Embodied Interaction with Guitars:
Instruments, Embodied Practices and Ecologies

Juan Pablo Martínez Ávila

Thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Computer Science

Faculty of Science
School of Computer Science
The University of Nottingham

2022

Abstract

In this thesis I investigate the embodied performance preparation practices of guitarists to design and develop tools to support them. To do so, I employ a series of human-centred design methodologies such as design ethnography, participatory design, and soma design. The initial ethnographic study I conducted involved observing guitarists preparing to perform individually and with their bands in their habitual places of practice. I also interviewed these musicians on their preparation activities. Findings of this study allowed me to chart an ecology of tools and resources employed in the process, as well as pinpoint a series of design opportunities for augmenting guitars, namely supporting (1) encumbered interactions, (2) contextual interactions, and (3) connected interactions.

Going forward with the design process I focused on remediating encumbered interactions that emerge during performance preparation with multimedia devices, particularly during instrumental transcription. I then prepared and ran a series of hands-on co-design workshops with guitarists to discuss five media controller prototypes, namely, instrument-mounted controls, pedal-based controls, voice-based controls, gesture-based controls, and "music-based" controls. This study highlighted the value that guitarists give to their guitars and to their existing practice spaces, tools, and resources by critically reflecting on how these interaction modalities would support or disturb their existing embodied preparation practices with the instrument.

In parallel with this study, I had the opportunity to participate in a soma design workshop (and then prepare my own) in which I harnessed my first-person perspective of guitar playing to guide the design process. By exploring a series of embodied ideation and somatic methods, as well as materials and sensors across several points of contact between our bodies and the guitar, we collaboratively ideated a series of design concepts for guitar across both workshops, such as a series of breathing guitars, stretchy straps, and soft pedals. I then continued to develop and refine the Stretchy Strap concept into a guitar strap augmented with electronic textile stretch sensors to harness it as an embodied media controller to remediate encumbered interaction during musical transcription with guitar when using secondary multimedia resources.

The device was subsequently evaluated by guitarists at a home practicing space, providing insights on nuanced aspects of its embodied use, such as how certain media control actions like play and pause are better supported by the bodily gestures enacted with the strap, whilst other actions, like rewinding the play back or setting in and out points for a loop are better supported by existing peripherals like keyboards and mice, as these activities do not necessarily happen in the flow of the embodied practice of musical transcription.

Reflecting on the overall design process, a series of considerations are extracted for designing embodied interactions with guitars, namely, (1) considering the instrument and its potential for augmentation, i.e., considering the shape of the guitar, its material and its cultural identity, (2) considering the embodied practices with the instrument, i.e., the body and the subjective felt experience of the guitarist during their skilled embodied practices with the instrument and how these determine its expert use according to a particular instrumental tradition and/or musical practice, and (3) considering the practice ecology of the guitarist, i.e., the tools, resources, and spaces they use according to their practice.

Selected Publications

Juan Martinez Avila, Adrian Hazzard, Chris Greenhalgh, Steve Benford, and Andrew McPherson. 2022. The Stretchy Strap: Supporting Encumbered Interaction with Guitars. In Journal of New Music Research. In Press. **(Featured in Chapter 6)**

Juan Martinez Avila, Vasiliki Tsaknaki, Pavel Karpashevich, Charles Windlin, Niklas Valenti, Kristina Höök, Andrew McPherson, and Steve Benford. 2020. Soma Design for NIME. In Proceedings of the International Conference on New Interfaces for Musical Expression (NIME 2020), Royal Birmingham Conservatoire, Birmingham City University, Birmingham, United Kingdom. **(Featured in Chapter 6)**

Juan Pablo Martinez Avila, Adrian Hazzard, Chris Greenhalgh, and Steve Benford. 2019. Augmenting Guitars for Performance Preparation. In Audio Mostly (AM'19), September 18-20, 2019, Nottingham, United Kingdom. ACM, New York, NY, USA, 7 pages. DOI: https://doi.org/10.1145/3356590.3356602 **(Featured in Chapter 4 and Chapter 5)**

Juan Pablo Martinez Avila, Chris Greenhalgh, Adrian Hazzard, Steve Benford, Alan Chamberlain. 2019. Encumbered Interaction: A Study of Musicians Preparing to Perform. In 2019 CHI Conference on Human Factors in Computing Systems Proceedings (CHI 2019), May 4-9, 2019, Glasgow, Scotland, UK. ACM, New York, NY, USA. Paper 476, 13 pages. DOI: https://doi.org/10.1145/3290605.3300706 **(Honourable Mention) (Featured in Chapter 4)**

