABILITY

In this section, I introduce perspectives on music and disability from two key areas: disability theory (that is the academic discipline Disability Studies, and the associated Disability Arts movement, both informed by earlier disability rights activism), and music therapy.

2.1.1 *Disability Theory*

> *There are a great many stakeholders, a plethora of views and agendas; most if not all warrant our serious consideration and critical engagement. Ultimately, however the preponderance of pathologizing and negating discourse about autism is so great that, if nothing else, there is a need to redress it and put it in better balance with the more ability-centered, affirming, and agentive perspectives of autistic self-advocacy, neurodiversity, and disability studies.* [Bakan, 2014]

Bakan's quote above highlights a crucial point on the topic of music and disability, not just limited to those on the autistic spectrum: much work has been done in various fields, from academic research, political activism, and policy-making, to better understand and articulate the lived experience of disability, and how disability relates to other factors such as technology and art, however the majority

of this work has been shaped by the *'pathologizing and negating'* discourse around disability.

In this section I introduce theory and terminology from *Disability Studies* (DS): the field of scholarship which relates to disability on a social science and political level. Theories and terminology of DS have largely been informed by the *'Nothing about us without us'* maxim of the UK disability rights movement - a call for researchers and policy-makers to ensure disabled people's voices are heard when researching or discussing disability.

Dan Goodley's *Disability Studies, An Interdisciplinary Introduction* introduces the concept of disability studies from an international and interdisciplinary perspective. Taking as a starting point the view that disability studies are a *'broad area of theory, research and practice that are antagonistic to the popular view that disability equates with personal tragedy'* [Goodley, 2016], Goodley goes on to introduce the social, minority, cultural and relational models of disability, as responses to dominant moral, medical and individual models. Goodley traces the development of disability studies as the culmination of numerous political and social movements, which have remoulded global conceptions of disability as a social problem that should be addressed by socio-political interventions.

One of the key points underpinning disability studies and the political and social activism that preceded and runs alongside it, is the distinction between *impairment* and *disability*. The definitions given by Disabled People's International in 1982 are as follows:

> *IMPAIRMENT: is the functional limitation within the individual caused by physical, mental or sensory impairment.*
> *DISABILITY: is the loss or limitation of opportunities to take part in the normal life of the community on an equal level with others due to physical and social barriers.* International [1982]

This understanding of disability as distinct from impairment has broadly come to be understood as the *social model* of disability[1]. The social model was originally introduced by Oliver [1983]. The social model is not necessarily an all-

1 More recently, DS scholars have criticised this severance between body and society - citing the painful, fatiguing and life-threatening effects of impairment as important and unavoidable when discussing disability [Watson and Shakespeare, 2001]. For the purposes of this thesis however, we will deal with an admittedly simplified reading of the social model of disability, taking as a point of departure the notion that people are disabled by external barriers, and their lives can potentially be improved by the explicit removal of these barriers.

encompassing theory, but more a means of understanding disability as the product of external barriers placed on individuals by society. The social model is often thought of as a challenge to the *medical model* of disability, which locates the 'disability' in the individual, as opposed to society, and so places the responsibility on individuals to adapt to environmental and societal barriers. The medical model is described as a once prevalent model among non-disabled people including researchers and policy-makers, and is criticised for its focus on the purely medical and physiological aspects of disability. This is seen as reductive and dehumanising, and removes responsibility of non-disabled people to locate and remove barriers to access. This re-framing of disability from the *medical* to the *social* model has been fundamental in challenging and influencing policy, and underpins the UN Convention on the Rights of Persons with Disabilities (CRPD)[2].

One of the key initiatives of the CRPD is on the removal of *barriers* which prevent access for disabled people. These can take the form of *physical barriers*, such as inaccessible buildings and venues, *social barriers*, such as lack of access to education, and *attitudinal barriers*, including prejudice, stigma and discrimination against disabled people.

One of the areas in which disabled people commonly face these barriers is access to music-making. Here the lack of availability of accessible music making tools can be primarily a physical access issue, but can also be a result of social and attitudinal barriers. This is the primary focus of this PhD thesis, and these barriers will be revisited later in this chapter.

Article 30 of the CRPD recognises the importance of enabling disabled people *'to have the opportunity to develop and utilize their creative, artistic and intellectual potential, not only for their own benefit, but also for the enrichment of society.'* This stance is echoed in Arts Council England's recent *Creative Case for Diversity* initiative, which seeks to reposition from a focus on *'addressing past imbalances and reducing deficits and structural gaps'* due to statutory requirements and legal duties, to a position which simply argues that *'diversity and equality are crucial to the arts because they sustain, refresh, replenish and release the true potential of England's artistic talent'* [ACE].

The CRPD and the Creative Case reflect society's progression from charity and medical models, through to the more emancipatory social model, to the present day, where the conversation is as much about the creative potential of disabled people as it is about their right to participate on a purely egalitarian level.

2 https://www.ohchr.org/EN/HRBodies/CRPD/Pages/ConventionRightsPersonsWithDisabilities.aspx#30

2.1.1.1 *Language and Terminology*

Armagno argues that the way we talk about disability in HCI discourse has *'practical, ethical and political consequences'* [Armagno, 2012]. As with other minority groups, language is a powerful tool that can be used both to emancipate and oppress. We have already discussed the distinction between *disability* and *impairment*, and how adopting this terminology can re-frame disability entirely. In this thesis, I attempt as much as possible to adopt the language and terminology of disability scholars and activists, some of which is explained in this section.

One of the more subtle uses of language in this field is the way in which disabled people are referred to. Here, we make a choice between using *Person-First* or *Identity-First* language. In short, person-first language means the use of phrases such as 'people with disabilities' or 'a child with autism', whereas examples of identity-first language would be 'disabled people', or 'an autistic child'. There is some debate over which is the most acceptable, with different professions and regions having different preferences. The argument for person-first language is that it 'puts the person before the disability' - a well-meaning attempt not to reduce a person down to a single characteristic while still acknowledging their disability status. The intention here is to act as a leveller, to avoid terms and labels which apply only to disabled people. Style guides which prescribe the use of person-first language often require that people without disabilities are also referred to in this way, for instance 'child with typical development' as opposed to 'typical child' [Gernsbacher, 2017]. On the other hand, identity-first language accepts that disability is itself an identity, on the same plane as race, gender, sexuality etc., and therefore something that shouldn't be reduced to a separable characteristic. Proponents of identity-first language argue that it *'allows the individual or group to "claim" the disability as fact, as well as reframe it as a point of pride'* [Dunn and Andrews, 2015].

In this thesis, I adopt identity-first language, in order to reflect the choices made by the majority of individuals and organisations I have encountered during the research, and the position taken by many critical Disability Studies writers.

Neurodiversity

The term *neurodiversity* and the associated self-advocacy movement are powerful tools for reframing our understanding of atypical neurological conditions. Benton et al. define 'neurodiversity' as

> *the subset of neurological conditions, which typically result in a child being labeled as having special educational needs (SEN). These conditions include (among others) attention deficit hyperactivity disorder (ADHD), autism spectrum disorders (ASD), dyslexia, anxiety disorders and intellectual disabilities* [Benton et al., 2014]

Neurodiversity not only frames these conditions as atypical, but reflects the strengths and advantages that come with them - what Armstrong describes as *'upsides'* [Armstrong, 2010]. These upsides can include enhanced interpersonal skills, creative thinking, attention to detail, and even a stronger likelihood to possess perfect pitch [Bonnel et al., 2003].

During my research, I have encountered communities and individuals using either 'neurodivergent' or 'learning-disabled' to describe themselves or others like them. I use both terms in this thesis, and would stress that while they are often used to describe similar attributes or communities, they are by no means interchangeable. Where possible, I refer to 'neurodivergent and learning-disabled people' to refer to the wider group of people who identify with one or both of these labels.

2.1.1.2 *My Role as a Non-Disabled Researcher*

As we shall see later in this chapter, Disability Arts is often rooted in politics and activism. When doing research on music and disability, I believe it is important to acknowledge this political background and how it relates to that research. As a non-disabled researcher, I recognise my privileged position as a non-disabled person within an academic institution, and acknowledge that my understanding of the lived experience of disability, and my ability to communicate it is limited. This research is primarily concerned with musical instrument design, and how it relates to issues present in Disability Arts and inclusive music practices. As much as possible, I have attempted to adopt theories and terminology from communities led by disabled people, such as Disability Arts and the Neurodiversity self-advocacy movement, and to avoid perpetuating any potential harmful conceptions of disability through my choice of language and research methods.

My stance on disability and access, and my motivation to undertake this research is informed by my musical background, interests and experience with disability. As a musician, my primary instruments are guitar and bass guitar, which I have played in a number of rock bands - I have always been fascinated by the electric guitar in particular. My undergraduate degree in Music Technology gave me

an understanding of many of the key concepts in computer science and electronic engineering behind modern music technology. I was also introduced to the unexpected ways that this technology was being used in non-commercial projects with the aim of doing 'social good': voice recognition techniques for detecting Parkinson's disease in patient's speech patterns, sonification of clinical data for muscle rehabilitation, and voice synthesis for communication aids. I became particularly interested in voice synthesis in assistive technology (AT) and worked on a research project aimed at developing more natural and flexible voice models. Studying this subject, I became aware of an important issue that is also central to this thesis: issues of accessibility are rarely so simple that they can be easily summarised as a set of specifications for an engineering problem - social and cultural phenomena play important roles in the effectiveness of any accessible technology[3].

This research comes from the convergence of these experiences, and the desire to develop technology for 'social good' - although my stance on what that means and how to go about doing it have developed somewhat since my days as an undergraduate music technology student. Developing an accessible guitar - for use within the specific context of mainstream Western music - became an obvious goal to pursue in my research, given these experiences and motivations.

2.1.1.3 *Disability Arts and Culture*

Barnes and Mercer [2001] state that *'[t]he politicization of disabled people has also highlighted the significance of an alternative disability culture, which celebrates a positive disabled identity and consciousness'*. Barnes and Mercer chart the representation of disability in culture, and the development of a disability culture in and of itself. Within popular culture, disability is often presented as one of a number of negative identities: something to be feared or pitied, set apart from the 'normalcy' of the non-disabled majority. Set against this, *'The emergence of a disability arts movement marks a significant stage in the transition to a positive portrayal of disabled people that builds on the social model of disability'* [Barnes and Mercer, 2001].

The National Disability Arts Collection and Archive (NDACA: `https://the-ndaca.org/`) provides a comprehensive archive and overview of the UK disability arts movement, charting its origins in the 1970s to the present day. Disability Arts

3 An example from the domain of voice synthesis is Professor Stephen Hawking's communication aid. While voice synthesis technology has dramatically improved since Hawking began using his original decades-old communication aid, he insisted on maintaining this outdated technology, often at great expense. His reasoning was that despite its idiosyncrasies, the voice used by his original device had become part of his identity.

Online (https://disabilityarts.online/) is an online platform where current and contemporary disabled artists' work is promoted and discussed.

Barnes and Mercer [2001] discuss two different approaches to disability arts: '*the disability arts movement ... [first] argues for disabled people to have access to the mainstream of artistic consumption and production. Second, it includes impaired-focused art that explores the experience of living with impairment*'. Swain and French [2000] discuss this second approach to disability arts as representative of an 'affirmative model' of disability, which *'directly challenges presumptions of personal tragedy and the determination of identity through the value-laden presumptions of non-disabled people'*. This model takes into account the political and social obstacles that disabled people face, but also uplifts and affirms the positive aspects of a disabled identity, for example the lyrics *'proud, angry and strong'* in Johnny Crescendo's protest song '*Pride*'.

Firth and Cane [2018] discuss disability representation in the operatic music performance industry, and use the terms 'assimilation/integration' and 'affirmation' to consider where to locate the stance of their *Access All Arias* program of inclusive practice. They describe assimilation as being an almost seamless integration into mainstream arts and culture, without necessarily making explicit reference to disability; while the affirmation approach seeks to uplift and embrace the performer's disability identity. Finding themselves torn between attempting to maintain a connection with the mainstream operatic industry, and wanting to affirm disabled cultural identity, Firth and Cane argue that the two need not be mutually exclusive, and explore ways that their practice, shaped by disability studies and disability arts, can achieve a balance between these two concepts. It is important to note that there is no value judgment necessarily placed upon either approach: it is equally as important for disabled people to take part in mainstream culture as it is to contribute to and nurture a positive and affirmative disability culture. As we will see later in this chapter, these two approaches are evident in the practice of a number of disabled musicians, and the ways in which they approach instrumentation.

2.1.1.4 *Music and Disability Studies*

In *Music, Disability and Society*, Lubet [2011] discusses the intersection of disability and music, from a Disability Studies perspective. Lubet introduces the notion of the 'social confluence' of disability: the ever-changing nature of one's disability status depending on the current social context. Taking Lubet's own impairment (a

hand injury which prevented his performing classical orchestral music) as an example, he discusses how throughout the course of a single day, his disability status changes. Lubet is a professor of music as well as Disability Studies. Following his impairment, which as interpreted by American law, left him *'permanently partially disabled'*, he was considered fit to work with minor adjustments to his office equipment. Within the context of classical music performance however, Lubet became 'totally disabled and in fact incapacitated', citing the rigid performance boundaries required by classical music: *'composers rarely, if ever, write to such individual specifications as might include ... a disabled body'*.

Throughout the rest of the book, Lubet discusses various aspects of disability in music through the lens of prominent disabled musicians, including jazz guitarist Django Reinhardt and pianists Paul Wittgenstein, Leon Fleischer and Horace Parlan. In the case of Reinhardt and Parlan, Lubet makes the case that the less rigidly-defined performance structures in jazz music offered the musicians an ability to perform in a way which not only made concessions to their impairments, but were influenced by them. Reinhardt, for instance, had an impairment which by current disability law would be deemed 'insignificant' in terms of his ability to work: an impaired left hand with two usable fingers. In classical guitar performance, this impairment would be insurmountable, but jazz allowed Reinhardt to adapt and ultimately define a style of guitar playing that is now revered and mimicked by many unimpaired musicians. Lubet points out that both Reinhardt and Parlan chose not to 'musically amputate' their affected limb by not using it in their performance, but instead adjust their playing style around their limitations and capabilities.

Early on in the book, Lubet points out that the majority of academic work on music and disability comes from music therapy research, stating that *'there is little extant published music research that employs social model theory as its foundation'*. While the value and need for music therapy research is recognised, Lubet points out that there is a need for both social and medical model thinking in music therapy as well as disability studies.

The Oxford Handbook of Music and Disability Studies [Howe et al., 2016] brings together essays on a range of topics concerning the intersection of music, musicology and disability. Some themes include the ways in which *'disability has been shown to be a core feature of the musical identity of music makers'*, the ways that *'disability has inflected reception of the lives and work of composers and performers'*, how disability is represented in musical works, disabled characters in opera and other

narrative forms, and the notion of disability as a performance (*'something you do rather than something you are'*).

Bakan [2015] proposes an *'ethnographic model of disability'* in his analysis of the Artism ensemble, a mixed-ability music group made up of Autistic children, their parents and carers, and professional musicians. He describes this model as an *'epistemological stance that differs fundamentally from what is described in Disability Studies discourses as the medical model of disability'*. The ethnographic model, rather than seeking to *change* anything about the disabled individual, in the sense that medically-focused approaches implicitly promote, instead seeks to understand their *'conceptions of community, personhood, social experience, humor, work and play, pleasure and pain, joy and suffering, and of course music'*. Through discussing the musical activities of a disabled community through a situated, ethnographic method, Bakan gives us an example of a way of thinking and writing about disabled musicians which celebrates and uplifts their musicianship, without relying on any further measures that might be construed as relating to an individual's medical 'progress', or otherwise seeking to change, alleviate, or move away from their disability identity.

Carlson [2015] continues Bakan's theme of reframing the epistemological stance on disability, in this case intellectual disability, from one of deficit to one which helps articulate and celebrate *'a positive identity for people with intellectual disabilities'*[4]. Invoking Small [2011], Carlson uses the notion of *musicking* as a means of exploring the significance of music on the lives of learning-disabled people.

Howe [2015] discusses the ways in which the conventions of musical performance can be disabling in the same way that architectural features have the *'potential to exclude and stigmatize bodily difference'*, stating that *'concert performance is a venue with especially high expectations for exemplary able-bodiedness'*. Drawing on the notion of disability being a performed act, Howe discusses the ways that the 'cultural scripts' of music performance and disability become entangled: *'disability informs the music performance, while music performance in turn informs the disability'*.

McKay [2015] discusses the way the punk subculture has embraced disability in many ways, and correspondingly how disability has embraced punk values. Referring to punk's 'antiesthetic', McKay shows how punk *'called out to and opened space for the new marginal musical competents and incompetents alike ... we should ... acknowledge the generosity of punk in producing this accessibility'*. McKay makes the case that the lack of any requirement for virtuosity or musical mastery in punk music

4 the term *intellectual disability* appears to be the preferred term in publications in the US, but is synonymous with *learning disability* used throughout this thesis

allows for performances by people physically unable to attain the performance standards of, say, classical music or jazz. He goes even further, to suggest that in fact punk directly celebrates and promotes bodies which deviate from normative standards. By looking at three key performers (Johnny Rotten, Ian Dury, and Ian Curtis), he shows that the values inherent in the punk subculture allowed them to 'claim' and celebrate their disability and difference.

2.1.2 *Music Therapy*

Bruscia [2013] defines music therapy as *'a systematic process of intervention wherein the therapist helps the client to promote health, using musical experiences and the relationships that develop through them as dynamic forces of change'*. In addition, Magee [2002] states that *'music therapy is a clinical intervention which can be defined as the planned and intentional use of music to meet an individual's social, psychological, physical and spiritual needs within an evolving therapeutic relationship'*.

Music therapy as it relates to disability tends to assume either a *didactic* or *medical* approach. Didactic practices, according to Bruscia [2013], are those *'focused on helping clients to gain knowledge, behaviors, and skills needed for functional, independent living, social adaptation, and quality of life'*. As Bruscia states, *'the boundaries between education, developmental growth, and therapeutic change are easily and frequently blurred'*. For learning-disabled and autistic children, didactic music therapy practices can be a means of developing speech and language as well as social skills, as well as curricular goals within a more general music education setting.

Medical music therapy is commonly associated with those undergoing rehabilitation from brain injury or stroke, and is often referred to as Neurologic Music Therapy (NMT). For these people, music therapy can be either '*compensatory:* e.g. using music to compensate for losses in conjunction with tools such as memory / communication aids; *psycho-socio-emotional:* using music to enable emotional expression, engagement in social interaction and adjustment to disability; or *restorative:* using music to regain skill and function' [BAMT].

Thaut and McIntosh [2014] provide an overview of common techniques and approaches within NMT for stroke survivors. With regards to instrumentation, Kirk et al. [2016] discuss the use of specialised electronic musical instruments and equipment to enable motivation to complete rehabilitation tasks. Schneider et al. [2007] discuss methods involving traditional or unadapted musical equipment to promote particular exercises in stroke rehabilitation to mitigate effects such as

hemiplegia (partial paralysis of one side of the body) or visual neglect (an ability to focus or attend to objects on a particular side of the patients' field of vision).

Music therapy is a broad discipline, consisting of a wide range of techniques, client needs, philosophies, and epistemological stances. Music therapy as it directly relates to disability is arguably informed by the medical model, by virtue of its goals of promoting positive change in health and wellbeing. This has resulted in some critical engagement from Disability Studies writers, however a dialogue is emerging between DS and music therapists which evidences a view of disability which allows for music therapy to exist alongside social model thinking. As Lubet [2011] suggests, *'few in [Disability Studies] would deny the value of [music therapy], though many would hope for a reciprocal recognition of social model values'*. Fortunately, it appears that social model thinking is becoming more common among music therapy discourses.

Tsiris [2013] responds to the lack of engagement with music therapy in some disability studies literature, regarding music therapy as a 'misunderstood guest'. Drawing from practices and theories from music- and culture-centred music therapy, Tsiris argues that music therapy offers perspectives on music and disability beyond its overt medically-centred goals.

Recent discourse on music therapy offers new perspectives that move beyond a reductionist, deficit-oriented or medically-focused approach. Magee [2002] discusses how music therapy practices can foster a sense of musical and personal identity, while Rolvsjord [2004] discusses a perspective on music therapy that focuses on 'empowerment' rather than curing.

2.2 INSTRUMENT DESIGN

> *'All musical cultures have ways of understanding their instruments that involve sorting them into meaningful categories. What could be considered a useful classification in one culture might be of little relevance in another, and we often find that extra-instrumental concerns, such as mythology, societal structure, cosmology, or religious function play part in defining the principles of categorisation.'* Magnusson [2017]

Organology is the term given to the study and classification of musical instruments. As Magnusson states, musical instruments can often be described in 'extra-instrumental' ways, that often defy their technological description and means of classification. Musicology, ethnomusicology and even the field of Science and Tech-

nology Studies (STS) have offered perspectives on these extra-instrumental features, and how they play out in society and culture.

Bates [2012] introduces the *social life of musical instruments*:

> *'Much of the power, mystique, and allure of musical instruments [...] is inextricable from the myriad situations where instruments are entangled in webs of complex relationships between humans and objects, between humans and humans, and between objects and other objects.'*

In his paper, he discusses how instruments can be thought of as active components of a network, rather than simply passive noise-producing tools. He uses as an example the *saz*, an instrument whose place among Anatolian, South Caucasian, and Southeastern European cultures demonstrates the way that instruments influence, and are influenced by, society and culture.

Bijsterveld and Schulp [2004] discuss tensions surrounding innovation in traditional instruments, through discussions with instrument manufacturers who have employed innovative approaches in their designs. A key example is the Pellegrina viola (Figure 2.1), a radical redesign of the traditional form allowing performers to access higher positions on the neck without risk of injury or discomfort. The Pellegrina's striking, asymmetrical shape led to initial shock amongst other orchestra players and garnered substantial press attention. According to its designer David Rivinus, *'if it had only sounded new, reporters wouldn't have been nearly as interested'*.

With respect to the use of technology, Benford et al. [2012] refer to the *'social demands of musical etiquette'* during folk sessions in Irish pubs. Despite the ubiquity of technology during the preparation for the sessions (predominantly the use of the web and social networks), members upheld an appearance of tradition by eschewing technology during the sessions themselves.

In this thesis, I am interested in the socio-cultural role of musical instruments, in particular, the ways in which musical instruments can enable disabled musicians to take part in musical culture. The perspectives on instrument design given provide an understanding of the 'extra-instrumental' or 'extra-musical' features of an instrument which might contribute to this. While not primarily concerned with instruments, Horn [2013] provides a valuable perspective in his paper on *cultural forms*, and the ways that interaction designers can 'intentionally shape objects and situations to evoke cultural forms as a means to tap into users' existing cognitive, physical, and emotional resources'.

Figure 2.1: David Rivinus' Pellegrina Viola (image source *stringsmagazine.com*)

2.2.1 *Digital Lutherie and DMIs*

The term 'Digital Lutherie' was coined by Jordà [2004] to describe the process of both interface design, sound design, and interface-to-sound mapping. Jordà proposes that digital luthiers concern themselves with *'concepts such as efficiency, apprenticeship, learning curve, path to virtuosity or expressivity; concepts that may help in describing and identifying the dynamic relations that exist between players and their instruments'*. As an example, he offers us the 'odd quartet', made up of the kazoo, kalimba, piano and the violin. Through reflecting on the learning curves of each instrument vs. the available musical complexity that each one affords, Jordá suggests that musical *efficiency* is of great importance to players engaging with a new musical instrument.

Jordà also discusses the *'efficiency'* of an instrument in terms of the complexity of the musical output and the complexity of the user's control input. Musical output complexity relates to concepts such as *'musical range'* and *'expressive range'*. Control input complexity could refer to degrees of freedom of control, and the complexity

of the mapping structure. Concepts such as the diversity of the musical output are also discussed, at three levels of detail: micro- mid-and macro- diversity. The first relates to the subtleties with which a performer can make a pre-composed piece her own: does the instrument allow sophisticated control of timbre and dynamics such that two performances of the same piece by different people will be distinguishable? An example of an instrument which began with no micro-diversity and later gained it through the development of new performance techniques is the turntable: before turntablist techniques came about, any 'performance' of a piece using a vinyl record would be identical. The second level relates to the diversity between different pieces on the same instrument. The more pieces playable on the instrument, the higher its mid-diversity. Finally macro-diversity relates to different playing techniques, genres and musical roles, or the 'chameleon-like' qualities of an instrument (for instance the electric guitar, found in almost all sub-genres of popular Western music).

A key concept that Jordà discusses is the idea of 'variability plus reproducibility'. An instrument must be capable of producing highly variable, even non-linear output, but maintain an ability to closely reproduce a performance in the right hands. This is also linked to predictability and control over the sound of an instrument. Jordà concludes with some helpful questions to consider when designing new musical instruments:

- What kind of music should the instrument be able to play?
- Who are we designing the instrument for?
- Are we constructing a musical instrument or a musical toy?
- Do we pretend to design an instrument that can appeal to a wide range of musicians, from the novice to the professional?
- Are we considering the different evolutionary steps of this possible relation?
- Are we guaranteeing the minimum of elements that can make this instrument enjoyable from the beginning and potentially learnable?

The field of digital musical instrument (DMI) design and research is a relatively new field, continuing the academic and artistic endeavours of experimental musicians and composers of the 20th century [Bin, 2018, p. 36]. Much of the academic work done in this field centres around the New Interfaces for Musical Expression (NIME) conference, and the associated 'NIME community' of researchers, artists and practitioners. Much of the ideas, tools, technology and theories of NIME are shared with the wider discipline of Human-Computer Interaction (HCI) and its associated CHI conference, where NIME was originally founded. This has led to

some debate around the nature of evaluating and discussing DMIs: can we apply the same methods and frameworks to new musical instruments as we do to other new technologies, and how can we write about instruments as both products of and tools for creative and artistic endeavours?

It is possible to discuss DMIs solely on their technical merits, a primary focus of which is the nature of the action-to-sound mapping (see [Hunt et al., 2002]), however other work also takes into account the 'extra-instrumental' features of DMIs. For example, O'Modhrain [2011] discusses a conceptual scaffold for the evaluation of DMIs which considers the perspectives of the key stakeholders in the design process, and at which point those perspectives come into play. The stakeholders include not only the designers and manufacturers of new DMIs, but the audience and performers, whose mode of evaluation tends to be of a more qualitative and reactive nature.

Tanaka [2000] discusses the role of DMIs with respect to the concept of a 'tool':

> *A musical instrument's raison-d'être ... is not at all utilitarian. It is not meant to carry out a single defined task as a tool is. Instead, a musical instrument often changes context, withstanding changes of musical style played on it while maintaining its identity. A tool gets better as it attains perfection in realizing its tasks. The evolution of an instrument is less driven by practical concerns, and is motivated instead by the quality of sound the instrument produces. In this regard, it is not so necessary for an instrument to be perfect as much as it is important for it to display distinguishing characteristics, or "personality". What might be considered imperfections or limitations from the perspective of tool design often contribute to a "personality" of a musical instrument.* [Tanaka, 2000]

An often-cited concept in DMI design is Wessel and Wright's notion that DMIs offer an opportunity for instruments with *'a low entry fee and no ceiling on virtuosity'* [Wessel and Wright, 2002]. This refers to the idea that the 'entry fee' to DMIs is a product of the interface designer and mapping strategy, and not bound to any physical properties relating to acoustics. They argue that DMI designers may have the unprecedented ability to design musical instruments which are instantly accessible in the early stages of learning, but are capable of sustaining an engaged practice with the instrument to the point that virtuosic performances are possible. They link this sustained engagement with the instrument to 'control intimacy' - the level to which the fine details of a performer's movement translates into the musical output of an instrument. Jack et al. [2016] draws a connection between

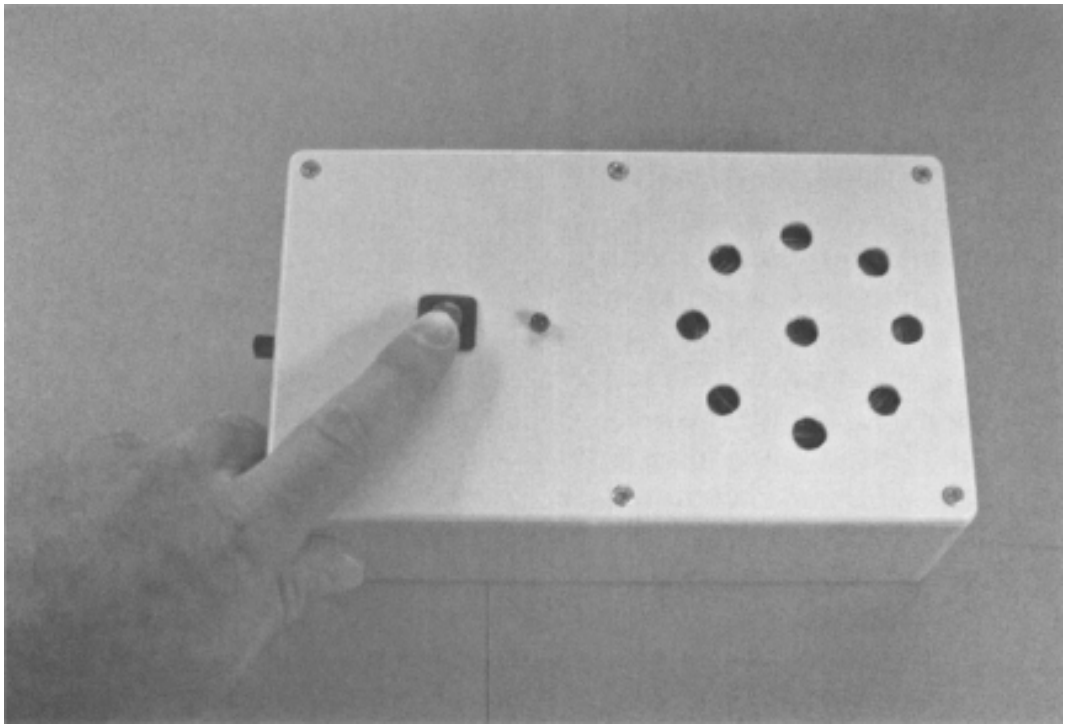


Figure 2.2: Gurevich et al.'s one-button instrument

perceived control intimacy and the level of action-to-sound latency an instrument possesses.

Gurevich et al. [2010] provide an example of a DMI study where the instrument itself is explicitly designed to study a particular feature of DMI performance. Exploring the notion of *constraint*, Gurevich et al. developed an instrument with a single input - a momentary pushbutton, and a single output: a sine tone generated by a 555 timer (see Figure 2.2). They noticed that despite the highly constrained and simplified interface, players developed their own stylistic tendencies in a subsequent study of their performances with the instrument. This allowed the authors to reflect that the potential for virtuosity in DMI performances is not simply a product of affordances (both perceived and hidden) and properties of the device, but also the artistic intentions of the player.

Zappi and Mcpherson [2014] expand on the subject of constraint in DMI design and explore how performers *appropriate* their instruments. Appropriation refers to the way that players seek out 'hidden affordances' and 'mis-use' an instrument as a means of developing a personal style with the instrument. They also discovered, through comparing an instrument with a single degree of freedom vs. an instrument with two degrees of freedom, that the diversity of playing styles and

explorative patterns of interaction was reduced with the more complex instrument.

2.3 ACCESSIBLE INSTRUMENTS

In the final section of this chapter, I review the state of the art of accessible instruments - the primary topic of this thesis. I conclude with an introduction of the term 'performance-focused' ADMI, and discuss how it relates to the existing work in this area.

2.3.1 *A Review of Existing Accessible Instruments*

I begin with a discussion of existing recent reviews of the literature, followed by brief descriptions of some of the most prominent accessible instruments. While the majority of the instruments here could be described as DMIs, there are a number of highly successful acoustic instruments included in this review.

2.3.1.1 *Reviews of ADMI Research*

In her review of the field, Frid [2019] shows that the topic of ADMI design is a burgeoning area of interest within the music technology research community, with the majority of papers on the subject being written since 2011. This perhaps closely correlates with the wide availability of tools and resources than previously, and reflects the prevalence of custom and bespoke designs within this field - although this could also be a result of the increase in published papers on DMI topics in general. Frid's comprehensive review reflects on some of the key issues within this field, including the varied terminology used to describe ADMIs and their associated practices.

In this thesis, I use Frid's definition of ADMIs as *'accessible musical control interfaces used in electronic music, inclusive music practice and music therapy settings'*. In a survey of 83 instruments that fit this definition, Frid finds a range of instrument types, with their number of occurrences as follows: *Tangible (30), Touchless (20), BCMIs (Brain-Computer Music Interfaces) (9), Adapted Instruments (8), Wearable/prosthetic (5), Mouth-operated (3), Audio (2), Gaze (2), Touchscreen (2) and Mouse-controlled (2)*. The key outcomes of this survey are the success of instruments which feature *'adaptability and customization, iterative prototyping, user participation, and interdisci-*

plinary development teams', as well as the need for more longitudinal studies based on systematic evaluation frameworks.

Larsen et al. [2016] present a comprehensive review of accessible instruments and associated technologies. They provide an overview of the use cases of accessible DMIs along with a discussion of two common causes of disability in adults (cerebral palsy and stroke). They briefly discuss music-supported therapy (MST) from the point of view of brain plasticity: the process by which the brain can reorganise and adapt itself through repeated cognitive processes. It is interesting to note that the majority of instruments included within this review appear to be designed for some therapeutic use. Indeed, by focussing so heavily on brain plasticity and MST, the authors take a highly medicalised approach to accessible instruments, framing their discussion of such technology around rehabilitation. Perhaps symptomatic of the ambiguity in language within this field is the fact that several of the examples of 'musical instruments' given in this review are not in fact instruments, but music-based systems designed with some effect of disability in mind. These include a robot-assisted Guitar Hero game [Taheri et al., 2012] and an art installation which uses an Assistive Technology (AT) product, but which is not explicitly aimed at users of assistive technology [Nam and DiSalvo, 2010].

Graham-Knight and Tzanetakis [2015] offer a less comprehensive overview of accessible musical instruments, but take a far less medicalised standpoint as a motivation to create musical instruments for people with physical disabilities, stating simply *'the field is important because it provides a way for people with physical disabilities to play music they could not otherwise play'*. They make the distinction between 'assistive' and 'adaptive' music technology, saying that the former 'implies an external source that provides aid to a person in need'. The term adaptive is preferred here as it suggests an ability to be refined according to the musician's needs. The authors structure their review of instruments into five categories: 'Touchless Sensor', 'Breath Pressure Sensor', 'Biosensor', 'Video-based' and 'Other'. They then go on to describe a method for future development of adaptive musical instruments, describing a process of co-design and refinement in order to arrive at an optimised instrument. More so than in other fields, the importance of co-design and specialisation for the end user is paramount, due to the often highly specific needs and requirements of the user. When discussing the evaluation of a participant's range of motion, the authors note that there is *'a difference between being able to move in a direction, and feeling comfortable moving in a direction'*, reflecting the fact that empirical measurements alone are not sufficient for designing the interaction with

an instrument. The authors' distinction between the terms 'assistive' and 'adaptive' reflects the need for disambiguation of the terminology in this field, much of which is borrowed from AT research.

2.3.1.2 *Commercially Available ADMIs*

Figure 2.3: Left to right: Jamboxx Pro (http://www.jamboxx.com), SoundBeam (https://www.soundbeam.co.uk/), Skoog (http://skoogmusic.com/)

The Skoog[5] (Figure 2.3) is a popular musical device for therapeutic contexts. Designed for a wide range of users, including musicians with specific learning disabilities as well as those with reduced or constrained motor function, the Skoog is a soft, robust cube-shaped device with a large malleable coloured button on five sides. The Skoog is designed to communicate with external devices and trigger software sounds. Its flexibility and durability make it an invaluable tool for music therapists and workshop leaders, but this presents another example of an accessible instrument whose emphasis on ease of use places a low ceiling on musical expression.

The Soundbeam[6] (Figure 2.3) is one of the most popular commercially available accessible instruments, marketed explicitly for users with both physical and cognitive disabilities [Swingler, 1998]. It comprises a sonar proximity sensor and several foot pedals, and is capable of producing either onboard synthesised sounds or controlling MIDI instruments. It has been used by musicians with and without disabilities and to varying degrees of impairment, due to the ability to calibrate the range, sensitivity, and quantisation steps. Interrupting the sonar beam produces a musical tone, and varying the distance of the limb from the sensor alters the pitch. Options for recording and playing loops are provided with the large buttons which can be used as foot pedals. Much like the Skoog, the Soundbeam places a focus on accessibility in the broadest sense, as anyone capable of movement to any degree is

5 http://skoogmusic.com/
6 https://www.soundbeam.co.uk/

theoretically able to trigger notes with the system. The Soundbeam's access affordances lie in its configurability and wide range of input gestures, supporting note and event triggering through mid-air gestures via the proximity sensor, or tapping or pressing the associated switches. A tradeoff of this approach is that there are few options for further expression beyond note triggering, such as vibrato or dynamic timbral effects.

The Jamboxx Pro[7] (Figure 2.3) is another commercially available product which is targeted at both disabled and non-disabled musicians. The design is based on a harmonica, with a breath sensor capable of accessing notes arranged horizontally using both sips and puffs. As with the Soundbeam and Skoog, as well as a majority of DMIs, the Jamboxx is a MIDI controller for use with a DAW on a connected device.

Apollo Ensemble[8], formerly midiCreator, is a system for rapidly interfacing sensors and controllers with MIDI outputs. Designed with accessibility and music therapy in mind, the Ensemble system takes the view that no single interface or controller will work for every user, so a range of input devices is made available. The PC-based software represents a simplified Max-like graphical environment in which sensors can be assigned to different musical events via modifier objects such as transposition or thresholding.

2.3.1.3 *One-Handed Instruments*

Several successful adaptations to acoustic instruments have been achieved, many of which as a result of projects supported by the One-Handed Musical Instrument (OHMI) Trust[9]. The majority of these are wind instruments, often involving a re-mapping of keys and switches to valve closures. This allows musicians who have full use of one arm the ability to perform an equivalent repertoire as non-disabled musicians. Adapting wind instruments for one-handed use is a conceptually straightforward approach: for many wind instruments, the two hands perform similar tasks (i.e. pressing buttons to close valves), while the mouth is used for note activation and modulation.

String instruments often require the two hands to perform separately (i.e. fretting and plucking), and so one-handed adaptation is less straightforward. A common approach to one-handed string playing is to couple note selection and activa-

7 http://www.jamboxx.com
8 http://www.apolloensemble.co.uk/
9 http://www.ohmi.org.uk/

tion either by 'tapping' a physical string (as seen on the Chapman Stick[10] or Bill Clements' playing style[11]) or using a multi-axis controller such as the Linnstrument [Linn, 2013] with a digital string instrument synthesiser.

2.3.1.4 *Guitar-based ADMIs*

Guitars are a common candidate for accessible instrument design, being one of the most popular instruments available. Examples of adapted guitars are the Actuated Guitar [Larsen et al., 2013], guitarMasheen [Meckin and Bryan-Kinns, 2013] and the adapted bass, discussed in Chapter 4 [Harrison and McPherson, 2017]. These three instruments all feature mechanical adaptations to an existing guitar. By contrast, the Kellycaster[12] is a bespoke guitar-based instrument designed for a specific user through a participatory design approach.

Bell [2014] posits the guitar's 'high value in cultural capital' as a factor in the explosion of Guitar Hero games during the previous decade, suggesting that such games allow entry into a 'musical experience that is enmeshed in popular culture'. Bell also cites the guitar's cultural value as a compelling argument for improving the accessibility of the guitar and its associated pedagogy to disabled musicians and beginners, an argument that is reinforced in the design philosophy of the Kellycaster. The requirement for an instrument that carries the same cultural weight (not to mention interaction techniques) as a guitar was paramount in its design.

2.3.1.5 *Bespoke Acoustic Instruments in Community Music*

Longden [2019] draws on his experience as a community music leader and discusses the ways that his approach to music-making have informed the designs of several acoustic Bespoke Musical Instruments (BMIs). Longden is both a researcher and community music leader, and has run the *Joy of Sound* (JOS) community music sessions for many years. These sessions are based around an improvisatory approach, with stringed instruments and tuned percussion tuned to an open E♭ tuning. He writes about how his approach to community music has informed the design of a large number of BMIs, all of which are co-designed with disabled people who take part in the JOS sessions. Figure 2.4 shows the Tree Song lap harp, an example of the bespoke string instruments co-designed with

10 http://www.stick.com/

11 https://www.youtube.com/watch?v=eskvyuzF1-Y&nohtml5=False

12 http://www.drakemusic.org/our-work/research-development/artist-led-projects/john-kelly-the-kellycaster/

members of the JOS group. This instrument's design allows access to the open-tuned strings, while concealing the tuning pegs beneath the top surface of the instrument. It is also designed to be held close to the player, providing a multi-sensory experience through feeling the vibrations of the instrument against the body. The instrument is emblematic of many of the BMIs that Longden discusses, being a unique design based around specific access needs, employing traditional instrument-building techniques.

Figure 2.4: The tree song lap hap - a bespoke musical instrument co-designed by Ina de Smit and participants from the Joy of Sound community music group

2.3.1.6 *Eye Tracking*

For musicians with limited motor functionality as a result of tetraplegia (a degree of paralysis in all four limbs), eye and head tracking is a common solution for interacting with digital devices. Several musical applications for eye and head trackers have been developed. An early example is Eyemusic [Hornof and Sato, 2004], a system geared towards composition and playback of eye-movement records. A more recent and well used musical eye-tracking interface is the Eyeharp[13] [Vamvakousis and Ramirez, 2011]. This open source software allows use of a webcam, head tracker, eye gaze hardware or similar devices to control MIDI notes or internal synthesis.

13 https://theeyeharp.org/

2.3.1.7 *MIDI controllers*

Many commercially available MIDI devices take the form of percussive 'drumpads', following the format of popular sampling hardware such as the Akai MPC. The Wambam [Jense and Leeuw, 2015], Touchtone [Bhat, 2010], Ingrid [McCloskey, 2014] and percussive MIDI controller [Vamvakousis, 2016] are all examples of accessible MIDI controllers with a percussive/drumpad based interface. The Touchtone and Ingrid were designed for users with Cerebral Palsy (CP), taking the broader, less precise movements of those with CP as a key design requirement. The Ingrid features recessed buttons, which constrain and channel the broad movements onto a more precise pressure-sensitive area.

2.3.1.8 *Breath Control*

Breath control provides a highly expressive means of triggering and modulating note onset for digital instruments, especially for musicians who lack the bimanual dexterity and precision required for many traditional instruments. Human Instruments have developed an array of breath-based musical controllers which make use sip/puff gestures for triggering note onsets and providing expression [Matossian and Gehlhaar, 2015]. These include the Headspace which uses head control to select note regions on a screen, and a breath sensor to trigger and modulate the notes; the Typhoon, a head controller which uses haptics to provide note selection feedback in place of a screen; Doosafon, a xylophone-like note selection layout, where the user selects notes with a baton held in the mouth (unlike a xylophone, striking the keys does not produce a note, but simply selects the note for the breath control to start); and the Puffin, which features a custom keyboard for note selection and a similar breath controller to the previous instruments. Other examples of breath control accessible instruments are the Flote [Aziz et al., 2008] and the Magic Flute[14], a similar device to the Jamboxx, but which features a built in synthesis engine as well as MIDI control.

2.3.1.9 *Brain-Computer Interfaces*

Brain-Computer Interfaces (BCIs) have been explored as potential music controllers [Chew and Caspary, 2011, Vamvakousis and Ramirez, 2014], but currently do not provide sufficient accuracy or temporal precision to be seriously considered as real-time musical controllers. Currently, BCIs have been used for controlling sys-

14 http://mybreathmymusic.com/en/magic-flute

tems such as software step sequencers to moderate success. They have also been explored as a means of generating material such as visual scores for live musicians to respond to e.g. [Eaton and Miranda, 2015]. It is clear that a 'perfect' BCI system would allow musicians with profound physical disabilities (such as locked-in syndrome) to perform and compose music, but pose similar problems to touchless sensor instruments in that the instrument is not embodied or physical.

2.3.1.10 *Interactive Machine Learning*

Interactive Machine Learning (IML) is another emerging technology that shows promise for future accessible instruments. Katan et al. [2015] discuss a workshop in which the IML software Wekinator [Fiebrink and Cook, 2010] was used as a means of rapidly prototyping complex gesture-to-sound mapping layers with gestural musical devices. It was initially explored as a means of developing bespoke musical instruments which closely matched individual's access needs and musical intentions. However, the result of the workshops was that the models weren't re-trained for each individual, but did provide researchers with a means of designing rich and complex control spaces, affording a variety of engagement styles by different participants.

More recent work on the use of IML with children and music therapists to develop custom musical interfaces is discussed in [Parke-Wolfe et al., 2019]. Here, they discuss the advantages of employing rapidly customisable music interfaces as means of *'recognising and exercising agency'*, *'encouraging moving and listening'*, and *'supporting social aims'*. They also show that IML-based approaches allow for musical scenarios not bound by MIDI-like note triggering, opening up spaces for deeper timbral exploration through complex mappings between the interface and sound generation software - with therapists and teachers seeing *'clear benefits to interfaces that allowed children to explore rich timbral spaces offered by digital synthesis methods'*.

2.3.2 *Performance-Focused ADMIs*

Through reflecting on existing ADMI designs as well as the literature from DMI research, I noticed two clear trends: that a common motivation for developing ADMIs was the therapeutic benefits of music-making, or as an education tool for use in Special Educational Needs settings; and that few ADMIs appeared to be

developed with the explicit purpose of enabling musical performance on the same terms as a 'traditional instrument' would for a non-disabled musician.

In order to problematise these trends, and propose a means of addressing them, I proposed two sub-categories of ADMIs: 'performance-focused instruments' and 'therapeutic devices'. The goal was to clear up ambiguity over the envisioned used-cases behind ADMI designs, and to encourage the design of new performance-focused ADMIs in order to address the imbalance I had observed from the literature. This definition was also in part motivated by a desire to bring social model thinking and other theories from disability studies into the field of ADMI design, for example by encouraging ADMI designers to consider other motivations for ADMI design, besides those linked directly to medical or therapeutic benefits.

Table 2.1 summarises the properties of these subcategories of ADMIs, compared with traditional instruments. I use the term *traditional instruments* to generally describe those instruments which are immediately recognisable as belonging to Western musical traditions and which require some degree of manual dexterity; are acoustic (or heavily based on acoustic instruments e.g. keyboards and electric guitars); have recognised role models and virtuoso players within Western genres such pop, rock, jazz and classical; and make use of existing pedagogy and traditions. These categories are compared with respect to four properties: *physical accessibility*, *learning process/acquisition of mastery*, *musical diversity* and *use cases*. In the following subsections, I will explore these properties and how they relate to existing instruments.

2.3.2.1 *Physical Accessibility*

Traditional instruments require a high level of motor control, almost exclusively with both hands. This is the cause of the 'inaccessibility' for many musicians with physical impairments. Many accessible instruments take the broadest interpretation of 'accessibility', being designed for a wide range of access needs resulting from both physical, cognitive and sensory impairments. An example of this is the Skoog, which embodies such 'universal design' principles, being malleable and resilient to high impacts (e.g. from squeezing or striking), but also offers capacitive touch capabilities for low impact gestures such as stroking or touching.

In contrast, the Kellycaster is representative of a number of bespoke, DIY projects, often connected to the 'maker' community as opposed to academic or commercial products. The instrument was designed collaboratively by John Kelly, and members of Drake Music, a community arts charity specialising in accessible music

Table 2.1: Comparison of properties of instrument types

		Accessible Instruments	
Property	Traditional Instrument	Performance-Focused Instruments	Therapeutic Devices
Physical Accessibility	High motor function required	Designed to accommodate specific impairment	Broad/inclusive range of motor function
Learning	Often extensive learning periods	Aimed towards low barrier, high ceiling. Possibility for complexity management	Low barrier, often low ceiling
Musical Diversity	High diversity. Existing repertoire and ensemble formats.	Aim to make use of existing repertoire/ensemble formats.	Often low diversity. Tend towards MIDI controllers for flexibility in sound sources
Use Cases	Performance, teaching, occasionally music therapy	Performance, teaching, potential for music therapy	Music therapy where physical access is an issue

making, with the goal of developing a guitar-like instrument that specifically addressed his access needs.

The Skoog and Kellycaster are examples of two distinct approaches to physical accessibility. The former's 'one-size-fits-all' approach makes it a valuable tool for group music making scenarios or applications where adaptation of the instrument prior to the musician learning it is not possible. The highly specialised, bespoke design of the Kellycaster shows a different approach, with careful thought given to every aspect of the instrument in relation to one specific user's access requirements. This raises questions about the nature of accessibility, and how different interpretations can impact the user in different ways. A broad scope of accessibility is desirable in many applications, and often a hallmark of good design, but in the case of the Skoog, appears to have an impact on the complexity of musical output. Meanwhile, the Kellycaster works so well because it is designed to fit to a single users' unique access needs, but is unlikely to be usable by a wide range of users in a community music setting, for example.

2.3.2.2 *Learning Process/Acquisition of Mastery*

Returning to Wessel and Wright [2002] and their notion of DMIs with a 'low entry fee with no ceiling on virtuosity', as well as the notion of instrument complexity introduced by Jordà [2004], we can consider the way that various ADMIs can accommodate different learning processes.

Traditional, acoustic instruments are often constrained by their physicality and afford few options for lowering the barrier to expressive music making. DMIs are not constrained by the requirements of acoustic sound production, and so may offer opportunities to bypass or shorten early stages of the learning period through their design. However, it is often the case that lowering the entry fee (i.e. making the instrument easier to learn and simpler to play) lowers the ceiling on virtuosity. Jordà [2004] explores this concept by comparing the learning efficiency curves of the piano, violin, kalimba and kazoo (reproduced in Figure 2.5). Jordá's concept of 'musical instrument efficiency' takes into account the complexity and range of musical output versus the complexity of the control input. For example, the curve for the Kalimba in Figure 2.5 shows a steep rise in musical efficiency during the early stages of practice; in other words, the performer very quickly has access to a relatively large range of musical output with minimal input complexity[15]. Once the performer has reached a certain point in mastery, the instrument's efficiency reaches a maximum: both performer input and musical output cannot become any more complex. In contrast, the time it takes for a violin learner to reach a similar level of efficiency to the kalimba is over twice as long. The freedom of performance is highly limited during the early years of practice, due to the requirement to master the most basic aspects of violin playing (intonation, tone, etc.) before building up a more complex repertoire incorporating the many and varied techniques involved in accomplished violin performance. Perhaps as a result of this, the efficiency curve rises well past the point of the kalimba and continues to rise after many years of practice.

Instrument efficiency is an important concept when considering accessible instrument design. For instruments designed to elicit or promote some therapeutic effect, a prolonged learning stage may prove frustrating and de-motivating. Larsen et al. [2014]'s actuated guitar is designed for children with hemiplegia, featuring a

15 It should be noted that this may represent an overly western-centric view of musical instruments and in fact there are many examples of what may be considered virtuosic kalimba performances which suggest a much longer learning curve than Jordá implies here - for example the high-tempo and distorted electric kalimba playing by members of Konono No. 1

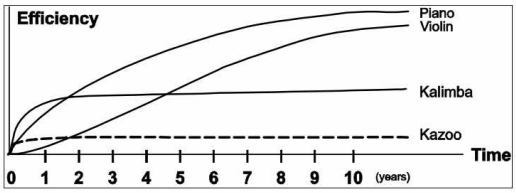


Figure 2.5: Jordá's approximate learning curves for four instruments [Jordà, 2004]

foot-pedal operated motorised fader for strumming the strings without using the affected hand. The learning curve is significantly shortened by tuning the strings to an open tuning, allowing the users (all non-musicians) to play harmonically appropriate chords by fretting all the strings at the same fret. The frets were colour coded to allow score following to simple major-key songs without any prior musical knowledge. This simple adaptation allows users to benefit from the therapeutic effects of playing the instrument - in this case performing functional motor rehabilitation exercises [Larsen et al., 2014].

While virtuosity isn't necessarily a goal for many musicians (it is even rejected in many genres such as Punk Rock), gaining some level of mastery over an instrument is a highly rewarding aspect of musicking. Even where virtuosity isn't a requirement, a high degree of competence is often necessary for meaningful performances, especially when performing with other musicians. This poses the question of where to set the barrier to entry for new ADMIs. Pardue [2017] introduces the concept of *complexity management*: 'intentionally altering the inherent difficulty of an instrument in order to assist practice motivation'. This work is focused on improving violin learning by altering the complexity of various aspects of the instrument. An example is the quantisation of pitches to the 12-tone scale. This allows the learner to focus on the task of bowing, already a highly complex kinematic process, while reducing the cognitive load of achieving good intonation.

While Pardue focuses on aiding existing learning practices for violin by augmenting an existing instrument, the goals for complexity management for novel DMIs are less fixed. ADMI design may require a thoughtful approach to complexity management, taking into account a particular user's set of available movements, perhaps reducing the complexity of a particular part of the instrument that relates to an impaired limb, or even working with music therapists to focus on a musical gesture that could contribute to rehabilitation exercises.

2.3.2.3 *Musical Diversity*

Returning to Jordà [2004]'s concept of *Musical Diversity*, we can consider ADMIs in terms of the range of music they offer, from micro-diversity (i.e. the nuanced ways that the same piece of music can be interpreted on a single instrument), to macro-diversity (i.e. the number of genres and musical contexts a particular instrument can be part of).

In therapeutic contexts, which often require repeatable and measurable outcomes, a lack of micro-diversity might be required. Ward et al. [2017] propose a set of design considerations for therapeutic instruments in Special Educational Needs (SEN) settings, including concepts relating to musical diversity. In particular, the feedback loop which takes place in music making is highly important for reinforcing cause and effect relationships. Ward et al. make clear that setting the right balance between constraint and expressivity is key, as the goal of the instruments is to be 'empowering not overpowering'. This takes into account the complexity of input modalities, but also the musical diversity of the output.

Setting the expressivity/constraint balance is a challenge that is not limited to the design of therapeutic devices. The range and scope of work on mapping in DMIs reflects the importance of balancing input complexity and rewarding musical results [Jack et al., 2017, Hunt et al., 2002]. The mapping process has a clear impact on micro-diversity, as described by Jack's concept of 'placing the bottleneck'. This refers to the 'projecting downwards from a multidimensional body language to a reduced set of sonic features'. The size and position of the bottleneck affect the overall range of sonic features available to the user, and thus the nuances with which the same piece of music can be performed.

Mid-diversity relates to the available repertoire of an instrument: to what extent does an instrument appear to be 'always playing the same piece'? Most traditional instruments in Western music have a high mid-diversity, with large established repertoires of music consisting of contrasting pieces. Therapeutic devices may not require a wide repertoire, depending on the specialisation of the task. As many of these devices take the format of a controller connected to a host DAW, it is worth considering to what extent changing the sound source changes the mid-diversity. For example, does changing the software instrument from a keyboard to a guitar while using the same controller extend the available repertoire to guitar based music?

Repertoire is an important factor in musical performance. A shared knowledge base of performable music is important for teaching and learning instruments, as

well as for ensembles and groups to be able to perform together. A performance-focused instrument should aim for an equivalent mid-diversity to a traditional instrument, and consider the role of repertoire in a musician's musical development.

Macro-diversity refers to the range of genres and styles that an instrument can easily fit into. A high macro-diversity is not a requirement of successful and enduring traditional instruments. The french horn, harp and banjo are examples of popular instruments that appear in a relatively small number of musical genres and styles. The guitar and piano are examples of instruments with a very high macro-diversity, appearing in classical, popular, experimental and folk styles. Jordá suggests that beginners might prefer instruments which offer 'more varied possibilities', while professionals might be happy with a more idiosyncratic approach. It is worth noting that macro-diversity is not necessarily something which is intrinsic to the instrument, and is largely down to socio-cultural phenomena: for example the saxophone could be said to have possessed relatively low macro-diversity for many years until it become adopted into jazz, pop and rock, without undergoing any change in its design.

2.3.2.4 *Performance-Focused ADMIs - Discussion*

I developed this formulation of ADMI properties during the early stages of this research. As we will see in Chapter 7, my stance on some of these issues has evolved since I originally set out to distinguish between these sub-categories using the properties highlighted in Table 2.1. Specifically, by setting up this dichotomy, issues of constraint and musical diversity may be oversimplified: constrained pitch-space does not necessarily preclude an instrument from being used in a 'performance-focused' sense, and also doesn't instantly place it in the 'therapeutic' camp either. I presented my original formulation in order to discuss these ideas in relation to existing instruments and NIME literature. While the distinction between therapeutic devices and performance-focused instruments may have turned out to be less clearly defined as is suggested in Table 2.1, I suggest that these categories are worthy of consideration when evaluating ADMIs, and may still provide a means of discussion the motivation and philosophies behind their design. What I learned from the subsequent studies described in the later chapters of this thesis, is that the context that instruments are used in has a significant bearing on how players interpret and appropriate them - in other words, considering only the inherent properties of instruments risks missing out on the larger picture.

For further in-depth discussion on how this formulation has evolved, see Section 7.2.1.

2.4 CONCLUSION

In this chapter, we have seen how the topic of music and disability is represented across a number of disciplines. Different domains necessarily treat the notion of access to music in different ways. A trend across much of the literature from ADMI design is the tendency to take an instrument-focused view of the issues of access to music. This is understandable from a discipline that is explicitly concerned with the design of new instruments, but perhaps risks missing out on insights from a more 'community-focused' view, which is apparent in much of the literature from disability studies. Literature concerning music and disability studies tends to avoid and even argue against invoking the medical and therapeutic potential of musical participation, instead focusing on the artistic and political implications of representations of disability in music. Conversely, much of the literature concerning new ADMIs directly cites the therapeutic benefits of music-making as the primary motivation to widen access to music through technology. To paraphrase Bakan [2015], there is perhaps a need to redress the balance towards more ability-centered, affirming, and agentive perspectives of disability within the field of ADMI research.

We have seen that discourse around music and HCI is increasingly becoming open to ideas and methodologies from social sciences such as musicology, anthropology and Science and Technology Studies. These fields offer us ways of considering instruments beyond the technicalities of their sound design, mapping strategies and so on. Much of the methodologies employed here are also evident in the 'third-wave' of HCI, which tends to focus on the 'messy' interactions between people and technology in long-term, situated contexts.

What is currently missing from the picture, perhaps, is the application of a 'community-focused' view of music and disability to the field of ADMI design, informed by disability studies. In the following chapters, I present interviews with two disabled musicians, followed by three instrument studies featuring prototype ADMIs. The studies themselves document a progression in my own approach from an explicitly instrument-focused view of accessibility via a lab-based user study of an adapted bass guitar, towards a broader scope of attempting to understand

the role of guitar-based ADMIs in an existing musical context, first in a lab-based study, and later situated within a community of learning disabled musicians.

3

CASE STUDIES: INTERVIEWS WITH TWO DISABLED MUSICIANS

3.1 INTRODUCTION

In this chapter, I present interview transcripts with two disabled musicians: Molly Joyce and John Kelly. Throughout the early stages of this research, I focussed my efforts on making connections with disabled musicians, practitioners of inclusive music, and charitable organisations working in this area. My goal was to understand some of the contextual factors around disability and music, to get a sense of some of the issues and challenges which lay outside of written works in secondary sources, as well as to build relationships with musicians that might later be willing to take part in future studies. Many of these conversations took place in informal settings, without the ability (or indeed permission) to record and share some of the ideas that were raised. It became apparent that some of these ideas should be presented in this thesis as primary sources, and so I approached a number of my contacts to take part in recorded interviews. Molly and John were both kind enough to offer their time to record interviews focussing on their musical practice, approach to instrumentation, and reflections on a number of concepts I had uncovered during the literature review stages. In particular, I was keen to discuss the wider context of their approach to music, as well as how their musical practice was representative (or not) of their disability identity, and how their choice of instrument reflected this.

3.2 MOLLY JOYCE

I was first introduced to Molly by a mutual contact from *Heart n Soul*, a London-based arts charity for people with learning disabilities. Molly was in the early stages of setting up a disability arts non-profit, *Beyond Ability* in the United States, and was reaching out to people working in this area in the UK for advice and ideas, and we met several times over Skype to discuss each other's work.

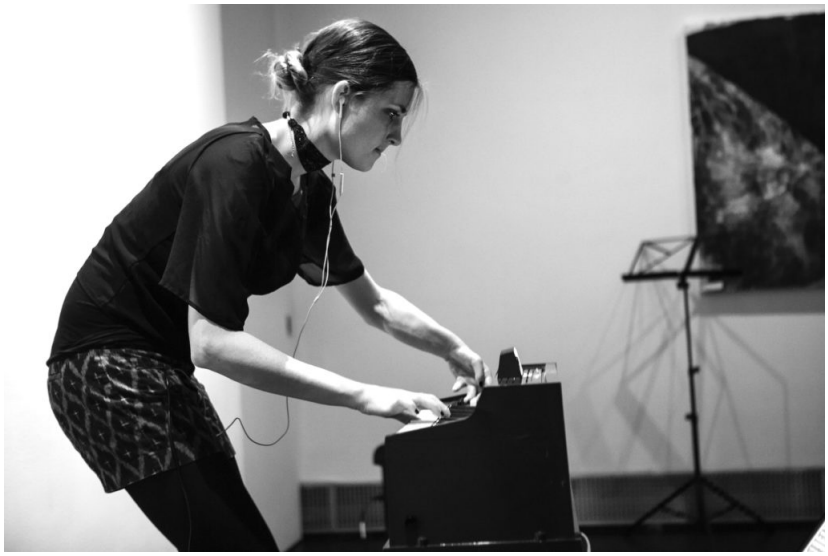


Figure 3.1: Molly Joyce performing with the toy organ (credit: disabilityarts.online)

Molly, based in the U.S., is a composer and performer of contemporary classical and electronic music. As well as composing for other performers, she performs her own music on a second-hand toy organ, which she says 'suits her body and allows her to engage with disability on a compositional and performative level' - in part due to the accessibility affordances that the chord buttons provide for her impaired left hand.

As well as composition and music performance, she engages with writing and speaking on the subject of disability, including a *TEDx talk*[1] and articles for *Disability Arts Online*[2], as well as collaborations with visual artists, choreographers and writers.

Following an early conversation with Molly, I sent her a version of the *Strummi* instrument (introduced in Chapters 5 and 6), with a view to working on future iterations and including it in her performance practice, and the potential to include her reflections as part of my evaluation of the instrument. At the time of writing, Molly has spent a limited amount of time with Strummi due to scheduling and travel constraints on both sides, and so it does not make up part of this thesis, although the topic of the Strummi does come up during the interview, and future work with Strummi is planned to resume. This interview was recorded with Molly over Skype in October 2019. The transcription presents the interview in full, with minor edits for readability and clarity.

1 https://www.ted.com/talks/molly_joyce_going_beyond_ability
2 https://disabilityarts.online/magazine/opinion/molly-joyce/

Jacob: How would you describe your career in music: how you got started, what instruments you played and how you got to where you are now?

Molly: It's definitely been a long and winding path. I started out on violin, private lessons at kindergarten. My mum wanted me to take private lessons as she saw it as a kind of future asset on my college resume but she didn't know that that would backfire. But then that switched to cello and trumpet at the age of 7. Because I had a car accident which nearly amputated my left hand, so therefore from there I played cello backwards, so I bowed with the left hand and fingered with the right hand with a splint on the bow which was made by my physical therapist and music teacher in collaboration. I always joked it was a good way to always be on first chair on the outside of the orchestra. And then I played trumpet shortly after that as I felt like trumpet was one of the few instruments I could play without much physical limitation, although I felt like later on I was still holding the trumpet with my right hand, which put a lot of pressure on my embouchure. But then going from there, I guess at the beginning of middle school or 6th grade I started composing a little bit. I didn't realise it at the time but I think what drew me so much to composing was that there was really no physical limitation, it was just on the computer. I kind of loved having that kind of immediate feedback from the computer notation software, like it was just a video game. And looking back that's what drew me to it at first, I didn't really have to think about my hand, in a good way, at least at the time. And then from there I went pretty seriously into the classical composition route, entering competitions and festivals, and applying to music conservatories for undergraduate studies, and just, I think along the way always just thinking *'we'll see what happens'* and one day I'll have to grow up. And then from there, I did undergraduate at Juilliard and there I was pretty much always a composer, but when I started there that was really the first institution or school that wanted to legally label me as disabled – which was hard to rectify at the time because I'd never been labelled as that. I felt like I went from public school and didn't have to deal with that – I guess I was more upset because they wanted to tell all the composition teachers that I was disabled, and I didn't want them to talk about me that way, although now I'd love for them to talk about me that way.

So [at Juilliard] I had to play a little piano, and I played it throughout undergrad and I would do what I did but I definitely didn't consider my disability

at all – I was just trying to make things work, and focus on composition. After that, I did one year of studies in the Netherlands, just as a composer and not really performing at all, and I recently completed my graduate studies at Yale in composition and that's where I really started doing disability studies and really rethinking my whole practice, and kind of realising that a lot of my practice has been very physically driven. I've been trying to explore these elements, especially with my electronic work, like trying to switch places, playing with the seen and unseen, the visible and invisible. And also at Yale I got into the situation where I started performing more on my vintage toy organ. I originally bought this during undergrad and I always joke I saw this was my ticket to Brooklyn, when I bought it I really just thought of it as a toy, I played in some bands with some people but really never thought of it as something I could do on its own. But it wasn't until I got to grad school and wanted to be self sufficient and not have to work to other people's schedules or do things that way, then I started putting electronics with it, and then when I performed I was like *'wow this is really made for my body'* because of the chord buttons on the left hand side and keyboard buttons on the right hand side. It just felt very comfortable to perform on and I started thinking about the kind of creative potential of disability, and going from there.

Jacob: That's a really nice summary. So, I'm interested, especially with regards to instrumentation but also generally talking about social and attitudinal barriers, did you experience many barriers to music performance, to access to performance spaces, as a result of your disability growing up, and what helped you overcome them, especially with instrumentation?

Molly: Just thinking back to when I was young, I mean obviously, my disability is quite minor compared to others so I was able to play something like the trumpet, so I guess there's some capability with those instruments but I still think they're all made for able bodied people, and have a very strict view of what a body can be or cannot be. And I think going from that, this is more personal, it was really hard for me during college – I'm not trying a pity story I guess it's just hard to rectify – I feel like a composer's instrument is almost always piano, and that's what really scared me at first when I got to college. They were like 'you have to play your own exercises when you bring them in' and obviously I could only play a bassline which is fine now, but at the time it just seems like so much

of what your identity should be as a composer, you should be a really able pianist, be able to play your own shows.

And yeah I think it wasn't until – I love the organ because of its tuning and it's very unique and has its own story, but I think just finding an instrument outside the mainstream helped me meet my body on its own level, and even kind of challenge it – but also not: I'm really big on having no comparison at all to an abled body, or just again meeting it on its own level, and I think an instrument outside the mainstream really helps that.

Jacob: I was at a music and disability studies conference in the summer, and one of the talks was about the representation of disability in music and opera, but I think it's relevant to all music genres. He talked about the tension between assimilation and affirmation, and I guess what he meant by that is, *'do disabled performers assimilate into non-disabled musical culture and hide their disability or do they affirm their disability identity through having very visible disabled roles, or bringing their experience of disability into the role in a very visible and explicit way'*. And I think that's a really interesting take that you have in choosing a non-mainstream instrument. I'm intrigued what your thoughts on this idea of a continuum between full assimilation into abled culture and a strong affirmation of disability identity, and where you might sit between those two.

Molly: Yeah this whole thing is relatively recent for me in my music career in the past two year or so, in a good way I think. It's something I still wrestle with quite a lot, and I still do regular commissions just as a composer, and I guess I never want to make it feel like a pity story, because that's the complete opposite: I don't know if I should display it, I don't want people to think I'm being like *'look at my suffering'* or something. But I think it's really important, and I guess I have a very biased view of this, and things are changing now but I feel like in my training, identity or social context was almost never discussed. There was this one class I took, called 'music and society' in grad school, and the teacher from that class became my advisor for my first Disability Studies dependent study and he was not a composer at all – which I think says a lot. When I tried to bring my identity into the work, and we would discuss it in the grad school seminars, they didn't know how to discuss it, like other people would bring identity and they wouldn't know how to discuss it. And I always felt like I wanted to go to the art school 'crits' in grad school: one of the first things they talked about was social

context or identity or experience. So the more I think about it, the more I'd rather be affirmative about it. And I feel like you see a lot of things happening, especially with dance, at least in New York with disability arts, so I'm like *'OK they're doing it and I can do it'*. I just feel like at the end of the day I'd rather go too far than not go far enough. Go big or go home!

Jacob: So how did you find the tradition and the social structures of that world [of classical music education]? How did you find that related to your disability and your musical practice?

Molly: I feel like I rarely discussed it at all. Looking back, I feel like I was 'passing' a lot of the time, passing as a non-disabled person or something. At least in my work, and I wasn't performing much too. But it wasn't until I started doing more of these residencies and being in contexts that are just general artistic contexts, I felt more free to just explore it and not worry so much about what people were saying. And looking back on it there were just a few other disabled people in the whole conservatory that I can think of, and not as much creative arts grounded in it.

Jacob: So you already mentioned your approach to cello playing - why did you stop that approach? I'm just intrigued why the toy organ worked, and why this cello splint solution didn't work?

Molly: Yeah it's interesting because I feel like, I've seen other cellists and violinists playing backwards sometimes, in professional orchestras, so I don't think it's unheard of now. And when I think back to it, I think I grew more to trumpet, I found trumpet easier, but with trumpet it was less obvious with my impairment. Cello was so obvious I was playing backwards, I would sit on the end or I would hit people. I grew to trumpet more and then I couldn't keep up the cello – I stopped practicing, it was just hard. And I guess with the organ, it's so outside the mainstream that there's no comparison to how an able-bodied person would play it, at least in my experience.

Jacob: That's really interesting, [with the cello] it's so similar to the norm, but then different in a crucial way that kind of... Would you say you felt it kind of amplified your impairment, or your identity as a disabled musician?

Molly: It was 20 years ago, so it's hard to think back to what exactly was going through my head. I know I couldn't keep up because I just didn't practice as much. And I think when you're that age like 10 or so you don't want to stand out, I was a very shy kid, and I think you just want to be normal. You don't want to be seen as receiving special attention. Which is why I first didn't want to be labelled as disabled, it says that you need extra care or extra help. Which of course now I love that label, but I still think at the time, when you're growing up it's not your preferred way of living.

Jacob: So have you considered going back to the cello or the trumpet, or even trying a new instrument with an adaptation - that sort of thing?

Molly: Yeah, not currently, I mean sometimes I try and play a little trumpet but I'm so bad at it. But I feel like it's just a matter of time and I obviously want to focus on my composing and there's still a lot to explore with the organ, and I'm really excited about your guitar [the Strummi]. At least not right now, and I guess with those instruments I know it just takes so much practice to get to where you want, and I have so many friends that I know play so much better than me, If I need something recorded or I don't know. I feel like even if I had all the time in the world I wouldn't totally be drawn to anything.

Jacob: So would you say there's interest in trying new custom made instruments or instruments that are designed specifically with physical accessibility in mind?

Molly: Yeah I think both, I'm kind of open to anything, I don't have all the time in the world to practice new things. I'm doing this small research academy in a couple of weeks which is more focussed on video, so I'm more interested in using my body in general, Like I don't want to be a dancer, again, I'd be starting from like negative 100 or something but it's just more ways to display my hand even without the organ. Which I guess is why I'm excited about the guitar, like with the organ it's not always possible to see both of my hands, depending on what angle you're watching from. So stuff like that, if that makes sense.

Jacob: What are your plans for future performances and compositions, and do any of them relate to disability in the same way that some of your recent ones

have?

Molly: Yes I hope so. I'm working towards a full album involving the organ, my voice, electronic samples of both. Which is really – not to say it's the best thing ever – but it's some of the deeper personal work I've written because it really explores my left hand, the creative potential of it, just exploring what it feels like, because I had a car accident so before I was able-bodied and exploring what happens when part of your body becomes physically silent and physically different. So I'm finishing up that just, going to record one more song and mix it and I'm hoping once it's released, since it's just me I'm trying to think of collaborators with it. I think I'm going to collaborate with the dancer and choreographer Jerron Herman. We did a video recently together which he, I did the music and he danced to it in the woods after. He's really great, he's New York based. He dances with Heidi Latsky Dance, I think they're similar to some of the UK groups you mentioned where it's half able bodied and half disabled people.

Jacob: Like Graeae theatre and Candoco?

Molly: Yeah exactly, I think they're amazing. So I've just started talking with him and I'm hoping, it might just be him but he might just do a live performance of the album like when I perform it I want to try and tour it a little bit if possible, just to add more to it, and maybe use lighting and projections from disabled artists as well. That would be the dream version of it, I think otherwise I would just tour it myself. Yeah so that's the biggest project right now and then I guess I have my other commissions as a composer, and I guess in all of those I try to kind bring the physical into the musical if possible or I think about ways of countering the typical human body, which I think has been more or less successful with different projects. But just trying to counter what you expect the human body or certain instruments to do and those relationships if that makes sense? And then I guess long term another big more disabled-led project is I hope to be collaborating with the librettist and dramaturg Magda Romanska and she wants to write an opera on Stephen Hawking. More of an abstract opera, but yeah.

Jacob: Great, that sounds fantastic. Talking about your recent works, *Form and Deform* is one that I've really enjoyed... it's incredibly catchy, every now and then I just find myself humming it, like *'wait what is that? It's great!'*

Molly: My friends tease me about that, but hey it's effective!

Jacob: Yeah it's super catchy. So in your own words what was your thinking behind that particular piece, and are there any other pieces that have a kind of similar inspiration?

Molly: Yeah, that was the second major piece that I wrote for the organ and electronics. Like I had my solo thing, and I think the first piece was like 20 minutes and much more 'trance-y'. So I thought with this one I wanted to make it much more physical and see what would happen if I could make my hand switch places. What would happen physically, musically, visually. And yeah it started off with the kind of anticipated position on the organ: the left hand on the chords, the right hand on the melody and then have the right hand eventually playing more chordal material and then give the left hand the melody. And yeah that was basically it and if you listen all the way through, obviously the left hand has to ... at first I thought I could do it at the same pace and then when I was practicing I was like *'oh, I can't do this'*, or I realised it has to slow down but in its own hopefully good way. Obviously, there's physicality in that. That was probably the most physical work I've written on the organ, and more recently the songs I've been writing for the album I think are similar, but they're more text driven and that's definitely something I'm still trying to wrestle with – like how to incorporate the physicality of my hands, like what will happen, but also the text and make it a listenable song, if that makes sense. Because I think it's very pop influenced too, so I want it to be somewhat enjoyable to listen to or at least followable. So I think a lot about how to listen to it as an album, like in the car or something without seeing me perform.

Jacob: When you say text-driven, are they your own lyrics or are they setting of other words to your music?

Molly: Yeah they're my own lyrics. I actually started with this song cycle I wrote for a Dutch group where they commissioned three composers to write on some sort of social evolution. So of course I wrote on the human body, and I just decided to write my own lyrics because they didn't want to deal with anything that wasn't public domain, and I was at grad school and probably inspired by my teacher David Lang who always writes his own lyrics. And I guess I was really influenced

by, because I had done my initial Disability Studies work, so I had all this text that I had written already in more formal format – so I just used a lot of those words. And after that song cycle, I just did that with more of my songs.

Jacob: Anything else you'd like to mention before we finish?

Molly: I realised I forgot to mention – and this is more of a long term goal – that I'm setting up a non-profit to support artists with disabilities, or at least starting with physical disabilities. That's all I wanted to say ... I feel like that's a future project with disability. Slowly but surely, it's such a long term project. At least right now while I'm travelling I don't want to do anything big, I feel like it will be better when I'm settled somewhere. But I think the first step is maybe presenting a program somewhere featuring artists, maybe just starting with physical disabilities but like from a couple of genres, visual art, drama, dance, theatre, music, maybe in one evening. Just to start with something like and then seeing how it goes. Just building the stepping stones slowly rather than establishing a whole organisation. And then just trying to meet people like you wherever I travel and just trying to set up the relationships and everything for the future. But we'll see!

3.3 JOHN KELLY

John Kelly is a musician and disability rights campaigner based in the UK. We first met at a 'hackmeet' for disabled musicians and technologists organised by *DMLab*, the research and design programme run by *Drake Music*[3], an organisation specialising in accessible music technology. John is perhaps best known for his performance of Ian Dury's disability rights protest song *'Spasticus Autisticus'* at the London 2012 Paralympic games opening ceremony. He has also performed Dury's music in *'Reasons to be Cheerful'*, a musical production produced by *Graeae* theatre company[4].

John designed the *Kellycaster*[5], a bespoke accessible guitar-based DMI, along with Gawain Hewitt and Charles Matthews, in a collaborative project supported by Drake Music. He currently uses the Kellycaster as well as other instruments in his practice as a performing musician.

3 https://www.drakemusic.org/
4 https://graeae.org/
5 http://www.drakemusic.org/our-work/research-development/artist-led-projects/john-kelly-the-kellycaster/

Figure 3.2: John Kelly performing with the Kellycaster at Graeae theatre. (image credit http://cdm.link)

This interview was recorded with John over Skype in June 2019. The transcription presents the interview in full, with minor edits for readability and clarity.

Jacob: So, where I'd like to begin is maybe just to get an overview of you as a musician, so we could go chronologically, or whatever you think is most relevant, how you got into playing music, and how your career has taken this route

John: I always relate right back to childhood in terms of my upbringing being really important to my introduction to music. My family are Irish, music was everywhere in the house, there was always vinyl everywhere and cassettes and that kind of stuff. And when mum and dad came over from Ireland to England, Irish radio was always really important, and I know it shows my age a little bit but I always remember on a Sunday tuning into the Irish radio station and trying to get a signal – you know the classic of the old days where you had an aerial and, my mum or dad would stand on the sofa to try and get a good signal. I remember any time there was an Irish artist that had a record out, mum and dad would head to the Irish shop and buy it and that would get played to death in the house. Mum and dad weren't musicians, but I've got one uncle who's a really famous

accordion player, and he played in an old Irish show band. But my mum had a beautiful voice and was always singing, so mum and dad loved music, so therefore I loved music. What I'm really saying is that my parents weren't musicians but it was culturally very important to us.

I went to a special school, which gave me a sort of certain experience of education. And that was quite interesting because I was at a special school at a time where the curriculum wasn't really that important. And the education act that was around at the time was kind of only just starting to say disabled people could learn and follow a curriculum. Until then it was just kind of quite an arbitrary school education.

Jacob: What kind of thing was on the curriculum?

John: It was all the usual stuff, but I don't know how they judged whether or not we did exams etc. The idea of special educational needs came about while I was at school. That was really new and my school was one of these sort of guinea pigs around educating disabled kids because we were a specialist school. What I learned was that it really split the teachers down the middle which was quite interesting. In terms of learning theory, there were quite big theories around the purpose of education, is it about happiness, or is it about learning skills, or preparing you for adult life or whatever, and all that was getting played out in my school really. I can't remember what the exact approaches where, but there were the sort of teachers who just wanted to have happy lessons and give us a good time and then there were the more theoretical teachers who wanted to give us a progressive education.

And therapy was big – our medical kind of baggage was more important than the curriculum really. We were pulled out of class a lot for therapy, and stretching and walking, and all that kind of stuff. So learning was quite difficult because it was always quite disruptive. And then you had mixtures of teachers who were quite relaxed and lessons were fun and enjoyable, and then some teachers were strict, so you were all a bit all over the place really. I actually loved my school, I really did enjoy it, even though in later years I realised the impact it had on my learning, I was disappointed I hadn't learned more, and even now I'm nervous about my grammar and my writing skills, even though I came out OK. And musically I think they probably could have pushed me. We didn't get an option to do music exams – it was a very basic curriculum.

Jacob: Was music part of your school experience at all?

John: I remember having a really good music teacher who just loved music and she was always writing songs. And so she taught me the basics, but I didn't have to learn to read music, so I didn't as I was really good at listening by ear. And she was really good at realising what I could do, and let me get away with it really. She was quite big in the school because she started introducing school shows and stuff like that, and that was quite a big move for our school. And I was always involved in those, she realised I could sing, and I remember at age eight or nine I was always singing and she always pulling me out for different things to go and sing at the old peoples home or, those sorts of things. So I was performing from then on really. And mum and dad were delighted with that because they wanted me singing. I would sing in the pub and stuff, Irish traditional sessions on a Sunday afternoon, I dunno if you know about Irish culture but everyone has a song, everyone has their song. Every town and village has a song about that place, one of my grandad's songs was Shanagolden because he came from that area so he would always sing that, or it would be a song that people could sing well and they knew the whole song. So I used to sing little ditties, or whatever they were at the time.

And there was a guy who was a helper at the school who'd play guitar and me and him used to jam. And I don't think they made money out of us but we used to travel around and do all these little shows, so I was gigging from quite early on really, and singing. We didn't have any music technology, it was all acoustic instruments, upright piano, little bits of percussion, there was an acoustic guitar and I started trying to pick strings and learn the notes. But that was more my inquiry rather than my teacher saying you have to learn it, it was more me going 'why'd you play two strings like that?'. And I would spend all the break times either playing football or trying to spread my hand across two or three notes to try and get a chord. So I was really lucky that I had a teacher that would let me experiment and was giving me loads of songs to learn. We had a really rubbish band, that was just horrendous! Just three or four of us who all kind of liked music and we tried to play together but couldn't really! It was good fun. But yeah I did all the school shows and each year my performances would get bigger and grander. And then before I left school, I got involved with youth clubs quite a lot, and I met with people outside who were also just starting to get guitars and that and

obviously I was alright at singing so, and we were all mates in the youth club so I kind of plucked up and said I'd be up for it and we started up a little band. We did really well actually, we got a little band together and then we just started playing in the youth clubs, and there used to be these camps and things and we'd play at them, just covers really. And then we got a bit tired of doing *Stand by Me*, and we were into punk and ska and all that and we just wanted to write our own songs.

Jacob: When was this?

John: So that would be, early '80s, mid '80s. So I was too young for punk in some ways, but it resonated for a long period of time after. It was still around for us, and ska and punk were big in my childhood, like Madness and the Specials, and obviously Ian Dury and the Blockheads, Sex Pistols and the Clash. I found the Pogues in the mid '80s and was like 'oh my god there's Irish punk!', and the Undertones and Stiff Little Fingers, so I kind of identified with all that lot. So by the age of 16 to my early 20s, I was gigging a lot, and we were playing all round the place, and we travelled quite a bit, learning how to work with a crowd that didn't want to listen! And I'd written a couple of songs, so we went from being a covers band called the Electrics, to being a band that did our own stuff and we called ourselves Another Dead Rabbit, and that was because we did a gig in the New Forest, and on our way home all we could see was dead rabbits on the road, and so we called ourselves Another Dead Rabbit – we had a great logo, like a bugs bunny in a leather jacket and jeans on a stretcher with the paw hanging down and "ADR" was underneath the stretcher, it was a great logo.

I don't know why I'm telling you all this, but there's something in it that's really important about me learning my craft. We got quite successful and started doing pub gigs. There was a pub in Aldershot that had a back room that they stored the beer in, and we said if we clear it out can we use it as a rehearsal space because we can't afford rehearsal room, and the landlord said 'give us a gig every few months and the rooms yours'. So we said 'alright game on'. We'd sleep in the car over the weekend – this was before access was important! – and we had this house to rehearse in for free. So every Friday night til Sunday we'd just rehearse and write and then once every couple of months we'd have a gig in that pub. It was brilliant, we loved it.

I remember it being quite an important learning period, around writing. I wrote a load, and some of it was good and some of it was rubbish, but we had quite a lot

of interest. There was a circuit at the time that bands played, and you knew there were going to be people from record companies in the audience, so we tried to get on that a little bit, and that's where I first realised most venues I couldn't get in, but I didn't mind getting carried in those days, so I was just like another speaker, I'd just get lugged in everywhere. I gigged loads, just for that period of time. And people paid to come and see me play, it was crazy!

Round about that time, my mum got ill, she got cancer for the first time. And I sort of realised I had to stand on my own two feet a bit, in terms of my independence. I had the music, and I was a youth worker, so I was doing music in my youth work a lot. And that sort of, rather than playing, that overtook my musical interests, I was just helping put gigs on, or using music to run workshops to engage young people.

Jacob: So you were putting on gigs with young people performing?

John: Yeah or running workshops, like drum workshops teaching rhythm, or I might organise gigs and put people into bands. I would DJ a bit and would bring my decks and show people how to do that. So I was more and more into youth work and less into performing at that point, because I had to earn money, and I wasn't earning so much from the band. So I suppose I got more professionally involved as a youth worker and learning about good youth work, and I got involved in learning and training because the youth workers were asking me if I could do some training with other staff. And I didn't really know how to do that, so I went on a massive learning curve around how to run workshops and facilitate, and getting qualified, because I came out of school with just a few CSEs.

Jacob: What were the young people like that you were working with?

John: A real mix. I suppose without knowing it there were probably kids that were excluded. I'd get to know their stories and get to know them but it wasn't as conscious as saying like 'right I'm gonna work with a group of excluded young people' or whatever, I would just work with whoever turned up.

Jacob: I guess I'm not really familiar with the term youth work...

John: Sorry I'm probably jumping round a bit, but a lot of my values around

the way in which people learn is to do with my own learning journey. Youth work is an approach which is about how you respect young people and you don't put them down as trouble makers but you see them as in a period of their life where they're trying to make sense of who they are and where they are in life, and if you try and take a positive approach with them, rather than say *'you've got to abide by adult's rules'*, then people who find it difficult to follow rules might be more open and more positive I suppose. So youth work was really important. What's important is there's a real validity in different ways of learning, you can learn formally, you can do academic stuff, and I didn't do academic stuff because I wasn't given that opportunity, and these people didn't do it because they didn't really fit in, so there was some sort of connection there. And the youth workers said actually informal learning can still make people rounded and good citizens and good people, and you find they can be very good at learning, but just not academic. So that kind of whole idea about informal learning was really important to me, because it was a way of me thinking, because school was so exclusive – and disabled and non-disabled people were hardly ever together in formal or informal education – there was this opportunity to come together on equal terms. Which is part of my rally now really. So I was starting to learn about inclusion and exclusion, and when people are excluded, what you need to do in order to change things. I was using music as a tool, and I was also getting encouraged to run workshops and talk about change and how you make it happen, how you develop programs to do all that. And what I know how to do is really write songs and do it that way, and I made a career out of it. I did a course at Goldsmiths on, for want of a better word it was adult learning, it was an MA level certificate in training. Which was all about how you develop learning programs and education programs outside formal education. And I've got into senior management and started managing teams that were delivering youth work, inclusive youth work, projects, holidays, lots of music projects. And then I was then asked to become a senior manager in an arts project called the Orpheus centre, which still exists. It was using performing arts with young disabled people to build their confidence around living independently. Around that time I also became a bit political, and I started going on demonstrations, and direct action, because the stuff that was frustrating me was lack of transport, and all the things we know about disabled people now, like lack of access to buildings. Even back in that day it was even worse, we didn't have any transport, buses were inaccessible, and so I went on a lot of direct action, that was late '80s, to mid '90s.

Jacob: So this was the height of disability rights activism?

John: Yeah and I got involved with that lot, and loved it really. My first real protest, they were talking about bringing in the Disability Discrimination Act. I went on a training course doing some disability equality training, and I heard that disabled people weren't happy with it and I couldn't understand why. So I started listening to a few people talk, and they explained that it was so wishy-washy, and it wasn't really about rights it was about just very piecemeal kind of stuff. The government at the time wanted it to be about education and awareness, rather than a heavy bit of legislation that would radically change things. The British disability movement were learning a lot from other issues, so we learned a lot from the black movement, the women's movement, the American civil rights movement and direct action. And they were saying that our legislation was going to be... actually what it still is today, which is very reliant on the individual, and not very well enforced. And we saw that coming back in the '90s, and it's still true today really. So I got involved with all that, and then I started writing political songs, and I wrote one of my most popular, successful songs then, which was 'Battle of Whitehall', and I wrote that in 1995 about the DDA. I wrote it the day it came into legislation. So my professional career and music were always really intertwined, I got more into disability issues, and you know the things we talk about now, we were talking about back then really. The change has been gradual and slow, and we all know that's the case, and it's a really long battle. So I've been in it for the long game. I remember doing a conference in Russia, we did this massive conference, and we booked hundreds of disabled people together for a festival of celebrating disabled people, because they were being told they should be put down. It was quite a bold radical thing – that was around 1992.

The Disability Arts movement was really vibrant. I wasn't that involved in it funnily enough as a musician. I just always looked up at all the others, like Ian Stanton, Johnny Crescendo, Barbara Lisicki, Nabil Shaban. All these legends who now I've got to know a bit better, but I always looked up to them. I was a bit young, I was in my '20s so I didn't really feel confident enough. But I was always involved in it all, going round doing access audits and learning my craft. The Social Model was only just coming about. Mike Oliver had only penned the phrase in 1986, so I remember learning about it in the early '90s. It changed my view on myself, it

changed the way I work, it changed all sorts of things but going through it all was still the music and my band and that sort of stuff.

And then 10 years ago I got a lucky break when Jenny Sealey at Graeae, who I always used to talk about a lot when I ran training, because I always used to say that Disability Arts was a really good way in for people to understand disability issues, you know going to see a bit of disability theatre or listen to an artist because it's a really good way to appreciate what's going on in disabled people's lives. I've always valued and believed that music and art is a much better way of changing people's attitudes than beating them over the head with a placard, although both have their place and sometimes you have to do both. And then I got a lucky break doing 'Reasons to be Cheerful'. So I went self employed, wrote a little resource pack for UK Youth, was doing lots of national stuff, and then Jenny said *'come and do some singing, we'll pay you for a couple of days'* and I thought *'blimey I'm living the dream'*. And when they asked if I wanted to come on tour, I suddenly realised that music was my bigger earner, I was no longer doing youth work and informal education, it was nearly all music and not very much of the other stuff. And so the last ten years I've been a professional musician, gigging and playing all over the world as you know!

Jacob: So was 'Reasons to be Cheerful', was that your first engagement with Graeae?

John: Formally yeah, I'd known of them and gone to see them. I'd known about a piece of work and I'd got young people that I worked with involved – I'd signpost them to Graeae. Because I've always held them up as something I'd really admired. But 'Reasons to be Cheerful' was my first engagement directly with them.

Jacob: I wanted to talk a bit about musical instruments and how they fit into your musical career...

John: I suppose all I've told you is relevant to the way my practice has always been about having a lot of encouragement, and having a real openness that people, if they really want to do something, they will find a way. Because that's what happened to me really. I always said when I was at Orpheus working with young people then, I had the best job in the world because I used to say to young people what is it you want to do, and my job is to say yes you can do it, let's just work

out how. And that's my attitude towards musical instruments. A lot of people get put off by formal musical education because they don't think they're good enough to do it, or they can't do it the perceived way you're meant to do it, and I knew right from the beginning that I was never going to be able to do that, so I got rid of that bag a long time ago. I knew that I was alright at music because of the reaction that the audience would give, I was being invited to do gigs and stuff. So I knew I was doing something that was alright, because if I was rubbish at it, people would pretty quickly tell me. And they did – if we were crap we were told! But actually what was really important was having positive messages and encouragement. And my attitude towards other disabled people was, have an expectation and an aspiration. I never saw disability as being about 'ability', because I thought that's really patronising. A lot of ideas about 'proving that you've got an ability' – it just smacks of tokenism, and inequality rather than equality. Because what I think disability is really about is not being able to reach your potential because of prejudice and attitudes, and lack of access. So I think to say, 'all disabled people have got ability' is quite patronising. Because, without wanting to use a cliché, everyone has got ability, disabled or not. I work with a lot of non-disabled kids who were excluded from school, because they were fighting or mucking about or not learning, and people saying they're never going to get a job and stuff, who are now very successful. And that was down to people like me believing in them, that they weren't trouble makers or stupid or whatever the teacher would call them, it was just that they needed to experience learning in a different way. And so I take that to my music technology in the sense that most of the time people I work with kind of know what they want to do, or they might have an idea of *'this is how I can do something, if only it behaved this way*'. And through technology, I've learned that it might take time, but that bit can be addressed.

Fundamentally I think there's still a low expectation in formal education for disabled kids around music. It is still very much about very basic music. There's still not an aspiration that this could actually be a career for someone, or this could be a really important thing that is the key to them learning English or Maths or whatever. You know, all the stuff we know about music, you know that comes up. Music technology doesn't need to be a limiting experience, it needs to be an opening experience that helps somebody reach their potential, or go as far as that person wants to take it.

Jacob: So what you're saying about music education for young disabled people,

how do you think those low expectations relate to the instruments available and music technology resources available?

John: I think there's a real problem with the dominant medical model in special education needs settings. So, a lot of the time, music is seen as therapy, or rehabilitation. It was in my school, they probably thought that me playing the piano is good for my hands, it's better than exercise or whatever. And no doubt there is an element of truth in that: what I'm not saying is that there isn't a role for therapy and rehabilitation, I'm not denying that those can be powerful tools, but the problem is that they're such dominant forces within education, that it limits the potential of music to be seen as music, rather than therapy. And because it's so dominant, we're only just starting to create a discourse about music technology which is actually capable of fulfilling disabled people's potential as artists or musicians or young people with things to express which aren't about therapy or whatever. They're just for the appreciation of music, for itself. For the good that it does someone in terms of their culture, identity, self belief, self esteem. Those things I think are really underestimated because of the dominance of the therapy-medical model. And people feel that's a bit threatening, because I'm trying to redirect people away from music therapy as the only route with this. And it's because the dominant group of people are music therapists.

Jacob: Within education?

John: Yeah, I think ... there is a change, and it's gradual and slow and small. And I think the discourse that we are having is more around community music and engagement with young people as young people. The whole medical model is about doing things *to* and it being good *for* the person, and that isn't self-discovered, that's imposed. And I think the kind of stuff that we're doing now that's really exciting is an individual being really motivated into wanting to make music, or get stuff out their minds or thoughts and wanting to express it in the form of music, and using technology as a tool to do that.

So I've come to realise that my Kellycaster, my guitar, I do play it as a guitar. But I think I've probably got quite a distinct style and way of playing I don't play it like a traditional guitar player, because I've learned it a different way. And actually when you really study guitar you realise that's true of every guitar player. I haven't come to it from an instrument maker's perspective, or even a technologist's per-

spective, all these things I've learned by accident as I've gone along. My whole life has been accidental learning really! I suppose the learning theory behind it is experimental learning. It's through what I've experienced in my life and making sense of it and critical reflection.

I think music technology is a really exciting thing. Somebody was asking me about what's the point of music technology replicating a traditional instrument, and I'd never really thought about that. And it's not really something I could get into, or I'm not trying to to, I do want the Kellycaster to sound good and work with a band. Because as an artist, you know I never want to be involved in something that's crap! I want to always try and make things that are good. And I always feel like the Kellycaster's always going to get tweaked, there's always things I'll want to do with it that I can't currently do, and that's just my personal drive, what makes me me. And there are people who just want to, who love music who just want to have instant gratification, and why shouldn't they? That's great. I think people should enjoy music for whatever they want, and however far they want to take it. So I think any instrument or any development is contextual.

So I'm definitely up for collaboration and I'm definitely up for self discovery, and a sort of collaborative model which is about ... it's definitely not about doing things *to* or *for* people, but working together in a sort of respectful shared values, shared understanding, shared goals kind of way. And sometimes you learn things that are valuable to others, so sharing it and not being so protective about it, being open to sharing. I haven't really got a view about how other people might ... there isn't *'this is the Kellycaster and that's how it's got to be and that's how it should be all the way'*. And I think it can be more accessible, but I've played it now with lots of people with different kinds of needs, and they've loved just being able to do something and make it sound nice, a bit like finding GarageBand for the first time and realising you can make a tune quite quickly. But actually then realising you've got to work really hard if you want to play it as a tool for performance or something you know.

Jacob: So one thing I've been thinking about recently is the idea of constraint in musical instrument design. I think with the case of Strummi, the fact that it's limited to eight chords, is obviously quite constraining, and the Kellycaster compared with the guitar, has certain constraints in the sense that it's, correct me if I'm wrong, but I'd see it as a chord by chord instrument rather than note-by-note instrument ...

John: Yeah I'm just actually starting to play around with that. It started very much as I wanted to be able to play chords. Going back to the Irish thing, just being able to play a folk song on an acoustic guitar and sing and strum along to it was what I wanted to do, but actually the technique of picking and picking out one or two strings through the strum, and then with the extensions realising what they do, started me realising that actually that changes the note on that string, so where that's taken me is in terms of little riffs. So although I would agree on that it's not particularly useful instrument currently to play a melody, I'm certainly playing riffs with it. I'll give you an example of one of the songs I've explored, is Billy Bragg's 'Between the Wars'. There's a really nice riff in the break of each verse. And I wanted to be able to do that, and I realised it was just part of an augmented chord, so I wiped the chord bit and just kept the augmented bit of the chord that I needed, and picked the strings, and so I've got the riff. And then I jump between, I write the augmented bit over three of the chords, and then the chord will be on the fourth note, so the riff will be 1,2,3, chord 4.

Jacob: When you were first developing the Kellycaster, was that something you were hoping to do with it, or has that goal developed as you've played it more?

John: All I knew was that the limitations of GarageBand was that the chords were locked in. And for certain blues songs or Irish songs, they detune the E string. So I knew that I wanted to be able to do that, it's mainly to do with my repertoire, there's one song called 'The Green and Red of Mayo' that I do, it's got two strings in it that stay all the way through the song like a drone. Very gaelic, droney sort of thing. I knew that I needed to be able to unlock the chords, which is where the chord chart thing came from. Charles said you can just re-write the numbers and that'll give you the chord change that you want. And I knew that I wanted to be able to hammer on and off like the rock n roll twelve bar blues thing, I knew that before the Kellycaster came into existence, and I didn't know the theory of it until recently until I understand what a locked in chord meant and what I needed to do to change it. So, to say, the thing you're talking about constraints. My immediate gut reaction is I'm totally with you, that I don't like constraints, as soon as you know there's that limitation, it puts you off it. And at the moment, there's always been a way round it with the Kellycaster. I'm not saying I'm going to do a Slash solo, or a complete blues solo, but I am starting to do little riffs and little embel-

lishments. Like the classic 'Johnny B. Goode' little riff in the middle of a verse, those kind of things I can see quite quickly I'm gonna be able to do once I can work out the numbers, so that constraint isn't there. And I can sort of see some slow riffs that are like ... thinking of a few songs, like there's a few four note riffs, like 'Sweet Child O' Mine' that's only four notes, so that's really easy to replicate on the Kellycaster. And before long that could easily be a bit of a solo.

Jacob: I think the reason I was interested in constraints, is because a lot of instruments that are presented as accessible, usually their accessibility lies in the fact that the pitch space or note space, or number of controls, is itself constrained. So for example the Soundbeam has this kind of monophonic thing. The way that you play it is obviously hugely accessible because it's gestural and possible to calibrate for a particular range of movement which is obviously really powerful. But then often the notes themselves are constrained to a particular scale. There's not a lot of opportunities for playing the wrong notes, or that kind of thing. And it's something I've talked with Charles a bit because I think he has some quite different ideas to me about when constraint is a good thing, especially in terms of limiting the pitch space. And what's interesting to me is hearing about you coming up against the constraints that you had with the Kellycaster as it first was and then developing your own method of coming around those constraints.

John: Yeah, at the moment, one constraint of the Kellycaster is that there's only ten chord changes at the moment. The majority of stuff that I play is fine, I get up to about eight or nine in most standard songs. At one level you can get away with three chords for a song, we all know that, and it's not until you want to take it further that you put more embellishments in. But one of the constraints is that I've got ten chords at the moment, and I said to Charles when it becomes a real issue and I've got 20 chords, then what I just need to be able to do, is have a very quick way of being able to bank them, so I can hit bank 1 and then bank 2 and I've got another 10 chords. So I've already got a way around it in my head. Or we could just write into the program and put another 10 in. So I don't fully see the constraints that you see in the Soundbeam, because I think you could write a scale that was the one you wanted, you could write a chromatic scale and pick out the notes, if you wanted.

Jacob: You're totally right. I think basically why I'm interested in it is that the

people that design the instruments tend to decide where the constraints go in, and what's interesting in the Kellycaster is that because you've designed it, you've arrived at the constraints that are appropriate for the music you want to play. And then also found ways of getting around those once you've realised you've wanted to play riffs on it as well. And I think with the Soundbeam and the Skoog and other accessible instruments, it's not as clear that the constraints have been placed as a result of where the user intends them to be but rather that they're being placed there based on a set idea of what should be played with it, if that makes sense?

John: Yeah, I mean I always said to Gawain, before the Kellycaster, and we were just reviewing the stuff that's out there, that with some of them the constraints are quite arbitrary and they're put in funny places where actually it would be really lovely, for me, some of the common things are about, well I use one finger, so being able to have sticky finger so you can press it and it holds while you press something else, or where you can adjust the velocity and lock it. So I really love Thumbjam[6], because it was quite a mainstream bit of kit but it had quite a lot of scope to go under the dashboard and change stuff. A lot of what you want to be able to do, it had it open so you could change it. You could change how much pitch bend, how much sustain, you could adjust whether it was a glided note, or full note, or a chord. I used to say it was about having as much control over the parameters of an instrument, that makes it more accessible. And making sure you can get to them accessibly. I mean most keyboards really frustrate me, because you have to hold down a mode button and then press or turn a knob and then let go and the memory stays there. And if it had the sticky finger thing, so if you just held the mode down and then it remembers that that sticks there while you turn a knob, it immediately becomes accessible again. And that sort of constraint is really frustrating. It's really limiting and frustrating, because I think people don't think somebody might need that in the future. I think, in honesty, the constraints in the Kellycaster are probably more to do with my lack of knowledge rather than anything else because it's doing most of the things I've wanted to do with my kind of music. And my kind of music isn't that complex or avant-garde, it's pretty straightforward effective music for me. And where I've come from, it's rooted in my style of music and how I perform. I'm against that kind of elite constraint, *'well someone doing this is only ever going to be allowed to do it this way because that's how it*

6 https://thumbjam.com/

works'. That sort of way of designing needs to be ripped up.

Jacob: I agree. So one of the things I'm really interested in about your performance practice and the Kellycaster, is, why the Kellycaster, and not the Thumbjam? What's the difference between those two instruments?

John: Well with Thumbjam there are limitations. Going way back in the '80s and '90s, I learned about sequencing and accompaniments, like with keyboards with decent presets, and being able to play them with a single finger, play songs with people and make songs up using presets, and getting them better and better sounding. And structures of songs, so that's how I played. And I was good at that and successful at that.

Jacob: Did that shape the music you made with them?

John: Definitely. It was quite limiting, but I could still play a lot of the songs that I wanted to sing. But you'd be sort of locked in to timings, and everyone else had to be tight, and you needed to be really well rehearsed to play together like that. It was harder to jam along or for me to pick up something by ear. It needed a certain amount of preparation. The Kellycaster responds almost immediately, and I've got very quick at being able to roughly get the chords in the right place, and to jam along with someone. As soon as I know what key it's in I'm fine. And then I can play at the pace somebody's playing rather than have to work out what tempo. A lot of the feel of it was just about having the strings so I could feel where I was and not look at it. And I don't look at my left hand when I'm playing the piano, so I wanted to keep hold of that. And Thumbjam still didn't quite – it still has some good sounds, like I would probably use a little harmonica or something on it. But I've just got a Magic Flute[7], and I'm gonna play a harmonica through that I think. The Kellycaster was just about being a bit more responsive, a bit quicker but also being quite simple so that I could just jam along with others and I could write my own stuff. And it was off the back of the limitations of GarageBand and Thumbjam and single finger chords and sequencers. I wanted to hold and play a guitar, and I could, but it was limited because of the way open chords work. So I knew I could do it, and I wanted to play guitar, so I needed it to be a bit more like a guitar, but to be able to change the left hand the way I play Thumbjam,

7 http://housemate.ie/magic-flute/

GarageBand and a keyboard all combined. And there was nothing like it.

Jacob: Am I right in thinking that you played with the Jamstik[8] at some point?

John: Yeah I still do and use it a lot.

Jacob: What are your thoughts on it as an instrument?

John: It works really well with the Kellycaster software. My biggest issue with it is that it doesn't have the string detection that the Kellycaster has.

Jacob: Like for muting notes?