Kristina Höök, Steve Benford, Paul Tennent, Vasiliki Tsaknaki, Miquel Alfaras, **Juan Martinez Avila**, Christine Li, Joseph Marshall, Claudia Daudén Roquet, Pedro Sanches, Anna Ståhl, Muhammad Umair, Charles Windlin, and Feng Zhou. 2021. Unpacking Non-Dualistic Design: The Soma Design Case. ACM Trans. Comput.-Hum. Interact. 28, 6, Article 40 (December 2021), 36 pages. https://doi.org/10.1145/3462448 **(Featured in Chapter 6)**

Adnan Marquez-Borbon and **Juan Pablo Martinez Avila**. 2018. The Problem of DMI Adoption and Longevity: Envisioning a NIME Performance Pedagogy. In Proceedings of the International Conference on New Interfaces for Musical Expression, Virginia Tech, Blacksburg, VA, USA, pp. 190-195 (Featured in Chapter 2)

Acknowledgements

I am extremely fortunate to say that doing a PhD was one of the most gratifying experiences of my life. During the past five years I had the opportunity to meet excellent people and publish my work at several academic conferences. I have grown professionally and personally, developing my technical and interpersonal skills. Ten years ago, I would have never imagined achieving any of the things that I have achieved to date. I truly owe my success and my development as an academic researcher, designer, musician and as a human being to many people that I wish to acknowledge here. Firstly, I want to thank my grandmother, my mother, and my wife, who are the most important women in my life, and for whom I am who I am. To my father who is a great listener and has always kept my mind curious and my imagination active, and to my uncle Edson for being the older brother I never had. To my friends in Mexico, South America, and the US (you know who you are), who continue to be on my side, regardless of the time and distance we have been apart. However, none of this would have been possible without the unconditional support of the Mexican government and its National Council for Science and Technology (CONACyT) which provided me with interest-free financial support for my tuition fees and a monthly salary. In addition, I must also thank my supervisor and mentor Steve Benford who resourcefully managed to help me cover the remainder of my tuition fees while simultaneously involving me in academic projects through the EPSRC-funded FAST project and Horizon research. Overall, I am truly thankful for all the support that I have received from the UK to develop my academic and professional career. I should also say that the research in this thesis would have not been possible without the participation of the wonderful musicians of Nottinghamshire who were exceedingly kind to welcome me into their home practice spaces and rehearsal rooms to interview them and watch them prepare for their performances; as well as by participating in my workshops and testing my prototypes, providing me with honest feedback. Their input shaped my design decisions, my research agenda, and findings. I was also truly fortunate to have had an excellent team of supervisors, Steve Benford, Chris Greenhalgh and Adrian Hazzard, to guide my research and mentor me through my PhD. I want to thank Steve for pushing me to do big things, to Chris for keeping my feet in the ground, and to Adrian for lifting my spirits with his motivational and kind words. I feel very privileged to have worked with them since my masters and to continue to do so in the early stages of my academic career. I also want to thank Adnan Marquez Borbón for shepherding me into the NIME conference by inviting me to write one of my most successful papers to date and introducing me to many people in the community like Miguel Ortiz, Paul Stapleton, and Barry Cullen. I also thank Andrew McPherson for inviting me to spend time at the Augmented Instruments Laboratory and for his mentorship, and Alan Chamberlain for his excellent academic advice. Together, my supervisors and mentors have shaped who I am now as an academic. During my PhD I was also truly fortunate to make many new friends. In good part I owe this to Edgar Bodiaj who introduced me to many other PhDs in the Mixed Reality Lab who are now my friends (Petros Ioannidis, Johann Benerradi and Andriana Boudoraki). I also was lucky to have started my PhD with old friendships (Gisela Reyes and Gustavo Berumen) and to make many new connections during its course at the MRL (Pablo Custodio, Giovanni Schiazza, Damla Kılıç, Richard, and Rachel Ramchurn, Horia Maior, Adrian Marinescu, Pepita Barnard, Dimitrios Darzentas, Hanna Wagner, Christine Li, Xin Liew, Jocelyn Spence, Velvet Spors, Paul Tennent, Feng Zhou, Pat Brundell, Joel Fischer, Martin Flintham, Kevin Glover, Roma Patel, and Stuart Reeves). I also made friends and collaborators during my stay at Queen Mary (Adán Benito, Teodoro Danemann, Giacomo Lepri, Andrea Martelloni, Antonella Nonnis, Cyrus Vahidi, and Andrea Guidi) as well as across Latin America during NIME 2019 (João Tragtenberg, Filipe Calegario, Hugo Solis, Javier Jaimovich, Juan Ramos, Martin Matus, Ximena Alarcon, Isabela Corintha, and Patricia Cadavid), and online, during subsequent NIMEs (Laurel Pardue and Anna Xambó). I must also say that writing this thesis was not an easy feat. Some of the chapters were written in transatlantic flights, train, and bus rides, on a recliner armchair whilst keeping my grandma company when she got COVID and needed an oxygen tank, and on a sofa next to my mother-in-law's hospital bed when she suffered from severe liver disease. Luckily, they both made it. I am particularly thankful to my mother for supporting me during this time, as well as my friends Luis Garcia, Diego Guerrero, Julian Grivel, Juan Badouin and Tannia Alvarez for sticking around during these particularly grim times. My supervisors and Paul Tennent were also very supportive during this period of my life, and I am incredibly grateful to them for that. Finally, I want to thank my examiners Simon Holland, and Joe Marshall for taking the time to fully read, comment, proofread, and examine my thesis, as well as for their uplifting feedback during my *viva voce*.