John: Yeah that sort of stuff. But there are ways around that as well, so I had to learn that. For me, the batteries are the biggest issue on the Jamstick. I run the battery out. As a professional artist, I work all day. If I'm on a roll, I can be 8 to 12 hours writing and jamming, and the battery goes flat and I have to wait. But I worry about playing the Kellycaster all the time and damaging it. So that's my special gig guitar, and the Jamstick is my rehearsal guitar. It's good enough to rehearse with. But then as I get closer to the gig and I know the setlist, professionally I will always do the last couple of rehearsals just with the Kellycaster, so that it's up to gig quality. I learned from Graeae that it's really important to do your last rehearsal exactly as the gig is, ideally in the space. Because that's the challenge for me, with the Kellycaster, is that to play it well the environment and conditions around me need to be really good. I need the time to set it up, soundcheck, run some songs through, and be ready to gig with it. That's the ultimate goal. But I have quite quickly got into a pub and set up within 15 minutes and jammed and it's been alright. But I realise for me to play it, like when I was with Extroordinary Bodies, that was the first time I've toured with the Kellycaster professionally, I need a good one or two hours on the stage setting it up, fiddling about, making sure it's all ready. And all that's from working with Graeae – I never forget having a four hour soundcheck, and I thought 'this is extravagant'. But people expect when they go to see a show that it's all right, and that's why the Kellycaster's really important that it's robust and it works. And it does work really well, even when there's a problem with it, there are workarounds and it is really reliable.

8 https://jamstik.com/

Charles has done an amazing job to make it so that there aren't those constraints, and there's flexibility to change things. And any time I've chucked something at him or I've said *'look I know I can do this because I've done it accidentally'*, and we've retraced it. And we've just been a bit of a team on it and worked out how to redo it. And it's lucky that we have those same shared values about making something good and quality.

Jacob: An idea I've come across recently is the idea of 'affirmation' and 'assimilation' in Disability Arts, how some disabled artists might want their art to be taken in its own right without reference to disability, whereas other disabled artists might produce art that is very affirmative of their disability identity. I was wondering what your thoughts are on that, and where maybe your practice as a musician, especially with the tools that you use, helps to either affirm your disability status, or otherwise produce art that isn't necessarily related to being disabled, if that makes sense?

John: I think the either/or, seeing as one or the other is quite limiting.

Jacob: Yeah what I meant to say is there's kind of a spectrum between the two.

John: Yeah I agree with that, and I think they're both really important and I flit between the two, but try and stay in the middle, haha! I do pub and club gigs to mainstream audiences that aren't disability or equality aware, or they don't necessarily know what's going on in the lives of disabled people, they're there to hear good music. So I have to be a good artist and a good musician and be able to work the crowd and play songs that they're going to like. And I believe my material which is about my experience as a disabled person works well, and works with those audiences, and they often will relate later on. So I don't hide either, they clearly see I'm a disabled person on stage, I don't hide my disability politics, and I'll bring that to everything I do, because it's silly to hide it. I do gigs that are just gigs, but I also do political gigs, which are totally affirmative of being a vocal loud disabled proud artist. And they're about inflaming disabled people into action. I don't agree with the model of empowerment, because empowerment suggests that I'm giving someone power, and I think that's problematic. I believe everyone's got the power within themselves and it often goes back to that 'potential' thing, about how people either have so much power taken away from them that they don't

realise they've got it, or the right to have a view or opinion, or that they're scared to use it.

I love gigs that are just disability pride, about 'this is who we are, and this song is all about us', celebrate us. I think it's problematic for anyone to say we should either be affirmative, or we should try and assimilate. I think both are important that there's platforms for both as well. And I think that's where there's a dilemma because we haven't got enough platforms, so they're either one or the other at the moment, and they're both limited and we just need more platforms. Because ultimately people should be able to make a choice, and there isn't enough choice. I can't really make a living as purely someone who works in the affirmative model, there aren't enough gigs for me just to work with disabled people as an artist. The problem with assimilation is the idea of fitting in. And I'm never going to fit in to the extent that I would deny where I'm from or what I'm singing about. I think they're both really important, and both artists and audience should have a lot more choice where they want to be on that spectrum, but for me as an individual artist, I think I'm somewhere in the middle. Definitely, I value the affirmative stuff because it is critical when we're being denied and oppressed so much. I really love those kind of gigs where it is just a disability pride gig because you can just cut through all the crap really. Whereas a more 'assimilated' gig you've got to think about it a bit more, but I'd still do it, even if I'm playing a pub gig, I'll do 'Battle of Whitehall' and I'll tell people what it's about, because I think it's a good song and people will get into it and identify with it. But I'll also sing another song that's about whatever, not to do with disability, in both kinds of gigs.

Jacob: How do the tools that you use like the Kellycaster and other technology relate to your approach to assimilation or affirmation – or are they separate from that?

John: Well I sort of branded the Kellycaster with the little logo, 'this machine kills oppression', taken after Woody Guthrie's 'this machine kills fascism'. So I think there's a real symbolic thing about the Kellycaster being part of a movement, part of the hacking movement, breaking rules: this is a non-traditional instrument but still an instrument - whether it's a guitar or not I don't care what people think, to me it is. It works and plays and sounds like a guitar so it probably is a guitar! I'm not too bothered in pigeonholing or limiting it, so I think I see it as being a bit of accessible music technology, but I also see it as being a good bit of music

technology. It's good for anybody who's interested in music, and I also think in terms of my style, as an artist, my way of performing, it's starting to fit in the way I perform and interact with the audience. I love sort of noodling and talking at the same time as I get into a song, and when I look at it, and go *'why do I do that, plinking and plonking while I'm talking?'*, and I realise that every Irish artist that I love does it, you know bands are always tuning up while they're talking to make sure it's in the right key or whatever. And I'm just replicating what I think I've taken on board from other artists.

Jacob: That's really interesting, the idea of the noodling between songs as an important feature of an instrument.

John: Yeah, and just feeling comfortable. What's really good about it is the way that when we rehearse I can do that, or equally go straight into the next song with no noodling. I think I've got a style of playing that's unique to me. It was really interesting, the one criticism I've had, and it's not necessarily negative, it's helpful, is when I was doing reasons to be cheerful, we played around with me playing the Kellycaster on 'If It Can't Be Right Then It Must Be Wrong'. It's a bit of a rabble rouser, and originally I played it on the Kellycaster. And Jenny wanted me to be able to move around and engage with different sides of the audience, and she felt I was kind of locked behind the guitar. And for that particular song, she needed me to be breaking down the fourth wall between the artist and the audience, and she felt that having the Kellycaster at that moment was almost building a wall. We were trying to get the audience up on their feet, and for them to deal with me playing guitar as well, there was too much for them to take on board. And I'm starting to think about how I sit so that I'm not completely behind a screen, so people can see that I'm playing strings and singing and welcoming them in, so they feel they can get close to me. Although the Kellycaster is precious to me, I like other people to try it and play it, have a go with it. There's an element of risk in that, but I really like that - it's very precious and changed my life definitely, but I like being able to say 'actually it's just a guitar and you could play it'. And that's very much what I'm about as an artist – I don't think I'm the best singer or best guitar player or songwriter, but I'm able to do what I do alright, and sometimes I do it well! And people like it, and I love it. And I'm still waiting for somebody to say get off stage.

3.4 DISCUSSION

In many ways, the experiences of these two musicians do not share many similarities: Joyce's experience as a classically trained musician in the United States is a world apart from Kelly's formative years playing punk music in 1980's England. There is little point in attempting to find similarities or to generalise their experiences for the purpose of identifying specific design approaches for future instruments. The purpose of presenting the full transcript of these interviews is to paint a full and detailed picture of the musical lives of these two musicians. As engineers and designers, we may be most interested in the technical challenges that these musicians overcame in either finding an instrument which suited their physicality, or co-designing one from scratch to their own specifications. However, Molly and John's experiences both before, and after, they began working with their instruments paint a fuller picture of the role of accessible instruments, beyond simply technical descriptors of how they accommodate each person's access needs.

Added further analysis and scaffolding around interview outcomes

So, what are the key takeaways for ADMI designers and researchers? What do Molly and John's experiences tell us that we can employ in our practices? I do not intend to put words in the mouths of my interviewees, but here I will offer my own interpretation of some of the key topics discussed in these interviews, which relate specifically to ADMI design practices.

1. A musicians' choice of instrument and performance practice is both a product of their physical access needs, as well as their individual artistic and personal values.

For Joyce, performing with an instrument not regarded as mainstream allows her to *'meet [her] body on its own level, and even kind of challenge it'* – it doesn't require her to meet pre-existing performance expectations associated with more mainstream instruments, and inspires her to push her technique and develop ways of incorporating her impaired limb as both a visible and audible component of her practice. The toy organ, in many ways, could be seen as an active rejection of the norms of Western classical music - Bontempi organs were never designed to be performed with in concert halls, but used in amateur settings in the home. The presence of this instrument in the musical world in which Joyce works could be seen as a direct challenge to the assumptions and expectations of this culture.

For Kelly, the Kellycaster is a pragmatic tool for overcoming the limitations of readily available software such as GarageBand, but also represents his philosophy towards music and learning: the highly collaborative nature of the co-design process, and his openness to future modifications and adaptations reflect his approach to learning and inclusion. Kelly's assertion that *'this machine kills oppression'* reflects the deeply political motivations behind the Kellycaster, and the kind of music he makes with it.

2. In order to understand the effectiveness of an accessible instrument, we need to see how it is lived with and used in practice.

This point has direct implications for the way that ADMIs are evaluated and discussed in academic literature. ADMIs, as with any musical instrument, take on a life of their own when they are incorporated into a performance practice - often being reappropriated, mis-used and modified. This rich relationship between performer and instrument cannot be fully understood through short-term user studies. By limiting the time and scope in which we evaluate an instrument, we risk missing out on the important socio-cultural factors that determine an instruments' success.

A relevant point here is Joyce's early experience with playing musical instruments shortly after acquiring her impairment at a young age. Joyce describes how she was encouraged to play the cello and trumpet, and in the case of the cello, using a modified bow and performing 'backwards' by holding the bow in her left hand and fingering with the right. She cites her shyness at that age and *'not wanting to stand out'* as a contributing factor to her choosing not to continue with the cello. Her decision appears to be as much to do with the social dynamics at play in school ensembles, as with the technical difficulty of re-learning her instrument. It's possible that a user-study based on common music-HCI evaluation techniques may have missed this crucial issue - while the adapted bow and modified playing technique clearly 'worked' in a technical sense, what didn't work for Joyce were the specific social factors in her music-making environment. This suggests that what we might consider 'longitudinal' research falls far short of what is needed to uncover these subtle, emergent interactions.

Looking to the Kellycaster, it is clear that this is a product of a deep and long-term co-design process which is still continuing. As with many musicians, Kelly has developed specific techniques with his instrument that he has only discovered over many performances. An example here being his use of custom chord voicings

to enable melodic lines - a feature not explicitly built into his system, but discovered through experimentation and experience.

3. ADMIs do not always need to be novel designs.

Joyce's use of the toy organ challenges the idea that design interventions are a requirement for overcoming barriers to access. In Joyce's case, an existing instrument provided her with an accessible means of music-making, which also reflected her musical and personal values. Comparing this with Kelly's experiences, I suggest that supporting *discovery* of existing instruments can be as effective as *co-designing* novel or bespoke designs, depending on the access needs and musical goals of the individual. The idea of an accessible instrument being designed without the involvement of a disabled person potentially runs up against the values behind participatory design practices and the 'nothing about us without us' approach of disability-led work. However Joyce's experiences with the toy organ suggest that novelty isn't always a requirement for accommodating a disabled musician's access needs.

I am not making this point to suggest that ADMI designers do not need to consider participatory design or disabled-led practices - these are still vital approaches. However, I do suggest that the way that ADMIs are currently documented and disseminated risks preventing these value moments of discovery of existing instruments. This is a contemporary issue in accessible music technology that has been addressed by the UK organisation Drake Music, who in 2020 announced the Accessible Musical Instrument Collection (AMIC) project. Part of the motivation behind the AMIC is the lack of resources documenting already existing accessible instruments. Even where instruments have already been developed that could be of benefit to disabled musicians, obtaining information on how to acquire them or to try them out is currently a gating factor for many people. This suggests that ADMI designers and researchers have a responsibility to document our projects in a way that extends beyond the boundaries of academia so that other musicians may discover them.

The common thread between the AMIC and participatory design projects, is the preservation of the *agency* of the individual. The takeaway for ADMI designers then is perhaps to avoid taking a prescriptive stance - either through making key design decisions without the involvement of a disabled individual, or deciding who an existing instrument is 'for'. This issue is discussed further by Skuse and Knotts [2020], who argue against 'colonialist' approaches in disability and tech-

nology, which they define as 'an attempt by a dominant group to impose their cultural practices on 'the other' group'.

What is clear from these case studies is that instruments in and of themselves are not the agents of enabling access to music: there are many and varied socio-cultural factors such as attitudes and context, as well as the cultural associations that instruments carry, that influence the ability of an instrument to enable access to musical performance. In the following three chapters, I describe performer studies in which I evaluate new DMI designs, with the goal of understanding how both the physical access affordances of the instrument, and their socio-cultural associations, interact to influence the way that musicians perceive them.

4

ADAPTING THE BASS GUITAR FOR ONE-HANDED PLAYING

4.1 INTRODUCTION

It is a fact often taken for granted that nearly all musical instruments are designed to be played with both hands at all times. Even for instruments on which it is possible to play one-handed, such as keyboards and some wind instruments, existing repertoire generally requires two hands. For many people, including those with upper limb impairments, this requirement is prohibitive to involvement in musical performance.

This chapter presents a system for playing bass guitar without the use of one hand and arm. This project began as a 6-month research and development placement with the OHMI Trust[1], a charity which supports the development of new instruments for musicians with upper-limb impairments, with a goal to *'remove barriers to music-making to enable full and undifferentiated participation in musical life'*. The text in this chapter is primarily reproduced from a previous publication: 'Adapting the Bass Guitar for One-Handed Playing' [Harrison and McPherson, 2017].

We developed a prototype actuated fretting mechanism for bass guitar with a foot-controlled MIDI interface, to allow for one-handed playing. We then evaluated the system through a performance study, gathering video data and subjective responses, in order to assess the viability of such a system for one-handed bass playing. This uncovered more general insights into the role of the plucking and fretting hands in string instrument performances, and could inform the design of future accessible string instruments.

4.1.1 *Research Questions*

This chapter addresses research questions RQ1a and RQ1b, in relation to the bass guitar: *'What role does interaction technique play in an instrument's identity?'* and *'How does interaction technique interact with prior experience of that instrument?'*.

Further to this, I ask the following:

1 https://www.ohmi.org.uk/

1. *What are the most important factors of bass guitar playing, and which hand do they relate to, the plucking hand or fretting hand?*
2. *To what extent can the role of either plucking or fretting hand be replaced using mechanical means?*

4.2 BACKGROUND

The work in this chapter draws on much of the related work on ADMIs and other adapted instruments, discussed in Chapter 2. In particular, this work follows on from previous accessible guitar projects, including the *Kellycaster*[2], the *guitarMasheen* [Meckin and Bryan-Kinns, 2013], and Larsen et al. [2013]'s *Actuated Guitar* (Figure 4.1).

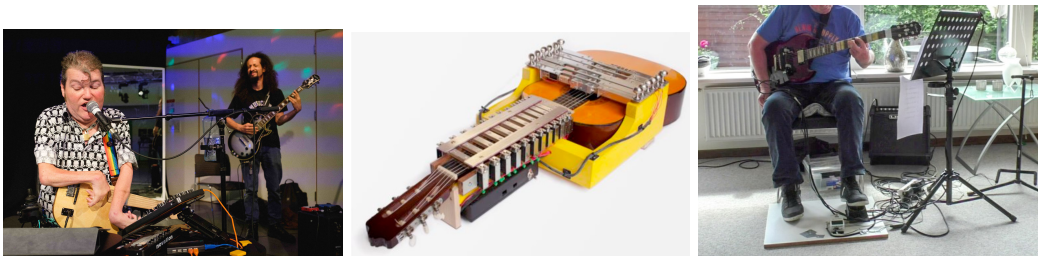


Figure 4.1: Previous guitar-based accessible instruments. L-R: the Kellycaster, guitarMasheen, and actuated guitar.

As well as related instruments, this work was foundational in developing the notion of a *'performance-focused'* accessible instrument. Through observing prior successful adaptations of one-handed instruments in the context of the state of the art of ADMIs, it became clear that the design philosophies amongst accessible instruments are not homogenous, and can be characterised in a number of distinct ways. Specifically, there is a clear difference between those instruments designed to address a specific physical impairment (e.g. upper limb loss or paralysis) via adaptation of an existing instrument design, and other instruments aimed at a broader range of users with mixed abilities and musical tastes. In this Chapter, I attempt to address the requirements for a performance-focused ADMI, as set out in Section 2.3.2. Specifically, I aimed to develop an accessible bass guitar design which could be played without the use of one hand, which replicates both the repertoire and performance characteristics of the bass guitar, and allows for development of virtuosic technique in a performance context.

2 http://www.drakemusic.org/our-work/research-development/artist-led-projects/john-kelly-the-kellycaster/

4.2.1 *Approaches to One-Handed Playing*

In this section, I discuss the subgroup of accessible musical instruments that are designed to be played without the use of one hand. Many recent successful one-handed adaptations have come from work supported by the OHMI Trust.

Some of the most successful one-handed instrument adaptations have been wind instruments. This is largely to do with the fact that both hands tend to play a similar role, i.e. pressing different combinations of buttons to open and close valves, while sound activation is achieved using the mouth. This playing method lends itself to a conceptually straightforward (albeit mechanically challenging) adaptation for one hand, whereby the mapping between valve closure and the buttons is reconfigured for a single hand. Examples of successful one-handed wind instrument adaptations can be found on the OHMI website[3]. Snedeker [2005] also summarises several earlier wind instrument adaptations for one hand or otherwise. For many wind instruments, successful one-handed adaptations have been achieved.

String instruments present a more challenging design problem, due to the fact that both hands perform entirely separate roles. Here we refer to the subset of composite chordophones that feature a fingerboard, and strings which can be shortened in order to affect pitch (i.e. not including variants of the harp, dulcimer or piano, which feature fixed length pre-tuned strings). These instruments require one hand to clamp the string to the fingerboard at a specific location (note selection), and the other to pluck, bow or otherwise excite the string (note activation). These two tasks are fundamental to string playing and expression; without one, the other would be rendered useless. Fretting is on the surface a relatively simple kinematic procedure, whereas plucking or bowing requires highly accurate placement and pressure, either sustained over a long period of time (bowing), or as an instantaneous gesture (plucking).

Previous approaches to one-handed string playing generally involve coupling note selection and activation processes into a single gesture. This can be achieved by 'tapping' on the fretboard with sufficient force to cause a note to ring out, as seen in Bill Clement's adapted playing style[4], and the Chapman stick[5]. This allows for highly accomplished performances but produces a timbre that is arguably distinct from a plucked string.

3 http://www.ohmi.org.uk/previous-winning-instruments.html
4 https://www.youtube.com/watch?v=eskvyuzF1-Y
5 http://www.stick.com/

Other approaches involve software synthesis of a string instrument, via physical modelling or high-quality samples, and expressive digital interfaces which allow gestures on multiple axes. One example is the use of the Linnstrument [Linn, 2013], a multi axis controller which provides X and Y position as well as pressure data, using buttons arranged in a grid layout similar to fretted stringed instruments. This allows a degree more expression than a standard MIDI keyboard could, making pitch bends, slides, and vibrato possible, in a mode more suited to fretting hand string technique than a keyboard layout provides.

Coupling note selection and activation, either acoustically via a 'tapping' method, or via expressive control of a software synthesiser, essentially reduces a string instrument performance to extended keyboard technique, albeit with the ability to modulate the note after onset. These solutions lack the variety of note onset articulation found on the original instrument.

We suggest that a method of maintaining the separation of note selection and activation would preserve the nature of interaction with a plucked string instrument, and therefore the subtle characteristics of the instrument that come from this interaction. While this could conceivably be achieved with a synthesiser and controller, a mechanical adaptation to a bass guitar would also solve this problem, while preserving the acoustic characteristics of the instrument.

A mechanical adaptation in this context would allow either note selection or activation to be transferred to an alternate limb, in a similar mode to Larsen's actuated guitar [Larsen et al., 2014]. This leaves two problems to be solved: the method of mechanical note selection and/or activation; and how these methods are mapped to a one-handed interface. A key design consideration is which hand to 'replace'. This decision has strong implications for the performance of the instrument, not to mention the mechanical complexity of the system.

4.2.2 *Robotic Stringed Instruments*

The field of musical robotics may provide some inspiration for a mechanical adaptation to the bass guitar. The following section describes automated instruments which are capable of playing back pre-composed pieces of music, however the means of note selection and activation could equally be used in a real-time interactive system.

Kapur [2005] summarises many robotic music instruments, split into piano, audio playback, percussion, string and wind robots, and the various motivations of

their creators. For this study, we are particularly interested in the 'plucked bots' subcategory of string robots.

Of the many plucked string instrument robots summarised in Kapur's paper and elsewhere, there appear to be two key approaches to note selection, and two approaches to note activation. Note selection is typically via a movable bridge as in Baginsky's 'Aglaopheme'[6], a robotic stringed instrument analogous to a slide guitar, or via fixed-position clamping systems analogous to a many-fingered hand performing on a standard guitar.

The fixed-position approach can be used to perform 'hammer-on' gestures, i.e. clamping the string with sufficient force that the note itself rings out (as seen in Jordà's 'Afasia' project [Jordà, 2002]) or to simply change the length of the string at discrete intervals as in typical guitar performance, seen in Squarepusher and Z-machines 'Music for Robots' collaboration[7].

There are advantages and disadvantages to both approaches to note selection. A moving bridge allows the system to perform continuous pitch variations as in vibrato, slides and pitch bends, but is unable to perform rapid discrete note changes easily (i.e. trills, hammer-ons etc.). Fixed-position systems lack continuous pitch variation but can perform rapid note changes in a way that is slightly more analogous to the human hand. Some machines feature a hybrid system consisting of a moving trolley with separate fixed-position clamps (Compressorheads' robot bassist 'Bones' for instance[8]). Such a system could in theory perform many more of the fretting hand gestures of a human player, including both pitch slides and discrete note selection.

Vindriis, McVay and colleagues discuss approaches to an automated bass guitar design, the 'Bassbot', later the 'MechBass' [Vindriis et al., 2011] [McVay et al., 2015]. Vindriis and Carnegie analyse three methods of string plucking using either stepper motor 'pick wheels' or linear solenoid actuators. Proposals for dynamic modulation by adjusting the height of the plucking mechanism are explored. The MechBass incorporates an added damping mechanism using a servo, to prevent strings from ringing out, and to perform muted plucks. Due to the moving bridge design of the MechBass, the strings are spatially separated, and the abundance of motors and actuators requires optical pickups (as opposed to magnetic) to prevent electromagnetic interference. While some amount of expression is achievable using height-adjusted pick wheels and adjustable dampers, the note activation methods

6 http://www.the-three-sirens.info/
7 http://warp.net/news/squarepusher-music-for-robots/
8 https://compressorhead.rocks/

afforded by these musical robots are by no means comparable to those offered by the human hand.

Bretan and Weinberg [2016] provide a more recent review of robotic instruments, with several examples of rather more sophisticated robotic stringed instruments. These include Shibuya's robotic bowing arm for a violin [Shibuya et al., 2012] and Chadefaux's plucking finger for harp [Chadefaux et al., 2012]. The latter describes the attempt to accurately recreate a harp string pluck via mechanical means. Chadefaux et al. attempt to recreate the *'complex mix of displacement, velocity and rotation'* seen in the initial conditions of a human-plucked harp string, using a robotic finger which is capable of reproducing the plucking finger's trajectory using two hinges. The robotic finger features a silicon fingertip which approximates the pad of a human fingertip.

4.2.3 *The Bass Guitar*

The bass guitar is a fretted, plucked stringed instrument. The four strings are typically tuned in 4ths, from E_1 to G_2. Basses commonly have between 21 and 24 frets. Common variations include alternate tunings such as drop D or E♭ natural (all strings tuned down one semitone), varying number of strings, fretless, and acoustic. The strings are plucked with the fingers and thumb, or with a plectrum.

Electric basses feature heavily in most western pop- and rock-influenced music, and are strongly associated with the rhythm section, although many virtuoso bassists often play 'lead' or melodic lines in these styles. There is some evidence to suggest that the emphasis on rhythm of lower-pitched instruments such as the bass is due to the increased sensitivity in human perception to timing on lower-pitched notes [Hove et al., 2014].

Bass guitars, among other rock band instruments have a recognised 'cultural capital', and are often used in classrooms and music therapy settings due to their recognisability and popularity [Bell, 2014, Westerlund, 2006, Burland and Magee, 2014].

4.3 PLAYER SURVEY

Designing a bass guitar for one-handed control is likely to involve some compromise: the instrument is ideally suited to two hands, and a mechanical approximation of plucking or fretting hand gestures is likely to be limited in some areas. As

well as this, due to the transferral of the interaction from the hands to an alternate limb, we expect to encounter some limitations and compromises in the control method. We designed an online survey in order to establish which elements of bass guitar performance were most important to a bassist's expression and personal style. This would allow us to mitigate against these inherent compromises. Players were recruited via a social media call for participation, which was shared by the OHMI Trust and on a bass guitar players' Facebook forum.

4.3.1 *Survey Contents*

The survey was divided into three sections: the first section dealt with the individual respondent's self-reported bass playing proficiency, as well as details such as their preferred genre, type of bass guitar, hand dominance and other instruments played. The second section asked respondents to rank ten different performance elements in order of importance. The final section dealt with how users split their practice time between plucking and fretting hand techniques, as well as which hand they felt contributed most to their playing style.

For the second section, we defined 10 key performance elements: rhythmic accuracy, choice of rhythm, choice of note, choice of string, picking style, picking hand articulation, dynamics, fretting hand articulation, timbre of instrument, and use of effects. Respondents were asked to place each element in order of importance by giving each one a rating out of 10.

The last section comprised of two questions: how much practice is spent on techniques concerned with either the plucking or fretting hand, and which hand is most important in terms of defining the respondent's own playing style. Respondents were invited to give long-form free text answers in order to invite fully-explored insights and not to introduce bias. A final question allowed participants to add any other thoughts that they considered relevant to the study.

4.3.2 *Results*

48 bassists responded to the survey. Respondents rated their proficiency on a scale from 1 (beginner) to 7 (expert), with an average response of 5.3. The number of years spent playing bass guitar ranged from 2 to 45 years, with an average of 20 years. 35 respondents had been playing bass for at least 10 years. The mean number of years receiving lessons was 2.5 years with a maximum of 10 years. Nearly

all respondents performed regularly with an ensemble, spending an average of 5 hours per week (max 22.5 hours) practicing their instrument or in rehearsals.

Respondents were asked which genres they played, mostly answering 'Rock' (67%), 'Funk' (42%), 'Jazz' (38%), 'Pop' (27%) and 'Blues' (21%). In total, 36 genres were named, 19 of which were only mentioned once (e.g. 'Psychobilly', 'Cowboy Punk' and '60s pop').

71% of respondents played fretted electric 4-string basses, and 40% played fretted 5-string. 10% played 4-string fretless and 8% played upright. Other bass types which were mentioned only once included 6-string fretted and fretless, acoustic bass guitar (fretted and fretless), and 3-string fretted (tuned EAD).

The mean score and standard deviation for the importance of each performance element, according to the survey results, is shown in Table **??**. There is a general consensus on the importance of rhythmic accuracy, note choice and rhythm choice, each scoring above 8 out of 10 with a relatively small standard deviation. Picking hand articulation and dynamics appear to be of equal importance, while fretting hand articulation, timbre and picking hand style received similar scores, although the larger standard deviation (between 2.2 and 2.5) suggests less accordance for these factors. String choice scored 4.9 on average, with a standard deviation of 2.4. Respondents seemed to be in agreement on the use of audio effects (i.e. effects pedals or stompboxes) being of the least importance to bass playing style, with a mean score of 2.9 out of 10.

Figure 4.2 displays the results for hand importance and practice time. Respondents' rehearsal and practice time was generally split evenly across both hands, with 54% on the fretting hand and 46% on the plucking hand. We then asked players which hand was most important to them in terms of their playing style, and invited further comments. 52% placed most importance on their picking hand, with 23% for fretting hand, and a further 23% for both hands. Those who specified their picking hand commented that it was most important for defining their timbre, dynamics and rhythm. Some respondents used terms such as 'feel' and 'groove' when referring to the role of their picking hand. Those who chose their fretting hand mostly commented that their choice of notes, melody and chord were most important to them, which was reflected in their responses to the previous question on performance elements. We did not notice any correlation between hand preference and style, ability or years spent playing, although no statistical tests were done to confirm this.

Table 4.1: Ratings of importance of various bass guitar performance elements, arranged from highest to lowest means.

Performance element	Mean score	Standard deviation
Rhythmic accuracy	9.25	1.04
Note choice	8.1	1.57
Rhythmic choice	8.02	1.47
Dynamics	6.6	2.25
Picking hand articulation	6.6	2.17
Fretting hand articulation	5.73	2.23
Timbre	5.73	2.57
Picking style	5.44	2.38
String choice	4.96	2.46
Use of effects	2.88	2.04

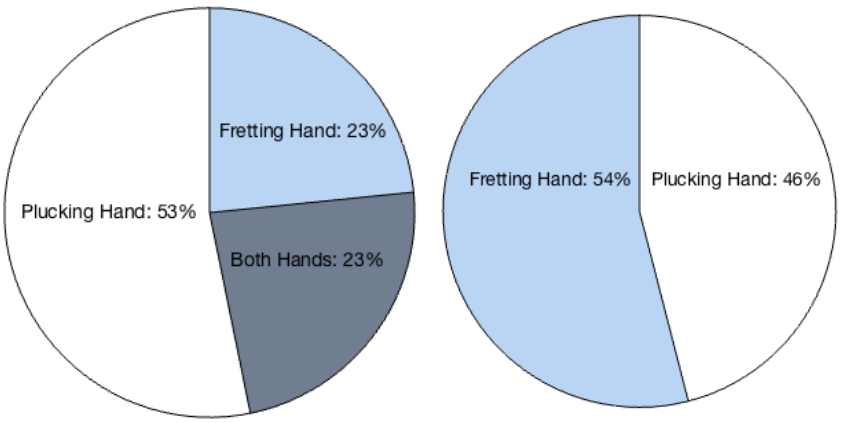


Figure 4.2: a) Importance of plucking and fretting hand technique to respondents' playing style; b) Amount of practice time focused on plucking and fretting hand techniques

4.3.3 *Discussion*

Most respondents appeared to agree that rhythmic accuracy was the most important element of bass guitar performance, with a roughly even split between note choice and rhythm choice for second most important. There was far less consensus amongst players over the remaining performance elements. Twice as many respondents said their plucking hand was more important to their style than their

fretting hand. Many players acknowledged the difficulty in answering such questions, with several comments referring to the fact that both hands are integral to bass playing. This is perhaps reflected in the fact that the vast majority of players spend equal amounts of time practising with either hand. The results of the survey do suggest that plucking hand artefacts such as rhythm, dynamics and timbre are more important for expression and performance than fretting hand articulation and even note choice. As one player comments: *'you could do so much simply by sticking to the [root notes] and differing where, how and how hard you play the notes'*.

This importance placed on rhythm, dynamics and 'groove' suggests that when, where, and how hard the string is plucked is a highly significant factor of bass playing. The pick wheel and solenoid based plucking mechanisms discussed in section 4.2.2 are not capable of similar degrees of freedom in terms of position, height and pressure as the human hand. We observe that transferring the role of the fretting hand onto an alternate limb would preserve the plucking hand's function, which we hypothesise will preserve the most significant expressive factors of bass playing from our survey.

4.4 DESIGN AND IMPLEMENTATION

Transferring the role of the fretting hand to an alternate limb requires a method of note selection that does not require manually fretting the strings with the hand. We opted for a foot-controlled mechanical adaptation which physically shortens the strings. This approach has the advantage of preserving the acoustic subtleties of a fretted, plucked string. This approach could be transferrable to any plucked string instrument, electric or acoustic, and does not directly colour the sound of the instrument. An alternative approach to note selection might be to incorporate a DSP stage for pitch-shifting an open string, as opposed to physically shortening it. This would have the advantage of removing the mechanical noise of the instrument, reducing weight and cost.

4.4.1 *Fretting Mechanism*

In order to test our hypothesis that replacing the fretting hand would preserve the most important aspects of bass performance, we designed a foot-operated fretting mechanism to be attached to the bass. We sought to demonstrate the electromechanical viability of the design and the usability of the interface, in a narrowly

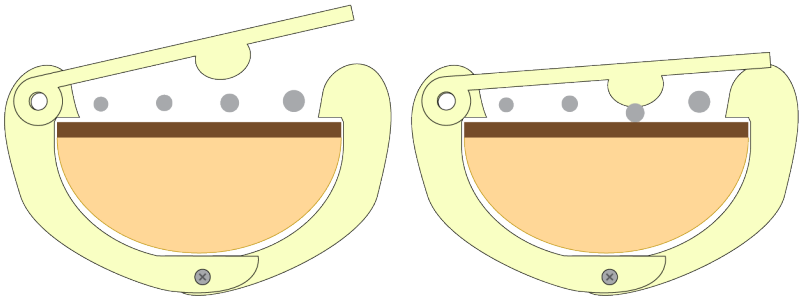


Figure 4.3: Basic design and functionality for neck clamp and fretting arm, with cross-section of bass guitar neck

focused environment. As such, we do not present a completed instrument, but a system suitable for the purposes of a proof-of-concept.

Since the electric bass is designed to be played amplified, replacing the fretting hand for note selection could be achieved either through an electromechanical solution or one based on audio pitch shifting. Digital signal processing methods are flexible and avoid mechanical bulk, but a mechanical fretting system retains the natural relationship between string length and timbre and a direct link between audio and vibrotactile feedback. Moreover, pitch shifting algorithms typically add latency and, when shifting more than a few semitones, can distort transients. Since our primary goal was to retain the natural action of the plucking hand, we opted for a mechanical approach.

We designed a clamp that could attach to a bass guitar neck, and a system of 'fretting arms', or levers, that are pulled down onto the string when a pull-type solenoid is activated. The fretting arms had to be designed such that they would let remaining strings ring whilst fretting, so a protrusion is added at the location of contact with the string (Figure 4.3).

We used a mechanical force gauge to determine the minimum force required for a note to ring true when fretted at the 2nd, 3rd and 4th frets on the A string. This gave an estimate of around 2 N. The height of the strings from the fretboard (action) is around 3mm. A further 3mm is required between the top of the strings and the fretting contact to prevent buzzing from the vibrating string coming into contact with it when not in use. From this, we require a linear motion actuator capable of exerting at least 2 N of force with a stroke length of at least 6mm. Pull-type solenoids are ideal for this as they are rapid, strong linear actuators. The user may wish to fret a note for a significant length of time, so larger solenoids are preferred, as they are capable of remaining active for longer periods of time without overheating. For this the BLP Components PED 42-120-611-620 pull-type

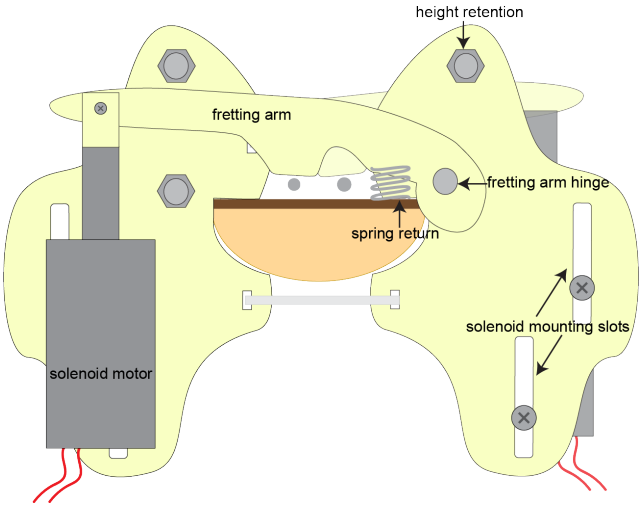


Figure 4.4: Schematic of final neck clamp design with solenoid mounts, with cross-section of bass guitar neck

linear solenoid actuator was chosen, as it is capable of exerting around 4.5N on a continuous duty cycle with a 6mm stroke.

Figure 4.4 shows a schematic of the final fretting mechanism design. We expanded on the neck clamp design to allow for the solenoids to be mounted perpendicular to the fretboard. The ends of the solenoid plungers can then be attached to the tip of the fretter arm. Vertical slots for the solenoid mounting screws allow the height of the solenoid to be adjusted relative to the fretboard. A spring return system prevents the fretting arm from coming into contact with the string. The fretting arm only needs around 6mm of clearance from the vibrating string, so its return height is retained by a rod running perpendicular to the neck. We used threaded rods for this purpose as it allows the horizontal position of the neck clamps to be held in place using nuts.

As this is a prototype device, we covered a limited area of the fretboard, in order to arrive at a proof of concept. We used 6 solenoid motors, with neck clamps at the 2nd, 3rd and 4th frets, providing fretting access to both A and D strings. This allows eight notes to be played, including the open A and D strings: A, B, C, C♯, D, E, F and F♯. Figure 4.5 displays photographs of the completed system attached to the neck.

The fretting mechanism uses the Bela platform[9] [McPherson, 2017] to drive the solenoid motors and to communicate with the interface. The Bela platform takes MIDI input messages from a USB controller and sets the corresponding pins be-

9 http://bela.io

Figure 4.5: a) side view of neck clamp; b) solenoid plunger attachment to tip of fretting arm

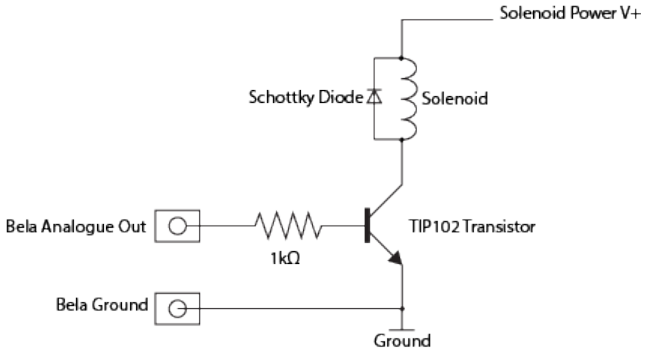


Figure 4.6: Circuit diagram for a single solenoid channel

tween 0V and 5V depending on the control message. The circuit design for a single solenoid channel is shown in Figure 4.6.

4.4.2 *Interface*

The design problem involved in this project boils down to two key decisions: which hand to 'replace', and which limb or body part to transfer the control of such a system onto. For the Actuated Guitar project, Larsen chooses a foot con-

troller, as the feet and legs are most suited to 'moving in rhythmic patterns for long periods of time' [Larsen et al., 2014]. Many assistive technology interfaces make use of eye gaze or head movement [Majaranta, 2011], however this might be suboptimal due to the neck muscle's primary use for stabilising the head, which as Larsen points out, are not suited to prolonged rhythmic movements. Voice control has also been explored for use with enabling devices [Hainisch and Platz, 2007]. For this project, we chose to work with foot controllers, but suggest that alternative input methods and devices could be used due to the MIDI-over-USB connectivity.

We expected to find examples of specialised foot-based interfaces designed for people with upper-limb disabilities who use their feet for everyday tasks, and base our foot controller around such a design. We found instead that in many cases, people with such needs use 'off-the-shelf' devices originally intended to be used with the hands, with little to no adaptations[10]. This may be simply due to a lack of available devices on the market, but suggests that given sufficient motor function of the feet, similar levels of dexterity as the hands is achievable. As a result of this, we opted to use an off-the-shelf MIDI controller as an interface. There exist foot controllers for performing music, which are not necessarily designed for those with disabilities, such as MIDI-enabled organ pedalboards or the Soft Step by Keith McMillen[11], but we felt that the size and layout of these devices was not appropriate for our eventual design.

The advantage of using a DMI-based interface for our instrument is that we are able to explore various mapping strategies. Unlike acoustic instruments, DMI interfaces are removed from any physical constraints caused by the interface construction, and allow for arbitrary controller layouts. We considered two approaches to the mapping between the controller and the fretting mechanism: 'natural' and 'optimised' mapping. Natural mapping, described by Norman [1990] as *'taking advantage of spatial analogies'*, is an attempt to make the relationship between the interface and the system as obvious as possible, enabling 'natural' or 'intuitive' control by the user. We define optimised mapping as an approach based on ergonomics: for example arranging note selectors in terms of harmonic relevance in order to minimise foot movement, similar to the layout of the bass keys of an accordion. A thoughtful optimised mapping approach could reduce the size of the required controller and reduce foot movement, but might require 're-learning' of the instrument due to its departure from the fretboard layout.

10 In particular, author and journalist Sarah Kovac provides video examples of her using her feet to type, apply makeup, and play the piano: http://sarahkovac.com/popularvideos/

11 https://www.keithmcmillen.com/products/softstep/

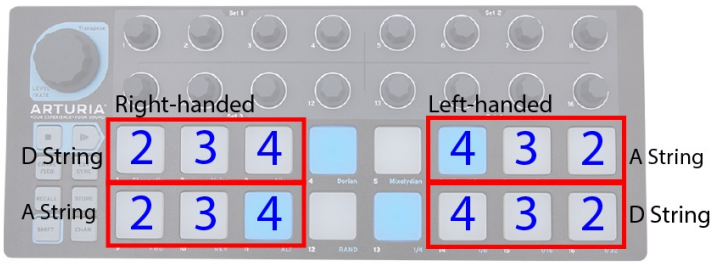


Figure 4.7: Arturia Beatstep MIDI controller. Annotations describe mapping from drum pads to frets

There are strong arguments for both mapping approaches, and factors such as the available motor function of individual users should be taken into account when considering which approach to use. For the purposes of this study we opted for a natural mapping approach. This would would mean representing the 6 available notes in two rows (representing the A and D strings) and three columns (representing the 2nd, 3rd and 4th frets). We used an Arturia Beatstep[12], which features two rows of 'drum pads', assigned to MIDI note numbers by default. The remaining rotary controllers and extra features were not used for this study. Figure 4.7 displays the mapping strategy used with the Beatstep. Since one of the participants in the following study was left-handed, we used six further drumpads to retain the natural mapping when the bass itself was reversed (the participant was comfortable with the strings themselves being reversed due to experience playing an 'upside-down' right-handed bass).

As seen in Section 2.3, many accessible instruments require bespoke designs, highly tailored to the individual's requirements. As such, we do not claim to have come across an ideal approach to mapping. Some users with dextrous use of the feet may prefer a naturally mapped foot controller with a layout resembling that of a bass guitar fretboard. Other users might have very limited movement of any available limbs and might prefer an optimised mapping approach, where minimal movement is required to transition between harmonically relevant notes and chords. There is no clear answer as to which mapping approach is best for this project, and exploring this problem further via a comparative study would provide some valuable insights into adapted instrument design. For the purposes of this project however, we opted for a natural mapping approach.

12 https://www.arturia.com/beatstep/overview

Figure 4.8 displays the bass being used with the feet and the MIDI controller placed on the floor, and alternatively with the free left hand. Supplementary material including video files of the adapted bass can be found at https://qmro.qmul.ac.uk/xmlui/handle/123456789/67358.

Figure 4.8: L: adapted bass being used with the feet and the MIDI controller on the floor and R: with the free left hand

4.4.3 *Latency*

McPherson et al. [2016] discuss the importance of latency and jitter in DMIs and measure the audio latency introduced by common prototyping arrangements. For this experiment, we are concerned with the latency between the initial key press on a MIDI controller, and the resultant string being fretted.

Figure 4.9 displays photographs of the experimental setup. We tested the latency of the system by attaching a piezo sensor to the fretboard, directly beneath the fretting arm at the 2nd fret on the D string, and another piezo on the corresponding drum pad on the MIDI controller. We measured the voltages of the two sensors using a two-channel oscilloscope. The delay between the voltage change onset of the two channels gave a good estimate of the latency of the system. We also measured the voltage change of the solenoid line against the two piezo channels. This gave us three separate measurements: overall latency (drumpad piezo $\rightarrow$ fretboard piezo), system latency (drumpad piezo $\rightarrow$ solenoid), and mechanical latency (solenoid $\rightarrow$ fretboard piezo). We repeated the test ten times for each measurement and calculated the average latency, standard deviation and jitter (the amount, in milliseconds, by which the latency varies above and below the mean). The results are displayed in Table 4.2.

The overall latency of around 54 ms is somewhat disappointing when compared with Wessel and Wright's quoted upper limit for latency tolerance of around 10 ms

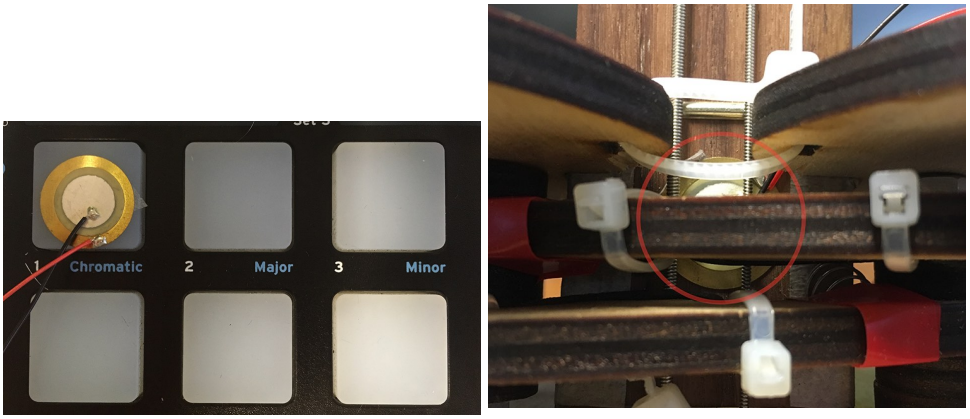


Figure 4.9: Experimental setup for latency testing: location of the two piezo sensors: a) drumpad, b) fretboard. A third oscilloscope channel measured the voltage change at the output from the corresponding pin on the Bela board.

Measurement (ms)	Total	Software	Mechanical
Mean	55	6	50
SD	0.9	0.3	0.5
Jitter	±1.6	±0.5	±0.8

Table 4.2: Values for three separate latency measurements: total (drumpad piezo → fretboard piezo), software (drumpad piezo → solenoid), and mechanical (solenoid → fretboard piezo)

for DMIs [Wessel and Wright, 2002]. However, Wessel and Wright are concerned primarily with the latency between note activation and the sound being produced. Here, we are measuring the latency between note selection and the corresponding string being fretted, in preparation for plucking. This is a preparatory gesture, that could occur at any point before note onset, and so the latency may be more easily tolerated than with note activation.

Secondly, we posit that the overall latency could be brought down considerably with future iterations of the fretting mechanism. We used basic prototyping tools such as laser-cut plywood and off-the-shelf parts to manufacture the neck attachment. A 3D-printed neck attachment might allow bespoke parts to be made to allow a closer fit to the neck and fretboard, reducing unwanted mechanical move-

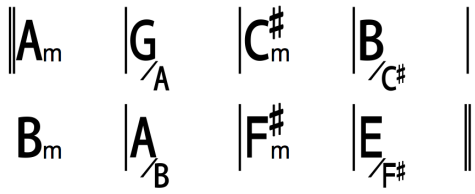


Figure 4.10: Chord chart provided for backing track accompaniment

ment, as well as weight. Alternative actuators might exist which could provide more speed and control over the fretting mechanism.

4.5 USER STUDY

We designed a study in order to assess the performance of the adapted bass and to highlight key design factors to consider for future accessible string instruments. Specifically we wanted to gain more insight into how the transferral of role of the plucking and fretting hands affects bass guitar playing. We were also interested in the efficacy of the natural mapping approach and interface design.

4.5.1 *Methods*

We conducted a user study comprising six bass players, with a variety of genre preferences and musical experience. They were given access to the adapted bass over three weeks, and asked to rehearse for a minimum of two hours during that time. Participants were asked to compose their own bass accompaniment to a pre-defined backing track, with a chord chart for reference (Figure 4.10). They were also given access to an unadapted bass, with the E and G strings removed, for use when rehearsing and composing their accompaniment.

Once all six participants had completed their rehearsal sessions, we recorded their performance of the 1-minute long accompaniment. Participants were given as many attempts as they felt necessary in order to perform the piece to a standard they felt reflected their proficiency with the instrument. We recorded audio and video of the performances for annotation.

After the recording was completed, participants filled in a questionnaire dealing with their responses to the bass guitar, as well as asking how much time they had spent with the instrument, and how many years they had been playing bass guitar for. Finally, they were asked to complete the 'melodic discrimination' task from the

Participant ID	Hours spent rehearsing	Years spent playing bass	Years spent playing any instrument	GoldMSI melodic discrimination IQ
1	4	10	30	106
2	2.5	16	18	91
3	2	15	20	103
4	1.5	14	22	121
5	1.5	5	15	103
6	2.5	17	17	92

Table 4.3: Study participant profiles

GoldMSI test battery [Müllensiefen et al., 2014] to provide an indication of each participant's musical proficiency (termed 'melodic discrimination IQ').

Table 4.3 summarises the participants' musical experience and melodic discrimination IQ.

We annotated each video with respect to four key areas:

Method of note activation: whether notes are plucked or activated using the fretting mechanism (similar to a hammer-on gesture)

Plucking hand technique: specific techniques employed by the plucking hand including muting the strings to stop notes ringing out, palm muting, playing with a plectrum and tapping on the fretboard

Passing notes: how participants transitioned from one note to another, using open strings or fretted notes.

Foot technique: whether participants used both feet or a single foot, alternated feet for different notes, or lifted the entire foot and replaced it in a different position for consecutive notes.

Finally, we analysed the results from the questionnaire to look for common themes and other salient points from the participant's responses.

4.5.2 *Results*

4.5.2.1 *Performance Recordings*

Table 4.4 summarises the annotations made of the performances, in terms of the emergent techniques and gestures observed, and how many participants used them. The techniques and gestures presented in the table were identified during the annotation process. While there may have been some slight differences in the way that these techniques were employed, these were identified as commonly used or clearly evident techniques that directly related to the way that the participants performed with the bass.

We noticed that a common feature employed by participants 1,2,3 and 4 was to mute the strings with the plucking hand. This is typically a function of both hands in bass playing, with fretting hand muting usually being employed to shorten the length of individual notes for staccato or rhythmic playing, or to prevent notes from ringing out after skipping strings, in preparation for the next pluck. Instead, functional mutes were transferred to the plucking hand, causing it to take on an additional role.

Two participants made use of the 'mechanical hammer-on' (i.e. the note onset caused by the fretting mechanism activating with sufficient force to cause a note to ring out). These were used in a similar way to a hammer-on played with a hand, i.e. to provide a legato style, and not played on strong beats of the bar.

Participant 5 employed a palm-muted style with a plectrum. This caused every note to be dampened, affecting the timbre and sustain of the note. It appeared that the damping was modulated to allow for some variation in dynamics. Another participant used their ring finger to dampen strings following string skipping, whilst plucking the adjacent string with the index and middle fingers. Perhaps the most unique case was participant 6's use of one-handed tapping with the plucking hand. This involved tapping the fretboard higher up the strings to produce a melody line, whilst changing fret with the fretting mechanism to modulate the bass note. Interestingly, these fret changes did not occur simultaneously with the note onset, but instead occurred during the sounding of the higher 'tapped' notes.

We examined the use of passing notes during the performances. We define passing notes as notes not played on a strong beat, but which immediately precede or follow a 'strong' note, and may link two such notes together. We observed that all players used the open strings as passing notes between fretted notes on strong beats, on several occasions throughout the performance. Three participants used

Playing Technique	No. of Participants	Description
Plucking Hand Technique		
Plucking hand mute	4	Stop notes ringing out using plucking hand
Mechanical hammer-on/pull-off	2	Activate note without plucking (using fretting mechanism)
Palm-muting with plectrum	1	Playing with a plectrum and resting palm on the strings
Plucking hand three fingers	1	Use of third (ring) finger to alternately pick and damp strings
Plucking hand tapping	1	Tapping on the fretboard using plucking hand in order to play notes higher up the fretboard
Passing Notes		
Open-to-fretted passing note	6	Play an open string while transitioning to or from a fretted note.
Fretted-to-fretted passing note	3	Play a fretted note while transitioning to or from a fretted note
Foot Technique		
Foot lift	6	Lift entire foot to change fret
Single foot	3	Use a single foot throughout the performance
Double foot	3	Use both feet throughout the performance
Foot change	3	Use alternate foot to change fret
Open string position change	3	Only change foot/fret position during the sounding of an open string
Foot barre	3	Use single foot to fret both strings at same fret position

Table 4.4: Emergent playing techniques and number of participants who used them

fretted notes immediately following or preceding another fretted note. There was nothing striking about the harmonic relevance of fretted or open notes, with both being used for strong harmonic notes (i.e. part of the triad of the current chord) or less harmonically related notes.