Table of Contents

List of Figures

List of Tables

*Si no es destiempo, es desfase, y sino desv*rgue*
—Jordan González

Chapter 1
Introduction

1.1 Background and Motivation

The guitar is perhaps one of the most phenomenally popular, culturally iconic (sonically and visually), accessible (in terms of affordability, portability, playability, and reproducibility), malleable and versatile musical instruments in the world (Dawe, 2017). The guitar is central to many musics and cultures around the globe (Bennett & Dawe, 2020), thus, its repertory is vast and is constantly being expanded—and kept alive—by the guitarists who are engaged in composing, learning, practicing, and performing it (Faulkner & Becker, 2009; Green, 2017). In recent years, guitarists are turning to the Internet more than ever to search for musical material to learn from, practice along to and discuss with other guitarists. With the emergence and widespread appeal of user-generated content (UGC) platforms such as YouTube, and other dedicated guitar forums such as Ultimate Guitar, the available resources are often contributed by a very active and global online community of guitarists (Waldron, 2013a).

Furthermore, in allusion to its malleability and versatility, the guitar has been aptly referred to as a "laboratory for experimentation" by San Juan (San Juan, 2020). Indeed, the sound of the guitar can be modified by alternatively tuning its strings in many different ways, and the instrument can be physically altered for extended performance techniques by *preparing*[1] or electrically augmenting it (Frengel, 2017; Hopkin & Landman, 2012). The guitar has technologically evolved to connect to other devices, such as audio and MIDI devices. Hence, when the instrument is electrically amplified, its sonic capabilities can be further expanded by processing its audio signal with audio equipment or software. Recently, the guitar has also been thought about as an artefact that could be augmented with a digital layer (Benford et al., 2015) and as part of the so-called "Internet of Musical Things" (Turchet et al., 2017; Turchet & Barthet, 2019).

[1] That is, altering the timbre of the guitar by placing various objects on or between its strings, among other physical interventions.

The design of the guitar has also evolved to ergonomically—and intimately—sit close to the body, but also to facilitate playing and adjusting the instrument. From more salient details such as the curves, cutaways, and nooks of the guitar to more nuanced ones like the inlays on the fretboard, the tuning pegs in the headstock, or the strap buttons, each of these design elements serves a bodily intent with the guitar, such as playing more comfortably or moving around the stage freely.

The popularity, ubiquity and cultural impact of the guitar are not only evidenced by its historical longevity and widespread adoption as a musical instrument, but also by the resulting development of resources, artefacts, technologies, and services revolving around the guitar, driven by a multitude of actors, such as guitarists, luthiers, technologists, merchants, and aficionados of the instrument. The complexity and richness with which the guitar has been driven to constantly evolve and adapt to the musical, cultural, artefactual, and technological landscapes in which it has been embedded, makes it an interesting subject of research in both academic and commercial spheres. In response to the sheer scale of the guitar phenomenon Dawe proposes the umbrella term “guitarscape” to refer to this convergence of perspectives, stakeholders, sounds, musics, cultures, artefacts, new media and technologies that are involved in guitar-related discourse (Dawe, 2013).

Moreover, Dawe notes that most of the works that account for the contemporary state of guitar and its intricate relationship with technologies and new media remains scarcely documented and limited in scope (ibid). It must be noted, however, that in the context of technology design and intervention, the guitar has been mostly addressed as an artefact that needs to be expanded sonically, i.e., augmenting its instrumental and expressive capabilities (Fasciani & Goode, 2021; Jensenius & Lyons, 2017; Jordà, 2004; Magnusson & Mendieta, 2007; Miranda & Wanderley, 2006). In this sense, there is a paucity of academic works that observe the already established practices of guitarists to inform the design process of innovative technologies for guitar.

Although previous works have unpacked the social, performative and informal learning practices of guitar players by conducting interviews and employing different kinds of ethnographic methods, and documenting to some extent the tools and resources employed in these activities (Dawe, 2013; Faulkner & Becker, 2009; Green, 2017; Waldron, 2013a), only a few works have employed similar methods to inform the design of guitar technologies (Avila, Greenhalgh, et al., 2019; Avila, Hazzard, et al., 2019; Benford et al., 2012, 2016).

Thus, the approach to technology and Interaction Design (IxD) presented in this thesis, is grounded on two general areas of knowledge, Human-Computer Interaction (HCI) and its intersection with music, i.e., Music Interaction (Holland et al., 2019), which encompasses preponderant areas of study, such as New Interfaces for Musical Expression (NIME) (Jensenius & Lyons, 2017), Computer Music, and Music Technology, among others. HCI research provides analytical frameworks that are helpful to address the interplay between humans, the artefacts with which they develop embodied practices and the contexts in which these interactions are enacted (Dey et al., 2001; Dourish, 2004a; Vyas & Dix, 2007).

These frameworks are in turn grounded on principles of embodiment, enactivism, ecological psychology and phenomenology which are applied to the understanding of technologically mediated human activities. Likewise, Music Interaction research embraces these principles but also provides alternative perspectives which emerge from the innovative uses that musicians give to technology and how they in turn influence technological developments beyond the music realm (Holland et al., 2013), as well as considering the processes, ecologies and specificities involved in instrumental musical practices when designing for musical instruments, rather than simply latching onto the "user and device" model, more commonly observed in traditional HCI (Rodger et al., 2020).

This thesis showcases a particular approach for designing embodied interactions for guitars, which consists of surveying, probing, and technologically remediating specific guitar ecologies. Here the concept of guitar ecologies is employed to refer to the to the interplay between guitarists, things, and spaces with which and where the different facets of embodied practice with guitar take place. These ecologies are dictated by the embodied practices enacted, which range from the more common activities with the instrument, such as performance, learning, practice, and rehearsal, to the more specialist ones, such as guitar building, modification, and performance and improvisation with DMIs and guitars. In this case, the ecology of performance preparation with guitar is observed and technological interventions to support its associated embodied practices are proposed.

1.2 Objectives and Approach

The main objective of this thesis is to propose an ecologically informed and musician-centred design approach for the development of new guitar technologies and embodied interactions. This endeavour is motivated by the predominance of technologies for guitar that are evidently designed with a techno-centric approach, i.e., the technology is designed first and then deployed with guitarists. Here a diametrically opposite design approach is explored, which involves the observation of guitarists in a specific context of practice and the subsequent design of technology and its deployment in that context. Given the plethora of existing guitar ecologies, the focus here lies in one of the least explored in terms of technology design—performance preparation with guitar.

Guitarists are increasingly using digital media to support their preparation activities, e.g., practicing repertoire and rehearsing with other musicians. As comprehensively charted by Burns et al., (2017) there are many existing technologies that support the search of musical material, and provide structured independent and collaborative learning, practicing and rehearsing experiences. Some of these technologies are designed as computer-assisted musical instrument training (CAMIT) systems, which aim to complement or substitute the tuition of an instructor by facilitating the instruction and learning activities, e.g. capturing and analysing the learner's performance input, structuring the learning path, prescribing learning materials, providing feedback and enhancing the self-regulation and motivation of the learner through game-like interactive elements, e.g. scores, leader boards, and milestones, among others.