Three participants used a single foot, while the remaining three used both feet. Those who used a single foot consistently lifted the entire foot and replaced it to change fret position. Those who used both feet alternated between feet to change note, removing the need to lift and replace the entire foot for each new fretted note. Three participants tended to only change the position of their feet during the sounding of an open note, and two occasionally used a single foot to fret two strings at the same fret position.

Participant 4 gave a particularly notable performance, featuring mechanical hammer-ons and pull-offs, and relatively complex syncopated bass lines. We noted a consistency in the dynamics of the performance, with the amplitude of plucked notes being similar to notes caused by mechanical hammer-ons. As well as this, participant 4 displayed greater synchronicity between the actuation of the fretting arms and plucking the corresponding string. There were no occurrances of accidental double note onsets, caused by the strong hammer-on from the fretting mechanism sounding a note before the string is plucked. These featured throughout the other performances (except for participant 5, whose use of palm-muting prevented these from occurring).

4.5.2.2 *Questionnaire*

Here, I present the questionnaire contents and a summary of paraphrased answers across the participants. The responses allowed us to identify participants' thoughts on the playability of common techniques and musical gestures, adaptations to technique, and general responses to the instrument.

Q1: Were there any musical gestures that you regularly use when playing bass guitar, that you felt were impossible to play on the one-handed bass?

- P1: *'The range of melodic movement was hindered by the number of string and frets. No ability to bend of move the strings after initial onset.'*
- P2: *'Ordinarily I use my fretting hand to slide up to notes and also to bend the strings. I found this impossible to achieve on the instrument. I also found through playing the instrument how often I use my fretting hand to deaden notes on the neck of the guitar. I hadn't realised that I did this so frequently, and it was not possible to achieve this with the instrument.'*
- P3: *'Bends, pull-offs, fast trills'*
- P4: *'Muting the notes was the hardest part. Slides and larger note range also were missing.'*

- P5: *'hammer ons, dead notes'*
- P6: *'Two hands tapping, fast licks with legato and sweep picking'*

Q2: Were there any musical gestures that you regularly use when playing bass guitar, that you felt were possible, with a lot of practice, to play on the one-handed bass?

- P1:*'I started to mute with the right hand by week two. This was [hard] in week 1.'*
- P2: *'[I like to] use gracenotes, and small runs between notes. The fluidity of playing did increase with time - during my initial run through I was not able to do this at all, but by the end of the practice I was able to roughly approximate this. I also often fret two notes while playing. This was tricky for some notes when playing ... however with further practice this might be possible by using two feet to control the fretting.'*
- P3: *'More right hand techniques require a lot more practice as you need to mute the bass completely with this hand. Hammer-ons required a lot more practice to get accurate. Playing legato takes a lot more practice, as well as playing stacatto. Palm muting requires a strap or other form of stabilisation for the bass - same with any slap/pops'*
- P4: *'Hammer ons (but I'm not using them too often).'*
- P5: *'fast passages'*
- P6: *'... with time I could play most of musical gestures. However, for pure mechanical reasons, toes cannot be as fast as precise as the fingers thus i won't expect somebody to be able to play fast pieces with this instrument, even if an ad-hoc pedalboard is designed.'*

Q3: Were there any musical gestures that you regularly use when playing bass guitar, that you felt were easy or intuitive to play on the one-handed bass?

- P1: *'hammer ons were possible with the device, however not very controlled.'*
- P2: *'Something I regularly use is hammer on and pull off. The way the instrument was constructed made hammer on particularly achievable, and was a very intuitive technique to use. Pull off was implied in the way the strings were fretted, but it wasn't as intuitive.'*
- P3: *'No'*
- P4: *'Hammer ons'*
- P5: *'sustained - re-triggered notes'*
- P6: *'tapping with my right hand. And also long notes are quite easy'*

Q4: Were there any musical gestures that you used with the one-handed bass, that would be impossible on a regular bass guitar?

- *'No'* [three participants: P1, P3 and P5]

- P2:*'Perhaps the strength of the hammer on / fretting was something I couldn't necessarily achieve with a regular instrument'*
- P4: *'Very fast mechanical trills. I did try to add these to the groove, but they require more practicing.'*
- P6: *'The very sharp hit of the hammers results in a idiosyncratic attack that is not doable with a regular bass. Other than that, in this current prototype, I don't think so. However, I think that the highest limitation is the foot controller. Maybe it worth exploring how to operate the hammers with other body parts - not sure which though'*

Q5: When playing the one-handed bass, how did your plucking hand technique differ from your regular bass playing?

- P1: *'I needed to incorporate mutes and stops with the right hand. These were usually done with the left. This additional muting limited the freedom I had with the two fingers. Limitations on string also hindered usual movements to the 5th or octave.'*
- P2: *'As I was playing the instrument upside down there wasn't a natural place to rest my thumb, so this did influence my plucking hand position. I found at the beginning of the practice when plucking the strings my fluidity was impeded as I was thinking quite a lot about the positioning of my feet ... By the end I think I had the same level of fluidity with plucking that I would normally have.'*
- P3: *'Yes, it was more focused on muting. I also needed to coordinate my pluck more with the buttons presses for fretting as I to get a clean sounding note the string ideally needed to be muted when the fretting button was pressed, then plucked.'*
- P4: *'Very different muting technique. I used my 3rd finger to mute the upper string a lot. When playing steady eighteen muted notes each finger (2 and 3) muted the string immediately after the other finger plucked.'*
- P5: *'having less strings makes the hand rest in a different way, so not easy to do palm-muting.'*
- P6: *'I did not differ'*

Notable comments:

- P1: *'I was surprised how quickly the I adapted to some of the limitations. Although dexterity and playing became easier, the lack of note range was an ongoing limitation.'*
- P2: *'After practicing with the instrument for around an hour I found it quite intuitive to play. Obviously due to the limitations of the notes available to play this did change the way I approached the piece of music, but I felt comfortable playing the instrument overall.'*
- P4: *'Trying different layouts for the foot controller will be interesting.'*

- P6: *'If I had to spend more time with this I would surely write ad-hoc scores in which I have 2 separate staffs, one for the hand and one for the feet. I'd probably write a "fingering" notation for the feet too, as sometimes I was using the left big toe and other times the right one.'*

Practical considerations:

- Weight of neck makes playing uncomfortable
- Electronics attached to body of bass obstruct plucking hand especially left handed playing
- Reduced number of strings affects palm muting
- Plucking hand and arm also used for stabilisation, making common techniques harder/uncomfortable/impossible (i.e. slapping and popping)
- Size of buttons makes playing with feet difficult
- Responsiveness for rapid repeated button presses requires improvement
- Additional 'function' buttons on the foot controller were often selected by accident

4.6 DISCUSSION

4.6.1 *Study Results*

The results from the questionnaire and analysis of the performance recordings highlighted the ways in which modifying a bass guitar in this way can affect a player's technique.

An unexpected result of the study was the impact that a fretting mechanism such as this has on string muting. A common theme in the questionnaire results was that participants hadn't expected to rely so heavily on their plucking hand to prevent unwanted notes ringing out or accidental activation. This emphasises the secondary role of the fretting hand as a means of muting the strings, by lightly touching the strings rather than clamping them directly onto the fretboard. It appears this is an almost unconscious process when playing bass guitar: only when this secondary role is removed do bass players realise how often they use it. This suggests that muting the strings is not simply a stylistic choice, but a highly functional technique, fundamental to bass guitar playing.

Another system limitation that produced an unexpected effect on playing style was the overall strength of the fretting system. The 'hammer-on' caused by the fretting mechanism produced a considerably loud note, on the same order of mag-

nitude as a plucked note. This could have several knock-on effects. The strength of the note onset caused by the hammer-on sets a lower limit on the strength of plucked notes: this makes softly played passages with hammer-ons quite impossible, as the performer has no control over the strength of the mechanically-triggered notes. Secondly, precise coordination of the fretting mechanism and the plucking hand is required in order to prevent two separate note onsets: the note cannot be fretted silently in preparation for the pluck, so both actions must occur simultaneously. We noted that there was some disagreement amongst participants regarding the playability of hammer-ons with the system. Two participants said they felt intuitive and easy to play, whereas another reported that hammer-ons were impossible. This disagreement could be due to the fact that the latter participant does not consider the idiosyncratic attack and amplitude produced by a mechanical hammer-on to be representative of a typical hammer-on. Another reason for the disagreement could be due to the latency of the system: although a 54 ms latency might be tolerable for note selection, when used for note onset as a hammer-on this is above the 10 ms upper limit quoted by Wessel and Wright [2002].

Participant 5 appeared to mitigate against several of these effects by using a palm-muting technique and plectrum. This prevented unwanted notes from sounding and removed the need to mute each note individually with the plucking hand. This was a stylistically appropriate and convincing use of muting, echoing Motown bassist James Jamerson's use of a piece of foam placed under the strings to reduce sustain, or the heavily palm-muted bass guitar featuring in the introduction to 'Little Green Bag' by the George Baker Selection. Here, the participant used a common stylistic technique as a workaround to mitigate against the limitations of the instrument. The modified functionality of the instrument may have informed the participant's alternative approach to playing.

Participant 4 recreated a typical finger-picked bass performance by adapting his approach to plucking hand muting, as well as maintaining consistent dynamics with the mechanical hammer-ons. The synchronicity between plucking hand and fretting mechanism also prevented any accidental note onsets. Here, the plucking hand technique has been heavily adapted to accommodate the limitations of the fretting mechanism. Participant 5's use of palm-muting evidenced a different approach to these limitations, which affected the timbre and dynamics of the bass. The latter approach requires less re-learning of plucking hand gestures, but limits the dynamic and timbral range of the instrument. The former requires new tech-

niques to be learned, but maintains many of the characteristics of a finger-picked bass performance.

Two participants who used both feet also made use of fretted passing notes. All three participants who used a single foot either only used open strings as passing notes, or created accidental note onsets during fretted passing notes due to the asynchrony between fretting and plucking. Playing an open string in between two fretted notes allows the user to change their foot position during the sounding of the open string, maintaining a fluid performance. A reliance on open passing notes here could suggest an avoidance of rapid foot movements. We suggest that using two feet increases dexterity with the controller and prevents users from being limited to the open strings when changing foot position.

All participants were quick to become accustomed to the naturally mapped interface. This suggests that when designing for musicians who have prior experience with fretted string instruments (for example, someone with an acquired impairment who previously played a string instrument with both hands), using an interface layout that is analogous to the fretboard might make 'relearning' the instrument a degree simpler. Many participants noted that the size of the buttons makes individual selection difficult. A bespoke controller should address the ergonomics of foot control, but take into account that larger buttons require a larger controller, and an interface designed for all four strings and up to 24 frets might become prohibitively large to use. The improvement in foot accuracy over a short space of time, backed up by evidence of existing users of similar sized devices, suggests that this is more a matter of experience: over time, users are likely to gain the precision and control required to access the interface with the feet. This in particular is an example of the requirements of the end-user being the most important: while a natural mapping approach makes for a highly intuitive design, an optimised approach might be appropriate for users whose range of motion with the feet is restricted.

4.6.2 *Implications for ADMI Design*

When reviewing the state of the art of accessible instruments, it became clear that there was an abundance of devices designed with a broad approach to accessibility, but a limited palette of possible interaction modalities. Alongside these commercially available products were a significant number of bespoke and highly specialised devices, intended to suit the access needs of a single individual, or a

group of people with similar impairments. There are strengths and limitations to both these approaches to ADMI design. In this study, I attempted to focus on the latter approach, and in particular to transfer some of the successes of the bespoke wind instruments discussed in Section 4.2.1 over to the bass guitar. Specifically, a goal of the adapted bass was to preserve both repertoire and technique, in other words the mid- and micro-diversity, of the bass guitar.

It was during the early stages of this study and accompanying literature review that I began to develop the notion *'performance-focused'* ADMIs - discussed in Chapter 2 - in terms of an instrument's access affordances, preservation of repertoire and technique, and scope for virtuosic performance. As a proof-of-concept, it was not expected that the prototype adaptation to the bass would fulfil this criteria, but it proved useful as a means to reflect on what makes a performance-focused instrument.

Reflecting on the results of the user study, what is striking is that though there are clear limitations to the instrument, participants were able to deliver convincing performances of a bass guitar accompaniment, and were consistent in referring to the instrument as a bass guitar, and not something else. The modifications to the bass not only affected the playing technique, but also the tonal quality and dynamic range of the instrument. This prompted questions around what it is that lends the bass guitar its identity: if we can strip away a significant portion of the technical affordances of a bass, without it losing its identity, does that mean there is something *else* that makes it a bass guitar? How important is it that it *looks* and *feels* like a bass, even when part of the method of interaction is significantly modified?

Acknowledging that instruments possess a 'cultural cachet' also recognises that instruments cannot be described and evaluated through technical description alone. As O'Modhrain suggests, in evaluating musical instruments, we should acknowledge the various stakeholders involved [O'Modhrain, 2011]. In the case of performance-focused instruments, we are not only concerned with the interaction between the instrument and player, but also its interaction with the wider musical *culture* surrounding that instrument, including the player, their bandmates, the audience, the recording engineer, and so on. In other words, we are concerned with these stakeholder's readiness to accept it as part of that musical culture, as much as we are concerned that the instrument lives up to the technical demands of existing instruments.

I do not suggest that all new ADMIs should attempt to accurately recreate the cultural cachet of existing instruments in this way: disability arts has a long-standing tradition of radically new ways of performing that openly challenge existing cultural practices - the 'affirmation' approach to disability arts described by Swain and French [2000] and Firth and Cane [2018]. However, in those cases where a performance-focused ADMI is intended to emulate an existing instrument, I suggest that it is not just a case of being able to perform the existing repertoire in a convincing way, but to draw on those existing cultural practices. As a result of this, I suggest it is the job of ADMI designers to 'zoom out' from the technical descriptors of new instruments, and to acknowledge wider questions of society and culture around ADMIs.

In the next chapter, I discuss a study that further investigates these questions, in terms of the importance of the *cultural form* of guitar playing, and how that relates to the more detailed nuances of interaction, when emulating existing instruments.

5

WHEN IS A GUITAR NOT A GUITAR? - INSTRUMENT FORM, INTERACTION MODALITY AND RICHNESS

This chapter presents the second performer study undertaken as part of the PhD research, and encapsulates the main body of work undertaken in year 2 of the PhD. The findings from the study are published in the proceedings of the New Interfaces for Musical Expression (NIME) conference in 2018 as two separate papers: 'When is a Guitar not a Guitar? Cultural Form, Input Modality and Expertise' by Harrison, Jack, Morreale, and McPherson [Harrison et al., 2018] and 'Democratising DMIs: the Relationship of Expertise and Control Intimacy' by Jack, Harrison, Morreale, and McPherson [Jack et al., 2018]. The study design, instrument development, evaluation of results and paper authorship were a collaborative work alongside Robert H. Jack.

5.1 BACKGROUND

In Chapter 3, we saw how two disabled musicians used instrumentation in their practice - how their choice of instrument reflected both their physical access needs and their artistic and philosophical approach to disability. In Chapter 4, we attempted to design a prototype instrument which would address a specific access need (a bass guitar playable without the use of one hand), and began to think about the cultural identity of the bass guitar as a key component of the users' readiness to accept the adapted bass as a viable instrument. In this chapter, I discuss a study intended to further investigate these ideas through a consideration of both the technological functions of the instrument alongside its sociocultural cues.

5.1.1 *The cultural role of musical instruments*

The findings from the Adapted Bass study in the previous chapter reflect a shift in thinking about ADMIs which could be characterised as a move from an *object-focused* view to a *culture-focused* view. Our primary interest in evaluating the adapted bass began with the physical and technological affordances and limitations of the

system, how well each participant could perform their accompaniment, and the techniques they used to do so. What we found was that all participants were broadly able to perform a convincing bass guitar part with the system, with the potential to improve with practice. The alternative techniques they employed (such as plucking hand string-muting) were of interest to us and could go on to inform future designs of similar instruments. However, after reflecting on the study, what became most intriguing was the notion that we had somehow significantly modified the bass, whilst preserving the identity of the instrument. Was this because the overall form of the bass had been preserved? Or is the act of plucking the strings so fundamental to bass playing that it didn't matter if fretting the strings with the hands was taken out of the equation? In other words, was it the *global form* of the bass guitar that preserved its identity, or the *interaction modality* of plucking physical strings, that was most important in preserving the identity of the bass? This brings into question not only the functional and technical opportunities presented by an ADMI design, but also the cultural role that an instrument plays, through a combination of functional factors such as availability of repertoire and technique, as well as 'extra-instrumental' factors such as overall aesthetics, materials and the choreography of playing.

In this study, we took as a starting point the idea that there exists a subset of accessible instruments - both digital and acoustic - whose primary purpose is to emulate an existing instrument whilst accommodating a specific access need (as seen in many of the one-handed wind instrument adaptations discussed in Chapter 2 and the Kellycaster discussed in Chapters 2 and 3). This led us to consider that for many successful accessible instrument designs, there is both a need to address specific access needs, while at the same time maintaining the social and cultural cues of an existing instrument. To explore this further, we began to think about what lends an instrument its identity, and which of these factors could be reasonably modified or altered before it assumes a different identity altogether. This line of enquiry opens up questions about the social and cultural roles of musical instruments, themes explored in the field of musicology, organology and science and technology studies.

In Chapter 2, I considered perspectives from musicology and organology that highlighted the roles that musical instruments play in society and culture. In particular, Bates [2012] posits that musical instruments have a social life of their own, playing active roles in sociocultural networks and carrying with them meaning beyond just being passive music-making tools. Also relevant here is Bijsterveld

and Schulp [2004], who discussed the ways that certain musical cultures respond differently to innovation in instrument design.

Focusing on guitars, Bell [2014] considers the guitar's 'high value in cultural capital' as a factor in the popularity of guitar hero games. The guitar's social and cultural importance is reflected on elsewhere, for example Waksman discusses in depth the role of the electric guitar in popular culture, providing a history of the guitar as a 'cultural phenomenon' [Waksman, 2001]. Halstead and Rolvsjord discuss the gendering of musical instruments with a focus on the electric guitar and its association with gender and sexuality in society, and its implication for music therapy [Halstead and Rolvsjord, 2017].

5.1.1.1 *Cultural forms*

Horn [2013] introduced the concept of *cultural forms* in interaction design, arguing that *'designers can shape objects and situations to evoke cultural forms as a means to tap into users' existing cognitive, physical, and emotional resources'*. As an example of this, Horn proposes a thought experiment whereby a length of rope is left in a classroom of children. Naturally, the children will play with the rope in any number of ways, from tying knots to tug of war. To illustrate the importance of cultural forms, Horn asks us to then imagine the same length of rope has been left in a classroom, only with wooden handles attached at either end. The likelihood in this scenario is that the children will being skipping with the rope. The technical affordances of the rope have not necessarily changed - it can still be tied in knots or used in a game of tug of war, and the rope without handles could be used as a skipping rope - however the material and aesthetic qualities now clearly evoke a *'strong and recognizable cultural form that ... activates intricate patterns of social activity'*.

We wanted to explore the idea that the definition of what constitutes a 'guitar performance' is a potentially flexible concept - that the *cultural form* of guitar playing contains aspects that don't necessarily require what is traditionally recognised as a guitar. For example, Godøy et al. [2006] explore the concept of 'air instruments' - i.e. reproductions or imitations of the sound-producing gestures involved in instrument performance. They define this activity as *motormimetic sketching*: an expression of tacit knowledge of instrument performance that is recognisable and reproducible by both novices and experts. This highlights the importance of choreography in instrumental performance, where both the macro-level gestures (such as moving the hands horizontally to suggest going up the scale on a keyboard)

Figure 5.1: Clockwise from top left: Kalichord Strum, BladeAxe, Tangible Virtual Vibrating String, Artiphon Instrument 1, Jamstik and KellyCaster

and micro-level gestures (moving the fingers vertically to suggest pressing on the keys) are strong enough indicators of a performance with a particular instrument.

We were also interested in the myriad DMIs and video games designed to evoke the cultural form of guitar playing either through a preservation of fretboard or plucking hand technique, overall aesthetics, or a combination of these (See Figure 5.1[1]). These include instruments which preserve both the acoustics and tactility of a plucked string such as the Kalichord, BladeAxe and Tangible Virtual Vibrating String [Schlessinger and Smith, 2009, Michon and Smith, 2014, Berdahl and Smith, 2008], as well as instruments which preserve or mimic either the strings, fretboard layout, or both such as the Kellycaster [Kelly and Matthews, 2018], Jamstik[2] and Instrument 1[3].

1 Image sources for instruments in Figure 5.1:
Kalichord Strum: https://www.dannymo.com/instruments,
BladeAxe: https://ccrma.stanford.edu/~rmichon/bladeaxe/,
Tangible Virtual Vibrating String: https://ccrma.stanford.edu/~eberdahl/Projects/TS/index.html,
Artiphon Instrument 1: https://artiphon.com/,
Jamstik: https://jamstik.com/,
KellyCaster: https://cdm.link/2017/09/take-a-look-at-the-kellycaster-a-unique-and-accessible-instrument-built-by-dmlabs/

2 https://jamstik.com/

3 https://artiphon.com/pages/instrument1

5.1.1.2 *Access to musical cultures*

Horn [2013] argues that incorporating cultural forms into the design process is something that can be valuable 'in situations where cueing certain forms of social interaction is essential'. In the case of ADMI design, we are not only concerned with developing instruments which provide a physically accessible means of playing music, but which at the same time support and are supported by existing social and cultural structures related to music performance.

Different conceptions of what is meant by 'performing music' lead to different approaches to accessibility. Where making music is understood to mean *making pitched sounds*, the 'problem' of lowering barriers/providing access to making music becomes relatively trivial: if there is a way of providing a means for a disabled person to make pitched sounds in an intentional way, then the 'problem' has been solved. However, where making music is understood to be inclusive of existing performance conventions and expectations, or the ability to tap into existing repertoires and styles, the method of removing or lowering barriers to access becomes more complex. To begin with, there is the process of developing an interface which accommodates a particular musician's access needs - this is the most commonly discussed aspect of ADMI design.

However, there are other requirements to be met in terms of the way that an instrument is able to support a musician taking part in an existing musical culture. This could be to do with the way the instrument *looks*: would it meet the (often unspoken) criteria to be welcomed in a metal band, Irish folk session, or classical music concert? This also brings into consideration aspects such as *repertoire* and *performance conventions*: the ability, for example, to perform a guitar solo in a rock and pop band, or to reproduce music from a written score.

How closely a new ADMI should align itself with existing conventions may also have to do with the individual musicians values in relation to the inclusion/affirmation continuum discussed in Section 2. To recap this idea: in Disability Arts there is a continuum from inclusion to affirmation where a disabled artist may wish to take part in an existing 'mainstream' or otherwise non-disability-informed musical culture or artistic practice, or conversely to express themselves artistically in a way that rejects existing conventions/expectations/requirements in order to affirm ones disability identity. This is presented as a continuum to acknowledge that there is no right or wrong way to approach this, and many disabled musicians may wish to position themselves in an an inclusive or affirmative way depending on the context of their performance or their artistic intentions.

5.1.2 *Preservation of musical role - technique, repertoire and expertise*

A primary concern with the adapted bass was the fact that the respondents to our survey generally seemed to suggest that plucking hand technique was a crucial factor in their bass performance. We have considered how factors such as global form, aesthetics and materiality can contribute to how well an instrument might fulfil the *cultural form* of guitar playing. However we should not throw out entirely the idea that a significant portion of an instrument's identity lies in more quantifiable terms such as existing repertoire, or common performance techniques. In order to preserve the musical role of the guitar in a new guitar-like ADMI, we should consider the extent to which these factors are preserved.

An important point to consider is that with the adapted bass, we only consulted experienced bass players on their ideas around the importance of difference performance aspects of bass playing, and based our design on the findings relating to the plucking hand. Would consulting non-musicians or those without any prior bass playing experience have provided the same answer? For this study, we were interested in finding out whether there was a difference between experts and novices in their evaluation of *what makes a guitar a guitar*: the micro-scale details of interaction technique, or the macro-scale qualities such as global form, materials and choreography.

5.1.3 *Technology probes*

We looked to *probe* methodologies for their ability to go beyond functional user-testing of the artefacts and to provoke reactions to the extra-technical (i.e. social, cultural) factors of the device. Gaver et al. [1999] introduced *cultural probes* as a methodology capable of gathering 'inspirational data' through provoking the users/participants to engage both the with the device and their environments in unexpected ways:

> *'We weren't trying to reach an objective view of the [participants'] needs through the probes, but instead a more impressionistic account of their beliefs and desires, their aesthetic preferences and cultural concerns'* [Gaver et al., 1999]

Hutchinson et al. [2003] build on this with the *technology probe* methodology. They define technology probes as serving three goals:

- The social science goal of understanding the needs and desires of users in a real-world setting
- The engineering goal of field-testing the probe
- The design goal of provoking users to reflect on their interaction with the probe

Technology probes are designed to be lived with in real-world settings, and so require a level of finish that allows them to be deployed and used independently. They are often lo-fi designs, concentrating on one particular aspect of a technology while simplifying or removing additional features. Gurevich et al. [2010] discuss the *one-button instrument*, an example of a musical technology probe designed to explore how musicians can develop style through built-in constraints in the design.

In this study, we were inspired by the technology probe methodology for their ability to provoke the users to reflect on the design features we were particularly interested in, and the importance of maintaining ecological validity in the designs and use setting. To clarify, the instruments developed in this study do not precisely line up with the technology probe methodology set out by Hutchinson et al. [2003], given that they do not passively collect data and were not used and lived with in the participants' daily lives.

5.2 GOALS

There are several intended outcomes and goals from this study, ranging from broader research questions around the nature of guitar-like DMIs, to more specific design goals concerning the DMIs that we designed to answer those questions.

5.2.1 *Research questions*

This chapter addresses RQ1a - RQ1d defined in Chapter 1:*'What role does interaction technique play in an instrument's identity?'*, *'How does interaction technique interact with prior experience of that instrument?'*, *'What role does the global form of an instrument play in an instrument's identity?'* and *'How does global form interact with prior experience?'*

In other words:

> *When designing a DMI intended to fulfil the musical role of a guitar, which is more important: global form or interaction modality?*

Where 'global form' refers to the overall aesthetic design decisions i.e. the degree to which the instrument *looks like* a guitar, and 'interaction modality' refers to the

sensor topology and the way in which it is played - how much the instrument *plays like* a guitar.

There are many inter-relating factors that come into play when addressing this question. One factor we were particularly interested in was the role of prior experience with the guitar. When addressing the question of how 'guitar-like' an instrument is, we are dealing both with the cultural identity of the guitar, as well as its technical descriptors (e.g. six strings, guitar sound). We aimed to tease these factors apart by addressing a population that was already familiar with the finer details of guitar playing, as well as one that would be more likely to identify a guitar with its aesthetic qualities and cultural connotations.

As well as the role of prior experience, we also acknowledged that a factor in how 'guitar-like' an instrument is might come from the musical context it is used in. We aimed to situate our instruments within a genre of music that is based on tradition and cultural expectations relating to instruments, but which would also allow us to develop a musical task accessible enough for non-musicians to take part within a short-term study. We chose Irish folk music as a genre which possesses fairly well recognised cultural expectations and traditions (for example the preference for particular types of acoustic instrument). This would also allow us to develop a musical task (strummed chordal accompaniment) which is appropriate for the genre but could be achievable for non-musicians.

With this in mind, we can address a number of more specific research questions:

1. *How does prior experience with guitar playing affect the way that players evaluate the 'guitar-likeness' of an instrument?*
    a) *Are experienced guitar players more informed by a familiar interaction modality (i.e. physical strings) in their evaluation?*
    b) *Are non-musicians more influenced in their decision by the preservation of familiar forms and aesthetic decisions?*
2. *What elements of an instrument are most important in terms of the perceived acceptability of that instrument within an established cultural context such as folk music?*
    a) *Do players consider an incongruous global form (i.e. resembling an electronic musical instrument) to be less acceptable within a folk music context?*
    b) *Does the ability to replicate techniques of a traditional instrument (i.e. strumming physical strings) affect perceived acceptability within folk music?*

5.2.1.1 *Richness of interaction*

An additional component of this study which was primarily informed by the co-researcher's area of research was concerned with the concept of *control intimacy* and the *richness* of interaction, originally discussed by Wessel and Wright [2002]. These terms relate to the level of control a performer has over an instrument: the range of gestures available to the performer that translate to distinct musical outcomes. Plucked acoustic string instruments can be regarded as possessing a great deal of control intimacy: the sound of the strings can be modified in myriad ways through often subtle changes in excitation such as how hard or soft a string is plucked, the location of the pluck, and what material is used. On the other hand, DMIs such as MIDI controllers or samplers often possess significantly reduced control intimacy: there is a much looser mapping between input gesture and acoustic outcome (although this mapping begins to become tighter as more sophisticated sensor topologies are introduced).

Within DMI design, richness of interaction is often seen as a goal to aspire to - there is an implicit assumption that a 'richer instrument is a better instrument' due to the wider availability of sounds achievable. In this study, we sought to interrogate this idea through modulating the richness of an instrument and observing how users with different levels of musical expertise responded to them.

The co-researcher's primary research question within this study was:

> *How does control intimacy (the degree to which a performer's actions are reflected in the behaviour of an instrument) affect the perceived quality of a DMI, and how does this vary with musical experience?*

While this question was primarily concerned with my collaborator's research, it has implications for the topic of ADMI design also. For example, in my framing of 'performance-focused instruments' in Section 2.3.2, I propose that ADMIs intended for a performance setting should possess high levels of musical diversity equivalent to that of a traditional instrument. The question of richness is directly correlated to the 'micro-diversity' [Jordà, 2004] of an instrument as it affects the range of available playing techniques that can alter the way that the same piece is performed.

5.2.2 *DMI design goals*

In order to answer these research questions, we set out to develop a series of technology probe-inspired DMIs that would be capable of separating out our various lines of enquiry (interaction modality, global form, control intimacy), in order for us to isolate and compare instruments which possessed these features to different extents.

Learning from the limitations of the adapted bass study, we wanted to ensure our instruments were both playable to participants of all levels of expertise, and taken seriously as completed instruments, as opposed to unfinished prototypes. This would allow us and the participants to focus on the elements of the instrument we were most interested in, rather than invite feedback on potential improvements to future designs.

We chose to use touch sensing technology to compare against physical guitar strings, for the affordances it could offer which are analogous to guitar playing. For example, swiping across a touch-sensitive surface requires a similar gesture to strumming across strings, and tapping on individual points is analogous to finger-picking or plucking individual strings.

As we had chosen folk music as our musical context, we also needed to consider the comparative case, for a 'non-guitar-like' instrument that would be incongruous with a folk music setting. For this, we looked to tabletop electronic music hardware such as sequencers and samplers, as a source for design cues.

Our requirements for the DMIs are as follows:

1. *Four instruments, representing different combinations of guitar-like global form and interaction modality:*
    a) *A guitar-shaped instrument with physical strings*
    b) *A guitar-shaped instrument with touch sensor mechanism*
    c) *A non-guitar-shaped instrument with physical strings*
    d) *A non-guitar-shaped instrument with touch sensor mechanism*
2. *For the guitar-shaped instruments: to resemble the look, feel, materials and playing position of a guitar*
3. *For the tabletop instruments: to incorporate design cues from electronic music hardware*
4. *For all instruments:*

a) Produce a consistent guitar like sound, independent of form or interaction modality

b) Ease of use for non-musicians: to provide the ability for non-musicians to take part in a musical task in a meaningful but accessible way

5.3 INSTRUMENT DESIGN

In order to address our design goals set out in Section 5.2.2, we developed the instruments depicted in Figure 5.2. They are referred to as Strings-Guitar (SG), Strings-Tabletop (ST), Touch-Tabletop (TT), Touch-Guitar (TG). In this section, I detail the process of designing each aspect of these instruments.

Supplementary material including video files of the four instruments can be found at https://qmro.qmul.ac.uk/xmlui/handle/123456789/67358.

Figure 5.2: The four instruments used in this study. Clockwise from top left: Strings-Guitar (SG), Strings-Tabletop (ST), Touch-Tabletop (TT), Touch-Guitar (TG)

5.3.1 *Hybrid acoustic-digital string modelling*

The earliest prototype instrument developed for this study was the result of an inquiry into preserving the nuance of plucked string interaction in a digital instrument. We had seen with the adapted bass (Chapter 4) that one of the more successful aspects of the instrument was its ability to preserve the plucking hand gestures that were deemed important to bass playing. Around this time, We had also come across the work on hybrid digital string instruments such as the Kalichord [Schlessinger and Smith, 2009]. Inspired by the Kalichord, We developed a thumb-piano like interface with four tines held in place over electret microphone sensors, with the intention of developing ways of preserving plucked string interaction without the need for mechanical shortening of the string.

The input to the electret microphones was used to excite a basic Karplus-Strong string modelling algorithm (discussed further in section 5.3.5). We experimented with a number of materials for the tines, and found that a loop of bass guitar string wrapped around a wooden coffee stirrer produced an ideal excitation waveform for exciting the Karplus-Strong algorithm. It was also found that attaching a small FSR to the tine and mapping its output to the damping parameter in the Karplus-Strong algorithm provided an intuitive method of damping the strings with the plucking hand, however integrating this with the loop of bass string wasn't possible. Figure 5.3 shows the early thumb piano-inspired prototypes.

From the thumb piano prototypes, two things became clear: firstly, that clamping a plucked material directly over either a piezo or electret microphone sensor was a viable method of exciting a Karplus-Strong algorithm in real-time (as opposed to the Kalichord for example where the player plucks a piezo sensor directly), and secondly, that the use of a loop of bass guitar string partially preserved the 'feel' and tactile response of a plucked string. This led us to consider ways that we could terminate a length of string over a piezo sensor to allow for a layout that resembled a guitar more than a thumb piano. We also moved away from electret microphones due to their sensitivity to feedback when playing at volume with a speaker.

We began to experiment with bridge designs which would provide a mechanical connection between a plucked string and a piezo sensor, and early experiments involved simply placing a piece of wood between the string and sensor and holding it to tension. When the string is held to a tension similar to that of a correctly tuned guitar, the fundamental frequency and harmonics of the physical string tended to

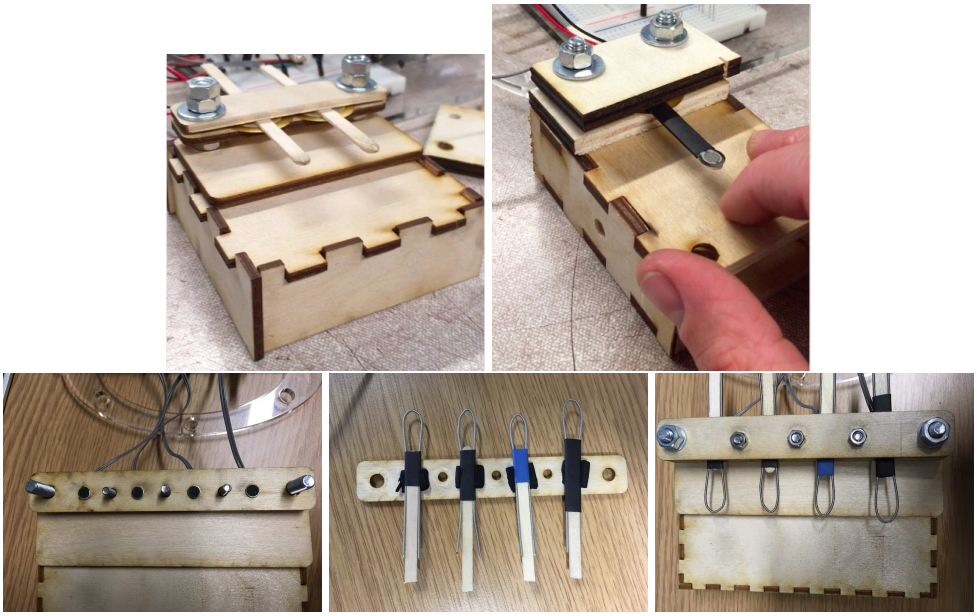


Figure 5.3: Thumb-piano based prototypes. Top row L-R: early iteration with coffee stirrer tines; with integrated FSR for damping. Bottom row L-R: embedded electret microphones; tines with looped bass string; final assembly of prototype

interfere with those of the Karplus-Strong virtual string with the result that different combinations of tunings of both strings resulted in highly inconsistent acoustic properties. In order to remove the resonance of the physical string and preserve only the 'percussive' excitation waveform of the initial pluck, a slack, heavy gauge string worked best. We opted for a 0.40 gauge string (commonly used as a bass guitar G string) for this purpose as its weight provided a sufficient impulse to excite the virtual string even when held to a low tension.

The low tension in the string meant that simply holding a bridge in place using friction was not a viable approach, so we designed a bridge piece that would allow the string to terminate over the centre of a piezo disc which could be held in place with adhesive. We also found that when attaching two strings and bridge pieces to the same surface, the acoustic coupling of the two bridge pieces meant that plucking either of the physical strings would excite the virtual strings equally. To resolve this, we experimented with materials to acoustically separate each string, eventually using discs of plastazote foam. Figure 5.4 shows the final design of the bridge pieces.

It was found that placing the strings further apart provided better separation but a wide string spacing felt less 'guitar-like' when strumming and strumming across the whole set of strings was potentially uncomfortable. We tested different

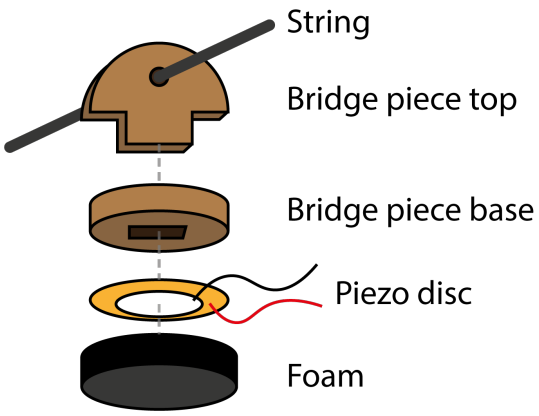


Figure 5.4: Schematic of the components of each bridge piece

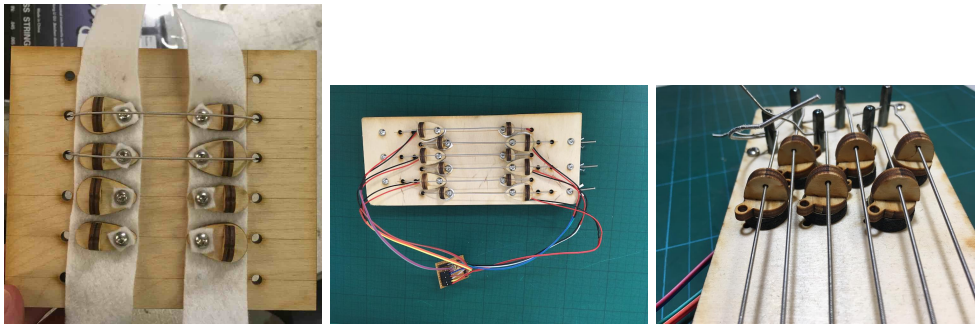


Figure 5.5: Prototype layouts of strings and bridge pieces for acoustic separation.

methods of spatially separating adjacent bridge pieces to provide further acoustic separation, along with different damping materials, resulting in a number of prototypes shown in Figure 5.5. We concluded that placing the bridge pieces at the same end of the string in an isometric layout provided sufficient acoustic separation in conjunction with the layer of foam, while also preserving similar string spacing to a guitar.

Two further design considerations for the 'strings' instrument were the method of adjusting the tension of the strings, and the construction of the non-piezo bridge at the other end of the strings. We found that zither tuning pegs allowed fine tuning of the tension of the strings, with a small footprint compared with a guitar tuner or similar methods. For the bridge, a layer of plastazote foam over a bottom layer of plywood provided a rigid termination point whilst acoustically separating the strings. Figure 5.6 shows the final prototype of the strings instrument before we began designing the enclosures.

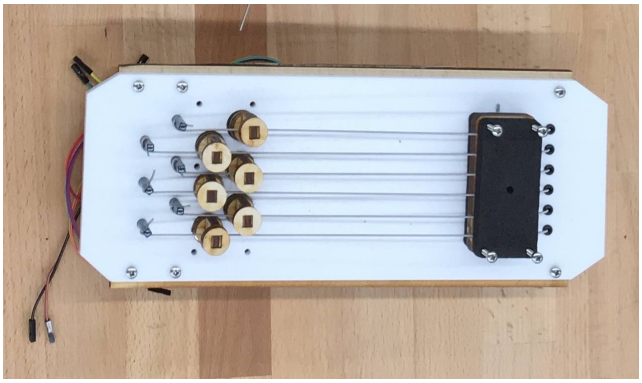


Figure 5.6: Final prototype of strings instrument

5.3.1.1 *Tuning the strings*

An important point to consider with the design of this instrument is the level of fine-tuning and 'crafting' that was required to achieve a consistent and pleasant sound across all six strings. We tried various methods of terminating the strings, attaching the bridge pieces, holding the strings to tension and so on, and found that even subtle changes in material and layout provided large variations in results. The clearest example of this was with the tension of the strings, which had to be fine-tuned using the zither pegs. We found that there was a 'sweet spot' where the strings were tight enough that they provided a tactile response similar to a guitar string, but not so tight that they produce a clear fundamental which would interfere with the acoustics of the modelled string. Tuning each version of the string instruments became a process of a trial-and-error, and we were unable to come up with a design that would easily produce consistent results every time, without the need for adjustment.

5.3.2 *Touch sensor*

For the touch sensor, we used a rectangular Trill capacitive touch sensor[4], which is capable of detecting multiple touch positions along its length. The trill sensor emulates strumming across or individually plucking individual strings by separating the touch sensitive surface into six equally spaced points along the length of the sensor. 'Tapped' notes are triggered when a new touch is sensed inside one of the six wider string areas. Once a touch has been registered, and if the finger is not removed from the sensor, 'swiped' notes are triggered when the finger crosses

4 https://blog.bela.io/2019/09/16/trill-touch-sensors-kickstarter-bela/

a narrower area of the touch strip at the centre of each string area. Figure 5.7 illustrates the string areas with the central position of each string area for swipe gestures.

Figure 5.7: Trill sensor divided into six string areas

To provide tactile feedback for the users, we added several layers of black paint to the surface of the touch sensor, indicating the centre of each string area (Figure 5.8).

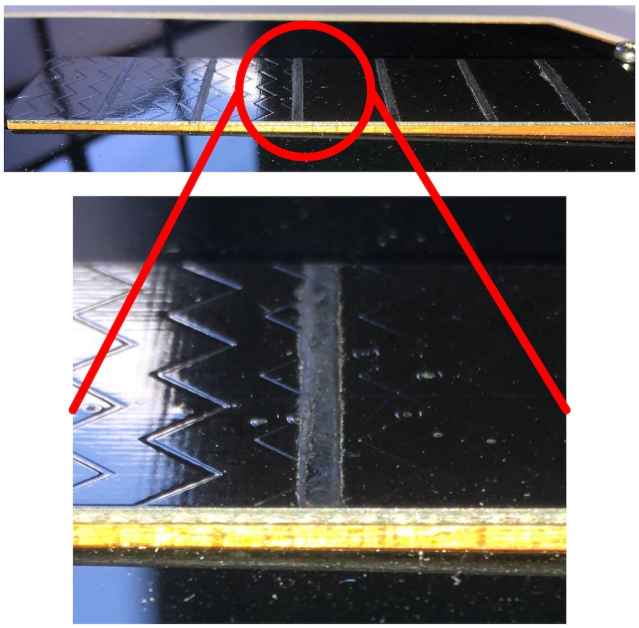


Figure 5.8: Paint applied to touch sensor to indicate string triggering location

5.3.3 *Chord selection buttons*

Our goal with the instruments from a technology probes perspective was to isolate a number of self-contained and clearly defined features, which meant reducing other elements of the instrument to a kind of 'minimum viable functionality'. In the case of pitch selection, we wanted to ensure that participants had the ability to

perform a stylistically appropriate strummed string instrument accompaniment to a folk tune, which required the ability to select chords and follow a pre-defined chord progression. However we did not want the participants to become overly distracted by the 'fretting hand technique', and so chose an intentionally simplified method of selecting chords.

We used six tactile push buttons laid out in two rows of three. We assigned chords I, IV and V in the key of G major to the top row of buttons, based on the chords used in the backing track we had recorded for this study (described later in Section 5.4.2). We arranged the chords in fifths, and assigned the remaining three buttons to the relative minors of the major chords, resembling the layout of the chord buttons on an accordion. The minor chords do not feature in the backing track, however they do provide players with a harmonically appropriate option for improvising chord changes. Figure 5.9 illustrates the buttons embedded in the neck of guitar-body version of the instrument.

Figure 5.9: Chord buttons labelled with the assigned chords

5.3.4 *Enclosure and materials*

5.3.4.1 *Guitar-shaped instruments*

For both the guitar-shaped instruments, we used a single enclosure and two modules containing either the strings or the touch sensor, allowing us to swap between the two sensor layouts during the study. We commissioned a guitar-inspired enclosure from Ailish Underwood, a model-maker from Arts University Bournemouth[5]. The enclosure is constructed out of hardwood with a sculpted neck with six push-buttons positioned roughly at the position of the lower frets on a traditional guitar

5 https://www.instagram.com/ailishmu_/

neck. Figure 5.10 displays the initial prototype design for the guitar body, constructed from acrylic and foam.

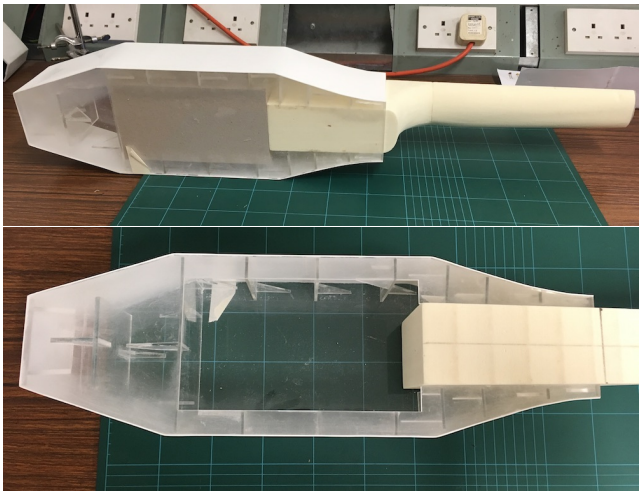


Figure 5.10: Prototype models for the guitar body designed by model-maker Ailish Underwood

The final design was carved out of hardwood, with a removable panel of wood on the neck and a hollow cavity running down its length, to allow for the wiring of the buttons to meet with the sensor module embedded in the body. It also features guitar strap buttons behind the neck and at the base of the body to allow for playing in the same position as with a guitar. Figure 5.11 displays the final guitar enclosure with the two sensor modules installed.

For the tabletop controllers, we designed two similar enclosures, made up of layered laser cut plywood for the sides and a black acrylic layer. The push buttons

Figure 5.11: The guitar body enclosure with the strings sensor module (SG, left) and touch sensor module (TG, right) inserted

Figure 5.12: The Strings-Tabletop instrument (ST, left) and Touch-Tabletop instrument (TT, right)

were located on the lower left hand corner of the instruments, with the strings and touch sensor placed at a 45°angle to the lower section of the instrument, as this was found to be a comfortable layout for strumming on a tabletop. Figure 5.12 shows the two tabletop instruments.

5.3.5 *Software*

The instruments use the Bela embedded computer [McPherson and Zappi, 2015][6] for sensor processing and synthesis. This allows the instruments to be self-contained, while running on hardware capable of performing audio processing tasks at low latency.

All four instruments feature basic implementations of the Karplus-Strong plucked string algorithm [Karplus and Strong, 1983, Jaffe and Smith, 1983] to generate tones with similar dynamic and harmonic decay to a plucked string. The algorithm follows from wavetable synthesis techniques, whereby a wavetable of length P samples is loaded with values and played back repeatedly. This produces a periodic tone, whose pitch corresponds to P and the rate at which it is played back. By gradually modifying the contents of the wavetable at each period, the timbre of the note evolves over time. Taking a two-point average of the wavetable at each sample low-pass filters the signal, meaning an initial burst of noise rapidly loses it high-frequency energy, preserving only the harmonics of the fundamental, followed by an almost pure sine wave. The excitation waveform for Karplus-Strong instruments is commonly a burst of white noise, but other waveforms can be used,

6 bela.io

for example pre-recorded samples of the onset of a plucked string, with more realistic results.

5.3.5.1 *String excitation - sample triggering*

For the touch sensor instruments, we recorded the onset from plucking the dampened strings used for the string instruments, and used this as the excitation waveform. When a string area is tapped or swiped across, the excitation waveform is played back as the input to the Karplus-Strong algorithm, for the corresponding string model.

We had originally intended for the final version of the string instruments to feature the audio-rate string excitation method discussed earlier in Section 5.3.1. However after developing the touch sensor software, we realised that it would not be possible to accurately replicate the full range of interaction possibilities with a touch sensor as with the hybrid acoustic-digital string method. For this reason, we constrained the string instruments to a sample-triggering excitation method, where the same waveform used with the touch instruments was also used as the input the Karplus-Strong model with the string instruments.

We developed a peak-detection algorithm that looks for peaks in the signal from the integrated piezo sensors, and plays back the excitation waveform when a peak is reached. This allows for consistency across both the string and touch instruments, at the expense of the advantages of audio-rate excitation discussed in Section 5.3.1.

5.3.5.2 *String excitation - comparing richness settings*

The 'full' audio-rate excitation method was still used for an additional component of the study relating to the research questions on control intimacy and richness, discussed in Section 5.2.1.1. For this part of the study, we added a switch so that participants could compare between the sample triggering and audio-rate excitation versions of the string instruments.

5.3.5.3 *Chord Selection*

To play a chord, we assigned each button to an array of MIDI values corresponding to typical voicings for each chord when played on a guitar. The MIDI values correspond to the fundamental frequency of each of the six string models. Table 5.1 displays the MIDI values corresponding to each button and chord voicing.

Button	Chord	MIDI values (low-high)
Top left	C (IV)	43, 48, 52, 55, 60, 64
Top middle	G (I)	43, 47, 50, 55, 59, 67
Top right	D (V)	42, 45, 50, 57, 62, 66
Bottom left	Am (II)	40, 45, 52, 57, 60, 64
Bottom middle	Em (VI)	40, 47, 52, 55, 59, 64
Bottom right	Bm (III)	42, 47, 54, 59, 62 ,66

Table 5.1: Chord buttons and MIDI values for each chord voicing

5.4 STUDY DESIGN

We designed a comparative user study where we enabled participants to make direct comparisons between two of the four instruments we developed. Our intention behind this comparative approach was that participants would focus on the differences between each instrument, allowing us to direct their focus to the elements we were most interested in: the method of interaction and the overall global form.

5.4.1 *Participants*

We recruited 32 participants: 16 'competent guitarists' and 16 non-musicians. Participants were asked to self identify at the recruitment stage using the following statements: *'you are comfortable strumming along to a tune'* (competent guitarists) and *'you have no or very little experience playing an instrument'* (non-musicians). We were not interested in recruiting participants outside of this group, for example experienced musicians who were not experienced with the guitar. In order to account for within-group variability in musical skill, we asked participants to complete the self-report questionnaire section of the Goldsmiths Musical Sophistication Index (GoldMSI) test battery [Müllensiefen et al., 2014].

Participants were given one of two combinations of the instruments, referred to as the 'congruent' or 'incongruent' pairing. The congruent pairing represents the two instruments whose form matches with the mode of interaction: the guitar-shaped instrument with strings (SG) and the tabletop instrument with a touch sensor (TT). The incongruent pairing represents the inverse: there is a mismatch

Figure 5.13: The two pairings of instruments: congruent (SG-TT) and incongruent (TG-ST)

between form and sensor topology, where the guitar instrument has a touch sensor (TG) and the tabletop instrument has guitar strings (ST). Our rationale for this was to use the 'congruent' pairing as a kind of control case, where we anticipated that participants would more readily associate the guitar shaped instrument (SG) with a guitar. The incongruent pairing was the more interesting case to us, which we hoped might tease apart the roles of global form and interaction modality: a strong preference for either in terms of guitar-likeness would suggest that either the presence of strings or the global design cues of a guitar were more important.

An equal number of guitarists and non-musicians were given each pairing, resulting in four groups under test: guitarists with the congruent SG-TT pairing, guitarists with the incongruent TG-ST pairing, non-musicians with the congruent pairing, and non-musicians with the incongruent pairing. Within each group, the order of presentation of the two instruments was reversed for half of the participants.