While some CAMITs focus on delivering engaging interactive learning content to practice along with one's own musical instrument, others aim to re-invent, mimic or modify existing instruments, or designing entirely new instruments that smoothly integrate with the interactive learning experiences (McPherson et al., 2019). Both design approaches have given rise to commercially successful products for guitar learning, such as Yousician[2] and JamStik[3]. However, the design approach explored here is not intended to provide a more engaging learning experience for novice musicians by designing interactive media or learning management systems nor is it to design new guitars for interactive music learning. Instead,

[2] https://yousician.com/
[3] https://jamstik.com/

the aim is to understand how proficient guitarists who are already acquainted with their instruments and that are often engaged in learning popular music material to perform live at various social events, on demand, on short notice and on a regular basis approach performance preparation activity with the guitars and the resources they already use (Figure 1). This kind of musicians is often referred to as 'working musicians', who are often part of a 'session', 'tribute' or 'covers' band (Faulkner & Becker, 2009; Green, 2017). Hence, a more specific objective of this thesis is to design technologies for the guitar that bridge the embodiment of guitar playing and the interaction with resources used in performance preparation (Avila, Hazzard, et al., 2019).

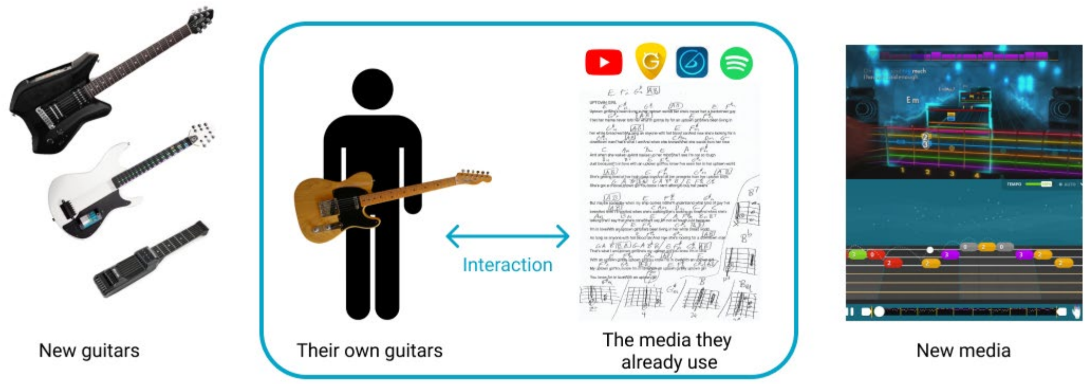


Figure 1. Scope of the thesis: Supporting guitarists' preparation practices by considering their existing instruments and the media they already use during practice.

Thus, the approach presented here consists of exploring interventions to existing artefacts from the guitar performance preparation ecology, including the guitar itself, noting that the guitar is seldom used in isolation during preparation but rather in conjunction with a diverse set of tools, resources, and services (Avila, Greenhalgh, et al., 2019). Hence, the resources that guitarists employ to support their embodied preparation practices are observed, as well as the practicalities that arise when attending to these resources whilst also having an instrument at hand, to design interactive technologies that can support these existing guitar-related practices and that fit their particular ecology.

To maintain consistency throughout the guitarist-centred co-design process, the same pool of guitarists—who can be considered as members of a community of practice (Wenger, 1999)—was recurrently invited to participate throughout these studies. Given that I am an experienced guitarist, my first-person perspective is also factored within the collective perspective of this community of guitarists. However, it should be acknowledged that those who participated in the design process (myself included) represent a limited range of performance paradigms and genres, so it may be that those working in other performance traditions or with other instruments may have different specific practices and engage with other digital resources and tools when preparing to perform.

Nonetheless, many of the observations presented here may potentially recur in other styles and genres, albeit with specific variations. Moreover, regardless of the diversity in the levels of instrumental proficiency from the overall group of guitarists, as well as individual and idiosyncratic approaches to preparation, commonalities amongst the group were generally observed, such as a frequent use of online music materials to support their preparation, similar spatial arrangements of their practice spaces, and a similar range of tools and resources used to carry out preparation activities.

Although the main focus here is in guitars, the results may also inform future design interventions in similar chordophones, such as the bass or the banjo. Likewise, although this work is presented from an academic perspective, it may also prove useful for those in the music technology industry who are interested on a musician-centred design approach for guitar technologies.

1.3 Research Questions

This thesis is driven by three principal questions, namely:

1. What are the embodied practices of guitarists preparing to perform?
2. What is the nature of the design space of embodied interaction with guitars?
3. How can we design embodied interactions for guitarists preparing to perform?

These inquiries are investigated with the methods proposed in Chapter 3 and through the studies presented in the subsequent studies' chapters, comprising of an ethnomethodologically inspired ethnographic study (Chapter 4), a participatory design-inspired study (Chapter 5), a soma design study, and a user evaluation study (Chapter 6).

1.4 Outline of the Thesis

This chapter presents an introductory overview of the guitar phenomenon, addressing the malleability and versatility of the instrument and how repertoire learning has been amplified by the emergence of Internet UGC platforms, such as YouTube. Likewise, the guitar is presented as an artefact that is part of an ecology of related tools, information resources, and Internet services, and as the focus for new product designs and technological innovation. The Introduction also foregrounds the research questions of this thesis, which are driven by a principal question, namely, "how can we design embodied interactions for guitarists preparing to perform?". Subsequently, the objectives and approach of the thesis are presented, namely, to propose an ecologically informed and musician-centred design approach for developing guitar technologies and embodied interactions, consisting of the intervention to existing artefacts from the guitar performance preparation ecology.

In Chapter 2, a historical overview of the material design of guitar and how it transitioned from an acoustic instrument to an electric instrument (in the search for amplification) is provided, also addressing how the instrument continues to evolve with new design features from time to time. Likewise, electronic, and digital augmentation to musical instruments and guitars in the form of sonic enhancements are also addressed, with examples from both commercial and academic spheres. Moreover, a series of design rationales for augmenting instruments are overviewed, including performance accessibility and support for novice learners. The guitar ecology is also addressed from an artefact ecologies perspective (Vyas & Dix, 2007), and similar frameworks proposed in DMI design are also addressed. Another aspect that is also addressed in the literature review chapter is the performance preparation practices of musicians from previous ethnographic (and auto-ethnographic) studies and phenomenological dissertations. Likewise, embodied interaction and embodied musical interaction are addressed to position the design interventions presented in this thesis. This chapter also situates this work within broader guitarscape research.

In Chapter 3 the research and design methods used in this thesis are introduced. These methods are grounded in a human-centred design approach and cover different methodological approaches, namely, (1) design ethnography, (2) participatory design, (3) embodied ideation methods and (4) evaluation methods, and their corresponding techniques and considerations are also addressed. This chapter also overviews the overall design process presented in this thesis, describing as a process of observing, and charting the embodied practices of musicians, and then probing it with technological interventions which are then evaluated with the aim of integrating them within said practices.

In Chapter 4, an ethnomethodologically inspired design ethnography study of musicians preparing to perform is presented. In this study musicians are observed during practice at home and rehearsals with their groups, as well as interviewed about their activities *in situ* and through semi-structured interviews away from their context of practice. The ethnographic corpus is then collated and transcribed for thematic coding analysis which resulted in a series of ethnographic vignettes. By unpacking the vignettes, this chapter proposes three principal areas of design intervention, namely for supporting (1) encumbered interactions[4], (2) contextual interactions, and (3) connected interactions with augmented guitars.

In Chapter 5, a participatory design inspired co-design workshop study with guitarists is presented. In this study, the design challenge of supporting encumbered interactions during performance preparation with guitar is addressed through a series of prototypes exploring distinct interaction modalities, namely, (1) touch controls on the body of the instrument, (2) pedal-based interactions, (3) voice commands, (4) musical notes from the instrument as control input and (5) gestural controls.

The prototypes are then deployed over a series of workshops with guitarists who tested and discussed the prototypes. The participants are then engaged in a series of co-design activities, involving sketching refinements to the prototypes presented. This study revealed a series of values and attitudes from guitarists towards intervening their guitars as well as their embodied practices and their ecologies of tools, resources, and spaces of practice.