5.4.2 *Study format*

Participants were asked to take part in a number of musical tasks, interspersed with questionnaires and semi-structured interviews. The musical tasks involved either free improvisation or a structured score-following exercise. Semi-structured interviews were recorded throughout the experiment during which participants were asked their thoughts on the instrument, and to demonstrate the techniques

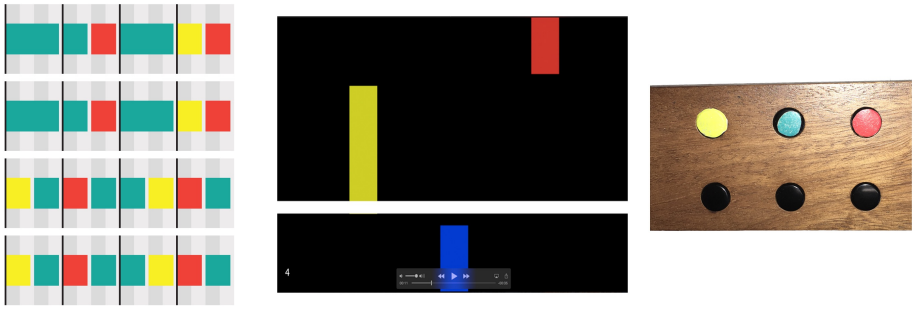


Figure 5.14: Colour-coded score and buttons designed to allow non-musicians to take part in musical activity with ease

they used and why they chose them. Two on-screen questionnaires were used during the experiment to gather quantitative data.

The score-following exercise involved rehearsing and performing an accompaniment to a pre-recorded folk song performed on fiddle and electric bass. We chose folk for this study due to the role of fretted string instruments as rhythmic harmonic accompaniments which are often strummed, allowing for a relatively accessible musical task to be set up, as well as to provide some cultural context to the task. We recorded a piece taken from the folk-RNN songbook [Sturm et al., 2015] for this purpose - allowing us to use source material that would be unfamiliar to the participants but remain stylistically appropriate. The recording had added percussion to allow participants to follow the beat. The chord structure of the song used chords I, IV and V in the key of G. We added coloured stickers to the buttons to indicate how these chords and printed a colour-coded score for participants to follow while playing. We also produced a video file displaying the chord colours and positions on screen as they appeared in the score, in a similar manner to the Guitar Hero games. Participants were allowed to use either or both of these methods to follow the backing track but were encouraged to use the printed score if they felt comfortable doing so. The buttons and score are presented in figure 5.14.

The free improvisation sessions involved leaving the room while the participant explored the instrument by themselves.

5.4.3 *Questionnaire*

The on-screen questionnaire consisted of the following 10 questions, loosely categorised into those that relate to *technical* factors (ease of use, naturalness of playing, responsiveness and proficiency with the instrument), *social* factors (preference for

playing in different environments, similarity to a guitar, how the sound met expectations) and *general preference* (which was instrument was more fun, and which was preferred overall). Unless otherwise stated, responses were given by placing a continuous slider on a horizontal plane, with 'Instrument 1' on the left and 'Instrument 2' on the right:

Technical:

- Which instrument was easier to play?
- Which instrument allowed you to play in the most natural way?
- Which instrument was more responsive to your style of playing?
- How well did you play the accompaniment on each instrument (*Two 5-point Likert scales for instrument 1 and 2*)

Social:

- Which instrument would you prefer to play at home?
- Which instrument could you imagine playing in a folk session?
- Which instrument was most similar to a guitar?
- Did the instrument sound like you expected (*Two 5-point Likert scales for instrument 1 and 2*)

General:

- Which instrument was more fun to play?
- Which instrument did you prefer to play?

A final question relating to the users' preference for the stringed instrument in either sample triggering mode or audio-rate excitation mode was included at the end of the study. This was also presented as continuous on screen slider with 'Setting 1' on the left and 'Setting 2' on the right. Participants were not made aware of (and did not use) the audio-rate mode (setting 2) prior to the final question.

5.4.4 *Order of tasks and timings*

The experiment was designed to last between 45-60 minutes. The order and approximate timings for each task in the experiment is given below:

Free improvisation with instrument 1 *(7 minutes)*
Accompaniment to folk tune with instrument 1 *(7 minutes)*
Free improvisation with instrument 2 *(7 minutes)*
Accompaniment to folk tune with instrument 2 *(7 minutes)*
On-screen questionnaire comparing instrument 1 and 2 *(5 minutes)*

Semi-structured interview comparing instruments 1 and 2 *(5 minutes)*
Free improvisation with string instrument, comparing setting 1 and 2 *(10 minutes)*
Semi-structured interview comparing setting 1 and 2 *(5 minutes)*
Final Questionnaire response *(<1 minute)*

5.5 RESULTS

5.5.1 *Participant Data*

19 Participants were male (13 guitarists and 6 non-musicians) and 13 were female (3 guitarists and 10 non-musicians). Participant age ranged from 18 to 62 with an avaerage 32 years old. The average GoldMSI score for each group were 89 (SD = 11) for guitarists and 55 (SD = 11) for non-musicians. Figure 5.15 displays the individual scores for each participant from lowest to highest. We noted

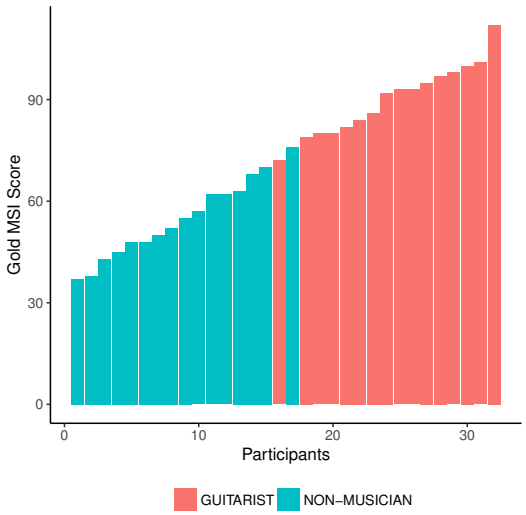


Figure 5.15: GoldMSI scores for each participant arranged in order

that the lowest-scoring participant from the guitarists group scored higher than the highest-scoring participant from the non-musicians group. After reviewing their responses to the questionnaires, it became apparent that the self-identified guitarist was in fact significantly less experienced than the rest of the group and struggled more with the musical task. The 'non-musician' appeared to have underestimated their musical experience when self-identifying, after disclosing that they were in fact able to play a number of chords on the guitar, and proving to be more

proficient at the musical task. We decided to swap these two participants in order to remove the apparent overlap in musicality between these groups. We chose to do this rather than remove them from the analysis, as our intended method of analysis required equal numbers in each group, and we reasoned that the overall musicality of these two participants was sufficiently equivalent to others in their re-assigned groups. This gave us the two 'musicality groupings' we were looking for in order to compare the effect of musical expertise.

5.5.2 *Questionnaire Ratings*

Results from the on-screen questionnaires are presented below. Each plot shows the median and interquartile range of responses to each question from both groups with the congruent and incongruent pairing.

Which instrument was easier to play?

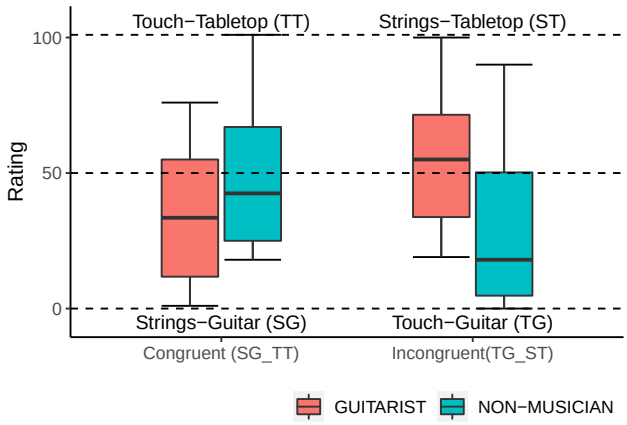


Figure 5.16: Response to Question 1

For the group with the congruent pair of instruments (SG and TT), a Mann-Whitney test indicated no significant difference in the ratings for ease of use between guitarists (*Mdn* = 33.5) and non-musicians (*Mdn* = 42.5), where a score of 100 indicates full preference for TT and 0 indicates full preference for SG, $U = 21.5$, $p = 0.29$, $r = 0.276$.

For the group with the incongruent pair (TG and ST), a Mann-Whitney test indicated no significant difference in the ratings for ease of use between guitarists (*Mdn* = 55) and non-musicians (*Mdn* = 18), where a score of 100 indicates full preference for ST and 0 indicates full preference for TG, $U = 49$, $p = .083$, $r = .45$.

5.5.2.1 *Which instrument allowed you to play in the most natural way?*

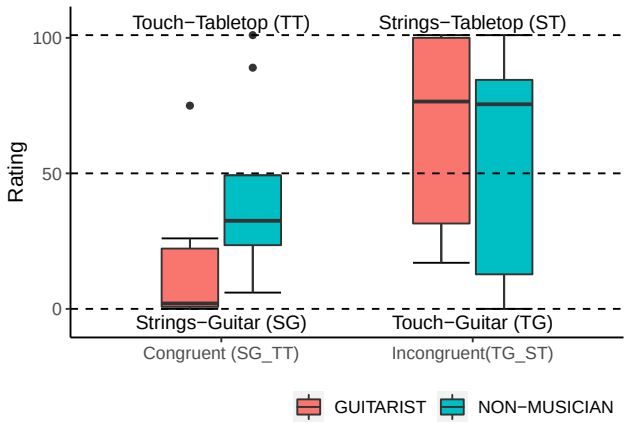


Figure 5.17: Response to Question 2

For the group with congruent pairing of instruments (SG and TT), a Mann-Whitney test indicated that guitarists rated SG as more natural to play (*Mdn* = 2) than the non-musicians (*Mdn* = 32.5), where a score of 100 indicates full preference for TT, and 0 indicates full preference for SG, $U = 10$, $p = 0.024$, $r = 0.578$.

For the group with the incongruent pair of instruments (ST and TG), a Mann-Whitney test indicated no significant difference in the ratings for naturalness between guitarists (*Mdn* = 76.5) and non-musicians (*Mdn* = 75.5), where a score of 100 indicates full preference for ST and 0 indicates full preference for TG, $U = 40.5$, $p = 0.4$, $r = 0.22$.

5.5.2.2 *Which instrument was most responsive to your style of playing?*

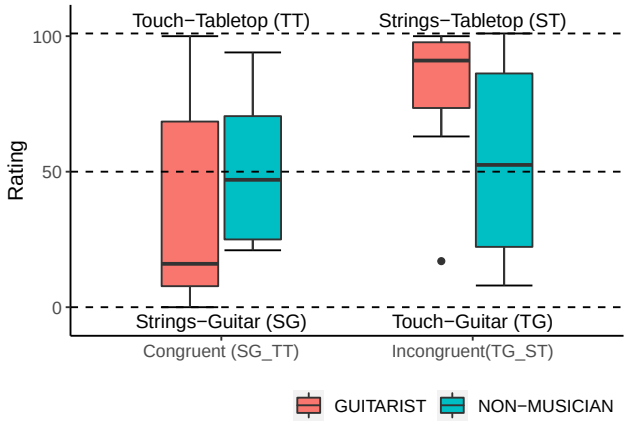


Figure 5.18: Response to Question 3

For the group with the congruent pair of instruments (SG and TT), a Mann-Whitney test indicated no significant difference in the ratings for responsiveness between guitarists (*Mdn* = 16) and non-musicians (*Mdn* = 47), where a score of 100 indicates full preference for TT and 0 indicates full preference for SG, $U = 20$, $p = 0.234$, $r = 0.315$.

For the group with the incongruent pair of instruments (ST and TG), a Mann-Whitney test indicated no significant difference in the ratings for responsiveness between guitarists (*Mdn* = 91) and non-musicians (*Mdn* = 52.5), where a score of 100 indicates full preference for ST and 0 indicates full preference for TG, $U = 44$, $p = 0.227$, $r = 0.315$.

5.5.2.3 *How well did you play the accompaniment on each instrument?*

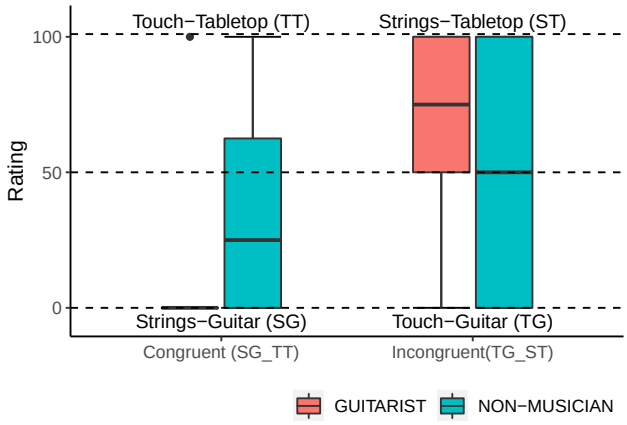


Figure 5.19: Response to Question 4

For this question, respondents were shown two 5-point Likert scales, indicating their rating for either instrument separately. In order to present this data in the same format as the other responses and perform the same statistical tests, we normalised these scores to a single rating of 0-100, where 0 indicates the performance is better on instrument 1, 100 indicates the performance was better on instrument 2, and 50 represents an equal rating.

For the group with the congruent pair of instruments (SG and TT), a Mann-Whitney test indicated no significant difference in the ratings for their performance between guitarists (*Mdn* = 0) and non-musicians (*Mdn* = 25), where a score of 100 indicates full preference for TT and 0 indicates full preference for SG, $U = 21$, $p = 0.178$, $r = 0.353$.

For the group with the incongruent pair of instruments (ST and TG), a Mann-Whitney test indicated no significant difference in the ratings for their performance

between guitarists (*Mdn* = 75) and non-musicians (*Mdn* = 50), where a score of 100 indicates full preference for ST and 0 indicates full preference for TG, $U = 38$, $p = 0.529$, $r = 0.172$.

5.5.2.4 *Which instrument would you prefer to play at home?*

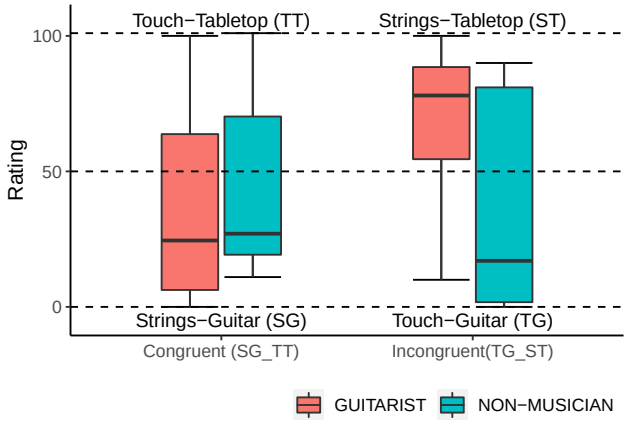


Figure 5.20: Response to Question 5

For the group with the congruent pair of instruments (SG and TT), a Mann-Whitney test indicated no significant difference in preference for playing at home between guitarists (*Mdn* = 24.5) and non-musicians (*Mdn* = 27), where a score of 100 indicates full preference for TT and 0 indicates full preference for SG, $U = 25$, $p = 0.505$, $r = 0.184$.

For the group with the incongruent pair of instruments (ST and TG), a Mann-Whitney test indicated no significant difference in preference for playing at home between guitarists (*Mdn* = 78) and non-musicians (*Mdn* = 17), where a score of 100 indicates full preference for ST and 0 indicates full preference for TG, $U = 45$, $p = 0.187$, $r = 0.343$.

5.5.2.5 *Which instrument could you imagine playing in a folk session?*

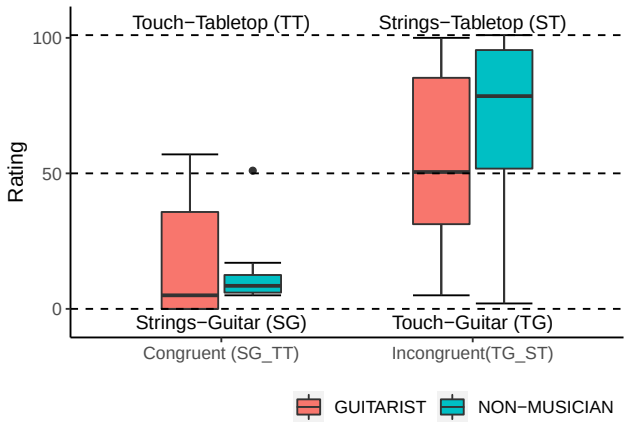


Figure 5.21: Response to Question 6

For the group with the congruent pair of instruments (SG and TT), a Mann-Whitney test indicated no significant difference in preference for playing at a folk session between guitarists (*Mdn* = 5) and non-musicians (*Mdn* = 8.5), where a score of 100 indicates full preference for TT and 0 indicates full preference for SG, U = 26, p = 0.561, r = 0.159.

For the group with the incongruent pair of instruments (ST and TG), a Mann-Whitney test indicated no significant difference in preference for playing at a folk session between guitarists (*Mdn* = 50.5) and non-musicians (*Mdn* = 78.5), where a score of 100 indicates full preference for ST and 0 indicates full preference for TG, U = 25.5, p = 0.528, r = 0.171.

5.5.2.6 *Which instrument was most similar to a guitar?*

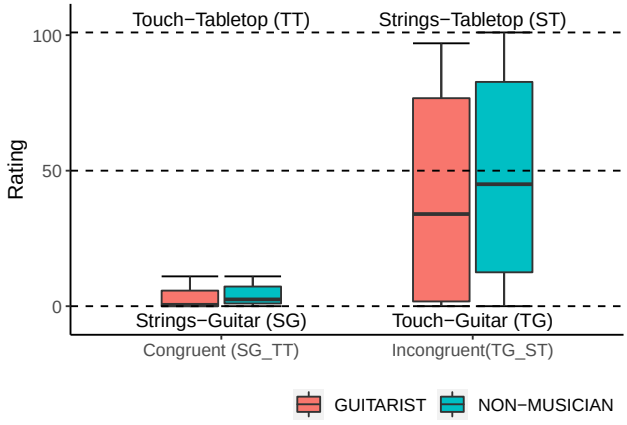


Figure 5.22: Response to Question 7

For the group with the congruent pair of instruments (SG and TT), a Mann-Whitney test indicated no significant difference in the ratings for guitar-likeness between guitarists (*Mdn* = 0.5) and non-musicians (*Mdn* = 2.5), where a score of 100 indicates full preference for TT and 0 indicates full preference for SG, $U = 24$, $p = 0.419$, $r = 0.216$.

For the group with the incongruent pair of instruments (ST and TG), a Mann-Whitney test indicated no significant difference in the ratings for guitar-likeness between guitarists (*Mdn* = 34) and non-musicians (*Mdn* = 45), where a score of 100 indicates full preference for ST and 0 indicates full preference for TG, $U = 28.5$, $p = 0.752$, $r = 0.092$.

5.5.2.7 *Did the instrument sound like you expected?*

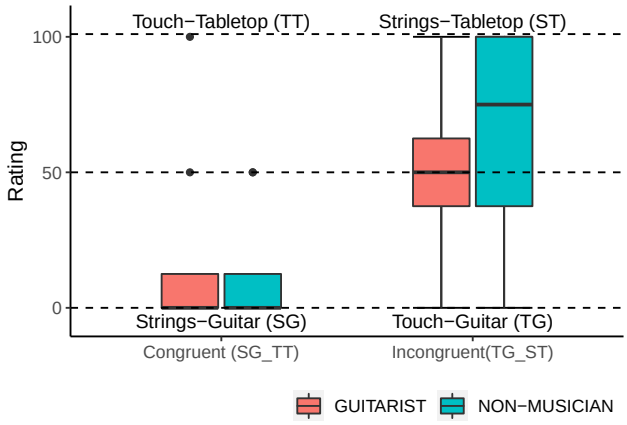


Figure 5.23: Response to Question 8

For this question, respondents were shown two 5-point Likert scales, indicating their rating for either instrument separately. In order to present this data in the same format as the other responses and perform the same statistical tests, we normalised these scores to a single rating of 0-100, where 0 indicates instrument 1 sounded most like they expected, 100 indicates instrument 2 sounded most like they expected, and 50 represents an equal rating.

For the group with the congruent pair of instruments (SG and TT), a Mann-Whitney test indicated no significant difference in the ratings for how well the instrument's sound met their expectations between guitarists (*Mdn* = 0) and non-musicians (*Mdn* = 0), where a score of 100 indicates full preference for TT and 0 indicates full preference for SG, $U = 33$, $p = 0.945$, $r = 0.0347$.

For the group with the incongruent pair of instruments (ST and TG), a Mann-Whitney test indicated no significant difference in the ratings for how well the

instrument's sound met their expectations between guitarists (*Mdn* = 50) and non-musicians (*Mdn* = 75), where a score of 100 indicates full preference for ST and 0 indicates full preference for TG, $U = 26$, $p = 0.539$, $r = 0.168$.

5.5.2.8 *Which instrument was more fun to play?*

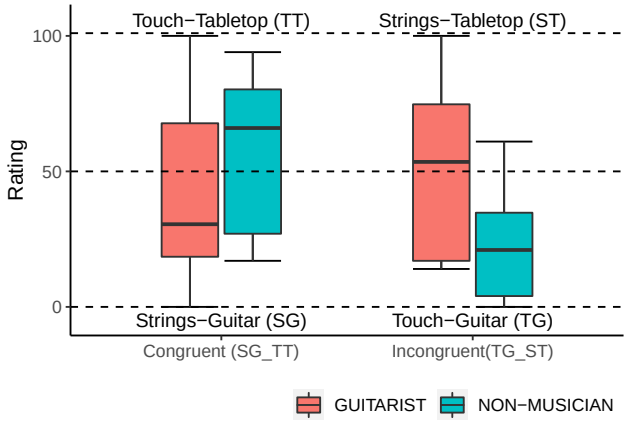


Figure 5.24: Response to Question 9

For the group with the congruent pair of instruments (SG and TT), a Mann-Whitney test indicated no significant difference in the ratings for which instrument was most fun to play between guitarists (*Mdn* = 30.5) and non-musicians (*Mdn* = 66), where a score of 100 indicates full preference for TT and 0 indicates full preference for SG, $U = 25$, $p = 0.495$, $r = 0.184$.

For the group with the incongruent pair of instruments (ST and TG), a Mann-Whitney test indicated no significant difference in the ratings for which instrument was most fun to play between guitarists (*Mdn* = 53.5) and non-musicians (*Mdn* = 21), where a score of 100 indicates full preference for ST and 0 indicates full preference for TG, $U = 48$, $p = 0.103$, $r = 0.420$.

5.5.2.9 *Which instrument did you prefer to play?*

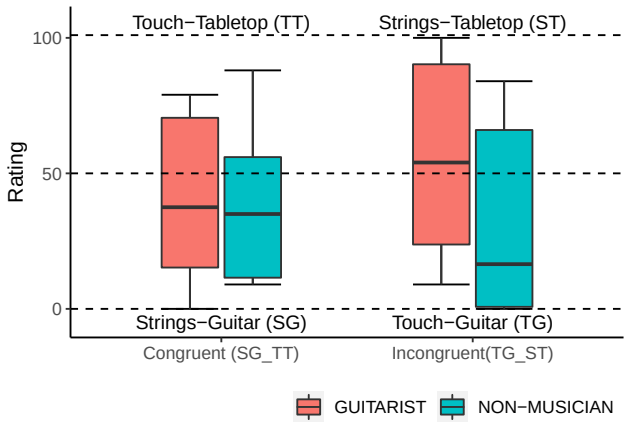


Figure 5.25: Response to Question 10

For the group with the congruent pair of instruments (SG and TT), a Mann-Whitney test indicated no significant difference in the ratings for which instrument they preferred to play between guitarists (*Mdn* = 37.5) and non-musicians (*Mdn* = 35), where a score of 100 indicates full preference for TT and 0 indicates full preference for SG, $U = 34$, $p = 0.875$, $r = 0.0525$.

For the group with the incongruent pair of instruments (ST and TG), a Mann-Whitney test indicated no significant difference in the ratings for which instrument they preferred to play between guitarists (*Mdn* = 54) and non-musicians (*Mdn* = 16.5), where a score of 100 indicates full preference for ST and 0 indicates full preference for TG, $U = 48$, $p = 0.103$, $r = 0.421$.

5.5.3 *Richness*

Figure 5.26 displays the results to the final question referring to the two richness settings. These results only take into account the difference between richness settings for the two stringed instruments (ST and SG), and so we are not considering the congruent or incongruent pairings as separate. A Mann-Whitney test indicated that guitarists preferred the richer (audio-rate sensing) setting (*Mdn* = 96) more than non-musicians (*Mdn* = 29), where a score of 100 indicates full preference for the rich setting and 0 indicates full preference for the less rich (sample-triggering) setting, $U = 237$, $p = 0.00004$, $r = 0.729$.

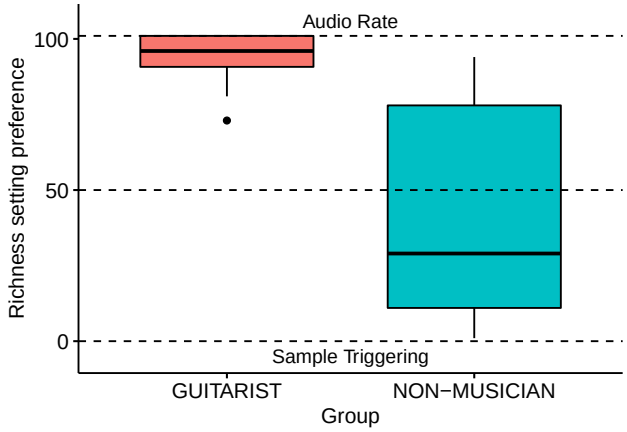


Figure 5.26: Preferences of both groups regarding the variable richness settings of the string instruments

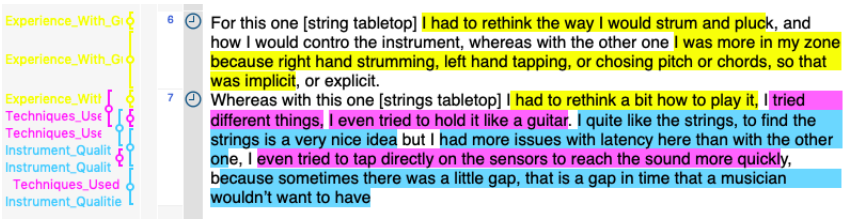


Figure 5.27: Screenshot of the coding process in MaxQDA software

5.5.4 *Semi-structured interviews*

We transcribed and analysed the semi-structured interviews in which participants were asked to compare the two instruments and demonstrate any techniques they used to play on either instrument. We then performed a thematic analysis of the transcriptions based on the methods described by Braun and Clarke [2006]. This involved familiarising ourselves with the data during the transcription phase, followed by an initial pass where both researchers were assigned half of the transcriptions each to identify themes in the data. We then verified the identified themes and swapped datasets for a second pass, where specific quotes were assigned to the agreed-upon codes.

Themes that appeared consistently across both user groups included comments on the *aesthetics* of the instruments, their *comfort or ease of use*, making direct *comparisons* between the two instruments and other traditional instruments, the perceived *authenticity* of the instruments, and their *familiarity*. Figure 5.27 shows a screenshot of the coding process in the MaxQDA software.

Below are quotes from the structured interviews, organised into the themes described above:

5.5.4.1 *Guitarists*

Aesthetics:

P32: *'I really liked the finish' [TG]*

P32: *'It looks like something from a luthier [TG]'*

P13: *'When I first saw [TG] I thought it looks cool, but it does feel like a game controller'*

P8: *'I really liked [TT], it was probably my favourite, it has a cool interface'*

Comfort / ease of use:

P32: *'For [ST] I had to rethink the way I would strum and pluck'*

P32: *'It was a bit awkward playing [ST] on the table, a bit constrained, whereas with the guitar [TG] it's more natural. I don't understand why both hands should be constrained like that [with ST]'*

P32: *'Strumming on [ST] there is an issue with the vertical position of the strings'*

P32: *'I like the fact that the strings are loose which makes it easy to strum [ST]'*

P28: *'[ST] feels quite uncomfortable for fingerpicking because it's on the table, so I found it quite difficult. The buttons are much more comfortable on the neck [TG]'*

P19: *'I played [ST] in lots of ways but playing it in guitar-oriented ways worked best'*

P19: *'I found [TG] harder to strum chords so just picked notes'*

P19: *'The lack of haptic response is a limitation [TG]'*

P16: *'The question was how do I actually orientate [ST] and make it comfortable to play'*

P16: *'I was trying to strum [TG] properly but I wasn't entirely convinced of my ability to do a decent sounding strum'*

P13: *'I found [ST] quite easy to play fingerstyle'*

P13: *'I played [ST] like this (holding it upright like an autoharp) which feels quite nice actually'*

P12: *'The touch sensor feels real nice to play with and I especially like that I can do things like this (rapid tapping on sensor) on one or multiple strings [TG]'*

P12: *'It was hard to find out how to play a melody, but I really liked playing [TG]'*

P10: *'It was easier to do chords with the buttons, but I would struggle to do anything more intricate than that'*

P10: *'[TT] was trickier, but then I was thinking about how I was playing [SG], so would try to strum it, but it's a slightly awkward motion with [TT].'*

P6: *'[TT] wasn't very intuitive at the beginning, and it took me a while to realise that the six lines represented strings'*

P4: *'I found it difficult to hit the right notes because although I can feel this separation it's not as easy as the guitar strings' [TT]*

P4: *'I wasn't able to hit the strings without practicing for a long time [TT]'*

P2: *'[SG] was very difficult because I've been playing guitar for a while, it was impossible to play when you pluck very lightly. If you're playing with chords and stuff like that then ok.'*

Comparison to other instruments:

P32: *'It's almost like you need to have a piano style to play it [ST]'*

P30: *'I was trying to see if [ST] could be plucked like a guitar, like a bass string with three strings in triplets'*

P30: *'[TG] said guitar to me as soon as a saw it, when I saw [ST] I thought 'yeehaa' those slidey country and western instruments like a lap steel'*

P30: *'With the strings [ST] it's very obviously a guitar'*

P30: *'I enjoyed playing [TG] more immediately because it's closer to a guitar'*

P28: *'I used my nail to Strum [ST] which is how I would play guitar'*

P27: *'[ST] is more preferable because it's like an autoharp'*

P27: *'[TG] is more akin to a keyboard in some ways'*

P19: *'It's interesting because in many ways [ST] leads me in a different way towards the guitar, with the strings, whereas with [TG] the neck and what you're doing with your left hand lead you towards a guitar.'*

P16: *'I tried to do some picky stuff with [ST] like a really guitar action which is fairly obvious'*

P16: *'The touchplate is cool, it seems more modular synthy than something you would do a guitar thing with. Like it's similar to a Buchla Touchplate. [TG]'*

P13: *'I would probably try and play [TG] like a lap steel'*

P11: *'[TT] reminded me a bit of a piano accordion, and [SG] obviously reminded me of a guitar, but the right hand couldn't be anything like as expressive'*

P10: *'I started trying to play [TT] like a harp'*

P9: *'For [TT] I was trying to do more of a piano-like approach, more percussive'*

P6: *'I didn't have to modify my playing position, it was like a ukelele or something smaller than a guitar' [SG]*

P6: *'For a rhythm guitar it's a perfect replica in a way' [SG]*

P6: *'With [TT] I discovered a technique to treat it like a keyboard'*

P2: *'I found [SG] more fun to play by tapping on the bridge pieces, like an accordion'*

Authenticity:

P32: *'It felt more natural to play [TG] compared with [ST]'*

P30: *'If you were playing in a band, if it was a folk thing, [ST] would be more deeply satisfying, whereas [TG] is more immediately available'*

P19: *'Lacking strings ... touching a bit of circuit board doesn't do it for me. I don't get the picture of how to gesturally interact with enough conviction to actually do it'*

P16: *'I think the strum gesture really needs the tactility of a real string' [TG]*

P16: *'Obviously [TG] feels more like a real guitar on account of it being, you know it's got that physicality, but I preferred having the strings (with [ST]) and didn't mind it being on the tabletop'*

P13: *'[TG] felt more like a game controller whereas [ST] felt more like a real instrument, but I think that's my prejudice from an instrumentalist's point of view'*

P12: *'Because I was just strumming with [ST], the overall performance was more accurate, or musical'*

P8: *'It felt more natural to strum [SG] than to pick, although for finger-picking it felt more conducive to classical guitar picking'*

P6: *'I used the string muting functionality to my advantage to create syncopation and that added a natural feel [SG]'*

P6: *'[SG] is better for strumming but [TT] feels more natural when I play it like a keyboard, tapping it'*

P6: *'[TT] feels more like a MIDI signal, it doesn't have the envelope coming from an actual strum'*

P6: *'I am assuming that guitarists would find it more comfortable to play [TT] like an autoharp, like also a guitar but a digital one'*

P4: *'Because I'm used to playing guitar, it was more natural to hold [SG]'*

Familiarity:

P32: *'It's held as a guitar which is nice, that's the instrument I'm familiar with' [TG]*

P32: *'With [TG] I was more in my zone because the right hand strumming, left hand choosing pitch or chords, was implicit'*

P30: *'[TG] said guitar to me as soon as I saw it'*

P30: *'I don't know if I maybe missed having the feel of different string gauges, even though I got used to it quickly' [ST]*

P28: *'The [TG] is a bit trickier because the touch sensor thing is not, it's a bit weird and feels unusual because I'm used to strings'*

P28: *'The shape of [TG] is much more comfortable as a guitar player'*

P27: *'[TG] didn't feel right, it felt like a weird approximation whereas with [ST] it felt familiar, the feel of strings and how you can touch the strings and pick the strings'*

P27: *'[TG] is made to look and feel like a guitar in some way but you're not used to playing a guitar with your fingers on buttons and this sensor is not as easy to play as these strings because of the way it responds'*

P19: *'The strings gave a nice feel [ST]'*

P19: *'I could play [ST] and it felt much better'*

P16: *'[ST] was fairly intuitive from the point of view of 'here's some strings, you pluck them"*

P16: *'Again with [TG] the obvious parallel is to try to strum it'*

P16: *'The buttons on [TG] are fairly intuitive straight away because you've got the physicality of the proper guitar shape and it's nice and heavy'*

P16: *'[TG] is more immediate in the way that you hold it, but I'm not entirely convinced about that as the input mechanism if you're trying to do a strum.'*

P13: *'I felt more able to play along to the backing track with [ST], I think because the tactility of the strings lends itself to more innate skill'*

P13: *'I prefer [ST] definitely as a player'*

P12: *'[ST] looks more familiar, it looks more like a guitar because it has six strings'*

P12: *'I felt like I could do less with [ST], which is funny because it's a more similar interface'*

P11: *'I guess because I'm more comfortable playing the guitar, I could strum [SG] more rhythmically'*

P10: *'I strummed [SG] like a guitar because I'm a guitarist'*

P9: *'Because you're given more of a guitar-ish thing you're more inclined to say ok I'm going to do a comparison of folk music, you're already biased to hear the strumming.' [SG]*

P9: *'With this kind of touch sensor, we're more biased towards pitch-shifting or amplitude or something. [TT]'*

P6: *'With [SG] I used pre-existing plucked string techniques, my right hand was doing exactly what it would do on an acoustic plucked string instrument '*

P6: *'With the left hand, we're all used to touching keys and buttons nowadays - it was very different to holding strings but I have played guitar hero before and it was bit like that' [TG]*

P4: *'Maybe because I'm used to guitar strings [SG] is easier.'*

P4: *'The strings are slightly different from what I'm used to, but it was easier to find my way with them' [SG]*

P3: *'[SG] is so similar to a guitar, you're comparing it to a guitar so that's what I was trying to do with my technique'*

5.5.4.2 *Non-musicians*

Aesthetics:

P29: *'I think if you combined the two instruments [ST] and [TG] that would be best'*

P26: *'[ST] has a weird shape'*

P26: *'I prefer having the strings visual and physical' [ST]*

P22: *'I preferred the more crisp sound of [TT] because it doesn't have physical strings'*

P18: *'[ST] looks like one of those folk lore instruments, too traditional, not too innovative. But [TG] looks better'*

Comfort / ease of use:

P31: *'[TT] was a bit, not hard to play, but not as responsive as you'd like it, whereas with [SG] you can just strum it and it does what you want'*

P29: *'With [TG] it was more difficult because I kept drifting away from the sensor. With [ST] I could feel the strings in front of me and it was more compact'*

P29: *'I found it easier to play [ST] on one side in more the position of a guitar'*

P26: *'[TG] was much harder because I couldn't see the single strings.'*

P24: *'I found it quite hard to get which notes I was playing with [TT]'*

P21: *'It wasn't that natural or easy to push the buttons' [TG]*

P21: *'I thought [ST] would be easier to play, but the strings were really confusing compared with [TG]'*

P21: *'[ST] was easier to hold compared with [TG] but I felt like I needed to be more precise about where I touched'*

P20: *'I had a bit of trouble knowing where to play my hands when I held [TG] like a guitar, as I had never played an instrument before'*

P20: *'With [ST], I was thinking about how to place my hands and my body in the most natural way'*

P18: *'[TG] was more convenient to place both hands'*

P18: *'I like the swiping thing with [TG] better, you can get used to it much faster, it's much easier.'*

P17: *'I found [TG] much easier because it didn't have those strings and you could just do it like (swiping fingers on the sensor) and feel like you were strumming'*

P17: *'However for the guitar hero thing I think I did better on [ST] because I kept missing the buttons on the neck with [TG]'*

Comparison to other instruments:

P26: *'[ST] has a weird shape, kind of like a guitar but all condensed into one so you can play with it, just because it has strings this looks and sounds more like a guitar. I was expecting it to sound like a classical guitar, whereas I was expecting [TG] to be more like an electric guitar'*

P25: *'[SG] is more similar to a guitar'*

P18: *'[TG] is much more fun, also it resembles the guitar. I hope it replaces the guitar.'*

P14: *'[TG] is quite like a guitar style for me '*

P14: *'For me [ST] is more like a santur (mimes tapping the strings with sides of fingers)'*

Authenticity:

P18: *'[TG] is more comfortable, but [ST] is the more natural version'*

P15: *'With [TG], the buttons were more fun to play with because it felt more like holding a guitar so the design of the instrument felt more authentic in a way'*

Familiarity:

P26: *'With [ST] I see the strings and know what to do, whereas with [TG] it was kind of weird and I didn't know if I had strummed them all or missed one.'*

P26: *'With [ST] I could recognised the introduction of songs and play them'*

P22: *'[SG] obviously feels much more like a guitar'*

P14: *'I don't think [ST] is a common type of instrument'*

5.6 DISCUSSION

5.6.1 *Global form vs. interaction modality*

The results from the questionnaires and structured interviews highlighted some interesting effects of modulating instrument form, interaction modality and richness across different user groups. Concerning global form and interaction modality, the instruments we presented the participants with represented two pairings, a *congruent* pairing made up of the Strings-Guitar and Touch-Tabletop instrument, and an *incongruent* pairing: the Touch-Guitar and Strings-Tabletop. Perhaps predictably, the preference and comparison ratings for factors such as 'guitar-likeness' fell to-

wards the Strings-Guitar instrument in this case - with these pairings global form and interaction modality are matched, and so a guitar-shaped instrument with strummable strings is reported as the most 'guitar-like', and most preferred for use in a folk session. This could be seen as a control case, which verifies that participants understood what the guitar form and strummable strings were intended to achieve.

The more interesting case then is the 'incongruent' pairing, where we have introduced a mis-match between form and interaction modality. Participants from both groups with either pairing were much less clear on their preference, especially when concerned with questions relating to guitar-likeness. We expected to find a difference between the two user groups with the incongruent pairing: our hypothesis was that those who had experience playing the guitar would prefer the preservation of interaction modality regardless of global form, whereas novice users would prefer the instrument which carried more of the cultural weight of a guitar i.e. in macro-level global form rather than micro-level interaction detail. What we found was that there was no significant difference between the two groups in this case, although there were some observable trends across the groups which could be backed up by findings from the structured interviews.

5.6.1.1 *Interaction modality*

In general, trends related to input modality concerned sensing strategy and the reinforcement of the participant's control through the physicality of the input device.

Guitarists: This group generally gave higher ratings to the stringed versions of the instruments regardless of the global form. From the structured interviews there were reports of the strings feeling more natural to play and allowing the use of existing techniques that they had from the guitar (P32: *'I was more in my zone because of the right hand strumming'*). The tactility of the strings was mentioned as an important factor as this provided a physical support for their gestures (P13: *'The tactility of the strings [ST] lends itself to more innate skills'*).

Criticisms of the touch sensor from this group repeatedly focused on the lack of an anchor, or reference point that would tell them where their hand was positioned (P28: *'it's a bit weird and feels a bit unusual, because I'm used to strings ... there's not a lot of tactile cues'*). Their hands would often drift away from the sensing area if they were not visually monitoring it.

Considering the various themes which were identified in Section 5.5.4, comments from guitarists related to interaction modality were mainly centered on *ease of use*, *comparison to other instruments*, *authenticity* and *familiarity*.

Despite the presence of physical strings, many guitarists cited the subtle differences in tactile response between the looser strings and those of an actual guitar, when commenting on the *ease of use* of the instruments. Some participants commented that this was a positive feature, making it easy to play (P32: *'I like the fact that the strings are loose which makes it easy to strum'*). However P2 found the strings on [SG] *'very difficult'* as a result of his prior experience with guitar, being unable to play by plucking very lightly.

Comments involving a *comparison to other instruments* often compared [ST] with a guitar due to the presence of strings: P30: *'With the strings [ST] it's very obviously a guitar'*, however P32 compared the playing style of [ST] with piano, and P27 compared [ST] to an autoharp rather than a guitar. P16 commented that the touch sensor on [TG] was *'more modular synthy than something you would do a guitar thing with'*, suggesting that the touch sensor was an inappropriate method of interacting with a guitar-like.

Some comments which were related to perceived *authenticity* of the instruments appeared to stem directly from the presence of strings. P19 stated that *'Lacking strings ... touching a bit of circuit board doesn't do it for me. I don't get the picture of how to gesturally interact with enough conviction to actually do it'*, suggesting that the authenticity of their performance was hampered by the lack of tactile strings. P13 stated that *'[TG] felt more like a game controller whereas [ST] felt more like a real instrument'*, suggesting that the presence of strings regardless of form was potential more 'real' or authentic than a familiar form with touch-sensitive approximation of strings.

With regards to the *familiarity* theme, guitarists in the incongruent group tended to reference the strings on [ST] as a familiar feature, as opposed to the shape of the body on [TG]. An example here is P27, who remarked that *'[TG] didn't feel right, it felt like a weird approximation whereas with [ST] it felt familiar, the feel of strings and how you can touch the strings and pick the strings'*. P16 and P13 both made references to the presence of strings being *'intuitive'*, or lending themselves to *'innate skill'*.

Non-musicians: There were diverse reports of preference from this group with a relatively even split between the two input modalities. Many in this group commented positively on the presence of the strings mentioning that when they saw

the strings they knew what to do (P26: *'I see the strings here so I know what to do and they are physical.'*), whereas with the sensor it was less clear what gesture was expected.

For the string instruments there was an increase in unconventional techniques reported in the structured interview (tapping on bridge pieces, tapping and pushing down stings, flat rolling of fingers to trigger strings). This group was more inventive in their interpretation of the strings than the guitarists. The touch sensor input modality was rated as more fun to play than the strings by the non-musicians regardless of global form. This suggests that the novelty of this interaction could have advantages with this group.

The strings input modality also seemed to act as a strong social cue: the tabletop instrument with strings was still compared to a guitar (P26: *'kind of like a guitar but all condensed into one ... because it has strings it looks and sounds more like a guitar'*), preferred for folk performance, and reported as more natural. This suggests that the strings are strongly associated with 'authentic' guitar performances even when global form is radically different.

Going back to the themes identified during the thematic analysis process, non-musician's comments were mostly centered around the comfort/ease of use of the instruments when discussing the interaction modality. P21 and P18 both considered the touch sensor on [TG] easier to use: *'I thought [ST] would be easier to play, but the strings were really confusing compared with [TG]'*, *'I like the swiping thing with [TG] better, you can get used to it much faster, it's much easier'*. P29 however found the touch sensor harder to use, and relied on the strings on [ST] for tactile feedback: '*With [TG] it was more difficult because I kept drifting away from the sensor. With [ST] I could feel the strings in front of me and it was more compact*'.

5.6.1.2 *Global form*

Guitarists: In the ST-TG pairing we still observed guitarists siding with the string version of the instrument regardless of global form. This also held true across the majority of the quality ratings aside from guitar-likeness and suitability for a folk session, where there was no consensus in the group. Perhaps this suggests that the guitarists consider a guitar-like instrument to be most socially acceptable in a folk context, but do not agree which instrument is indeed most guitar-like. Two guitarists in the ST-TG group reported preferring the TG to ST: the ergonomics of the guitar form, in terms of positioning of the right hand and being able to hold the instrument like a guitar, were given as reasons (P32: *'it's held as a guitar ... that's*

the instrument I'm familiar with so it felt more natural'). A common approach with the ST instrument was to lift it up or place it on their lap to make it easier to play.

Guitarists' comments on the *aesthetics* of the instruments were understandably focused on global form, but were varied in their views: P32 stated that [TG] *'looks like something from a luthier'*, while P13 commented *'when I first saw [TG] I thought it looks cool, but it does feel like a game controller'*. Interestingly, one guitarist (P8) stated that [TT] was *'probably [their] favourite, it has a cool interface'*, despite [TT] being the least 'guitar-like' instrument. Perhaps in this case, the more guitar-like instruments enter into an 'uncanny valley', where the approximation of a guitar-like instrument is more off-putting than an instrument which looks and plays nothing like a guitar.

In terms of *comparisons to other instruments*, there were fewer comments regarding the global form of the instrument. P30 stated that '*[TG] said guitar to me as soon as a saw it, when I saw [ST] I thought 'yeehaa', those slidey country and western instruments like a lap steel'*, suggesting that the guitar form of [TG] was indeed evocative of a guitar for this participant. Interestingly, the presence of strings on [ST] still elicited a comparison to guitar-like instruments for this participant, albeit a lap steel guitar. The idea that the strings were themselves a visual cue was also introduced by P19: *'It's interesting because in many ways [ST] leads me in a different way towards the guitar, with the strings, whereas with [TG] the neck and what you're doing with your left hand lead you towards a guitar'*.

Concerning *authenticity*, guitarists were less focused on the physical form of the instrument than the interaction modality. One participant commented that *'[TG] feels more like a real guitar on account if [its physicality] but I preferred having the strings (with [ST]) and didn't mind it being on the tabletop'* (P16). For this guitarist, they were well aware that the tabletop form was less guitar-like, but conscious of the fact that global form was less important to them than the presence of strings.

In terms of *familiarity*, comments such as *'[TG] said guitar to me as soon as I saw it'* (P30), *'the shape of [TG] is much more comfortable as a guitar player'* (P28), and *'[TG] is more immediate in the way that you hold it'* (P16), suggest that preserving the guitar form was successful in evoking guitar-likeness for these participants. Interestingly, one participant commented that *'[ST] looks more familiar, it looks more like a guitar because it has six strings'* (P12). This was an unexpected insight: the presence of strings was more than a familiar physical interface for the guitarists - it also provided a visual cue that suggested guitar-likeness.

Non-musicians:

Generally speaking, we found the comments made by non-musicians to be less in-depth than the guitarists, and identified fewer comments relating explicitly to the global form of the instruments. Echoing the comments made by P12 in the guitarists group, one non-musician (P26) made a similar comment on the strings as a visual cue: *'[ST] has a weird shape, kind of like a guitar but all condensed into one ... because it has strings it looks and sounds like a guitar'*. Other noteworthy comments from the non-musicians group regarding global form were focused on the *aesthetics* of the instruments: P26 *'[ST] has a weird shape'*, P18: *'[ST] looks like one of those folk lore instruments, too traditional, not innovative. [TG] looks better'*.

We also noted that one participant (P14) compared the form of ST to a santur, an Iranian folk instrument. Our goal with the design of the ST instrument enclosure was to evoke modern bespoke music technology, but we had inadvertently incorporated design cues from the santur, being a horizontally placed string instrument of a similar shape. In this case, the participant was familiar with santur playing, and so the form of ST suggested a technique (percussive tapping on the strings) that we didn't intend to suggest with the global form.

5.6.1.3 *General reflections*

The results from the questionnaire failed to highlight a significant difference in the way that non-musicians and guitarists rated the instruments (with the exception that guitarists with the congruent pairing of instruments rated SG as more natural to play than the non-musicians did). However, the structured interview responses gave us insights into the reasonings behind individual's ratings, which highlighted some interesting insights which appeared to be predicated on individuals' prior experience with the instruments.

With this study we attempted to isolate two factors that we hypothesised would influence players' evaluation of how 'guitar-like' an instrument was, in order to identify strategies for developing new guitar-like DMIs that preserve the role of the guitar in more accessible form factors. This line of enquiry was influenced by the previous study on the adapted bass (Chapter 4), where we reflected on the fact that there were two significant factors at play: the preservation of plucking hand techniques, and the overall visual cues of the bass guitar body. We had begun the prior study being mainly concerned with the 'object-focused' idea that preserving technical functionalities of the bass was the solution to an accessible adaptation,

but later moved towards a 'culture-focused' view that perhaps the presence of the recognisable bass guitar body was just as, if not more, important in preserving the role of the bass.

Reflecting on the original research question presented in Section 5.2.1:

> *When designing a DMI intended to fulfil the musical role of a guitar, which is more important: global form or interaction modality?*

The implied question here, with respect to ADMI design, could be formulated as:

> *When designing a guitar-based ADMI, how can designers best utilise/evoke the cultural form of guitar playing: through familiar interaction techniques, or guitar-like aesthetic qualities?*

The results from both the questionnaire and the structured interviews do not paint a clear picture of how global form and interaction modality evoke the cultural form of guitar playing, although they do hint towards a prioritisation of maintaining familiar technique for those with prior experience. What we can perhaps take away from this lack of clarity is that global form and interaction modality are not as cleanly separable as we first assumed in our study design. This can be seen in the fact that the strings acted as both a physical support for prior guitar experience, and a visual cue that suggests 'guitar-likeness'.

The implication for ADMI designers is that there is perhaps more to providing access to existing instruments than simply developing a physically accessible means of playing back the sound of that instrument.

5.6.2 *Richness*

The findings from the portion of the study comparing the variable richness settings of the strings instruments are primarily relevant to the co-researcher's work, published in [Jack et al., 2018] and [Jack, 2019]. However, the notion of constraining or expanding control intimacy based on musical expertise and ability has direct relevance to the topic of ADMIs.

The fact that the guitarists unanimously preferred the richer setting for the strings instrument, whilst the non-musicians were much more split in their opinion, challenges the notion that a 'richer instrument is a better instrument'. We were unsurprised by the response of the guitarists as we had anticipated a level of frustration with the less rich instrument due to the inability to translate familiar gestures to the expected musical outcome. However, the ambiguity of the

non-musicians' response challenged us to question our own values around control intimacy and how it relates to the quality of an instrument. Reasonings for preferring this setting amongst the non-musicians tended to relate to the consistency and clarity of sound that was achievable with the sample-triggering setting. When presented with the audio-rate excitation setting, many players reported that the instrument was quieter, and required more energy to produce a consistent volume and tone.

What do these findings mean to ADMI designers? In my formulation of what makes an ADMI 'performance-focused' (discussed in Chapter 2), I proposed that in order to remove barriers to existing musical cultures, an ADMI should possess similar levels of musical diversity - a concept taken from Jordà [2004] - to a traditional instrument. My reasoning here was that many existing ADMIs reduce the availability of both repertoire and control intimacy through constraints in the gesture-to-sound mapping. An example might be with the Skoog, which allows a maximum of five playable notes before needing to change instrument parameters in the software. This is clearly restrictive in cases where a user might want to fluidly perform a piece containing more than five notes. Conversely, the Kellycaster has a much wider range of available repertoire and thus higher musical diversity.

What the outcome of the richness study suggests to us however, is that the constraint put in place by the less rich setting in fact acts as a support to the players with less experience playing guitar, providing consistent, clear notes, at the expense of micro-diversity in playing technique. This suggests that lower musical diversity isn't by default a negative aspect of an instrument, and is very much dependent on the personal preference, musical goals, and prior expertise of the player. For future ADMI designers, I propose attempting to place the constraints of the interface and mapping in line with the musical goals of the player.

The 'variable constraint' of the two richness settings could also be seen as a form of 'complexity management', a concept proposed by Pardue [2017] as a means for assisting with musical instrument learning. Complexity management essentially means modifying the musical complexity of an instrument relative to the expertise of the learner - in the case of violin playing, this might mean 'auto-tuning' the pitch of the strings in order to allow the learner to focus on bow technique without worrying about intonation. Complexity management might also be a valuable concept within ADMI design, providing agency over where the constraints / complexity of an instrument are set.

5.7 REFLECTIONS

In this chapter, we set out on an ambitious task to tease apart several essential features of the guitar, in order to uncover how best to preserve the role of the guitar, while modifying other aspects. Somewhat unsurprisingly, we found that there are no clear answers here: the roles of global form and interaction modality are tightly coupled. What we did find was that 'what makes a guitar a guitar' is something perhaps more elastic than simply its sound, looks, or playing technique.

In our shift from an 'object-focused' to a 'culture-focused' view of accessibility, we've shown that there perhaps is more to making an accessible guitar than providing a means of playing guitar-like sounds. This is likely something that is already well known to ADMI designers, but in the technology-focused arenas in which many ADMIs are discussed, the role of culture and context can end up being left out of the conversation. If nothing else, I hope that this study can serve to reinforce the argument that we should be addressing questions of cultural context in our attempts to lower or remove barriers to musical performance.

A major limitation of this study with respect to ADMI design is of course the fact that we did not recruit disabled musicians for the user test, and so we cannot say anything about how the instruments we developed might fit in the lived experience of a disabled musician. We cannot also assume that the musical goals and values of the non-disabled participants in the study would align with those of disabled musicians. The goal with this study was to take as a starting point the idea that a guitar-like instrument with an alternate chord selection method and a preservation of strumming technique would be a candidate for a successful ADMI - but not to assume anything relating to accessibility for a specific person or community.

Another limitation is the short-term, lab-based nature of the study. While this was useful to us in terms of recruiting enough participants to hopefully observe trends across different groups, and setting up a rigidly defined set of musical tasks, it meant that we were not able to observe how participants' appraisal of the instrument might evolve over time, or in the context of a real-world setting.

These two limitations are addressed in the following chapter, in which I describe a longitudinal, situated research activity with a group of learning disabled musicians, in the context of a community music jamming session.

6

THE STRUMMIS IN THE WILD

This chapter presents the final research engagement undertaken as part of the PhD. A late-breaking work paper describing the early reflections on the engagement with Heart n Soul was published at the CHI conference on Human Factors in Computing Systems in 2019 as 'Accessible Instruments in the Wild: Engaging with a Community of Learning-Disabled Musicians' by Harrison, Chamberlain and McPherson [Harrison et al., 2019]. The discussion of research products features in the paper 'Digital Musical Instruments as Research Products' by Jack, Harrison and McPherson [Jack et al., 2020].

6.1 INTRODUCTION

In this chapter, I will attempt to collate the theories and approaches around music and disability developed over the course of the previous chapters, and set them in the context of an in-the-wild study with a group of learning-disabled musicians. In previous chapters, we have discussed the notion that musical instruments carry with them a set of social and cultural roles and values beyond the scope of their technical functionality. In this chapter, I describe a study which is aimed at probing how viewing instruments in this way within the context of disability can shape approaches to access and accessibility.

I will begin with a discussion of the key methodologies and working approaches relevant to this study. In particular, this study has been informed by ethnography-based HCI research, for its ability to take into account sociocultural factors of design beyond measures of usability/functionality. I will provide an overview of *In-the-Wild* approaches in HCI, and the accompanying topics of ethnography and reflexivity.

I then introduce *Heart n Soul*, a creative arts organisation who work with young people and adults with learning disabilities. Heart n Soul have acted as collaborators in this research, and the entirety of the fieldwork described in this chapter has been conducted through Heart n Soul's organisational framework. In keeping with a 'thick description' approach to ethnography (as described by Rode [2011]),

I provide a brief history of Heart n Soul and a description of their day-to-day activities, in order to contextualise our engagement with them.

Following this description of Heart n Soul, I report on my own long-term engagement with them in the role of researcher, volunteer and facilitator, and how this engagement has shaped and been shaped by the research goals described in this chapter.

Finally, I present a field study consisting of two music-making sessions with a range of rock band instruments including three versions of a guitar-like instrument which we called the Strummi. This concludes with a discussion of the key themes and observations made from a thematic analysis of the study footage, and how they contribute to an understanding of the issues involved in designing accessible musical instruments.

6.1.1 *The Strummi*

The guitar-like instruments described in the previous chapter were informally referred to as the 'Strummy instruments'. Prior to the study described in the current chapter, we had settled on 'Strummi' as a name for the instrument in its various forms. In this chapter, we are discussing two generations of Strummi: the original instruments described in the previous chapter, and a set of new instruments designed to address a number of usability issues with the first generation. The design of the second generation Strummi is described later in Section 6.4.1

Figure 6.1: All seven versions of the Strummi to date. The four instruments on the left are the first generation Strummi, and the three on the right are the second generation.

6.1.2 *Research Questions*

This chapter addresses research questions RQ2a and RQ2b defined in Chapter 1: *'What tools and techniques do practicing disabled musicians use in their music performance?'* and *'What roles do ADMIs and unadapted musical instruments play in community music settings?'*.

Further to this, I ask the following:

1. *To what extent is improving access / removing barriers to music making a question of environmental / ecological practice, rather than instrument functionality / physical accessibility?*
2. *To what extent does the preservation of prior technique and global form contribute to 'performance-focused' ADMI design?*
3. *Do the Strummi succeed in removing or lowering barriers to music performance for this group, and what are these barriers?*
4. *What role does instrument form/interaction modality play in removing or lowering these barriers?*

6.2 METHODOLOGIES

Our approach to this final study has been informed by two issues which arose from the earlier stages of this PhD research. Firstly, Chapters 4 and 5 introduced the idea of the success or an acceptability of an instrument being to do with more than its functionality - that the cultural capital of the guitar was a factor in how people perceived the instruments. This has led us to consider methodologies which capture these 'extra-technical' factors which affect the perception of an instrument's ability to perform a particular musical role. Secondly, through a consideration of the social and political discourse around disability-adjacent research, we have found ourselves moving towards methodologies which do not reduce the topic of access to music to a set of technical problems to be solved, and which are able to accurately reflect the every day lived experience of disability in the context of music making.

In this section, I will introduce the key theories, frameworks and methodologies that contributed to the following study.

6.2.1 *HCI in the wild: ethnography, reflexivity and design probes*

Rogers [2011] introduces *in the wild* research as a recent movement in HCI, to denote HCI studies which take place in the environments in which the technology is envisioned to be used in. Kjeldskov and Skov [2014] suggest that this provides a *'high level of ecological validity [but] a low level of control'*. Performing studies in the wild allows for long term relationships between people and technology that might not occur in controlled lab settings. Ethnography is not always a feature of research in the wild, but allows salient activities and features to be discovered [Crabtree et al., 2013].

Our motivation to adopt ethnography-based methodologies comes from two related goals. Firstly, we are interested in the social and cultural role of musical instruments, in a general sense. Ethnography based approaches, which originated from and were refined by the social sciences, have been shown in previous HCI studies to be highly effective at collating and communicating findings related to the sociocultural role of design artefacts [Dourish, 2007]. Secondly, wider discourse around disability (for example Disability Studies and Disability Arts) has influenced our approach to researching disability-adjacent issues. The Social Model (see Chapter 2) allows us to frame disability as a product of social and cultural attitudes as opposed to an embodied, functional deficit, so it follows that our approach to researching disability and music incorporates methodologies which take into account the social structures and cultural reference points which occur in music making. Any attempts to generalise or formalise the technical access requirements of this community runs the risk of supporting a deficit-oriented, Medical Model approach. This is not to suggest that the technical challenges in addressing a person's impairments and access needs should be ignored, but simply that they would not represent the intended findings of this research.

In *Implications for Design*, Dourish states that

> *Ethnography provides insight into the organization of social settings, but its goal is not simply to save the reader a trip; rather, it provides models for thinking about those settings and the work that goes on there ... [it] has a critical role to play in interactive system design, but this may be as much in shaping research ... strategy as in uncovering the constraints or opportunities faced in a particular design exercise.* Dourish [2006].

Dourish's justification for the use of ethnography ties in with our goals of adopting the theory and language of the Social Model of disability. Our goals in this

study are not to define a set of design requirements for accessible musical instrument design, through attempting to average across a population of learning disabled musicians, or an overly medicalised view of learning disability with relation to music making.

Ethnography in this case presents us with a 'methodological win-win': regardless of the politicised nature of the community we are studying, ethnography has shown to be a powerful tool in HCI research where there is an interest in the sociocultural context of designs. In the particular case of disability and music, it also allows us to do HCI research which can more closely align with the Social Model, taking into account the political and moral imperative in framing disability as a social issue, and avoiding overtly medicalised approaches.

Much of the methodological groundwork for ethnography in HCI comes from the field of Computer-Supported Cooperative Work (CSCW), which as a discipline is concerned with ways that technology is used within a community or society. The methodological approaches used in this discipline are also appropriate here as we are concerned with the role of a new music technology within the communal activity of a group music making session.

Rode [2011] discusses the importance of understanding the *'real world appropriation of technology and how it is situated within social conventions'* as a vital part of design, and the need for research approaches which strive to understand the 'messy bit' (i.e. Ackerman [2000]'s *socio-technical gap*, defined as *'the divide between what we know we must support socially and what we can support technically'*). In order to do this, Rode advocates for *reflexivity* in digital anthropology, as a contrast to more positivist approaches which are prevalent in HCI.

Rode uses Burawoy [1998]'s definition of reflexivity based on four criteria: 1.) embracing intervention as a data gathering opportunity, 2.) understanding how data gathering impacts the quality of the data itself, 3.) attempting to find structural patterns in what has been observed, and 4.) in doing so extending theory. Rode suggests that *confessional* ethnography is more suited to reflexive approaches than *realist* ethnography. Realist approaches tend to avoid the first person and aim to present a neutral account of what has been observed - working on a *'good faith assumption'* that *'whatever the fieldworker saw and heard ... is more-or-less what any similarly well-placed and well-trained participant-observer would see and hear'* [Van Maanen, 2011]. This approach attempts to *'convey a certainty over a correct interpretation of behaviour thereby guaranteeing reproducibility'*.

Confessional ethnography, by contrast, does not assume authority on a subject or attempt to convey certainty, instead attempting to demystify the fieldwork process through accounts of specific relationships between the fieldworker and the informants, and *'directly addressing the inherent subjectivity of ethnographic practice'*.

Rode also discusses ways of framing ethnographic practice: as either *formative*, *summative* or *iterative*. *Formative* ethnographies aim to understand current practice surrounding technologies with the aim of improving existing technologies or creating new ones. *Summative* ethnographies evaluate the technology at the end of the design process, attempting to understand the socio-technical gap for its own sake. The third form, *iterative* ethnography, is coined by Rode, and addresses the issues raised by formative and summative approaches, drawing on participatory design tradition by allowing informants to participate in the design process in an indirect fashion: *'while perhaps somewhat contrary to the spirit of traditional participatory design, ... it does still give [the users] a voice'*.

Inspired by Rode [2011], I adopt a first-person, confessional ethnography approach in this chapter. With regards to the previously defined framings of ethnographic practice, this work comes in most neatly under the 'summative' category, in the sense that I am attempting to understand the 'socio-technical gap' at the end of the instruments' development phase. However, the findings from this ethnography are intended to help shape and refine future ADMI research, although not necessarily with the Strummi instruments.

Ginsburg and Rapp [2013] discuss doing ethnography with learning-disabled communities, and the issues which arise from having stakes in this research as both anthropologists and parents of learning-disabled young people. They coin the term *entangled ethnography*, to describe the nature of being both an insider and outsider within the community under study, for example in the way that they *'often found [themselves] productively caught up in the projects [they] were studying, at times taking an active role in enabling the very activities [they] were examining'*. They draw on the changing attitudes towards ethnographic work over the past few decades, stating that *'these shifts, both epistemological and methodological, continue to generate lively debates about the insider/ outsider identity of the anthropologist, and the balancing act of participant/observation as a method, underscoring the significance of reflexivity in the field'*.

6.2.1.1 *From technology probe to research product*

The Strummi was originally designed for a music-HCI study which in part sought to explore ideas of 'guitar-likeness' in DMIs Harrison et al. [2018] (see Chapter 5). We looked to *technology probe* Hutchinson et al. [2003] and *cultural probe* Gaver et al. [1999] methodologies as a basis for our study design. Hutchinson et al. define technology probes as

> *'a particular type of probe that combine the social science goal of collecting information about the use and the users of the technology in a real-world setting, the engineering goal of field-testing the technology, and the design goal of inspiring users and designers to think of new kinds of technology to support their needs and desires.'* Hutchinson et al. [2003]

A similar concept to technology probes is Odom et al.'s 'research products' [Odom et al., 2016], a response to the use of 'unfinished' prototypes in design research:

> *'The complexities and challenges in researching questions about human-technology relations in everyday life over time suggest that the notion of a 'prototype' within research may not be sufficient' [Odom et al., 2016]*

They define research products as an artefact which possess the following qualities: *inquiry driven* ('designed to ask particular questions about potential alternative futures'), *finish* ('designed such that the nature of the engagement that people have with it is predicated on what it is as opposed to what it might become'), *fit* (designed 'to be lived with and experienced in an everyday fashion over time') and *independent* (the ability to be 'freely deployable in the field for an extended duration ... without the intervention of a researcher'). Research products place an equal emphasis on non-technical design choices such as materiality, 'feel', and visual aesthetics alongside the more technical details of sensor technology, mappings and sound-design.

While research products may share many qualities with technology probes, the epistemological stance behind them might align somewhat more closely with an ethnography-based approach as described earlier. Our goal with employing ethnographic methods in this study come from a desire to understand the social and cultural factors at play in an inclusive music environment. The goals of research products, to be lived with and taken for finished artefacts, fit in with an ethnographic study where we are not directly seeking to improve upon an unfinished

design, but to observe how that design fits in within an existing musical ecosystem.

6.3 PRE-STUDY ENGAGEMENT WITH HEART N SOUL

Prior to the formal research engagement, I spent some time working with Heart n Soul. My relationship with this community developed spontaneously and organically as the result of meeting during outreach work at a 'SoundLab' event with my colleagues from the Augmented Instruments Lab research group. In this section, I provide some context with an overview of Heart n Soul, followed by a description of my engagement with this community prior to the formalised research activity.

6.3.1 *An Overview of Heart n Soul*

Heart n Soul describe themselves as a *'creative arts charity [who] believe in the power and talent of people with learning disabilities'*. They provide long term professional artist support to learning disabled musicians and artists, as well as hosting regular creative arts 'taking part' sessions. Three of their key initiatives are Do Your Own Thing (DYOT): monthly events for young people aged 10-25; Allsorts: regular 'seasons' of weekly events for adults; and SoundLab, which produces a variety of events aimed at bringing music technology companies, digital music researchers and sound artists in contact with people with learning disabilities. Each of these initiatives is run collaboratively with learning disabled and non-disabled people.

DYOT and Allsorts sessions take place at the Albany arts centre in Deptford, South-East London, where the Heart n Soul offices are located. DYOT occurs one Saturday every month, from 12-4pm, with anywhere between 20-50 young people in attendance. They take over several spaces throughout the Albany, including the main theatre space, where DJ decks are set up alongside hands on arts-and-crafts and digital arts activities. There is also a radio show which runs throughout the duration of DYOT, and is broadcast via Heart n Soul's website. A staple feature of DYOT is the 'the music room', where a drumkit, microphones, electric guitar and bass, a synthesiser, electric keyboard, and occasionally other electronic instruments such as drum pads, vocal effects or Kaoss pads are set up. The music room is an opportunity to play loudly with others, and there is no requirement for prior knowledge of the instruments to take part. Other regular music activities include recording in a dedicated studio, and one-to-one songwriting sessions. Each activity

is supported by a session leader, typically someone with expertise in the practice they are supporting (e.g. digital arts, community music, DJing), and volunteers, who take part in the activity alongside the participants and provide individual support when required. Many young people attend DYOT without a parent or carer present, although some young people require one-to-one support, especially where communication or behavioural issues are particularly acute. Young people at DYOT are free to move between activities as much as they want, although they are encouraged to remain focused and engaged by facilitators. The atmosphere at DYOT is one of fun, experimentation, and creativity, with facilitators open to embracing the sometimes chaotic and noisy environment - people are rarely told to 'be quiet' at these events. Where there are desired outcomes of an activity, for instance making a music video, designing a poster or writing a song, the volunteers and facilitators respond in an open and encouraging way to participants' ideas, and do not tend to try and discourage particular ideas or shape the outcome to their own artistic values. At the end of every DYOT, there is a 'sharing' session, where everyone moves into the main hall and the outcomes from each activity are discussed and shown to the wider group. This typically ends in a performance from the music room, or playback of the day's recordings from the studio.

Allsorts events are similar to DYOT except made for learning-disabled adults (18+). They are scheduled as regular 'seasons' of six weekly events, occurring on Thursdays from 10am-5pm. The days are divided into four hour-long sessions with breaks in between. There is often an arts and crafts activity, while other activities include spoken-word poetry workshops, dance and choreography workshops, and digital arts. Participants can also take part in the Heart n Soul radio show which broadcasts throughout the day. A 'sharing' activity also closes each Allsorts event.

The Strummi was first introduced to Heart n Soul members at a SoundLab event as part of a showcase of technologies developed using the Bela embedded computer. SoundLab sessions are open to people with learning disabilities of all ages, and so attract a wider audience than Do Your Own Thing events. SoundLab is a less structured and more noisy environment than Allsorts, with many instrument demonstrations and interactive displays occurring in the same space. Visitors are welcome to come and go as they please, trying out different instruments and moving between demonstrations. Unlike at DYOT, there are no facilitators present to encourage a particular outcome from the session, as the focus is more on exploration of a range of music technologies.

Heart n Soul attendees do not represent a common series of traits associated with a 'learning disability' label, but represent a broad spectrum of conditions as a result of developmental disorders and learning disabilities. Their events are a platform for promoting wellbeing through developing artistic skills and socialising, and as such are not designed to alleviate, cure or counter symptoms of any specific condition. As such they are explicitly free of stigma or medicalising language. This affects the way that design research is done within this community. Each encounter is treated as a unique experience, almost always with no prior knowledge of that person's condition.

Access requirements for music making within this group are often subtle, if present at all. Many attendees are able to use musical instruments and controllers to varying degrees, although a significant number have physical access requirements alongside less visible access needs stemming from cognitive or sensory impairments.

Music technology plays an important role in much of Heart n Soul's activities. In the music room, synths and standalone devices such as vocal effects processors and the Korg Kaossilator are often featured. The recording studio is very popular and participants are encouraged to try out a range of hardware and software. Much of Heart n Soul's regularly performing artists use software such as Ableton Live with the Push controller, electric drum-pads, and synths.

6.3.2 *Initial engagement*

My engagement with Heart n Soul emerged following an invitation to demonstrate some of Augmented Instruments Lab instrument prototypes and demo instruments at a SoundLab event. This resulted in a conversation around how our work could be aligned in a research partnership. I began working with Heart n Soul as a volunteer during DYOT and SoundLab events, in order to get to know the way that Heart n Soul worked, and continue a conversation on what a research collaboration might entail. This resulted in the Strummi being introduced to the DYOT music room sessions as well as Allsorts and SoundLab events.

In this section, I report my own observations and reflections from this engagement, which lasted around one year before the study took place. These are intended as snapshots of salient moments to provide some context to the final study and do not provide a comprehensive account of this period. I use pseudonyms here to preserve participants' anonymity.

6.3.3 *Do Your Own Thing*

My primary engagement with Heart n Soul has been as a volunteer at Do Your Own Thing. I have attended roughly 12 sessions since March 2018, usually in the music room, although I supported a small number of recording and one-to-one songwriting sessions.

The Strummi was introduced to DYOT attendees as an additional instrument to use alongside the guitars, bass, drums and synths in the music room. During the first few sessions, responses ranged from interest and curiosity to ambivalence and even outright disdain. Some of the young people who regularly took part in the music sessions are highly accomplished musicians, and spent no more than a few minutes exploring the Strummi before returning to the guitar or keyboard.

The first young person to become engaged with the Strummi was Alex (pseudonym). Alex had previously shown interest in song-writing and singing his own lyrics but had not played an instrument in the music room at a DYOT session before. Alex is male and in his mid-late teens. He is communicative but softly spoken and has no physical impairments. He was offered the guitar-body Strummi to try out and became engaged with it for the rest of the session, asking which buttons related to which chord and immediately grasping the concept of chord selection (at a later session, Alex revealed that he had previously taken guitar lessons). Most striking was Alex's immediate take up of 'guitar-like' choreography, using the guitar strap to play standing up and striking familiar front-man poses. He was offered the use of guitar effects pedals and appeared to enjoy using large amounts of phaser and delay, which disguised the sound of the Strummi to a large extent.

At the time of this session, preparations were being made for the upcoming Squidz Club, a nightclub event for young people with learning disabilities, and the impromptu band which Alex was playing in was asked if they wanted to write and perform a song. Alex chose the name 'Something Strange, Something Different' for his band, and wrote a song called 'Space Magic' to perform. At the end of the session, DYOT staff commented that they had not expected Alex to take the role of frontman based on his behaviour at previous sessions.

James (pseudonym) spent two sessions with the Strummi in February and March 2019. Like Alex, James is a young male in his late teens. James does not usually attend the music room, but usually uses a microphone or hand percussion when he joins in. James has physical disabilities: he uses a walking frame and has motor impairments in both hands. He was originally drawn to the guitar-body Strummi

but found it difficult to play while standing up due to its weight and his walking frame. He tried the tabletop Strummi while sitting down and played it for a short time before leaving the room. At the next session, James returned to the guitar-body Strummi and played it sitting down, with his left hand over the top of the neck which was more comfortable for him than holding it like a guitar. Unlike with Alex, the Strummi here presented an explicit physical access improvement over the guitar. James made enthusiastic comments at the end of the session saying *'I grew up around music'* and commenting that his family would be happy to see him play the guitar.

Alex and James are not representative of the entire group at DYOT sessions. In general, there were more people uninterested in the Strummi than those who were. Many people appeared confused by the instrument, asking questions like 'what does it do?', 'why does it look like that?' and 'is it a guitar?. Most of the enthusiasm for the instrument came from the session leaders, who showed a lot of interest in the instrument and how it was made. The session leaders also acted as ambassadors for the Strummi, asking the young people to try it out during the sessions. Those who showed interest in the Strummi from the start were generally engaged with using it for the remainder of the sessions they attended.

6.3.4 *Allsorts and SoundLab*

During the course of three SoundLab events, the Strummi reached a wider audience than at DYOT, but was not engaged with in a cooperative music-making context. We noticed many similar reactions to the Strummi as at DYOT, ranging from confusion and boredom, to focused exploration and engagement.

The strongest reaction to the Strummi was from Vanessa. Vanessa is an adult in her mid-late 30s, and has learning disabilities, as well as a physical impairment to her right hand. She encountered the Strummi at the second SoundLab event we attended, where she played with both the tabletop and guitar-body versions. During this event, she spent roughly 2 hours with the Strummi, improvising lyrics and preparing a song to perform at the end of session.

Vanessa used her left hand to strum and her impaired right hand to select the chords. She placed the guitar-body strummi on a table, resembling the playing position of a lap-steel player. She faced difficulty accurately and consistently pressing down the buttons. This meant that for a lot of the time she was strumming on 'muted' strings, but continued strumming nonetheless. Throughout this first

session, Vanessa repeatedly made positive comments about the Strummi, saying that she 'never thought she would be able to play the guitar' and that her parents would be very pleased to see her play. Vanessa immediately picked up the strumming technique without guidance, and had a positive reaction to the sound of the Strummi after being shown how the chord buttons worked.

Following this first encounter, Vanessa requested Heart n Soul staff for further opportunities to play the Strummi, resulting in a visit to an Allsorts event. Vanessa proceeded to spend several more hours with the Strummi here. Her third encounter with the Strummi was during another SoundLab event, by which time she was well acquainted with the technique, and showed confidence in teaching other SoundLab visitors how to play it. Over the course of these three encounters, Vanessa showed improved ability to select and hold chords using the buttons.

A common theme for Vanessa was videoing her performances, either with her own mobile phone in 'selfie-mode', or asking others to film for her. She stated that she wanted to show the videos to her family as they could see her using her impaired hand. She made several references to the fact that she had to keep using her hand in order to improve its strength. Vanessa's lyrics were usually to do with her immediate environment and reflections on her positive experiences such as *'I'm at Heart n Soul, today has been a great day and I've played the guitar'*.

6.4 THE STRUMMI SESSIONS: RESEARCH-FOCUSED MUSIC SESSIONS WITH HEART N SOUL

Our early observations and reflections from Heart n Soul events highlighted several key issues involving music making and learning-disabled communities. We learned that the barriers to accessing music making and the arts are multiple and varied: from stigmatising attitudes towards the artistic capabilities of learning disabled people, to societal issues such as lack of access to regular arts programs, and physical access issues arising either out of cognitive or physical impairments. We observed a broad and diverse range of approaches to making music including recording covers of pop songs, free improvisation jamming and work on solo performances. Many Heart n Soul participants performed with instruments using recognisable techniques and playing styles, often to a very high standard of musicality. Others used instruments in unexpected ways, either out of preference or as a result of a physical access need (for instance strumming open strings on a guitar due to difficulty holding down chord shapes). Organisational methods of

overcoming access issues include attitudinal approaches such as open-mindedness towards different performance styles and preferences.

The longitudinal, situated nature of our engagement with Heart n Soul provides us with a rich set of experiences and observations concerning the use of musical instruments in a learning disability context. However, we experienced a number of practical constraints regarding data collection which meant that we were unable to perform a formal research-focused engagement during the day-to-day activities of Heart n Soul. Our main obstacle was the collection of recorded video and audio data during the DYOT music sessions, which were the locus of activity around the Strummi. The 'walk-in' nature of these events meant that obtaining informed consent from each person present during the sessions was impractical, and would likely negatively impact the nature of the DYOT sessions. A requirement for gathering video data of any population under research is to obtain informed consent before any filming takes place, via a Research Ethics Committee sanctioned consent form. This process is somewhat more involved with a population which includes learning-disabled young people, as parents and guardians are also required to provide consent, and the forms must be presented in an easy-read format.

Due to these practical considerations, we organised two music-making sessions, dubbed the '*Strummi Sessions*', which were scheduled outside of the regular DYOT events. In this section, I describe our motivations and objectives in organising the Strummi Sessions and the practical considerations involved, followed by an overview of the format of the sessions: the instruments used, our approach to participant recruitment, and the intended activities during the sessions.

6.4.1 *Instruments*

From the first few visits to DYOT sessions, we observed that for some members of the group, the Strummi possess accessibility affordances due to the reduction of the chord selection to a push-button interface, whilst maintaining the responsiveness and acoustic properties of the strumming interaction. The early stages of the project highlighted usability issues with the original Strummis. These include the weight of the 'guitar body' enclosure, which made playing for long periods uncomfortable, and inaccessible for many users with mobility issues. We also noted that the push-buttons used in the first generation were prone to mechanical failure. Finally, the use of a 3.5mm headphone output meant that the Strummi could not easily be swapped with an electric guitar when using a standard jack lead.

6.4.1.1 *Second-generation Strummi*

Prior to the Strummi sessions, I designed and built a second generation of Strummi instruments based on the original designs but incorporating improvements which addressed the issues of the first generation. As well as addressing the usability issues, I also wanted to further explore how guitar-like visual cues would influence people's responses to the instruments. The second generation of Strummi comprises of three instruments. All instruments featured eight silicon pads to replace the failure-prone mechanical switches used in the previous versions. I used the Sparkfun 2x2 button pads[1] for this purpose as they are designed specifically for musical applications e.g. DIY MIDI controllers, and are similar in action and materials to modern MIDI controllers. I also replaced the output on each instrument with a 6.35mm guitar jack (wired in mono), so that they could be easily interchanged with electric guitars and basses using the same amplifiers. I designed a custom PCB to act as a breakout for the six piezo channels and eight buttons. The second generation Strummi are all based on the Bela Mini[2] which reduced the required size for the instrument enclosures.

The source code and design for the tabletop enclosure remain largely similar to the instruments described in the previous Chapter, designed in collaboration with my co-researcher Robert Jack. The modifications and new designs incorporated into the second generation instruments and described here were my work.

The first instrument (herein referred to as 'S1') was largely based on the original tabletop instrument described earlier (see Figure 6.2).

The second instrument ('S2') was designed to replace the 'guitar body' Strummi. I used a similar manufacturing process as S1, using layers of stacked 5mm birch plywood, to maintain a consistency in the size, weight and materials used. The shape was based on a Les Paul style guitar body, but with a smaller size and shorter 'neck'. Figure 6.3 shows S2 during the build process and completed.

In order to go one step further towards 'guitar-likeness', I built a third Strummi instrument ('S3') using an actual Les Paul copy guitar as the enclosure, with the push-buttons embedded in the neck. This involved removing material from the neck and body of the instrument and designing a custom acrylic pick guard to house the electronics. The truss rod was removed from the neck to allow for wiring from the buttons to the Bela mini enclosed in the guitar body. I also designed a

1 www.sparkfun.com/products/7836
2 shop.bela.io/products/bela-mini-starter-kit

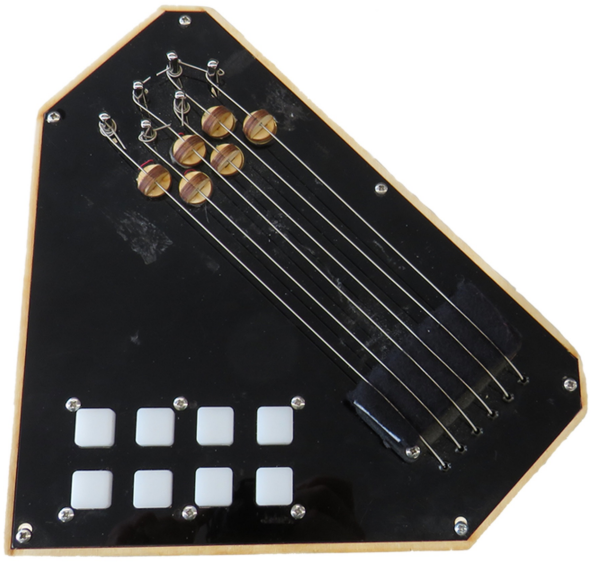


Figure 6.2: S1: tabletop Strummi based on first generation design

Figure 6.3: L: build process of S2 instrument using layers of glued plywood. R: finished S2 instrument

new PCB for the silicon push buttons as the original PCBs from Sparkfun were slightly wider than the neck.

Supplementary material including a video demonstration of S1 can be found at https://qmro.qmul.ac.uk/xmlui/handle/123456789/67358.

Although the touch sensor versions of the first generation instruments was brought to a number of DYOT sessions, we decided not to include these in the second generation. This decision was based mainly on the fact that we wanted to

Figure 6.4: L: Les Paul body with material removed for electronics. R: completed S3 instrument. Bottom: custom PCB made to fit neck width

further explore the audio-rate excitation method described in Chapter 5. The sample triggering method was introduced both to provide a fair comparison between the strings and touch sensor, and to observe the difference in control intimacy between sample triggering and audio-rate excitation - the latter being the primary research interest of my co-researcher for this prior study. While the sample triggering method was sufficient for this purpose, we made the decision to provide consistency across all instruments by using only the string versions with full audio-rate excitation.

6.4.2 *Participants and Recruitment*

Participant recruitment took place during one DYOT and one Allsorts event. Information sheets were handed out to people who had previously been identified as being interested in making music outside of the regular sessions. Their names were recorded and handed to Heart n Soul staff who coordinated with them to find two dates that the majority of people could attend. In total, 17 people were

Table 6.1: Participants, staff and fieldworkers present at Strummi Sessions (X denotes presence during a particular session, * denotes use of pseudonym)

Person	Session 1	Session 2
Oscar*		X
Raphael*	X	
Ismail*	X	X
Liam*		X
Jared*	X	X
Imogen*	X	X
Vanessa*	X	X
Felix* (and carer)		X
Edwin* (Facilitator)	X	X
Abraham* (Facilitator)	X	X
Jacob	X	X
Alan (co-researcher)	X	
Giacomo (assistant)	X	
Jack (assistant)		X

approached during the Heart n Soul events (9 at DYOT, 8 at Allsorts), and a further 3 people contacted Heart n Soul directly after hearing about the sessions through their peers. Eight people attended the sessions (3 from DYOT, 5 from Allsorts).

Pseudonyms will be used to refer to Heart n Soul participants and staff. Two staff members were present, Edwin and Abraham, who are regular facilitators for music making sessions at DYOT and Allsorts. Ismail, Jared, Imogen and Vanessa were present for both sessions. Raphael was only present for session 1, while Oscar, Liam and Felix were only present for session 2. Two assistants were present from our research group: Giacomo for session 1 and Jack for session 2. A co-researcher Alan Chamberlain was present for the majority of session 1 but left before the feedback session began. Felix also had a carer with him who was present throughout the day and assisted him during the music-making activities. Table 6.1 presents participants and the sessions they attended.

All participants were already familiar with the earlier iterations of the Strummi instruments to varying degrees, except for Felix. Vanessa had the most experience

with the Strummi instruments, and her earlier interactions are described in section 6.3.

6.4.3 *Session Format*

We attempted to recreate the format of the music room at DYOT events, by arranging for two of the regular music facilitators (Edwin and Abraham) from DYOT to attend, and to use the same instruments and spatial layout. A major difference between these sessions and DYOT was that we were unable to use the Albany as a venue, so were relocated to Deptford lounge, a library and community space about three minute's walk from the Albany. We had recruited members from both DYOT and Allsorts, so there was a larger age range than typical DYOT music room sessions, and several participants who had not previously attended a session together before.

Both sessions began with a brief introduction, where everyone was sat in a circle and introduced themselves, then a discussion of how we wanted to begin the music making. We also used this time to obtain written consent from each participant.

Following the introduction at the beginning of session 1, I introduced each of the Strummi instruments by demonstrating how to play them. For session 2, Vanessa and Liam demonstrated the Strummis instead. Introducing the instruments is often a feature at DYOT music sessions, where participants are encouraged to try out each instrument themselves before a jam occurs.

After this, the facilitators encouraged jamming in a free-improvisation format, encouraging ideas to develop into more structured jamming. For the final half an hour of both sessions, we returned to the circle of seats and conducted an audio recorded feedback session. Both sessions lasted around two and a half hours.

6.4.4 *Data Collection and Analysis*

I used the *ELAN* software [Wittenburg et al., 2006] to annotate and transcribe the two synchronised video streams from both cameras (see Figure 6.5).

The first stage in annotating the video footage was to divide the timeline into discrete 'activities', in order to get a sense of how each session was structured over time. We defined activities as whatever the majority of people in the room were currently focused on at that time, e.g. a group jam, or collectively waiting

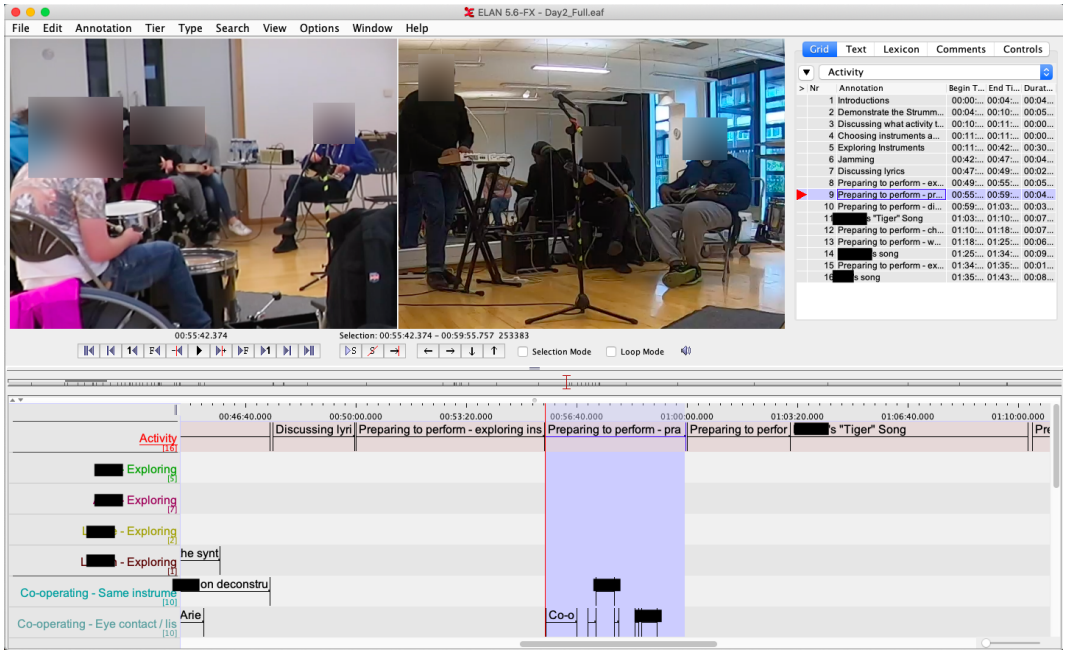


Figure 6.5: Video annotation process in ELAN software (names redacted)

for a participant to learn their part. As the sessions were loosely structured, there was no formal guidance from the facilitators as to when one new activity would begin or end, and as such many activities were overlapping or did not involve every member of the session. However this annotation category was useful for providing an overview of the progression of events during the session, and how much time was spent on them. These annotations are provided in tables 6.2 and 6.3.

6.5 AN ETHNOGRAPHIC ACCOUNT OF THE STRUMMI SESSIONS

As with earlier DYOT sessions, these sessions were predominantly made up of a mixture of structured and unstructured jamming. The unstructured jams were similar to the free improvisation rehearsals described in Martin and Gardner [2019]: there were no instructions given as to what to play and when, and each musician was free to come in and out as they pleased. Communication between musicians and facilitators was largely non-verbal, consisting of encouraging gestures such as eye contact, smiling and head nodding. These seemed to be a way of showing approval or encouragement without distracting from the task at hand.

During the unstructured jams, several participants were primarily focused on exploring their instrument, without much apparent interest in what the other mu-

Begin time	End Time	Duration	Activity
00:00:21	00:02:46	02:25	Jacob Demonstrating the Strummis
00:02:52	00:21:20	18:28	Exploring instruments
00:21:31	00:23:51	02:19	Settling down, getting ready to demonstrate each person's instrument
00:24:07	00:31:01	06:54	Demonstrating each instrument
00:31:04	00:33:49	02:45	Arranging order that everyone plays
00:33:54	00:34:14	00:19	Waiting for silence
00:34:14	00:46:16	12:02	Jamming
00:46:22	00:53:47	07:24	End of jam / food and comfort break
00:53:51	01:07:45	13:54	jam / unstructured
01:08:36	01:11:39	03:02	Ismail learning to play Strummi / Edwin explaining it
01:11:55	01:14:09	02:14	Jam emerging
01:14:23	01:29:00	14:37	unstructured jamming / free improv
01:29:13	01:29:57	00:43	Raphael and Ismail swap instruments
01:30:18	01:32:49	02:30	free improv / conversations
01:32:59	01:41:28	08:28	jam - based around Raphael and Ismail's drumming
01:41:47	01:46:48	05:01	discussion about which chords to play
01:46:51	01:51:54	05:03	writing Imogen's lyrics
01:52:00	01:55:41	03:41	rehearsing parts / showing them to each other
01:55:48	01:07:28	11:39	focused jam / performing Imogen's song
02:07:32	01:11:22	03:50	jamming starts to wrap up

Table 6.2: Activities and timings during Day 1

sicians were playing. An example of this was Liam who spent large amounts of time playing on the S3 Strummi, facing away from the other participants and looking at himself in the mirror.

While session 1 was weighted more towards free improvisation, exploration and unstructured jams, a feature of session 2 was more focus on structured jams, with a view to developing songs. These typically consisted of a preparatory stage where a facilitator would ask each participant to demonstrate the sounds they

Begin time	End Time	Duration	Activity
00:04:54	00:10:21	05:27	Demonstrate the Strummis
00:10:29	00:11:23	00:53	Discussing what activity to do first
00:11:26	00:11:56	00:29	Choosing instruments and starting to explore them
00:11:58	00:42:52	30:53	Exploring Instruments
00:42:55	00:47:23	04:28	Jamming
00:47:28	00:49:55	02:27	Discussing lyrics
00:49:58	00:55:40	05:41	Preparing to perform - exploring instruments and deciding on parts, learning chords
00:55:42	00:59:55	04:13	Preparing to perform - practicing parts, jamming
00:59:59	01:03:05	03:06	Preparing to perform - discussing song structure
01:03:05	01:10:16	07:10	Vanessa's "Tiger" Song
01:10:24	01:18:10	07:46	Preparing to perform - choosing different instruments and exploring them
01:18:14	01:25:02	06:48	Preparing to perform - waiting for silence before beginning
01:25:03	01:34:09	09:05	Jared's song
01:34:14	01:35:16	01:02	Preparing to perform - exploring instruments
01:35:17	01:43:40	08:23	Liam's song

Table 6.3: Activities and timings during Day 2

wished to make with their instrument - either a specific rhythm, keyboard preset or playing style. After that, a conversation about how the song would be structured in terms of who was playing when would take place. A clear distinction between the preparatory stage and the jam itself was made by the facilitator asking for silence before anyone played an instrument.

We noticed three distinct structured jams occurring in session 2. The first was Vanessa's 'Tiger' song, with the instrumentation as follows: Felix played S1, Oscar played S2, and Jared played S3. Imogen played synthesiser and Abraham played electric bass, with no-one playing electric guitar. The drums were rearranged with

the kick drum laying flat on the floor so that Ismail, a powered wheelchair user, could play the kick drum with a beater in his right hand - although during this jam, Ismail played only the snare drum and Liam sat next to him to play the kick drum (see Figure 6.6).

Figure 6.6: Two camera angles depicting the spatial arrangement of participants during the first structured jam.

The jam began with Imogen holding a sustained note on the synth with a pad setting. Edwin was conducting, bringing in each player at the points they agreed during the preparation for the jam. Edwin motioned to Oscar to start playing, who was playing the S2 Strummi. Oscar played by strumming a regular pattern of up and down strokes on every 2nd beat, in an exaggerated, performative gesture, and using a travel card in place of a plectrum. After about thirty seconds, Edwin then motioned to Felix to start playing. Felix's carer, sat to his left, held down the chord buttons and provided verbal support, for example confirming with Felix that he should start playing. After Felix had played with just Imogen's synth as a backing, Edwin motioned for Ismail and Liam to start playing drums, but had to give some direction in order for the snare and kick drum parts (played separately)

to synchronise. Once this beat was established, Abraham and Jared came in on the electric bass and S3 Strummi and a more noticeable groove emerged. At this point (around two minutes into the jam) Vanessa began performing her lyrics that she had written in a continuous spoken word style. She had earlier written some lyrics about being a tiger who was hungry and bad tempered, and who was a Taurus. Despite having the lyrics written down, her performance was almost entirely ad-libbed, using lines and words from her lyrics as cues. The jam lasted for seven minutes, with Edwin continuing to signal for people to come in and out. Oscar and Felix were instructed to play more quietly during Vanessa's vocal parts, and then were brought back in for a few bars before Vanessa began singing again. Towards the end of the jam, Ismail stopped playing the kickdrum and Liam played more arhythmically. This had the effect of causing the other players of dropping the groove in order to create a 'wall of sound' effect of drum rolls and rapid strums, which built to a crescendo before finishing.

6.5.1 *Interactions with Instruments*

As well as jamming and performing, activities also included more exploratory moments, especially during the beginning of both sessions. I encouraged the participants to try out each Strummi as well as the other instruments during the session and both the facilitators and I asked participants at several moments if they would like to try a different instrument. Around 20-30 minutes at the beginning of both sessions consisted of people playing instruments in a more individual manner - i.e. not making eye contact or appearing to listen to other players, but focused on their own instrument.

A number of salient moments occurred during these moments. At the beginning of session 1, Imogen attempted to slide the bridge pieces up and down the strings of the S1 Strummi, and in doing so damaged the piezo wires attached to them (see Figure 6.7). For the remainder of this session and for much of session 2, she predominantly played the keyboard and didn't return to the Strummi until she was encouraged to do so. Towards the end of session 2, all participants were encouraged to try out different instruments that they hadn't yet played, and Imogen chose the electric guitar. Her playing style was sitting down with the guitar on her lap, strumming the strings at the neck end rather than over the pickups. She appeared to be focused on exploring the instrument: turning tuning keys and volume pots and trying out unconventional ways of playing.

Figure 6.7: S1 (tabletop Strummi) after being damaged shortly after the session began

We also noticed moments of collaboration between participants, for example during session 2 when Vanessa and Felix began playing the same Strummi. Vanessa had identified early on that Felix had a similar impairment to his left hand as her, and took on a role of showing him how to play the S1 Strummi in the way that she did. Vanessa is an adult while Felix is in his teens, so a kind of mentor-student relationship emerged in which Vanessa gave encouragement on Felix's playing and his ability to use his impaired hand. For a while during the session, Vanessa was holding the chord buttons while Felix strummed the strings. Felix's carer later took on this role during the structured jam sessions, presumably after observing Vanessa's approach.

Other moments of cooperation also involved de-constructing the drum kit so that Ismail, a powered wheelchair user, could access the kick drum. By taking the drumkit apart and placing the kickdrum so that the skin was facing upwards,

Figure 6.8: Co-operation between Vanessa and Felix: Vanessa drew on prior experience with the Strummi to teach Felix how to play it.

Ismail could hit the kick with a drumstick in one hand and play the snare and hi-hat on the other. During session 1, Raphael joined in with Ismail so that they were both playing on the same drum kit in synchrony. This occurred again in session 2, this time with Liam joining Ismail instead.

6.5.2 *Feedback Sessions*

Following the video recorded music making activities, at the end of each session we recorded audio of a feedback session which took the form of a semi-structured interview / focus group activity. All participants and facilitators sat in a circle and were invited to answer questions relating to the session itself as well as the Strummis and other instruments. Responses included feedback on technical usability aspects of the Strummis, suggestions and comments on how the sessions were run, reflections on how and why the Strummis were useful to them, and the lived experiences of disability in relation to creative activities.

We note that, as expected from a mixed ability group, participants had a diverse range of communication styles. In particular, Jared tended towards one

word responses or non-verbal gestures whereas Imogen favoured highly verbose, tangential answers, drawing on obscure pop-culture references and trivia. I have attempted to present the feedback quotes as accurately as possible without paraphrasing in order to avoid misrepresentation.

I used inductive Thematic Analysis on the interview transcripts in order to divide the feedback quotes into a set of themes: *pop culture / rock band references*, *feedback relating to the Strummi*, *experiences with other instruments*, *reflections on performance*, *general feedback on the session*, *instrument de-construction and cooperation*, *values and personal goals*, *lyrical ideas and values*, and *interactions with others in the group*. Below I present a selection of quotes which illustrate those themes. For readability, I present a selection of quotes which illustrate each theme. Full transcripts relating to each theme are given in appendix A.

Pop culture / rock band references

References to existing pop culture figures, likening the experience of the Strummi sessions to playing in a band, plans for forming a band out of the Strummi sessions, desire to record and perform music:

Imogen: There should be a studio session so we can lay down our ideas and get them edited, we can do a film of it in the studio, like a lot of the bands do - A backstage video, a backstage audio!
Abraham: So think about the name of the band yeah?
Vanessa: That's the bit we've got to get together and try and think of a nice name what we would call it.
Jacob: Is there anything that comes to mind?
Imogen: 'The Expansives'
Abraham: Any idea?
Ismail: It depends, I don't know to be honest I hadn't really thought, I didn't realise we were going to try and think of band names in the first session!
Ismail: Maybe if we do more sessions like this, further down the line
Ismail: If you write the first song you could get a band name out of that
Imogen: Sounds like a band that could play at New Cross, or Canterbury University
Imogen: The expansives! Please welcome on stage... and they have a laser thing with the name on it and it all disappears.
Vanessa: [Jared] what do you think of the name for the band, if you had a dream what

would you call it?
Jared: I would call it 'The Super Stars'

Jacob: [discussing what to do during the next session] So there might be a bit of free [improvisation], like it was today. But if you have any suggestions for things you'd like to, like we could maybe write a song
Vanessa: Yes please
Jacob: Or we could play some kind of musical games, so like...
Imogen: Mmmm no, lay down the songs, we're a band!

Reactions and feedback relating to the Strummi instruments

Usability feedback, preference for one version over the other, ideas for improvements to future versions:

Edwin: The Strummi systems worked well with the percussive systems. Not just the tuning. And yeah and people really got into really getting comfortable with playing their own instrument, I've not seen people kind of get comfortable with the Strummis [before], so it felt it was an instrument it wasn't something else...

Jacob: How about [Jared], what kind of music do you think the Strummi's are made for?
Jared: Rock, and pop.
Imogen: Oh yes, pop is the one

Giacomo: What do you think is the main difference between the guitar and the Strummi?
Vanessa: Well the Strummi is very small and compacted. More than the guitar. The guitar you have to hold all the time.
Abraham: Its long neck as well

Jacob: If you had to describe the Strummi to someone that's never seen it before or heard of it, how would you describe it?
Liam: The Strummi is a special guitar, you press these buttons to play and if you can't play the strings like that, you press these buttons and you play the guitar to make chords
Jacob: Was there anything that you liked or disliked about playing it?
Liam: The thing I liked playing it was when I'm playing guitar and stuff, it plays like a

guitar and I press the chords and then I start playing, you know, if it's a certain note and stuff like that. But the stickers fell off which is what I disliked about it.

Experiences with other instruments

Preferences for other instruments in the room, reasons for preference, how they were used, references to different instruments and ways of playing:

Liam: My best bit was playing the drums it was really good and I also liked playing the Strummi as well

Jacob: [Jared], what did you enjoy today?
Jared: The drumkit

Imogen: Yeah I had a go at the sort of 50s rock guitar over there [S3]. Not really me, I'm more keyboards and mixing. And maybe a bit of drums, but mainly keyboards. And [Vanessa] was getting funky with the keyboards!

Reflections on performance

Techniques used, ways of communicating and shaping performance during jams, reflections on how well the jams/performances went:

Abraham: Yes it was quite fun, free flow, I thought it was nice that everyone tried a bit of all the instruments before settling on the one that they liked which you could see that everyone kind of liked a certain kind of ... and yeah, a really good time, it was nice to see you guys just going for it ... I didn't want to spoil it with my guitar playing. It wasn't necessary you guys did brilliantly.

Edwin: People have a go of like a harp or something, they kind of tentatively do something on it, they don't try and sit with it to play it. So everybody was kind of sitting with the instruments which I thought was nice. And as an extension of that were the drums: pull the kit apart and then instantly people felt to be able to ...

Edwin: It just brought out different singers, cos I haven't really heard much Jared. It

was good you were taking your time.
Abraham: We've heard you rapping but never singing.
Edwin: You were singing you had a chorus that was developed there. And it felt great. And so did you [Liam], I've never heard you be that relaxed and think about what you were singing. I think in short it's nice to see it, it's a new instrument that allows you to do things in different way

General session feedback

Feedback relating to enjoyment of the session itself:

Vanessa: It was a good day, it's not a bad day I really enjoyed it. Need a bit more sessions, extra sessions

Oscar: I think it was really good it was really enjoyable, really amazing
Jacob: Was there anything that worked well in the way that everyone was working together?
Oscar: I think it really worked well we all worked as a team
Imogen: It all sounded like we were listening to each other.
Jacob: Was there anything that didn't work so well?
Oscar: Nothing
Liam: All positive reviews

Jacob: Is there anything else you'd like to say about today?
Vanessa: It was good, I'd like to do a bit more
Liam: A bit more actually
Vanessa: What do you think Jared, would you like to do a bit more? What's the best bit about it?
Jared: Music.
Imogen: I think we should meet regularly every month if you can do that Jacob

Values and personal goals

Relating the session activities to personal values and beliefs, or to goals in personal life (e.g. health and wellbeing goals)

Jacob: do you want to play a bit more or?
Vanessa: yeah cos it helped my hand.
Jacob: how did it help your hand?
Vanessa: It helps my hand to open a bit more, never used to use this hand much. This hand is a bit lazy. So I tried to use this one more. Make it stronger. Like to do a bit more. ... it would be nice to have other people come out their house ... and see other people ... there's people indoors in the house just day in they don't do things and I keep calling them to come downstairs. It would be nice for other residents to have a go
Jacob: to have a go with the Strummi?
Vanessa: Yeah ... All they do is sit there eating and playing dominoes.
Vanessa: It'd be good for other people to see it and things ... They're just sitting going 'all I'm doing is watching telly'
Imogen: Better than being excluded or at home doing nothing.
Vanessa: Some people just sit in the house and all they do is ah I'm bored.