In Chapter 6, a soma design study consisting of two workshops with soma designers, my supervisor and myself (joining as proficient guitarists) is presented. During this workshop, the guitarists in the group provided insights from their first-person perspective of guitar playing and the embodied practices involved in preparation, as well as their knowledge of the guitar ecology. Through a series of embodied ideation techniques and material encounters, the workshops led to the conceptualisation of a series of guitar augmentations involving familiar artefacts such as guitar pedals and straps, but with estranged affordances and interaction techniques, by exploring deformable interfaces through stretch and soft materials.

[4] In the context of mobile interactions, encumbered interactions emerge when the user's hands are simultaneously occupied interacting with other artefacts (Ng et al., 2013). In this thesis, encumbered interactions emerged when guitarists needed to simultaneously interact with computing devices whilst their hands were occupied with a musical instrument.

This design concepts led to the subsequent design of the Stretchy Strap; a guitar strap augmented with stretch sensors made with electronic textiles to allow the guitarist to navigate media by using their strap as a controller through a series of discrete bodily movements with the guitar. The strap is then evaluated by guitarists in the context of performance preparation. This chapter reflects on soma design as a tool for exploring existing artefact ecologies and perturbing them through methods such as estrangement to generate new design ideas by latching on familiar artefacts. Moreover, it also addresses guitarists impressions of the Stretchy Strap as an artefact that supports encumbered interactions during practice at home.

In Chapter 7, the general conclusion of the thesis responds to the initial research questions and provides three considerations for designing embodied interactions with guitars, namely, (1) considering the instrument, (2) considering embodied practices, and (3) considering the practice ecology. Furthermore, the contributions of this thesis to the study of musical practices in ethnography and soma design are presented, as well as to the design of musical instruments and guitar augmentation using human-centred design methods. Methodological reflections on the design process are also presented, as well as its limitations, proposing actions for future work.

Lastly, in Chapter 8, an appendix of the data collection instruments used in this thesis, namely, the interview schedules used with guitarists in the ethnographic study and the Stretchy Strap's evaluation; the slides used during the co-design workshops with guitarists; a sample of coded transcript for analysis of the Stretchy Strap evaluation results; the Pure Data patches and the scripts used to run the Stretchy Strap as a media controller with SoundSlice. In addition, in Section 8.6 an illustrated glossary of some of the guitars, accessories, interventions and musical instruments mentioned in this thesis is provided.

Chapter 2
Literature Review

2.1 Introduction

In this chapter, a literature review is provided on: (1) current examples of technology interventions in traditional musical instruments and guitars, as well as the development of digital musical instruments (DMIs) from academic and commercial spheres, (2) observational studies of the preparation practices of guitarists and their informal learning practices, and (3) embodied interaction and embodied musical interaction. The aim of this review is to address the state of the art on the areas outlined above as well as to pinpoint gaps in existing research and previous works.

2.2 Augmenting Guitars

The guitar is a musical instrument that has evolved throughout centuries of cultural, stylistic and design influences. Arguably, the guitar can be traced back to the oud, as the precursor of the Spanish guitar (Zayadine & Al-Asad, 2000), whose design (along with that of the classical guitar) is attributed to Antonio de Torres Jurado (Poyatos Andújar, 2014). Following the addition of a sixth string and the standardised guitar tuning used today (i.e., tuning the strings from the sixth to the first to the musical notes: E, A, D, G, B, and e) by Jacob Augustus Otto (1833), Torres introduced other modifications to the guitar that can be appreciated in modern guitars, such as reinforcing the fretboard and raising the frets, adding inner braces for improved resonance and the introduction of the mechanical tuning heads.

Then, with the uptake of the guitar in the USA in the early 1900's, further substantial innovations and guitar inventions were introduced. For example, the American guitar manufacturer C.F. Martin & Company introduced the "dreadnought" acoustic guitar body shape (Achard, 1996), which became widely popular and influential during the 20th century and was adopted by musicians like Elvis Presley, Bob Dylan, and John Lennon (among others)[5]. C.F. Martin's modifications to the guitar are generally associated with seeking a louder sound

---

[5] https://www.martinguitar.com/about-martin-martin-history.html

from the instrument—as the dreadnought body construction is larger than that of classical guitars. For the same reason, the resonator guitar was invented by Ján Dopjera (1980). Though these instruments still exist and are widely used on their own behalf for stylistic reasons, their initial intent to overcome the inadequate amplification of the guitar in wider instrumental ensembles, was superseded by the invention of the electric guitar.