Vanessa: [Referring to Felix's impairment] Cos we've both got the same dilemma. Cos both of us have got paralysed one side from childhood and I said don't worry cos I've been there, done that, thought I'd never, my mum said my hand might never work again. Get stronger, take time, get patient for yourself and use your hand more.

Jacob: Liam can I ask why you come to the music making session at Heart n Soul?
Liam: Because I wanted to try out playing some Strummis and the guitar and I like playing the drums. I was playing some hip hop style music.
Jacob: And Jared?
Jared: I like coming to the music class to do music and sometimes record in the studio.
Jacob: Was there anything from today that you want to record?
Jared: I wanted to record that song that I was singing.
Imogen: We never have the opportunity to get together and be as a band.

Lyrical ideas and values

Ideas and values that came up in people's lyrics:

Vanessa: Well I was making my own song. Cos I'm a tiger. I was being a really horrible tiger.
Jacob: So was it a song about being a tiger?

Vanessa: Yeah. It was about tigers we are vicious and they are taurus. They're bad tempered.
Abraham: Talking about me? I'm a taurus
Vanessa: (laughs). Taurus are bad tempered. And angry tempered.

Liam: I've been singing a bit of comic rap. All about Kendall Jenner, Theresa May and all the ... it's not my style
Imogen: Those naughty naughty politicians who need to be taught a lesson
Abraham: Socially and politically aware well done
Liam: Those naughty politicians need to be learned a lesson.
Jacob: And they're not your style, is that what the song was about?
Liam: It's not my style, yeah. That's what I wrote that about.

Interactions with others in the group

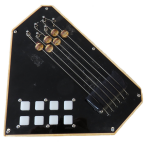
Descriptions of how people interacted with others:

Vanessa: I liked it when [Felix] came in that had the same problem, that was very nice. And I noticed that he was getting shy quite a bit, and he came out of his comfort zone. He wasn't sure about me and I said look, you've got the same problem I've got, don't worry cos it'll come in time. So I gave him a bit of confidence.
Jacob: When you two were playing the same instrument, what did you think about that?
Vanessa: Well teaching him, is a different category, he didn't know me and I didn't know him, and he's got the same issues that I've got and his mum said thank you for teaching him. Cos we've both got the same dilemma ...
Vanessa: ... he looked at me and said what do I do, and I said here come bruv I'll show you how it works.
Jacob: And he was using both his hands at the end wasn't he.
Vanessa: Yeah because I helped him. Because I said to him look I've done that, been down that road. And his mum said he's got the splint so have I and then look at me I didn't wear mine I said look, I'm bad I haven't worn mine for two days. And he looked at me and went what you didn't wear yours? No. I said don't worry it'll come.
Jacob: That was great that you were teaching him today. It was nice that you had something to connect over, that you could show him the technique you were using

6.5.3 *Instrument Preference*

Towards the end of the second feedback session, we asked the participants and facilitators who were present to rank the Strummi instruments in order of preference. Note that not every participant was in attendance for this part of the feedback session. Table 6.4 presents their responses. We can see that there was no clear overall preferred instrument, although S1 and S3 received the highest number of favourite/least favourite ratings, while S2 was placed as the middle preference by the most participants.

Table 6.4: Each of the Strummi designs ranked in order of preference. 1 = favourite, 3 = least favourite - Raphael and Felix were not present during this discussion.

Participant	Instrument Preference		
	S1 	S2 	S3 
Oscar	3	1	2
Ismail	1	2	3
Liam	3	2	1
Jared	2	3	1
Imogen	1	2	3
Vanessa	1	2	3
Edwin	2	3	1
Abraham	3	1	2

6.6 DISCUSSION

6.6.1 *Emergent Values*

The open-ended nature of the jam sessions and feedback discussions allowed for personal values relating to music-making and disability to emerge. Brown et al. [2011] reflects on the role of 'lead participants' in in-the-wild studies. Lead partic-

ipants are described as a subset of participants who *'engage with the technology and reflect on its use by themselves and others in a particularly insightful way, or alternatively work so as to encourage involvement by others who are involved in the trial'*. During the Strummi sessions, we observed that Vanessa had taken on this role, through her enthusiastic feedback on both the instrument and the way the sessions themselves were structured. She also at several points lead the discussion during the feedback sessions, asking for feedback from others in the group, as well as providing encouragement and support for Felix while sharing the instrument.

Vanessa's responses during the feedback session were focused on music-making activities as a means of improving health and wellbeing. She was focused on the Strummi as a tool to improve her left hand (*'I'd like to play a bit more because it helped my hand'*) as well as a concern that other assisted living residents are not busy enough socially / creatively (*'It would be nice to have other people come out their house ... all they do is sit there eating and playing dominoes'*). Vanessa's values in music making appeared to be concentrated around these issues which were explicitly to do with the lived experience of disability.

During session 2, Vanessa took on the role of showing Felix how to use the Strummi, and stated in the feedback session *'It was very nice to teach somebody else, I find it was useful to teach somebody else who's got the same needs as I've got.'*. This highlighted values which are not explicitly related to music making: opportunities for developing strength in an impaired limb, promoting socialising and creatively stimulating activities, and connecting with other people with a similar impairment. We did not design the Strummi as a platform for muscular rehabilitation, or as a tool to promote social interaction (although designs which explicitly seek to address some of these issues do exist - e.g. [Kirk et al., 2016]). However it was clear in the feedback session that these were important values associated with music making for Vanessa. These concerns didn't appear to be shared by others in the group, whose comments were in general more concerned with the playability of the Strummi and the musical aspects of the sessions.

A prominent feature of the feedback sessions were comparisons to existing popular music performers and bands, as well as expression of interest in forming a band out of the Strummi Session group. In particular, it emerged that between the two sessions Imogen had decided on a name for the band *'The Expansives'*, and designed a logo. Vanessa expressed several times that she wished to continue the music making sessions, and others expressed a wish to record the songs. While it is potentially stating the obvious to suggest that groups of disabled musicians

show a strong interest in taking part in culturally relevant activities, we believe that this is sometimes left out of the literature on accessible musical instruments, which can have a tendency to treat music-making as though it exists in a vacuum. As with any music ensemble, creating musically pleasing sounds is only one of many motives for taking part: the 'musicking' activities that also take place such as recording, performing to an audience, designing logos, considering band names, stage production, are all part of the cultural fabric of playing in a rock band which make this kind of musical expression so appealing.

Other values which emerged from the feedback sessions and people's lyrics include Oscar's belief in the importance of recording and disseminating Heart n Soul artists' musical output, not just in CD format but with lyric booklets for people that are hearing impaired or speak another language.

6.6.2 *Constraint in Accessible Instrument Design*

Early on in this PhD research, we identified an imbalance in the field of accessible instrument design, where a majority of instruments appeared to be designed specifically to promote therapeutic effects, without a concern for the performative aspects of music making We problematised this by considering whether an accessible instrument could be described as *performance-focused*, or a *therapeutic device*. This distinction may not be as clear-cut as we first presented it however, as Vanessa's focus on the Strummi as a tool for muscular rehabilitation illustrates.

Our initial criticism of the 'therapeutic device' approach to accessible instruments is that they often tended to simplify or constrain some aspect of music making. Our original distinction between 'performance-focused' and 'therapeutic' instruments worked partly on the assumption that constraining pitch space to a smaller set of notes than what might be termed 'traditional instruments' (i.e. several octaves of the 12-tone scale) was not 'performance-focused'. This assumption was partly based on a concern about the repertoire available to the user - that any instrument not capable of allowing the user to perform an existing repertoire of the genre of their choice was a limitation, compared with existing 'traditional' instruments. This overlooks genres and musical performance contexts where a constrained pitch space doesn't preclude a performative role - Gamelan music being a notable example.

Perhaps more problematic than the limitations on repertoire that a pitch-constrained instrument would impose, is the implied value system that the role of an acces-

sible instrument is to make the performer more 'correct' more often by ensuring they cannot play 'wrong' actions. The assumption here is that being 'wrong' about some musical idea is frustrating or off-putting, so that therapeutic goals are better served by ensuring that people can play 'correctly' more easily. There is limited evidence to suggest that gentle constraints can be motivating for instrument learners (see Pardue [2017]) as it allows for focus on other elements of practice.

In the context of the Strummi sessions, we noticed that the Strummi's constraint to a selection of eight chords wasn't an issue for many users, with the exception that the facilitators made several comments and enquiries about the ability to change the key or otherwise assign chords to Strummi, and that they had difficulty working out how the chords were arranged. For the users of the Strummi we observed a diversity of plucking hand techniques which suggest a lack of constraint on musically-meaningful modes of interaction with the strings.

6.6.3 *Environmental Factors*

The DYOT music sessions, and by extension the Strummi sessions based on them, could be categorised as 'free-improvisational community music'. Community music as a discipline is broad and makes up for a large amount of the grey area between *music therapy* and *amateur music making*. Where community music is understood to involve *'an active intervention between a music leader or facilitator and participants'*, it can be defined as an *'intentional intervention involving skilled leaders, who facilitate group music making in environments that do not have set curricula'* [Higgins, 2012]. Through community music's recognition of *'social and personal growth alongside musical growth'*, and awareness of the *'need to include disenfranchised and disadvantaged individuals or groups'*, it is closely aligned with music therapy, but remains an entirely separate discipline.

This setting is valuable to us as a place to explore what makes a musical activity or instrument design therapy focused. In the case of Heart n Soul, implicit therapeutic benefits of music making are gained through an explicit focus on performance, song-writing and creative expression - goals arguably shared by amateur music ensembles for whom therapeutic and wellbeing benefits are not an explicit focus. This has served to complicate our distinction between *performance-focused* and *therapeutic* instruments as it has shown that there exists a context / environment in which there is no such distinction.

This idea of environmental factors complicating pre-existing notions of an instruments' status as performance-focused or not also extends to a more general question of the *accessibility* of an instrument. Our earlier ideas around accessibility framed the unadapted guitar as an in-accessible instrument, requiring significant adaptation and re-design in order to remove barriers to guitar playing. The Strummi sessions have helped illustrate the notion that access and accessibility are not always possible to measure or quantify for a general population. For Imogen, the design and intended functionality of the S1 Strummi may not have been clear, resulting in her inadvertently damaging it and choosing not to return to it later. Later in session 2, she used the unadapted guitar for a significant amount of time without changing instrument. In this context, the Strummi was not suited to Imogen's mode of exploration, due to a combination of fragility and unfamiliar design, whereas the guitar, being both a familiar and robust instrument, was better suited to her mode of playing. This could primarily be read as a lesson in designing durable instruments, but potentially points towards a more subtle point to do with *false affordances* (See [Gaver, 1991]). The novel design of the Strummi's bridge pieces suggested an affordance which did not exist, and resulted in her damaging the instrument, and potentially being put off returning to it.

The approach to performance practice, repertoire, acceptability of instruments and playing styles during Heart n Soul creative sessions is fundamental in removing barriers to music making that learning-disabled people face. These barriers can manifest as physical access issues with instruments and performance environments, as well as attitudinal barriers towards what constitutes musical skill and musicality. The Strummi addressed individual access needs for some participants (most explicitly, Ismail, Vanessa and Felix who had physical impairments which made holding and playing an unadapted guitar difficult). De-constructing the drum kit for Ismail to play also addressed his individual access need (using a powered wheelchair prevented him from being able to access the kick drum pedal). However these adaptations only remove barriers to music making if the structure around them supports these actions - the context allows a drumkit to be deconstructed and new and unfamiliar instruments to be brought into the mix, alongside unconventional ways of playing traditional instruments. This poses an important question to the wider field of accessible instrument design: can an instruments' claims of accessibility be taken at face value, without regarding the context in which it is performed with?

6.6.4 *Effect of Instrument Form*

Table 6.4 showed the individual preferences for each of the Strummi instruments. It is interesting to note that the S2 Strummi (guitar-shaped, similar size to the tabletop S1 strummi, but styled like a Les Paul), was more frequently the 2nd most preferred, whilst S1 and S3 were most commonly either most or least favourite. While this isn't a large enough sample size to draw any statistically significant conclusions, we note that Ismail and Vanessa both opted for S1, which they had previously stated was easiest to play in terms of their physical access needs. Liam and Jared, who had no physical impairments relating to guitar playing, opted for the S3 as their favourite.

S2 was originally designed to address two issues: firstly, the usability issues of the original guitar-body Strummi discussed in chapter 5 necessitated a more lightweight design; secondly, we wanted to test our idea of harnessing the cultural capital of the guitar within an accessible instrument by utilising a guitar-like form, and S2's Les Paul-inspired shape and black colouring was conceived as occupying the middle ground between the tabletop S1 and the S3 modified Les Paul guitar.

A soft hypothesis for these designs was that those with more explicit physical access needs would prefer the S2 over S1, as it both addresses some of those access needs (ability to play on tabletop, lightweight, compact) while still resembling the guitar and hopefully retaining some of the guitar's cultural cachet. Interestingly, it appears that this is not the case, at least for Ismail and Vanessa.

In our line of questioning around the preservation of guitar form in accessible instruments, there is an implicit suggestion that novel designs which do not closely resemble existing instruments might be 'othering' or 'stigmatising' when performing within an established musical genre such as pop and rock. It might be stating the obvious to say that *'Raphael and Vanessa's preference show that this is not always the case'*, but it is worth drawing on the ideas of *assimilation* vs. *affirmation* discussed in chapter 2, and whether or not someone's preference is to *'play the guitar in a way which is accessible to me'*, or *'play an accessible instrument which best addresses my access needs'*.

6.7 CONCLUSION

In this chapter, I introduced a shift in methodology from a lab-based, time-limited user study to a longitudinal and situated approach. This shift was in part informed

by the practical considerations of doing research with a community such as Heart n Soul, but primarily it allowed us to take an approach which moves towards more open-ended enquiries. With the Strummi, we did not set out to design the most accessible instrument possible for the population we worked with, but took a base level of accessibility as a starting point and allowed for people to bring their own values and approaches to the instrument. This resulted in unexpected interactions with the instrument to emerge, most notably the co-operation between Vanessa and Felix, that were not explicitly built into the instrument or indeed a goal of the study design. Our methodologies in this chapter, in particular ethnography and research products, represent a move away from 'solutionist' approaches to ADMI design, towards methods which are capable of capturing not only the functional requirements of disabled musicians, but also their musical goals, personal values, and individual techniques. In the final chapter, I will conclude this thesis with a recapitulation of the work done so far, and discuss how the findings from the three studies inform the way we might think about ADMI design and research at present and in the future.

7

DISCUSSION

The previous chapter detailed a study which attempted to bring together the key issues surrounding disability, accessibility and musical instruments and put them into practice in a formal research engagement. In this concluding chapter, I hope to expand on the conclusions drawn from this study and look back at the foundational work done in the literature review, case studies, and two preceding user studies.

I begin with a summary of the research undertaken in this PhD, followed by a recapitulation of the key issues related to ADMIs which were developed from the literature review presented in Chapter 2. I then go on to reflect on the original research conducted in this thesis: on the methodologies used, and how the findings of the three instrument studies relate back to the original research questions. This is followed by a discussion of potential future directions for research on the topic of ADMIs, and the wider themes of technology, instruments and access to music.

7.1 SUMMARY OF RESEARCH

The work done in this thesis comprises of original contributions resulting from the three user studies conducted during the PhD, and the distillation of key themes in the background literature review and case studies. Here, I summarise both of these strands of work, in order to set the reflections at the end of this chapter in context.

7.1.1 *Findings from literature review and case studies*

7.1.1.1 *ADMIs: the state of the art*

The literature review of existing ADMIs and related devices showed that there is little homogeneity across the instruments in terms of both the physical design and sensor mappings, as well as the design approaches adopted. Frid [2019] shows that interest in ADMI design has increased in recent years amongst academic communities related to DMIs and music HCI, such as the NIME and ICMC conferences.

Within academic discourse, there tends to be a focus on the participatory methods used to develop the ADMI designs (e.g. [Grierson and Kiefer, 2013]), and the medical, therapeutic, or educational benefits of ADMIs (e.g. [Larsen et al., 2016, Meckin and Bryan-Kinns, 2013]). Outside of academia, there are a number of commercially available devices which tend to focus on universal accessibility: placing an emphasis on as broad a range of accessible input modalities as possible, either through a modular system of sensors (e.g. Apollo Ensemble[1]), hands-free interaction (SoundBeam[2]), or a constrained yet robust tactile interface (Skoog[3]). These commercially available devices tended to take the form of controllers for software running either on home computers or tablets, or proprietary hardware. We also saw examples of the DIY/maker community developing ADMIs. These tended to encompass one-off designs made exclusively to address a particular users' access needs, such as the Kellycaster[4].

7.1.1.2 *Performance-Focused ADMIs*

From my initial exploration of the literature on ADMI research (predominantly from the NIME conference proceedings and related areas), as well as an observation of two of the leading commercially available ADMIs (SoundBeam and Skoog), I came to the conclusion that there was significant ambiguity around whether instruments were designed to be performed with in a purely artistic sense, or with more explicitly therapeutic goals - and that there was a distinct lack of instruments which appeared to fit the former category. I proposed a way of categorising ADMIs as either Performance-Focused Instruments (i.e. instruments designed solely for the purpose of enabling access to music making) or Therapeutic Devices (i.e. instruments or devices whose primary focus is on therapeutic or educational benefits of music making).

I originally distinguished between the two categories of accessible instrument through a comparison with 'traditional instruments' i.e. the majority of existing musical instruments which are not explicitly designed with access requirements in mind. I classified existing accessible instruments in terms of their *physical accessibility*, *learning process/acquisition of mastery*, *musical diversity* and *use cases* (see table 2.1 in chapter 2), borrowing concepts from Wessel and Wright [2002] (low barrier to entry, high ceiling on virtuosity) and Jordà [2004] (musical diversity). To briefly

1 http://apolloensemble.co.uk/
2 https://www.soundbeam.co.uk/
3 https://skoogmusic.com/
4 https://www.drakemusic.org/technology/instruments-projects/the-kellycaster/

restate these distinctions: Therapeutic Devices tend towards universal accessibility, low barrier to entry coupled with a low ceiling on virtuosity, low musical diversity, and strictly defined use cases in therapy and education settings. By contrast, I suggested that Performance-Focused instruments should aim to accommodate access needs on an individual level, provide a high ceiling on virtuosity, be musically diverse, and appropriate for use in performative settings such as concerts, rehearsals and jams.

This provided a useful means of problematising the field, and suggesting new approaches to ADMI design that would tie in with a Social Model understanding, however my understanding of what 'meaningful participation in musical performance' means in practice has evolved over the course of this PhD, and the distinction between *Performance-Focused instruments* and *Therapeutic Devices* has blurred - which I discuss in later in Section 7.2.1.

7.1.1.3 *What I Learned from Disability Studies*

A major contribution to this work from the field of Disability Studies is the introduction to the Social Model of disability. Originally coined by Oliver [1983], the social model directly challenges the prevailing Individual and Medical models of disability. The social model frames disability as a product of external barriers placed on people by society - as opposed to the medical or individual model which places the source of disability within the individual as a result of their impairments.

Directly related to the social model is the delineation between *impairment* and *disability*, whereby the former refers to the functional limitations of the individual, and the latter refers to the 'loss or limitation of opportunities' to take part in society due to external barriers [International, 1982].

The social model challenges us to take a more equitable view of disability, reframing the challenge of 'accessibility' to a collective effort to improve society and remove barriers. For ADMI researchers and designers, the social model challenges us take these environmental, societal, and attitudinal barriers as a starting point, as opposed to any functional limitations on the part of disabled musicians. By extension, it invites us to acknowledge the artistic merit and potential of disabled people as artists, rather than as medicalised individuals in receipt of medical or therapeutic intervention.

Alex Lubet's book *Music, Disability and Society* [Lubet, 2011] was the first introduction I had to disability studies and music, and was significant in shaping the

way I conducted this research. He introduces the concept of the *social confluence of disability*, which describes the way a person's disability identity can shift as they move through different environments and social contexts. He provides an example of his own shifting disability status as a music professor with an upper limb impairment: he is deemed fit to work in his office environment with minor adjustments by the Americans with Disabilities Act, however the strict performance requirements of orchestral classical music preclude him from taking part in performing the violin on the same level as his peers. This mutability of disability status reinforces the idea that disability is an external factor imposed on impaired individuals by society, and that attitudinal shifts around the nature of music performance are a key component of 'accessibility', as much as provision of appropriate accessible music-making tools.

The Disability Arts movement is strongly linked with both Disability Studies as a discipline as well as the social and political movements of disabled people worldwide. Firth and Cane [2018] use the terms *assimilation*, *inclusion* and *affirmation* to describe the way that disabled artists and organisations can frame their disability in their artistic practice. While the term *assimilation* carries potentially negative connotations, here it is taken to mean a process of disabled people taking part in mainstream arts on an equal footing to non-disabled artists, for example taking part in an orchestra via the provision of accessible tools - as Firth and Cane put it, more than simply *'patronisingly giving disabled people a go'*. 'Affirmation' refers to the way that some disabled artists produce art that directly deviates from the mainstream through explicit accounts of the lived experience of disability, often unapologetically embracing differences in aesthetic qualities. Recognising that processes of assimilation and affirmation both exist and have value for disabled artists is key when considering ways to remove barriers to music making: we should not assume that taking part in a 'normalised' idea of music making is the only goal, and that we can adjust our concept of what music-making means relative to the values of each individual.

7.1.1.4 *Insights from Case Studies*

In Chapter 3, I interviewed John Kelly and Molly Joyce, two disabled musicians who perform music that deals with their disability identity, as well as use instruments that directly address their physical access needs. John Kelly uses the custom-made *Kellycaster*, a digital guitar-inspired instrument with physical strings, a guitar body, and a means of accessing chords via a MIDI controller. The instru-

ment was developed through a process of co-design with two technologists, and supported by Drake Music, a charity who support the development of new accessible music technology. Molly Joyce is a composer who writes music for various ensembles, but also performs her own music with a Bontempi-style 'toy organ'. The organ has keys on the left hand side to select chords, which is well suited to Joyce's left hand impairment.

For both musicians, their choice of instrument and performance practice was not only a product of their physical access needs, but also reflected their artistic and personal values. For Joyce, performing with an instrument not regarded as mainstream allowed her to *'meet [her] body on its own level, and even kind of challenge it'* – it didn't require her to meet pre-existing performance expectations associated with more mainstream instruments, and inspired her to push her technique and develop ways of incorporating her impaired limb as both a visible and audible component of her practice. For Kelly, the Kellycaster is a pragmatic tool for overcoming the limitations of readily available software such as GarageBand, but also represents his philosophy towards music and learning: the highly collaborative nature of the co-design process, and his openness to future modifications and adaptations reflect his approach to learning and inclusion.

7.1.2 *Review of Contributions*

I hope that this research can contribute to future work in the realm of disability, music and instruments, through technical presentations of the instruments developed so far, and methodological and theoretical foundations for conducting research in this area. This research project has gone through several stages of evolution and I do not presume I have reached a final destination in my approach towards researching music and disability, and I would hesitate to suggest that the outcomes of this research present a 'right' way of doing things. At the very least however, I hope to have highlighted some key issues which have been missing from much of the discourse in DMI research, and to have got closer towards bridging the gap between Disability Studies and the development of ADMIs. Here I present the contributions of this research in terms of specific findings from the three studies, research artefacts designed to support the study enquiries, and reflections on the methodologies used.

7.1.3 *Findings regarding instrumental interaction*

Highlighted the roles of the fretting and plucking hands in bass guitar performance (Chapter 4): An unexpected outcome from the one-handed bass study was the observation of the different styles of string muting attributed to either hand during bass guitar performance. Through replacing the fretting hand with a mechanical analogue not capable of string muting, we had inadvertently shifted all string muting duties to the plucking hand. This highlighted not only the importance of the fretting hand for more than note selection and articulatory gestures: fretting hand muting was shown to be a subtle but highly functional role in bass playing. While this is not necessarily a new finding, especially for those with experience in bass playing, it highlights a key design issue for future accessible bass guitar designs that should not be overlooked, and is an argument against approaches which condense note selection and activation into a single gesture, for example with an advanced MIDI controller and sophisticated software instrument.

Highlighted the adaptability of plucking hand gestures in compensating for loss of fretting hand functionality (chapter 4): We found that some players showed an aptitude for adapting their own technique, suggesting that some shortcomings of the prototype fretting mechanism may be overcome through adaptation to technique, rather than further modification of the design. A number of players adopted different methods of accounting for the lack of fretting hand muting, either by transferring this functionality to the plucking hand, or adopting palm-muting to prevent the strings from ringing out. These two findings highlight a potential source of tension in accessible instrument design, especially when attempting to develop an accessible version of an existing instrument: how much should the player be expected to adapt their technique to a new instrument, and how much should the instrument be able to accommodate for existing technique? The answer might be very different for different players, dependent on previous experience with the un-adapted instrument, personal preference, and physical access needs - presenting a case for a participatory approach to design (as illustrated in the way that the Kellycaster preserves fretting hand muting as a specific design requirement emerging from John Kelly's performance technique and preference - see Chapter 3).

An investigation into the effects of instrument form versus interaction modality in DMI design (Chapter 5): We presented participants with a *congruent* and *incongruent* pair-

ing of instruments, where the former comprised a guitar shaped form with strings, and a tabletop instrument with a touch sensor - and the latter comprised a guitar shaped instrument with touch sensor and a tabletop instrument with strings. We were most interested in the incongruent pairing as we hoped participant's preferences for either version of the instrument might shed some light on whether the global form of the guitar or the physical support of the strings would be more important in our attempts to develop a *'guitar-like DMI'*, and whether prior experience with guitar playing would affect this outcome. We found no statistically significant differences between the groups from our questionnaire, which coupled with the findings from our thematic analysis of structured interview responses, suggest that - at least with the instruments we designed for our study - global form and interaction modality are not entirely separable concepts. We did find that guitarists focused on the presence of strings more often than non-musicians in their reflections on the instrument, regardless of the global form. This suggests that for different stakeholders, different elements of instrument design are more or less important. In particular, when designing DMIs with the explicit goal of taking on the musical role of an existing instrument, socio-cultural cues given by the global form should be considered alongside preserving existing technique, especially if prior experience playing that instrument is non-existent.

The effects of richness of interaction across differing levels of instrumental experience (Chapter 5): This was the focus of my co-researcher, Robert Jack's research, but is also of relevance to this thesis. We found that when given the same instrument with two different levels of richness (i.e. sample triggering based on reaching an amplitude threshold vs. continuous audio-rate excitation of a synthesis algorithm), there is a difference in the preferences of non-musicians and experienced guitarists. The guitarists unanimously preferred the richer and more nuanced setting which afforded them greater control over the resulting signal, whereas non-musicians were less decided, with some preferring the less rich setting, perhaps as a result of the predictability and lower complexity of the gesture-to-sound mapping. These findings complicated the widely held notion that 'a richer instrument is a better instrument' - a value in DMI research articulated in Wessel and Wright's paper on 'intimate musical control' of computers [Wessel and Wright, 2002] - and puts forward a case for managing the complexity of an instruments' affordances relative to the expertise of the user - a topic also touched on by Pardue [2017]. Although richness and control intimacy has not been an explicit avenue of enquiry within

this research, it contributes to our ideas of *constraint* in ADMIs and presents a case of constraint in DMI design being of value to the user.

Highlighted the roles of instrumentation and environmental factors in access to music (Chapter 6): As instrument makers, much of our attention in the NIME community is given over to the functionality of the instrument and its technical descriptions. While these factors are of great importance to researchers, this study highlighted the necessity for understanding the environmental context of the interaction between player and instrument. This is perhaps of more relevance to ADMI research specifically than NIME as a whole, but any study which takes into account a specific community of players could benefit from the approach taken here. Specifically, this study made clear that the role that instruments play in providing access to music making is limited as much by the environment as any technical affordances or constraints. The attitude and approach of the facilitators and participants during the Strummi sessions meant that instruments which might be deemed inaccessible in other contexts (the drum kit, pre disassembly, for example), could be used in musically meaningful ways that suited the goals of the session.

7.1.4 *Research Artefacts*

A method of mechanical adaptation of the bass guitar for MIDI-controlled note selection (Chapter 4): A major contribution from this study is the design of a relatively low-cost, removable system for mechanically fretting the strings of a bass guitar using solenoid motors. Drawbacks to the design include the size and weight of the solenoids which affect the playability and scalability of the adaptation, and I would not suggest that this system presents a viable route to creating a fully accessible bass guitar. This design might present more of a contribution to the field of musical robotics than ADMIs, however we have demonstrated the viability of real-time control of a mechanical system in bass playing, so there is scope for further exploration of live performance with mechanically-adapted instruments. The study went some way to demonstrating the viability of the natural mapping approach for transferring the role of note selection to an alternate limb (in this case the feet), and this could be a source of enquiry for future studies into one-handed string instrument playing.

The Strummi: a new guitar-based DMI using acoustic-excitation and string-modelling techniques (Chapters 5 and 6): The *Strummi* instruments have been the focus of much of the latter stages of this research. Drawing from earlier designs such as the *Kalichord Strum* and *BladeAxe* (Schlessinger and Smith [2009] and Michon and Smith [2014]), it uses the technique of using an audio-rate signal as the excitation for a digital model of a string (in this case the Karplus-Strong plucked string algorithm). A key development here is the use of real guitar strings to preserve the interaction technique of a guitar. In order to achieve this, we developed a method of individual string sensing using custom, low-cost bridge pieces with integrated piezos. The Strummi has been formally evaluated both in a lab-based performer study and an in-the-wild field study, as well as extensive use at a number of events and conferences. Our findings from these use cases will shape future developments to the Strummi.

7.1.5 *Methodological Reflections*

A comparative study design (Chapter 5): The comparison between the *incongruent* and *congruent* pairings of instruments, as well as the responses of non-musicians and experienced guitarists, allowed us to infer findings by looking for the differences between the opposing groups. Creating a congruent and incongruent set of instruments allowed us to attempt to separate out the relatively complex notions of global form and interaction modality, while maintaining the probe's viability as a musical instrument within the context of the study. This allowed us to preserve the performative element of the musical task without having to strip the instrument down to a single component under analysis.

An ethnographic account of an in-the-wild research activity with a learning-disabled community music group (Chapter 6): I set previous research on accessible instrument in context through a longitudinal, situated research engagement with *Heart n Soul*, an arts organisation for learning-disabled people. Ethnographic accounts provide the research community with a more in-depth understanding of the issues and values that relate to people's interaction with technology. Rather than generalising across the group, the ethnography allowed us to signpost salient points that related to people's individual experiences. In particular, Vanessa's feedback and interaction with the Strummi highlighted a number of issues: firstly, that the music

making sessions provided her with a platform for social interaction and personal expression which she felt others in her community weren't accessing, secondly, that the Strummi instrument in particular was a means of playing the guitar that also exercised her impaired hand, and thirdly that using the Strummi instruments provided a platform for co-operation and shared experience with another person with a similar impairment. The ethnography provided a space for understanding the heterogeneity of people's responses to the instruments. Some of the most rewarding findings were specific to a small number of participants due to their own musical tastes, personal values, and access needs.

7.2 REFLECTIONS ON CONTRIBUTION

Over the course of this research, it has become increasingly evident that the topic of disabled people's access to the arts is a hugely multifaceted issue, with a broad spectrum of stakeholders, often with well-meaning yet opposing notions of how to go about working in this space. This evolving understanding of access to the arts has challenged and shaped the way I have conducted my research, to the point that some of my earlier ideas and approaches now seem outdated with the benefit of hindsight. Self-reflection is an important stage of any academic endeavour, but becomes more politically charged when conducting disability-adjacent research as a non-disabled academic. I hope that through presenting the entire story of my research efforts and critically reflecting on the relative merits of my methods, I can offer insights into accessible instrument design whilst moving forward the discourse around how research is conducted in this field, by whom, and for whom.

The overall goal of this thesis is less to do with prescribing a framework or guidelines for designing new ADMIs, but to highlight the environmental factors that contribute to an ADMI's success, and hopefully to shape the way that future research and development is done in this field. In this section, I present reflections on the work undertaken, in order to both provide a full picture of how my personal understanding has evolved, as well as to provide takeaways for the broader field of ADMI research and design.

7.2.1 *Reflections on Performance-Focused ADMIs*

In this section, I will look back at the notion of *performance-focused* ADMIs, first discussed in chapter 2, and my initial criteria for an instrument's inclusion within this category.

7.2.1.1 *Constraint, Agency and Richness*

My initial conceptualisation of the *Performance-Focused* instruments suggested that the constraint on musical diversity put in place by a reduction of pitch space was a significant factor in preventing meaningful participation in musical performance. Following the 'Strummi Sessions', and reflections on my conversations with disabled artists and community music leaders, I would no longer make the case that constraint in pitch-space is an inherently problematic feature in ADMI design. Constraining pitch-space in order to prevent the player from accessing the 'wrong notes', can potentially be a case of the designer imposing their own values of what is 'good music' onto the player. However, it would be wrong to suggest that the availability of every pitch in the 12-tone chromatic scale is the 'be-all and end-all' of musical freedom, and to suggest otherwise simply *'prioritises one arbitrary musical system over another'*[5]: for example many musical genres and cultures such as Gamelan use a single pentatonic scale with different tuning systems.

That said, it would be wrong to suggest that there is no *need* for ADMIs which provide access to several octaves of the 12-tone scale. To some musicians, access not only to existing repertoire but stylistic conventions of Western rock and pop styles is a key concern, and is only afforded by instruments which are not constrained to a single scale or arpeggio.

As well as avoiding the imposition of values on what is 'good music', there is also an argument to be made for instruments which allow for mistakes or 'wrong notes', with respect to a pedagogical system or repertoire. Bin [2018] writes that *'a good instrument will allow an artist to do it wrong, in order to discover a new way of doing it better'* - pointing towards the value in making mistakes, both for the instrument learner and the audience.

With this in mind, it is worth considering the following questions when evaluating a pitch-constrained ADMI:

1. Is the constraint on pitch-space designed to prevent the 'wrong notes' from being played?

5 Charles Matthews 2019, Personal Communication.

2. Is the constraint on pitch-space designed to simplify the interface in order for the user to focus on other musical parameters?
3. Can the user set the constraints (e.g. scale, chord, number of octaves) in a way which is accessible to them?

I propose that there is no definitive answer to the question of constraint in ADMI designs, but a key concept to consider is *agency*. Murray-Browne [2012] discusses the challenges of providing immediately accessible interactive music systems (in this case, in the context of a public installation for non-musicians), which provide a sense of agency. Framing constraint in DMI design as the removal of perceived agency, Murray-Browne states that this can be interpreted by the player / audience as dishonest, inauthentic, or an *'unjustified imposition'*. While the design goals and embedded values in Murray-Browne's case differ from those of performance-focused ADMIs, a commonality here is the importance of preserving a sense of agency whilst removing or avoiding points of inaccessibility. The point at which a constraint becomes an 'unjustified imposition' on the player's agency is a contextual one, and it is worth considering that as musicians, we choose instruments with built-in constraints all the time: the violin requires hundreds of learning hours before it can be performed with, the electric guitar can't be made to sound like a flute, an *Ableton Push* can't be strummed. In the context that these instruments are used, the players *expect* these constraints, and either ignore them or even work with / against them in a process of appropriation. In these cases, the constraints of the instruments are an integral part of the support system of the instruments, provided that they align with the desires of the player in that musical context - and that player has the agency to appropriate and innovate.

An aspect of musical constraint not linked to pitch is that of the *richness of interaction*, which was explored in chapter 5. In the study, we found that the instrument with the least variability in terms of gesture-to-sound mapping (i.e. the most constrained) was more popular amongst non-musicians. Where a goal of a musical activity is to provide an immediate entry point into creating musically meaningful performances, for example in a time-limited community music session, there might be something more *democratic* about providing a consistency of sounds that is achievable with a wide range of input gestures.

Implications for future research: the key point here concerning future work in this domain, is for ADMI designers to understand the deeper role that constraints can play, and to ensure that where constraints are a design feature, they are reflective

of the player's musical goals and values. In other words, is the imposition on the player 'justified'? Constraints can be used in instrument design to provide more immediate access to a musical performance. For example through constraining pitch-space to the key of a particular piece of music might allow a musician to take part in a jamming exercise without requiring prior knowledge of the relevant musical theory to produce stylistically appropriate musical phrases - a perfectly valid and potentially empowering musical experience in some contexts. However, if an instrument with such a built-in constraint was intended for use by a musician who wishes to compose new music, or to improvise on a chromatic scale, then that constraint might become 'unjustified'.

7.2.1.2 *Cultural Forms*

A thread which has run throughout this research is the notion of *cultural forms* and how it applies to accessible instrument design. Horn [2013] discusses how cultural forms can be used in interaction design: to 'intentionally shape objects and situations to evoke cultural forms as a means to tap into users' existing cognitive, physical, and emotional resources'. The adapted bass study led us to consider what the effect of using an actual bass guitar body was in the way that players appraised the instrument. In the latter two studies, we wanted to probe this further to see how we could use the design of the instruments to evoke the cultural form of guitar-playing.

In terms of *performance-focused* instruments, the notion of cultural forms leads us to consider whether an ADMI should aim to evoke and 'tap into' existing musical and cultural practices, and what are the implications of mimicking or avoiding existing instrument designs. The diverse range of responses to the different global forms of the Strummi suggest that there is no obvious answer to the question of whether an accessible instrument should aim to mimic an existing instrument in order to 'fit in' to a performance context. This brings us back to Firth and Cane [2018]'s notion of 'assimilation and affirmation' discussed in chapter 2. It may be the case that there are performance contexts in which the novel design of an ADMI serves to affirm the performer's status as a disabled musician/pioneer/adopter of new music technology, for example in Kris Halpin's use and championing of the MI.MU gloves[6]. It may also be the case, especially where physical access needs are present, that the player simply 'doesn't care' how much the instrument resembles a guitar (or other instrument) - for example Vanessa and Ismail's preference for

6 https://www.drakemusic.org/technology/instruments-projects/mi-mu-gloves/

the tabletop Strummi seemed to be largely to do with its accessibility affordances and not an aesthetic decision.

Looking again at the Kellycaster, there is a strong case for an instrument which evokes the cultural form of guitar playing in a punk-inspired singer-songwriter performance. I would suggest that part of the strength of the Kellycaster is the speed with which the audience forgets that it is a novel technology. The playing field has been levelled not only by the accessible affordances that the Kellycaster provides, but by the ease with which Kelly can slot into a performing rock band without asking the audience to fill in any gaps. This allows Kelly's 'loud and proud' disability-affirming songwriting to take the foreground, building on the existing cultural cachet of punk and protest singers, rather than the instrument itself making a statement.

Implications for future research: There is a temptation to offer a conclusive answer to the question of ADMIs evoking existing cultural forms, in order to guide future instrument makers in the way that they design ADMIs. However coming down one side or the other would not reflect the heterogeneity of values of disabled people (and people in general) when it comes to performing with a musical instrument. The implications for instrument designers is then to *make no assumptions* about what is best practice, and to understand that there are often cases for an ADMI fitting into an existing cultural practice, while some cases call for more radical and esoteric designs.

Considering the role of cultural forms also applies to the way that ADMIs are discussed and evaluated. Researchers should not limit their evaluations only to the affordances an instrument provides a disabled musician. For example, if a gesture controlled software instrument running on a laptop offers more degrees of freedom than, say an acoustic guitar tuned to an open tuning, does this necessarily make it a 'better' instrument for performing in a folk context? I do not propose this as an argument for 'settling' for instruments with reduced degrees of freedom, but I would suggest that there are performance contexts in which the evocation of a particular cultural form might be more important than the technical opportunities an instrument provides.

7.2.1.3 *Music Therapy and Music Performance: Tensions and Harmonies*

My initial concept of what placed an ADMI into the 'therapeutic device' category perhaps came from a limited conception of what entailed music therapy, as well

as a narrow view of what counted as 'meaningful participation in musical performance'. This was partly based on the assumption that where therapeutic outcomes are the primary goal of a musical activity, goals of creative expression and musical performance are suppressed. This is a viewpoint that has been espoused in the past, for example in the following (somewhat inflammatory) quote from Sutherland [1989] in *Disability Arts, Disability Politics*:

> *'The term art therapy is one of those phrases, like 'military intelligence' that contains an internal contradiction. Art therapy uses the forms of art for entirely unartistic ends. In particular, it leaves out communication, for it assumes we have nothing to communicate'*

This reflects the frustration at the medicalisation of disabled peoples' access to the arts, which arguably may have been much more prevalent in 1989 when this paper was written. However, it is evident that these attitudes still persist, in the way that therapeutic outcomes are often presented as a primary motivator for the development of ADMIs or other accessible creative tools.

This is, however, not the full picture: while music therapy as a discipline is by definition a medical act, recent discussion on clinical music therapy reframes the process from one of healing or curing, to one of *empowerment*. Rolvsjord [2004] explains that *'therapy is not only about curing illness or solving conflicts and problems, it is also about nurturing and developing strengths and potentials'*. In terms of acquiring virtuosity and musical skill, Rolvsjord suggests that 'musical empowerment' is *'not so much a process of acquiring a certain amount of culturally valued musical skills and resources as it is a process of regaining rights to music'*. Referring more broadly to Art Therapy for people with dementia, Lazar et al. [2017] state that *'in art therapy, people with dementia are positioned as capable, competent, and engaged artists who express themselves in meaningful ways'*, perhaps reflecting a more empowering approach in art therapy than those encountered by Sutherland and his contemporaries.

Going back to the Strummi Sessions, discussed in Chapter 6, for players such as Vanessa, there was no distinction between an activity which benefitted her health through exercising her impaired limb, and which also allowed her to express herself creatively[7]. The Strummi in this case is neither a purely therapeutically motivated device, nor solely for the purpose of supporting creative musical performance.

7 Importantly, this is not to suggest that the Strummi Sessions themselves were a form of Music Therapy, which is a highly methodical clinical intervention provided by a trained therapist, and not simply any musical activity which might present therapeutic outcomes.

While the distinction between 'performance-focused' instruments and 'therapeutic devices' may have turned out to be a false dichotomy with the benefit of experience and further reading - it does point towards something, perhaps more nuanced, at play in the space of ADMI research and design. This may be partly to do with what it is when we talk about *'music'*, and specifically the notion of *'access to music'*. There appear to be several interpretations of what it means to *make music* that can influence the way the design of an ADMI is approached. Where 'making music' is taken to mean 'producing a sequence of pitched sounds', the requirements of an ADMI become removed from any sociocultural expectations attached to music: any accessible means of triggering a sequence of pitched sounds becomes a successful ADMI. However, other interpretations of 'making music' carry with them cultural associations and expectations, which in turn affect the acceptability of an instrument to support the music making process. A (non-digital) example here would be the adapted saxophone played by David Nabb - a professional saxophonist who lost movement in one arm. In this case, the musical values inherent in Nabb's practice as a saxophonist explicitly require a saxophone-like instrument - in terms of the sound, playing technique, materiality and visual aesthetics.

Other means of producing pitched sounds, no matter how sophisticated or more suited to his access needs, would risk shifting Nabb's musical practice away from saxophone performance, into something completely different. The barrier to accessing musical performance may be lowered in a general sense, but not in the sense that Nabb requires to realise his musical goals as a saxophonist.

This presents two different approaches to providing 'access to music': one in which the concept of 'music' is seen as mutable, where cultural expectations and conventions are largely avoided, and the player is enabled to make music that best fits the affordances of the instrument. The other approach represents a process of designing the instrument around the pre-existing cultural associations of a musical culture, with the goal of enabling the player to make music which best fits those associations and expectations.

Implications for future research: The ambiguity around the intended use-cases for ADMIs formed part of the motivation for considering the terms 'therapeutic devices' and 'performance-focused' instruments. I propose that being more explicit about whether an instrument is designed to be used as part of a therapeutic process or for performance might help the research community to better understand the thinking behind certain design features. This is also relevant to social model

thinking about disability: while devices for use in music therapy is a worthy research topic, we should be careful to avoid unnecessary references to medical issues related to disability, and further stigmatising the community of musicians who play music for its own sake as opposed to reach some medical or therapeutic goal. Having said this, the line between music performance and music therapy is less well defined than my initial formulation allowed for, and I would hesitate to suggest that ADMIs should be discussed in such absolutist terms as being either performance-focused *or* therapeutically-motivated.

The implications then, are perhaps more concerned with the way we evaluate and discuss new ADMIs, than approaches to designing them. Articulating the often highly specific contextual factors behind the way a particular musician uses an instrument could provide greater clarity and a deeper understanding of the issues a particular instrument is intended to address. Knowing what 'making music' means to a particular musician would allow the research community to understand the effeciveness of particular design choices, and how they might be used in other areas.

7.2.2 *Methodologies*

My motivation to use a mixture of lab-based and real-world study methodologies was informed partly by the kinds of questions I intended to ask with each study, and partly by an evolving understanding of the issues present in disability-adjacent research. It became more apparent during this PhD that lab-based studies can only capture so much about the nature of people's interactions with musical instruments, and risk diminishing the important role of the culture which any musical practice exists in. The methodologies we use in any research activity will have an outcome on the kinds of knowledge we gain from them, and it is important to reflect on how this knowledge should be interpreted.

In *Critical Realist HCI*, Frauenberger [2016] discusses the idea of stratified knowledge, and the relative merits of the various methodologies favoured by the different waves of HCI. In the context of research on mobile phone use in public transport, he writes:

> *highly situated studies on what makes people want to communicate while sitting on a train contribute to our understanding of reality as well as a highly controlled study on typing speeds in a usability lab, as long as we put each mechanism into the perspective of the whole and relate it to the real thing.*

I believe this approach could be invaluable to accessible instrument research: there is a clear need for research which is capable of taking into account the wider social and structural issues that come into play in enabling access to music for disabled people, however this does not nullify research which focuses on developing technological *solutions* to observable *problems* in instrument design.

In this section, I discuss three approaches which I employed at various stages and to varying degrees throughout the research: *Technology Probes / Research Products*, *Lab-based Studies* and *Research in the Wild*. By considering these methodologies through the lens of stratified knowledge, I aim to signpost where and how the findings from this research can be used in the real world, who it applies to, and to what extent.

7.2.2.1 *Technology Probes and Research Products*

A core ideology of this research is the notion of treating new ADMIs as artefacts which 'make sense' in the context of an existing musical culture - instruments capable of drawing on pre-existing notions of instrument design and musical performance. This led us towards Gaver's inspirational *cultural probe* methodology and Hutchinson et al.'s related work on *technology probes* [Gaver et al., 1999, Hutchinson et al., 2003]. The 'probe' approach centres around deploying artefacts into an existing culture and learning about both the artefact and the community under enquiry through observing the ways that people interact with those artefacts. In the case of this work, this brings us closer to the notion of adopting cultural forms than classical usability studies would allow, taking into account the more uncertain, qualitative findings (Gaver's 'inspirational data').

In the case of the study presented in Chapter 5, rather than aiming to design the best possible or most usable guitar-like DMI, we aimed to design a selection of instruments which would be best at provoking our participants to thinking about the notions of global form vs. interaction modality, and the richness of interaction available. Despite conducting the study in the lab, we were concerned with a real-world performance scenario, that of an Irish folk session. We intuited that an unfinished, prototype instrument would be insufficient as this would lead the users to focus on those parts of the instruments which needed refining - an insight which we gained from the one-handed bass study, where participants' feedback tended to focus on usability issues with the instrument we were already well aware of. This led us to think deeply about the visual aesthetics of the instrument during the design process, as well as the instruments' durability and usability factors.

We came across the notion of *research products* relatively late in the process of this research, but have found it to be a highly valuable concept in considering our approach to the design and use of the Strummis. Odom et al. [2016] describe research products as research artefacts which emphasise 'the nature of the engagement that people have with an artifact predicated on *what it is* as opposed to *what it might become*'. This reflects our approach to the design of the Strummis for the initial study, and perhaps is a better fit than the 'probe' approach which also features some form of passive data collection, which the Strummis do not possess. For the Strummi Sessions, this approach was particularly valuable as it allowed the Strummis to be used alongside the typical rock-band instruments - importantly without requiring any additional setting up or calibration, enabling us to consider the reaction to the Strummis as an instrument in its own right.

Implications for future research: research products are valuable to ADMI designers and researchers for their ability to be deployed in real-world environments, where we can observe how they are used alongside unadapted instruments, in real performance contexts. This not only highlights issues of access and usability that might relate to future iterations of the instrument, but also those less tangible properties of an instrument, such as the playing style and choreography they inspire in players, or the cultural associations that players make with genres of music and specific bands/artists they listen to.

7.2.2.2 *Lab-based vs. In-the-wild studies*

The first two studies (discussed in Chapters 4 and 5), were conducted in the lab, with non-disabled participants. This limits the level of knowledge of that we can infer about the nature of these instruments both in real-world performance settings, and in the context of disability and music performance. However, the lab studies allowed us to set up musical activities in a controlled setting that sought to answer our research questions: specifically in the way that we evenly split the groups between 'congruent' and 'incongruent' instrument pairings, and could control from demographic effects such as instrument experience. This approach helped us uncover factors such as the effect of musical experience on perception and enjoyment of instrument richness, and how the physical support of guitar strings tended to be more important to those with experience of playing guitar, while some non-musicians preferred the global form that most resembled a guitar regardless of the presence of strings. These findings were valuable to us as designers and re-

searchers, and shaped the way that we thought about the Strummi instruments in future studies and engagements with users of the instruments.

However, I would emphasise that the findings from the lab-based study can not contribute to an understanding of the access needs of disabled musicians, due to the fact that no disabled musicians took part in the study. What this study did was provide us with a controlled and isolated observation of the roles of interaction and global form, which could be carried forward into the situated, longitudinal study.

Moving this research into the wild was a valuable and necessary step in this research. Conducting ethnographic research in the context of a community of disabled musicians allowed us to challenge or confirm our ideas of what makes a 'performance-focused' ADMI - for example the importance of evoking cultural forms, constraint on pitch space, and richness of interaction. The early stages of this process (the initial engagement with Heart n Soul and subsequent volunteering during their regular sessions) helped establish design issues with the Strummi such as the weight of the 'guitar-style' body. This also allowed us to observe how people used the Strummi, and confirmed that at least for some people at Heart n Soul, the chord buttons were a point of accessibility that opened up guitar-like playing.

During the Strummi sessions themselves, we observed the benefits of an in-the-wild approach that were previously discussed by Brown et al. [2011]. A notable example of this is the presence of *'lead participants'*, who *'engage with the technology and reflect on its use by themselves and others in a particular insightful way, or alternatively work so as to encourage involvement by others'*. In the case of Vanessa, her pre-existing enthusiasm for the Strummi instruments, her stated values of rehabilitation and mastery of the guitar, and co-operation with Felix during the second session, generated a number of highly valuable insights as well as promoting interaction amongst the other participants. However, Vanessa was not a 'typical' user of the Strummi: her motivation for using it and her performance technique were unique to her. As Brown et al. acknowledge, these *atypical* uses are actually the most interesting (*'the frequency of an observation has no relationship to insightfulness'*).

As well as the benefits to HCI researchers in general, the in-the-wild approach could be argued to be complementary with an inclusive and egalitarian approach to research with disabled people - in the way that it captures and validates the individual experiences of participants, and its flexibility to acknowledge both sociocultural and physical access issues without relying on measurable access re-

quirements alone. The ability to treat participants as experts in their own use of technology rather than 'passive users' is of particular relevance to this point.

7.3 FUTURE DIRECTIONS IN ADMI RESEARCH AND DESIGN

Research into the design of ADMIs is a relatively young field, and there are a great many avenues for further exploration. An advantage of working within a field as young as this is the opportunity to develop new methods of researching and writing, and to help define how future work will be done. There is a temptation then to offer some kind of framework or methodology for future ADMI researchers to follow. However, this is somewhat antithetical to the findings of the final study, which made clear the importance of a reflexive and flexible approach to conducting research, due to the highly contextual nature of the insights we gained. In this section, I offer considerations to future ADMI researchers and designers, based on my own interpretation of the work done in this thesis. I do not intend this to be taken as a recipe or framework to work from, but a 'jumping off point' for future researchers to consider the key issues at play.

1. The way an ADMI looks is important, and can evoke different cultural forms.

The guitar-inspired physical design of the Strummi, both in terms of the presence of real guitar strings, and the guitar-style body of two of the Strummis, was a factor in some of the player's preference. We considered it important that in the case of Vanessa, her comments touched on a prior wish to 'play the guitar', which appeared to have been fulfilled by her interaction with the Strummi. This is echoed in the design of the Kellycaster, which evokes the cultural form of guitar playing so successfully that the audience quickly forgets he is performing with a bespoke piece of novel technology.

On the other hand, Molly Joyce's preference for the non-mainstream Toy Organ reflects her wish to embrace her physical differences - meeting her body on its own level. Kris Halpin, who performs with the MI.MU gloves, refers to the gloves as 'cyborg-looking'[8] and it is clear that the evocation of a science-fiction-like design is part of the appeal of them.

It is clear that the aesthetic properties of these instruments play a significant role in their success and adoption as tools for removing barriers to music perfor-

8 Kris Halpin 2019, Presentation at Drake Music DMLab event

mance. Evoking existing cultural forms aids musicians in fulfilling personal goals of performing music in a pre-existing musical tradition, for example playing guitar. Novel or non-mainstream designs meanwhile allow some disabled musicians to embrace the differences between the way that they make music and the way a non-disabled musician would. This ties into the continuum between assimilation and affirmation observed by Firth and Cane [2018].

The implication for future ADMI design is to consider the role of existing cultural forms and how they might interact with a musician's personal goals in terms of the way they express their disability identity. In practice, this means that ADMI designers should look not only to solving issues of physical access needs, but also to address the artistic intentions of the performer. The co-design process involved in the Kellycaster shows that these intentions can emerge naturally through a participatory approach to design, as long as both parties are aware of their presence. Where the 'end-user' is not known, for example when designing an ADMI intended to be used by large groups or made commercially available, it is of course not possible to address these musical goals. With the Strummi, we didn't have a specific user in mind when we designed it, and didn't seek to identify any specific users within the Heart n Soul group. What we found was that a number of people developed quite close relationships with the Strummi over time, while others chose not to engage with it. Had we set out to design an instrument that did not evoke any specific cultural form, but was intended to fulfil as broad a range of musical intentions as possible, we might have seen a greater number of people engage with it, but may have risked missing the moments of deeper connection, for example the way that the Strummi appeared to directly address Vanessa's goal of playing guitar.

2. 'Access to music performance' can be interpreted in many ways. Different interpretations will lead to different approaches to ADMI design.

When considering the field of ADMI design and research, it is clear that while there are many designers, researchers and makers focusing on the development of new musical instruments for use by disabled musicians, there is no single interpretation of what 'making music' means in practice, and therefore what removing the barriers to accessing music performance entails. Longden [2019]'s emphasis on the inclusive, improvisatory and community-oriented practices of non-Western indigenous music sets up a performance context in which open-tuned string in-

struments provide a means of full participation in musical expression for all participants. Meanwhile, instruments such as Peter Worrell's one-handed recorders[9] are examples of bespoke instruments designed to provide access to mainstream music education for pupils with upper-limb impairments - they are explicitly designed to provide access to Western music traditions and conform as closely to a traditional recorder's design as possible.

In both of these examples, the design philosophy of the instruments is rooted in differing interpretations of 'music-making'. While these interpretations are contrasting, what is common to both approaches is the acknowledgment of the cultural expectations of these approaches to music, and the values inherent in both. The one-handed recorder is a recognition of many young musician's goals of taking part in what we recognise as Western musical traditions: learning music theory, notation, ensemble performances etc. Meanwhile the open-tuned harps, guitars and zithers employed by Longden are well suited to the rhythmic, drone-based and improvisatory community music sessions, drawing on musical traditions from non-Western cultures.

While it is true that moving away from Western music traditions can open up opportunities for less rigidly-defined and more egalitarian performance structures, we should not dismiss the fact that many musicians aspire to take part in existing Western musical cultures. In the design of new ADMIs, we must work to address the access needs of disabled musicians, but ensure that we are not redefining what is meant by 'performing music' in order to suit the affordances of the instrument. Just because an instrument provides an accessible means of triggering pitched sounds, does not mean it is inherently capable of providing access to music-making - it depends on the *kind* of music-making the instrument is designed to support.

This has implications both for the way that new ADMIs are designed, and the way they are evaluated and discussed. To address the first point, I suggest that prior to any design work, we must ask the question *'what kind of musical culture is this instrument intended to enable access to?'*. Again, it is easy to imagine this being readily answered in a participatory design process, where the intentions of the performer are addressed from the beginning of the design process. In other instances, answering this question may be a matter of, for example, ensuring that the repertoire of a particular musical tradition is accessible - an instrument tuned to a fixed pentatonic scale may be sufficient for taking part in an improvisatory

9 http://www.peterworrell.co.uk/onehandedrecorder.htm

community music session, but not necessarily for performing a set list of folk songs in different key signatures. To address the second point of evaluation, I suggest that when writing about new ADMIs, we avoid generalised claims along the lines of 'enabling access to music-making', and aim to specify the parameters of the music-making activity.

By considering the issue of ADMI design from the perspective that 'music-making' is a loosely defined concept, we can also avoid 'technosolutionist' stances that frame ADMIs as a solution to a problem, and consider them more as a broadening of the palette of available tools for musical expression. It invites us not to stop at the point that we have solved the technical hurdles of providing physically accessible means of producing notes, and encourages us to move further to consider the instrument as a component in a rich ecosystem of people, their attitudes and environments. This is a concept that has recently been explored in NIME by Morreale et al. [2020].

3. Consider longitudinal, situated research methods, and embrace unexpected results.

There is a growing body of work in 'third-wave' HCI that favours the more complex or 'messy' encounters between people and technology in real world settings over the more measurable and quantifiable outcomes from controlled user-studies in the lab. In particular, we were inspired by the in-the-wild approach to HCI research described by Rogers [2011], and the use of ethnography as a method of enquiry as decribed by Dourish [2007]. The benefits of situated and ethnographic approaches have long been understood by HCI researchers in general, but their benefits to ADMI research are well worth noting. As discussed in Section 7.2.2.2, long term fieldwork allows us to develop collaborative relationships with the communities we wish to work with in a way that supports a more egalitarian and inclusive model of disability: we can afford to make no assumptions about what the outcome of working with these communities may be, because we have the time to allow these outcomes to naturally develop and emerge. We do not need to reduce disability down to a set of observable physical characteristics in order to identify where barriers to access occur: with enough time, we can learn the personal goals and values of individuals as they relate to their disability as well as other aspects of their identity, and consider ways that musical instruments may fit into this rich tapestry. This notion has already been well explored in Participatory Design projects, which aim to uncover a particular group's values over a

long-term design project and incorporate those values within the eventual design. I do not suggest that the long-term 'situatedness' of this research is anything new to ADMI design, but I wish to emphasise the importance of spending considerable time with a particular community before any new designs are considered or data collection is undertaken.

A practical note related to this is that participant recruitment for ADMI studies is a potentially complex and time intensive undertaking, due to the need to accommodate additional access needs while maintaining research institution's ethics standards. This was the biggest organisational challenge of this PhD and led to several dead-ends where research projects were discussed with disabled musicians but never came to fruition due to various difficulties - for example where travel to the university facilities would be difficult, but meeting the participants in their own homes would be considered inappropriate from a research ethics point of view. It wasn't until I became familiar with Heart n Soul and had developed mutual trust and enthusiasm for the research that I felt comfortable with setting up a dedicated data-gathering exercise - this was after a year of developing this relationship. I would advise future ADMI researchers not already affiliated with a community of disabled musicians, either through a community music organisation or otherwise, that the time and effort involved in developing these relationships should not be underestimated. Working with an organisation such as Heart n Soul was valuable on many levels. On a purely practical level, their existing organisational structure meant that safeguarding measures were in place from the very beginning, and the university research ethics council's concerns regarding working with 'vulnerable' groups were satisfied. More importantly, the kind of insights and knowledge I gained from working with professionals with many years experience in this field were invaluable, offering perspectives on music making that I would not have otherwise reached. It is important to recognise that this relationship should not be one-way, and I took care to ensure that any research activity would also align with the goals of Heart n Soul's everyday activities.

7.4 CONCLUDING REMARKS

This research began by working from the assumption that the challenges to be overcome in increasing disabled people's access to music-making were largely technical, and could be solved by innovative design solutions. As the work became more situated, and informed by the work of Disability Studies scholars and

disabled artists, it became increasingly clear that technological solutions are only one part of the wider fabric of disability, access and music. This does not diminish the more technologically-focused work done by others in the field of ADMI research and design, which has provided us with accounts of designs and technologies which suit a broad array of music making situations. However, what I have learned from working closely with a community music group in the later stages of this PhD research is that it is far more often the case that it is people (and people's attitudes) who are the agents of access to music, and not solely the technology they use. This is true of musical instruments in a wider context, not just disability - it is only when people begin to appropriate new technologies and mould them into new ways of listening and understanding music, that the technologies themselves become 'useful' - we cannot assume 'usefulness' without seeing the technology being used in context. I hope that by 'zooming out' from the world of academic research, and the results-oriented method of disseminating the outcomes, ADMI researchers can continue to discover innovative ways of enabling music making with technology, while first and foremost promoting the creative potential of disabled musicians. As a relatively young discipline, we are capable of adopting ways of researching and discussing our work from primarily disabled-led practices such as Disability Studies and Disability Arts, which offer us an invaluable counterpoint to the engineering and therapy-focused narratives that currently exist.

BIBLIOGRAPHY

ACE. What is the Creative Case for diversity? URL https://www.artscouncil.org.uk/diversity/creative-case-diversity.

Mark S. Ackerman. The Intellectual Challenge of CSCW: The Gap Between Social Requirements and Technical Feasibility. *Human–Computer Interaction*, 15(2-3): 179–203, September 2000.

Gustavo Armagno. The Role of HCI in the Construction of Disability. In *The 26th BCS Conference on Human Computer Interaction 26*, 2012.

Thomas Armstrong. *Neurodiversity: Discovering the Extraordinary Gifts of Autism, ADHD, Dyslexia, and Other Brain Differences*. ReadHowYouWant. com, 2010.

Amal Dar Aziz, Chris Warren, Hayden Bursk, and Sean Follmer. The flote: An instrument for people with limited mobility. *Proceedings of the 10th international ACM SIGACCESS conference on Computers and accessibility*, 2008.

Michael B. Bakan. View of Ethnomusicological Perspectives on Autism, Neurodiversity, and Music Therapy. *Voices: A World Forum for Music Therapy*, 14(3), 2014.

Michael B. Bakan. Toward an Ethnographic Model of Disability in the Ethnomusicology of Autism. In *The Oxford Handbook of Music and Disabilitiy Studies*. Oxford University Press New York, 2015.

BAMT. British Association for Music Therapy. URL //www.bamt.org/.

Colin Barnes and Geoff Mercer. Disability Culture: Assimilation or Inclusion? In *Handbook of Disability Studies*, pages 515–534. SAGE Publications, Inc., 2001.

Bates. The Social Life of Musical Instruments. *Ethnomusicology*, 56(3), 2012.

Adam Patrick Bell. Guitars have disabilities: Exploring guitar adaptations for an adolescent with Down syndrome. *British Journal of Music Education*, 31(3):343–357, 2014.

Steve Benford, Peter Tolmie, Ahmed Y Ahmed, Andy Crabtree, and Tom Rodden. Supporting Traditional Music-Making: Designing for Situated Discretion. *Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work*, 2012.

Laura Benton, Asimina Vasalou, Rilla Khaled, Hilary Johnson, and Daniel Gooch. Diversity for Design: A Framework for Involving Neurodiverse Children in the Technology Design Process. In *Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems - CHI '14*, 2014.

Edgar Berdahl and Julius O. Smith. A Tangible Virtual Vibrating String: A Physically Motivated Virtual Musical Instrument Interface. *Proceedings of the 2008 Conference on New Interfaces for Musical Expression (NIME08)*, 2008.

Soumitra Bhat. TouchTone: An Electronic Musical Instrument for Children with Hemiplegic Cerebral Palsy. In *Proceedings of the fourth international conference on Tangible, embedded, and embodied interaction*, 2010.

Karin Bijsterveld and Marten Schulp. Breaking into a World of Perfection: Innovation in Today's Classical Musical Instruments. *Social Studies of Science*, 34(5): 649–674, 2004.

S Astrid Bin. *The Show Must Go Wrong: Towards an Understanding of Audience Perception of Error in Digital Musical Instrument Performance*. PhD thesis, Queen Mary University of London, 2018.

Anna Bonnel, Laurent Mottron, Isabelle Peretz, Manon Trudel, Erick Gallun, and Anne-Marie Bonnel. Enhanced Pitch Sensitivity in Individuals with Autism: A Signal Detection Analysis. *Journal of Cognitive Neuroscience*, 15(2):226–235, February 2003.

Virginia Braun and Victoria Clarke. Using Thematic Analysis in Psychology. *Qualitative Research in Psychology*, 3(2):77–101, 2006.

Mason Bretan and Gil Weinberg. A Survey of Robotic Musicianship. *Communications of the ACM*, 2016.

Barry Brown, Stuart Reeves, and Scott Sherwood. Into the Wild: Challenges and Opportunities for Field Trial Methods. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, 2011.

Kenneth E. Bruscia. *Defining Music Therapy*. Barcelona Publishers, 2013.

Michael Burawoy. The Extended Case Method. *Sociological Theory*, March 1998.

K. Burland and W. Magee. Developing Identities Using Music Technology in Therapeutic Settings. *Psychology of Music*, 42(2):177–189, 2014.

Licia Carlson. Music, Intellectual Disability, and Human Flourishing. *The Oxford Handbook of Music and Disabilitiy Studies*, pages 37–53, 2015.

Delphine Chadefaux, Jean Loic Le Carrou, Marie Aude Vitrani, Sylvere Billout, and Laurent Quartier. Harp Plucking Robotic Finger. *IEEE International Conference on Intelligent Robots and Systems*, 2012.

Yee Chieh Chew and Eric Caspary. MusEEGk: A brain computer musical interface. *Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '11*, 2011.

A. Crabtree, A. Chamberlain, M. Davies, K. Glover, S. Reeves, T. Rodden, P. Tolmie, and Matt Jones. Doing Innovation in the Wild. In *Proceedings of the Biannual Conference of the Italian Chapter of SIGCHI on - CHItaly '13*, Trento, Italy, 2013.

Paul Dourish. Implications for Design. *Proceedings of the SIGCHI conference on Human Factors in computing systems*, 2006.

Paul Dourish. Responsibilities and Implications: Further Thoughts on Ethnography and Design. *Proceedings of the 2007 conference on Designing for User eXperiences*, 2007.

Dana S. Dunn and Erin E. Andrews. Person-first and identity-first language: Developing psychologists' cultural competence using disability language. *American Psychologist*, 70(3):255–264, April 2015.

Joel Eaton and Eduardo R Miranda. The hybrid brain computer music interface-integrating brainwave detection methods for extended control in musical performance systems. In *International Symposium on Computer Music Multidisciplinary Research*, pages 132–145. Springer, 2015.

Rebecca Fiebrink and Perry R Cook. The Wekinator: A System for Real-time , Interactive Machine Learning in Music. *Proceedings of The Eleventh International Society for Music Information Retrieval Conference (ISMIR 2010)*, 2010.

Kerry Firth and David Cane. Access all Arias: An exploration of the challenges of inclusive practice within the operatic music performance industry. In *Cripping the Muse*, Leeds, 2018.

Christopher Frauenberger. Critical Realist HCI. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '16*, Santa Clara, California, USA, 2016.

Emma Frid. Accessible Digital Musical Instruments—A Review of Musical Interfaces in Inclusive Music Practice. *Multimodal Technologies and Interaction*, 3(3):57, July 2019.

Bill Gaver. Technology affordances. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems Reaching through Technology - CHI '91*, pages 79–84, New Orleans, Louisiana, United States, 1991.

Bill Gaver, Tony Dunne, and Elena Pacenti. Design: Cultural Probes. *Interactions*, 6(1):21–29, January 1999.

Morton Ann Gernsbacher. Editorial Perspective: The use of person-first language in scholarly writing may accentuate stigma. *Journal of Child Psychology and Psychiatry*, 58(7):859–861, 2017.

Faye Ginsburg and Rayna Rapp. Entangled ethnography: Imagining a future for young adults with learning disabilities. *Social Science and Medicine*, 99:187–193, 2013.

Rolf Inge Godøy, Egil Haga, and Alexander Refsum Jensenius. Playing "Air Instruments": Mimicry of Sound-Producing Gestures by Novices and Experts. In *Gesture in Human-Computer Interaction and Simulation*, volume 3881, pages 256–267. Springer, 2006.

Dan Goodley. *Disability Studies, An Interdisciplinary Introduction*. Sage Publications, 2016.

Kimberlee Graham-Knight and George Tzanetakis. Adaptive Music Technology - History and Future Perspectives. *International Computer Music Conference Proceedings*, pages 416–419, 2015.

Mick Grierson and Chris Kiefer. NoiseBear: A wireless malleable multiparametric controller for use in assistive technology contexts. *CHI '13 Extended Abstracts on Human Factors in Computing Systems*, 2013.

Michael Gurevich and Jeffrey Treviño. Expression and its discontents: Toward an ecology of musical creation. In *Proceedings of the 7th International Conference on New Interfaces for Musical Expression*, 2007.

Michael Gurevich, Paul Stapleton, and Adnan Marquez-borbon. Style and Constraint in Electronic Musical Instruments. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2010.

Reinhard Hainisch and Michael Platz. Phonetic control: A new approach for continuous, non-invasive device control using the vocal tract. *2007 IEEE 10th International Conference on Rehabilitation Robotics, ICORR'07*, 00:688–692, 2007.

Jill Halstead and Randi Rolvsjord. The gendering of musical instruments: What is it? Why does it matter to music therapy? *Nordic Journal of Music Therapy*, 26(1): 3–24, January 2017.

Jacob Harrison and Andrew P. McPherson. Adapting the Bass Guitar for One-Handed Playing. *Journal of New Music Research*, 2017.

Jacob Harrison, Robert H. Jack, Fabio Morreale, and Andrew P. McPherson. When is a Guitar not a Guitar? Cultural Form, Input Modality and Expertise. In *New Interfaces for Musical Expression*, 2018.

Jacob Harrison, Alan Chamberlain, and Andrew P. McPherson. Accessible Instruments in the Wild: Engaging with a Community of Learning-Disabled Musicians. In *CHI '19 Extended Abstracts on Human Factors in Computing Systems*, Glasgow, UK, 2019.

Lee Higgins. *Community Music: In Theory and In Practice*. Oxford University Press, June 2012.

Michael S. Horn. The role of cultural forms in tangible interaction design. In *Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction*, 2013.

Anthony J Hornof and Linda Sato. EyeMusic: Making Music with the Eyes. *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2004.

M. J. Hove, C. Marie, I. C. Bruce, and L. J. Trainor. Superior time perception for lower musical pitch explains why bass-ranged instruments lay down musical rhythms. *Proceedings of the National Academy of Sciences*, 111(28), 2014.

Blake Howe. Disabling music performance. In *The Oxford Handbook of Music and Disability Studies*, page 191. Oxford University Press, 2015.

Blake Howe, Stephanie Jensen-Moulton, Neil William Lerner, and Joseph Nathan Straus. *The Oxford Handbook of Music and Disability Studies*. Oxford University Press, 2016.

Andy Hunt, Marcelo Wanderley, and Matthew Paradis. The Importance of Parameter Mapping in Electronic Instrument Design. *Proceedings of the 2002 Conference on New Interfaces for Musical Expression*, 32(4), 2002.

Hilary Hutchinson, Wendy Mackay, Bosse Westerlund, Benjamin B Bederson, Allison Druin, Catherine Plaisant, Michel Beaudouin-Lafon, Stéphane Conversy, Helen Evans, Heiko Hansen, Nicolas Roussel, Björn Eiderbäck, Sinna Lindquist, and Yngve Sundblad. Technology Probes: Inspiring Design for and with Families. *Proceedings of the SIGCHI conference on Human factors in computing systems*, (5), 2003.

Disabled Peoples International. Disabled peoples international: Proceedings of the first world congress. DPI Singapore, 1982.

Robert H. Jack. *Tangibility and Richness in Digital Musical Instrument Design*. Thesis, April 2019.

Robert H. Jack, Tony Stockman, and Andrew P. McPherson. Effect of latency on performer interaction and subjective quality assessment of a digital musical instrument. In *Audio Mostly*, 2016.

Robert H. Jack, Tony Stockman, and Andrew P. McPherson. Rich gesture, reduced control: The influence of constrained mappings on performance technique (unpublished). In *Proceedings of the International Conference on Movement and Computing*, 2017.

Robert H. Jack, Jacob Harrison, Fabio Morreale, and Andrew P. McPherson. Democratising DMIs: The relationship of expertise and control intimacy. In *New Interfaces for Musical Expression*, Virginia, US, 2018.

Robert H. Jack, Jacob Harrison, and Andrew P. McPherson. Digital Musical Instruments as Research Products. In *New Interfaces for Musical Expression*, 2020.

David A. Jaffe and Julius O. Smith. Extensions of the Karplus-Strong Plucked-String Algorithm. *Computer Music Journal*, 7(2):56–69, 1983.

Arvid Jense and Hans Leeuw. WamBam : A case study in design for an electronic musical instrument for severely intellectually disabled users. *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2015.

Sergi Jordà. Instruments and players: Some thoughts on digital lutherie. *Journal of New Music Research*, 33(3):321–341, 2004.

Sergi Jordà. Afasia: The Ultimate Homeric One-man-multimedia-band. *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2002.

Ajay Kapur. A history of robotic musical instruments. *Proceedings of the International Computer Music Conference*, 2005.

Kevin Karplus and Alex Strong. Digital Synthesis of Plucked String and Drum Timbres. *Computer Music Journal*, 7(2), 1983.

Simon Katan, Mick Grierson, and Rebecca Fiebrink. Using Interactive Machine Learning to Support Interface Development Through Workshops with Disabled People. *Proceedings of the SIGCHI conference on Human factors in computing systems*, 2015.

John Kelly and Charles Michael Matthews. The Kellycaster: Examining collaboration and equality in instrument development (Video Poster), August 2018. URL https://crippingthemuse.com/presentation-recordings/.

Pedro Kirk, Mick Grierson, Rebeka Bodak, Nick Ward, Fran Brander, Kate Kelly, Nicholas Newman, and Lauren Stewart. Motivating Stroke Rehabilitation Through Music : A Feasibility Study Using Digital Musical Instruments In The Home. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 2016.

Jesper Kjeldskov and Mikael B. Skov. Was it worth the hassle?: Ten years of mobile HCI research discussions on lab and field evaluations. In *Proceedings of the 16th International Conference on Human-Computer Interaction with Mobile Devices & Services - MobileHCI '14*, pages 43–52, Toronto, ON, Canada, 2014.

Jeppe Veirum Larsen, Dan Overholt, and Thomas B Moeslund. The actuated guitar: A platform enabling alternative interaction methods. In *SMC Proceedings of the Sound and Music Computing Conference*, pages 235–238, 2013.

Jeppe Veirum Larsen, Dan Overholt, and Thomas B Moeslund. The actuated guitar: Implementation and user test on children with hemiplegia. In *NIME '14 Proceedings of the 2014 Conference on New Interfaces for Musical Expression*, 2014.

Jeppe Veirum Larsen, Dan Overholt, and Thomas B Moeslund. The Prospects of Musical Instruments For People with Physical Disabilities. *NIME '16 Proceedings of the 2016 Conference on New Interfaces for Musical Expression*, 2016.

Amanda Lazar, Caroline Edasis, and Anne Marie Piper. A Critical Lens on Dementia and Design in HCI. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*, Denver, Colorado, USA, 2017.

Roger Linn. LinnStrument and other new expressive musical controllers. *The Journal of the Acoustical Society of America*, 134(5), November 2013.

William Longden. *Inclusive Participatory Design of Bespoke Music Instruments and Auxiliary Access Equipment, as Emancipatory Arts Interventions Advocating for Equality and Wellbeing*. PhD thesis, London Metropolitan University, 2019.

Alex Lubet. *Music, Disability, and Society*. Temple University Press, 2011.

Wendy Magee. Disability and Identity in Music Therapy. In *Musical Identities*, pages 179–198. Oxford University Press, 2002.

Thor Magnusson. Musical Organics: A Heterarchical Approach to Digital Organology. *Journal of New Music Research*, 46(3):286–303, 2017.

Päivi Majaranta. *Gaze Interaction and Applications of Eye Tracking: Advances in Assistive Technologies*. IGI Global, 2011.

Charles P. Martin and Henry Gardner. Free-Improvised Rehearsal-as-Research for Musical HCI. In *New Directions in Music and Human-Computer Interaction*, pages 269–284. Springer International Publishing, 2019.

Vahakn Matossian and Rolf Gehlhaar. Human Instruments: Accessible Musical Instruments for People with Varied Physical Ability. *Studies in health technology and informatics*, 219:202–207, 2015.

Brendan McCloskey. *inGrid: A New Tactile, Tangible and Accessible Digital Musical Instrument for Enhanced Creative Independence amongst Musicians with Quadriplegic Cerebral Palsy*. PhD thesis, Ulster University, 2014.

George McKay. Punk rock and disability: Cripping subculture. In *Oxford Handbook of Music and Disability Studies*. Oxford University Press, 2015.

Andrew P. McPherson. Bela: An embedded platform for low-latency feedback control of sound. *The Journal of the Acoustical Society of America*, 141(5), May 2017.

Andrew P. McPherson and Victor Zappi. An environment for submillisecond-latency audio and sensor processing on BeagleBone Black. In *Audio Engineering Society Convention 138*. Audio Engineering Society, 2015.

Andrew P. McPherson, Robert H. Jack, and Giulio Moro. Action-Sound Latency: Are Our Tools Fast Enough? *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2016.

James McVay, Dale Carnegie, and Jim Murphy. An overview of mechbass: a four string robotic bass guitar. *2015 6th International Conference on Automation, Robotics and Applications (ICARA)*, pages 179–184, 2015.

David Meckin and Nick Bryan-Kinns. moosikMasheens: music, motion and narrative with young people who have complex needs. pages 66–73, 2013.

Romain Michon and Julius O. Smith. A Hybrid Guitar Physical Model Controller : The BladeAxe. *ICMC: International Computer Music Conference*, 2014.

Fabio Morreale, SM Astrid Bin, Andrew P. McPherson, Paul Stapleton, and Marcelo M. Wanderley. A nime of the times: Developing an outward-looking political agenda for this community. *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2020.

Daniel Müllensiefen, Bruno Gingras, Jason Musil, and Lauren Stewart. The musicality of non-musicians: an index for assessing musical sophistication in the general population. *PloS one*, 9(2):e89642, 2014.

Tim Murray-Browne. *Interactive music: Balancing creative freedom with musical development.* PhD thesis, Queen Mary University of London, 2012.

Daniel Müllensiefen, Bruno Gingras, Jason Musil, and Lauren Stewart. The Musicality of Non-Musicians: An Index for Assessing Musical Sophistication in the General Population. *PLOS ONE*, 9(2), February 2014.

Hye Yeon Nam and Carl F DiSalvo. Tongue music: The sound of a kiss. *CHI Extended Abstracts*, 2010.

Donald Norman. *Design of Everyday Things*. 1990.

William Odom, Ron Wakkary, Youn-kyung Lim, Audrey Desjardins, Bart Hengeveld, and Richard Banks. From Research Prototype to Research Product. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, Santa Clara, California, USA, 2016.

Michael Oliver. *Social Work with Disabled People*. Macmillan International Higher Education, 1983.

S. O'Modhrain. A framework for the evaluation of digital musical instruments. *Computer Music Journal*, 35:28–42, 2011.

Laurel S. Pardue. *Violin Augmentation Techniques for Learning Assistance*. Thesis, Queen Mary University of London, June 2017.

Samuel Parke-Wolfe, Hugo Scurto, and Rebecca Fiebrink. Sound Control: Supporting Custom Musical Interface Design for Children with Disabilities. In *New Interfaces for Musical Expression*, 2019.

Jennifer A. Rode. Reflexivity in Digital Anthropology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, New York, NY, USA, 2011.

Yvonne Rogers. Interaction design gone wild: Striving for wild theory. *interactions*, 18(4), July 2011.

Randi Rolvsjord. Therapy as Empowerment: Clinical and Political Implications of Empowerment Philosophy in Mental Health Practises of Music Therapy. *Nordic Journal of Music Therapy*, 13, July 2004.

Daniel Schlessinger and Julius O. Smith. The kalichord: A physically modeled Electro-Acoustic plucked string instrument. *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2009.

S. Schneider, P. W. Schönle, E. Altenmüller, and T. F. Münte. Using musical instruments to improve motor skill recovery following a stroke. *Journal of Neurology*, 254, 2007.

Koji Shibuya, Hironori Ideguchi, and Katsunari Ikushima. Volume control by adjusting wrist moment of violin-playing robot. *International Journal of Synthetic Emotions*, 3(2):31–47, July 2012.

Amble Skuse and Shelly Knotts. Creating an online ensemble for home based disabled musicians: why disabled people must be at the heart of developing technology. *Proceedings of the 2020 Conference on New Interfaces for Musical Expression*, 2020.

Christopher Small. *Musicking: The Meanings of Performing and Listening*. Wesleyan University Press, March 2011.

James P. Snedeker. Adaptive engineering for musical instruments. *Medical Problems of Performing Artists*, 20, June 2005.

Bob Sturm, Joao Felipe Santos, and Iryna Korshunova. Folk music style modelling by recurrent neural networks with long short term memory units. In *16th International Society for Music Information Retrieval Conference*, 2015.

Allan Sutherland. Disability arts, disability politics. *Framed: Interrogating disability in the media*, 1989.

John Swain and Sally French. Towards an Affirmation Model of Disability. *Disability & Society*, 15, June 2000.

Tim Swingler. The invisible keyboard in the air : An overview of the educational , therapeutic and creative applications of the EMS Soundbeam ™. *2nd Euro. Conf. Disability, Virtual Reality & Assoc. Tech*, 1998.

Hossein Taheri, Justin B. Rowe, David Gardner, Vicky Chan, David J. Reinkensmeyer, and Eric T. Wolbrecht. Robot-assisted Guitar Hero for finger rehabilitation after stroke. *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, 2012.

Atau Tanaka. Musical Performance Practice on Sensor-based Instruments. *Trends in Gestural Control of Music*, 13, 2000.

Michael H Thaut and Gerald C McIntosh. Neurologic Music Therapy in stroke rehabilitation. *Current Physical Medicine and Rehabilitation Reports*, 2(2):106–113, 2014.

Giorgos Tsiris. Voices from the 'ghetto': Music therapy perspectives on disability and music (A response to Joseph Straus's book Extraordinary Measures: Disability in Music). *International Journal of Community Music*, 6, December 2013.

Zacharias Vamvakousis. *Digital Musical Instruments for People with Physical Disabilities*. PhD thesis, 2016.

Zacharias Vamvakousis and Rafael Ramirez. The eyeharp: An eye-tracking-based musical instrument. *8th Sound and Music Computing Conference*, 2011.

Zacharias Vamvakousis and Rafael Ramirez. P300 harmonies: A Brain-Computer Musical Interface. *Proceedings - 40th International Computer Music Conference, ICMC 2014 and 11th Sound and Music Computing Conference, SMC 2014 - Music Technology Meets Philosophy: From Digital Echos to Virtual Ethos*, 2014.

John Van Maanen. *Tales of the field: On writing ethnography*. University of Chicago Press, 2011.

Richard Vindriis, Ajay Kapur, and Dale Carnegie. A Comparison of Pick-Based Strategies for Robotic Bass Playing. In *Proceedings of the 2011 Electronics New Zealand Conference*, 2011.

Steve Waksman. *Instruments of Desire: The Electric Guitar and the Shaping of Musical Experience*. Harvard University Press, 2001.

Asha Ward, Luke Woodbury, and Tom Davis. Design Considerations for Instruments for Users with Complex Needs in SEN Settings. In *NIME '17*, 2017.

Nicholas Watson and Tom Shakespeare. The social model of disability: An outdated ideology? In *Exploring Theories and Expanding Methodologies: Where We Are and Where We Need to Go*, volume 2 of *Research in Social Science and Disability*, pages 9–28. Emerald Group Publishing Limited, January 2001.

David Wessel and Matthew Wright. Problems and Prospects for Intimate Musical Control of Computers. *Computer Music journal*, 26:11–14, 2002.

Heidi Westerlund. Garage rock bands: A future model for developing musical expertise? *International Journal of Music Education*, 24, 2006.

Peter Wittenburg, Hennie Brugman, Albert Russel, Alex Klassmann, and Han Sloetjes. Elan: a professional framework for multimodality research. In *5th International Conference on Language Resources and Evaluation (LREC 2006)*, 2006.

Victor Zappi and Andrew P Mcpherson. Dimensionality and Appropriation in Digital Musical Instrument Design. *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2014.

APPENDIX

A

APPENDIX: STRUMMI SESSION FEEDBACK TRANSCRIPTS

Pop culture / rock band references

References to existing pop culture figures, likening the experience of the Strummi sessions to playing in a band, plans for forming a band out of the Strummi sessions, desire to record and perform music:

Imogen: There should be a studio session so we can lay down our ideas and get them edited, we can do a film of it in the studio, like a lot of the bands do - A backstage video, a backstage audio!
Abraham: So think about the name of the band yeah?
Vanessa: That's the bit we've got to get together and try and think of a nice name what we would call it.
Jacob: Is there anything that comes to mind?
Imogen: 'The Expansives'
Abraham: Any idea?
Ismail: It depends, I don't know to be honest I hadn't really thought, I didn't realise we were going to try and think of band names in the first session!
Ismail: Maybe if we do more sessions like this, further down the line
Ismail: If you write the first song you could get a band name out of that
Imogen: Sounds like a band that could play at New Cross, or Canterbury University
Imogen: The expansives! Please welcome on stage... and they have a laser thing with the name on it and it all disappears.
Vanessa: [Jared] what do you think of the name for the band, if you had a dream what would you call it?
Jared: I would call it 'The Super Stars'

Jacob: [discussing what to do during the next session] So there might be a bit of free [improvisation], like it was today. But if you have any suggestions for things you'd like to, like we could maybe write a song
Vanessa: Yes please
Jacob: Or we could play some kind of musical games, so like...

Imogen: Mmmm no, lay down the songs, we're a band!

Oscar: Those songs that were recently made, they really deserve a CD release. All the Heart n Soul songs they really need to be put on CD for people to listen to. That's something that should be looked into in the future.

Abraham: Well you already worked out the name of the band didn't you
Imogen: yes, The Expansives
Abraham: She was going round the Albany with the full logo
Jacob: You made the logo? That's so good! ...
Abraham: It was nice to feel the excitement from you guys
Vanessa: It would be nice to show other people, they haven't seen ...
Imogen: We should do a showcase of it, like they did for Heart n Soul, promotion at Battersea Arts Centre.
Vanessa: You can't just rush it!

Reactions and feedback relating to the Strummi instruments

Usability feedback, preference for one version over the other, ideas for improvements to future versions:

Ismail: I found the shorter one was easier to play than the longer one because you've got the buttons at the top of the neck on the longer one, if they were where the strings normally stretch across, if they were there it would be a lot easier. But I do like the shorter one because you can get your fingers onto the buttons easier than you can with the longer one

Edwin: The Strummi systems worked well with the percussive systems. Not just the tuning. And yeah and people really got into really getting comfortable with playing their own instrument, I've not seen people kind of get comfortable with the Strummis [before], so it felt it was an instrument it wasn't something else...

Ismail: it's a kind of, I don't know, it's hard to tell what it's made for
Ismail: what category, I don't know.
Jacob: why do you think that is?

Ismail: because you've got certain instruments for certain categories.
Jacob: so what's an example of another instrument
Ismail: you've got the bass guitar that goes with like a rock band and then you've got the other guitars that kind of for country and western kind of.
Imogen: you might have high pitched guitars for metal and hard rock
Abraham: So you think you can play more style of music with the Strummi or is it?
Ismail: I think it's kind of, slow, stuff
Imogen: Ballads, Jazz
Ismail: Kind of like the ones that you use fo kind of tea dances and stuff
Imogen: A waltz or a fox trot
Ismail: Like for slow dancing and stuff like that.
Jacob: Slow, kind of
Imogen: Perhaps some ballet and Russian music
Abraham: What about you?
Imogen: It's gonna be like synth rock
Abraham: Can it fit with the synth?
Imogen: Like Level 42 and Mark King, they had a load of synthesisers and different guitars.
Abraham: So you think the Strummi would be funky?
Ismail: It would be nice if you could, cos it's kind of classical at the moment, but if you could make them into kind of rock ones as well?
Vanessa: I find it was brilliant to play. Just need to make some more music

Jacob: How about [Jared], what kind of music do you think the Strummi's are made for?
Jared: Rock, and pop.
Imogen: Oh yes, pop is the one

Jared: I liked playing the guitar.
Jacob: This one? The guitar shaped Strummi [S3]
Jared: Yes.
Jacob: What did you like about it?
Jared: How it worked.

Jacob: If everyone could say which instrument was their favourite to play today?
Ismail: the small one [S2]

Abraham: I like the small one very much as well [S2]
Imogen: definitely synthesisers cos my dad was a computer engineer . . .
Jared: That one [S3]
Vanessa: I played all three so (laughs).
Jacob: did you try all three?
Imogen: Yeah
Ismail: Spent more time on it than anybody else.

Giacomo: What do you think is the main difference between the guitar and the Strummi?
Vanessa: Well the Strummi is very small and compacted. More than the guitar. The guitar you have to hold all the time.
Abraham: Its long neck as well

Oscar: My favourite bit was playing the instrument [S2].

Jacob: I have a question for [Oscar] and [Liam] - if you had to describe the Strummi to someone that's never seen it before or heard of it, how would you describe it?
Oscar: I would describe it as a type of instrument that you play, and it would also be good to have a tutorial video that people can watch to see how you play it and they can get inspired and they can soon somehow take an interest.
Jacob: Was there anything that worked about the Strummi?
Oscar: I think it worked very well with pressing the right buttons and the sound coming out. Because it really worked very well and it really stood out.
Liam: The Strummi is a special guitar, you press these buttons to play and if you can't play the strings like that, you press these buttons and you play the guitar to make chords
Jacob: Was there anything that you liked or disliked about playing it?
Liam: The thing I liked playing it was when I'm playing guitar and stuff, it plays like a guitar and I press the chords and then I start playing, you know, if it's a certain note and stuff like that. But the stickers fell off which is what I disliked about it.
Imogen: Trying to see which notes are and the stickers fell off.

Abraham: I liked the new Strummis. They're really cool cos you can pick them up you can play them like that they're not just having only this way of playing them and I thought . . . I liked the versatility of the three different Strummis all of them have different techniques of different ways you can play them which was really exciting.

Experiences with other instruments

Preferences for other instruments in the room, reasons for preference, how they were used, references to different instruments and ways of playing:

Jacob: What were your thoughts about todays music making session?
Imogen: Yes it was great to be able to use synths, and a good German one that can do most things … the cables didn't work … possibly use something more advanced it's not supposed to go through the speakers once you plug the amp cable in. Supposed to be direct drive like my high definition cassette machine goes straight to the JVC amp …
Jacob: So the synth wasn't really up to scratch today then
Imogen: it needs to be the full size one. Korg is the best brand for what we do here. Yamaha won't cut it.

Jacob: I think some of you have played the normal guitar, the electric guitar. Can you explain the difference between the electric guitar and the Strummi?
Vanessa: Well the electric one, the thing kept coming out, and it's specially for people who are left handed, it's a bit, I remember used to, I know that bit. You put the guitar on there and you do like, you have it on your chest, and you use the stick
Edwin: Oh a cello, like a big violin
Vanessa: We can try that one day maybe?
Jacob: Try a cello?
Edwin: Oh with a bow?
Jacob: we can play [the strummi] with a bow, that would be fun
Vanessa: Yeah, see what the difference is

Liam: My best bit was playing the drums it was really good and I also liked playing the Strummi as well

Jacob: [Jared], what did you enjoy today? Jared: The drumkit

Imogen: Yeah I had a go at the sort of 50s rock guitar over there [S3]. Not really me, I'm more keyboards and mixing. And maybe a bit of drums, but mainly keyboards. And [Vanessa] was getting funky with the keyboards!

Reflections on Performance

Techniques used, ways of communicating and shaping performance during jams, reflections on how well the jams/performances went

Abraham: Yes it was quite fun, free flow, I thought it was nice that everyone tried a bit of all the instruments before settling on the one that they liked which you could see that everyone kind of liked a certain kind of ... and yeah, a really good time, it was nice to see you guys just going for it ... I didn't want to spoil it with my guitar playing. It wasn't necessary you guys did brilliantly.

Giacomo: And I really liked that the last half an hour of what we did and I guess we got more into a kind of almost structured thing where each of us was getting a role
Abraham: People were listening a bit more to each other.

Edwin: People have a go of like a harp or something, they kind of tentatively do something on it, they don't try and sit with it to play it. So everybody was kind of sitting with the instruments which I thought was nice. And as an extension of that were the drums: pull the kit apart and then instantly people felt to be able to ...

Abraham: [to Vanessa] The way you were playing it was like a tiger! I liked that you actually gave the right attitude

Jacob: What was the difference for you between playing the Strummi and the keyboard?
Vanessa: Well I'm just doing the bass on the keyboard, but Strummi's different kettle of fish.
Jacob: Because you're strumming the strings with the hand that you would use to play bass?
Vanessa: Yeah

Ricky: [comparing session 2 to session 1] I thought it could be a bit more messy but as [Oscar] said people were listening to each other after trying out little things here and there. The songs if you like that came out were really nice and yeah, seemed like people were finding their part and fitting in and you know what's going on. And yeah it was nice to, to have time to explore a little bit more the jam side of it, and today there was a bit more focus. And more people get something done with it than just carry on jamming with it, which was maybe more the first bit and then the second was really interesting to see everybody in

the room with a different idea. [Liam], your song was really nice, [Vanessa] with the lyrics I really enjoyed that, and the fact that you sang was really nice. It was interesting. I won't say very different session, but definitely different. Not in the outcome but the process, in how people, last time there was more of a kind of an unknown and today people really jumped on it with a different confidence. From especially the people that were there before.

Vanessa: Well I noticed he was singing
Jacob: Who was singing? Jared?
Vanessa: yeah. Well I kept to his beat as well.
Vanessa: And he was singing too. And working the beat as well just taking a bit of time. Different people singing different songs.

Edwin: Yeah it was quite different from the last session. What I really liked was just seeing how it's gone from exploring all the instruments including all the Strummis and this time round, you know, three tunes that came out of just today that sounded like tunes you could sit and listen to. It's nice to see, there was more interest for the [S3]. And there was a real kind of central point, with vocalists.
Jacob: That was really nice to see. I think [Liam] and [Jared] both doing the frontman thing
Edwin: Yeah that's it. But as well, to see the other Strummis being used ...

Edwin: It just brought out different singers, cos I haven't really heard much Jared. It was good you were taking your time.
Abraham: We've heard you rapping but never singing.
Edwin: You were singing you had a chorus that was developed there. And it felt great. And so did you [Liam], I've never heard you be that relaxed and think about what you were singing. I think in short it's nice to see it, it's a new instrument that allows you to do things in different way

General feedback on the session

Feedback relating to enjoyment of the session itself:

Jacob: Anything else?
Jared: I enjoyed the music.

Jacob: Are you coming back on Friday?

Vanessa: Yeah.
Jacob: Brilliant. We can do the tiger song
Imogen: For all we have to work on it's not long enough.
Jacob: Yeah that's true.

Vanessa: It was a brilliant day.
Ricky: It was nice just to have time just to dedicate

Vanessa: It was brilliant, I tried to make some songs, really need to make some words, write down some words what we know and some of them we don't know.

Vanessa: Yeah. So it was a good day, it's not a bad day I really enjoyed it. Need a bit more sessions, extra sessions.

Oscar: I think it was really good it was really enjoyable, really amazing
Jacob: Was there anything that worked well in the way that everyone was working together?
Oscar: I think it really worked well we all worked as a team
Imogen: It all sounded like we were listening to each other.
Jacob: Was there anything that didn't work so well?
Oscar: Nothing
Liam: All positive reviews

Jacob: Cool. Everyone that was here on Tuesday as well. What worked well today and what didn't in the way that everyone was playing together?
Liam: Well they started playing -
Imogen: Vanessa was getting funky with the keyboard

Ismail: I think it was trying to get everybody to play to the beat ... listen to the drums and trying to get people ... at certain time

Jacob: And how about you Vanessa, did you enjoy playing different instruments today, singing and playing the keyboard?
Vanessa: Ummm, yeah. Another thing, that could be my other baby. Jacob: Yeah that was really nice to see. Ricky what were your thoughts about today, versus Tuesday? Anything that worked better or worse?

Ricky: It was nice to have more people in the room, I thought it could be a bit more messy but as Oscar said people were listening to each other after trying out little things here and there. The songs if you like that came out were really nice and yeah, seemed like people were finding their part and fitting in and you know what's going on. And yeah it was nice to, to have time to explore a little bit more the jam side of it, and today there was a bit more focus. And more people get something done with it than just carry on jamming with it, which was maybe more the first bit and then the second was really interesting to see everybody in the room with a different idea. Liam, your song was really nice, Vanessa with the lyrics I really enjoyed that, and the fact that you sang was rally nice. It was interesting. I won't say very different session, but definitely different. Not in the outcome but the process, in how people, last time there was more of a kind of an unknown and today people really jumped on it with a different confidence. From especially the people that were there before.

Vanessa: I asked Felix has he made any friends and he said no, and I said it'll come in time. And I said to him today, you need to be extended extra class for people who really enjoyed it.
Jacob: It would be nice to do some more of these sessions, I think Felix said that he'd like to do the same as well. Well we can do some extended classes.

Jacob: Is there anything else you'd like to say about today?
Vanessa: It was good, I'd like to do a bit more
Liam: A bit more actually
Vanessa: What do you think Jared, would you like to do a bit more? What's the best bit about it?
Jared: Music.
Imogen: I think we should meet regularly every month if you can do that Jacob

Instrument de-construction / co-operation

Thoughts on alternative ways of playing the instruments in the jam session, and co-operating with others using the instruments:

Ned: People have a go of like a harp or something, they kind of tentatively do something on it, they don't try and sit with it to play it. So everybody was kind of sitting with the instruments which I thought was nice. And as an extension of that were the drums: pull the kit apart and then instantly people felt to be able to ...

Jacob: That was great seeing you and Raphael either side
Imogen: Opening out the instrument has opened our minds out as well
Ned: Well yes, I agree with that the whole session felt like that kind of exploring.
Vanessa: We can try that one day maybe?
Jacob: Try a cello?
Ned: Oh with a bow?
Jacob: we can play it with a bow, that would be fun
Vanessa: Yeah, see what the difference is
Jacob: Yeah that's a really cool idea!
Ismail: I think the one with the long neck (S3) would actually lend itself to that

Vanessa: Well I can, since I'm so clever with my baby, I have to teach them to play it
Jacob: I would really like that, if you could, 'cause this time I showed everybody but I think if next time you can show everyone how to play it and explain to everyone that would be really ...
Vanessa: I did it in the last session, remember when we were at Euston I was ...
Jacob: You were teaching everyone yeah, so that would be really good

Values and personal goals

Relating the session activities to personal values and beliefs, or to goals in personal life (e.g. health and wellbeing goals)

Vanessa: (thumbs up) bit more
Jacob: do you want to play a bit more or?
Vanessa: yeah cos it helped my hand.
Jacob: how did it help your hand?
Vanessa: it's made this one much ... this one is a bit weak. It helps my hand to open a bit more, never used to use this hand much. This hand is a bit lazy. So I tried to use this one more. Make it stronger. Like to do a bit more. Like I just asked them it would be nice to have other people come out their house to come to the house and see other people ... there's people indoors in the house just day in they don't do things and I keep calling them to come downstairs. It would be nice for other residents to have a go
Jacob: to have a go with the Strummi?
Vanessa: Yeah. Well I'm going to ask Susan to see what she says. All they do is sit there eating and playing dominoes.

Imogen: all the family games ...
Vanessa: It'd be good for other people to see it and things. But we do do that at the other club.
Imogen: MIDI music?
Vanessa: No it's for people with disability that go on Monday that does the same thing drumming comes and plays drumming as well.
Jacob: Is that with Heart n Soul or is that a different?
Vanessa: It's a different club. For different people with different needs.
Vanessa: It would be nice for other members to do stuff.

Vanessa: Plus get other people to use things. They're just sitting all I'm doing is watching telly
Imogen: Better than being excluded or at home doing nothing.
Vanessa: Some people just sit in the house and all they do is ah I'm bored. Come downstairs, nonono. I got 'jakey jakey', I got Jacob I don't need you leave me alone!
Vanessa: I got my tutor leave me alone I got my tutor.

Vanessa: Cos we've both got the same dilemma. Cos both of us have got paralysed one side from childhood and I said don't worry cos I've been there, done that, thought I'd never, my mum said my hand might never work again. Get stronger, take time, get patient for yourself and use your hand more. I noticed I been more using my hand more at the Albany, but at the other place no. Before I moved there, I got another resident who's got the same problem, so he's not on his own
Jacob: I think he was quite shy about his hand because he kept it under a blanket
Imogen: Yeah and music definitely helps with shyness. Cos we're expressing ourselves

Vanessa: I found it was useful to teach somebody else who's got the same needs as me. Nobody else has got the same needs as what I've got

Oscar: I think usually if they have new ideas they can do that. They can explain their ideas and take them and the group can pursue the ideals and they can make original songs
Jacob: Is that something that you want to do? Do you want to write your own songs and bring them to the group?
Oscar: Well that's not what I had in mind, what I was saying was that people can write new song ideas and show it to others so that you can take an interest. That's lovely as time goes by new songs are being written and performed. I think the songs really. Those songs

that were recently made, they really deserve a CD release. All the Heart n Soul songs they really need to be put on CD for people to listen to. That's something that should be looked into in the future.
Jacob: The songs from today?
Oscar: Oh just from over the years and from today, so they can have a CD release with a lyrics booklet for people that don't understand the words. CD releases and lyric booklets, they should be looked into.
Oscar: Yes because I think lyric booklets that's something that really has to be looked into. Because there are people in this world who are hard of hearing or English is not their first language. So if they want to listen they need to understand the words. That is something that really should work for new songs past and present.

Jacob: Liam can I ask why you come to the music making session at Heart n Soul?
Liam: Because I wanted to try out playing some Strummis and the guitar and I like playing the drums. I was playing some hip hop style music.
Jacob: And Jared?
Jared: I like coming to the music class to do music and sometimes record in the studio.
Jacob: Was there anything from today that you want to record?
Jared: I wanted to record that song that I was singing.

Imogen: We never have the opportunity to get together and be as a band.

Lyrical ideas and values

Ideas and values that came up in people's lyrics:

Vanessa: Well I was making my own song. Cos I'm a tiger. I was being a really horrible tiger.
Jacob: So was it a song about being a tiger?
Vanessa: Yeah. It was about tigers we are vicious and they are taurus. They're bad tempered.
Ricky: Talking about me? I'm a taurus
Vanessa: laughs. Taurus are bad tempered. And angry tempered. Well it'll be my birthday next month.
Jacob: Are you a taurus as well?
Vanessa: Yeah

Ricky: Welcome to the family.
Imogen: the lyrics in the song I was coming up with sounded rather rock protest didn't they.

Liam: It was really good and I loved the instruments and I've been singing a bit of comic rap. All about Kendall Jenner, Theresa May and all the ... it's not my style
Imogen: Those naughty naughty politicians who need to be taught a lesson
Ricky: Socially and politically aware well done
Liam: Those naughty politicians need to be learned a lesson.
Jacob: And they're not your style, is that what the song was about?
Liam: It's not my style, yeah. That's what I wrote that about.

Interactions with others in the group

Descriptions of how people interacted with others:

Vanessa: Well [Felix] looked at me and said what do I do, and I said here come bruv I'll show you how it works.
Jacob: And he was using both his hands at the end wasn't he.
Vanessa: Yeah because I helped him. Because I said to him look I've done that, been down that road. And his mum said he's gt the splint so have I and then look at me I didn't wear mine I said look, I'm bad I haven't worn mine for two days. And he looked at me and went what you didn't wear yours? No. I said don't worry it'll come.
Jacob: That was great that you were teaching him today. It was nice that you had something to connect over, that you could show him the technique you were using

Vanessa: Well, I know this is, I noticed his mum felt my arm, she couldn't believe it about the movement I used, and I said don't worry it'll come, it's just that the disability money and all that stuff. We had a conversation with his mum / carer.
Vanessa: And I said you've been a good mum and a good carer teaching him and things.

Vanessa: It's very nice to teach somebody else. I found it was useful to teach somebody else who's got the same needs as me. Nobody else has got the same needs as what I've got.
Vanessa: I enjoyed working with a d different person.
Edwin: That was great as well to see you working together especially with the Strummis.

Felix and Vanessa.