The first electric guitar, the Stromberg-Voisinet Electro, emerged from Chicago in 1929, although it was not as commercially successful as the Rickenbacker "Frying Pan" (1931) (Atkinson, 2020). Nonetheless, this latter guitar was mostly adopted by Hawaiian-style musicians, and hence surpassed by Gibson's 1936 ES-150 "Spanish-style" hollow-body electric guitar, due to its stylistic versatility—as it could be played while standing up by attaching the guitar with a strap rather than sitting down and positioning the guitar on the lap (as with the Rickenbacker).

Then in the 1950's Leo Fender introduced the solid body Broadcaster guitar and then in the 1954's the Fender Stratocaster which featured the "tremolo" bar (also known as the "whammy" bar) which allows for raising or lowering the pitch of the strings by pushing or pulling the bar (ibid). Both the Fender Stratocaster and the Gibson Les Paul (1952) guitar models are still widely used to date. In parallel, the Bahian guitar (a form of electric mandolin) had also been developed in the 1940s by Adolfo "Dodô" Nascimento and Osmar Álvares Macêdo, in Salvador, Brazil (Vargas, 2014).

Henceforth, the electric guitar has featured new design features from time to time (Figure 2), ranging from the introduction of new mechanisms (e.g., Paul Bigsby's vibrato tail piece, Floyd Rose's locking tremolo or Gene Parson's "string bender"), technologies (e.g., the piezo pickup and onboard amplifier in some electro-acoustic guitars), ergonomic explorations (e.g., Ola Strandberg's EndurNeck featured in Strandberg's headless electric guitars) and stylistic interventions, such as Linda Manzer's Pikasso guitar (a guitar with an extended range of 42 strings, popularized by Pat Metheny), or Kamala Shankar's Shankar guitar (a guitar-sitar hybrid). Other interventions to the guitar are more transient, such as in the case of prepared guitars, where found objects are temporarily placed, attached on, or clipped to the guitar to explore alternative techniques and sounds (Frengel, 2017; Hopkin & Landman, 2012; San Juan, 2020). A notable prepared guitar performer is Fred Firth (Dawe, 2017).

In this thesis, the focus mostly lies in technological interventions and inventions for the electric guitar, which are either presented in the form of new guitars, accessories or add-ons for the guitar, augmentations or alterations to the guitar, or new devices that can be used in conjunction with or that interface with the guitar. In this section an overview is provided on the state-of-the-art of DMIs, Augmented Musical Instruments (AMIs), Smart Musical Instruments (SMIs)—and their implications to guitar intervention and innovation—among other variants of technologically-intervened musical instruments and guitars, as well as augmented devices from the guitar ecology, both from academic and commercial spheres of Music Technology.

Figure 2. Changes to the design of the guitar over time.

2.2.1 Digital Musical Instruments/Interfaces/Interactions

The invention of audio technologies such as the microphone, the speaker, and thus sound recording, encoding and decoding devices (e.g., sound recorders, physical audio formats—like vinyl or cassettes; and music players—like record players or cassette players, respectively) impacted the composition, production and performance of new music, as it can be evidenced in the works of mixed music and musique concrète artists like Edgar Varèse and Iannis Xenakis, who experimented with musical instruments and magnetic-tape playback. The electric guitar can also be considered as an instrument that was impacted by these technological advances, as the amplification of the instrument's sound became possible due to the addition of electromagnetic pick-ups to the guitar and the electronic circuitry that allows for it to be connected to a speaker.

Furthermore, advances in electronics also gave rise to the development of new electronic musical instruments (or electrophones) that employ electronic circuitry to synthesize and produce sound, which is then amplified through a speaker. Early examples of these instruments are the Theremin or the Ondes Martenot. Then, in the digital era, new music technology paradigms emerged such as digital synthesis, and computer music—as well as the introduction of MIDI[6] and Open Sound Control[7]. Thus, MIDI controllers became a widespread method to interface with digital audio workstations (DAWs).

These controllers come in various presentations such as pianos and button grids like the Novation Launchpad or the Ableton Push. A range of MIDI guitars or guitar-inspired controllers have recently been introduced in the market, such as Jammy, the JamStik and the Artiphon Instrument 1 (McPherson et al., 2019) (Although the former two later on became full-sized MIDI guitars), as well as guitar “add-ons”, such as the Fishman MIDI hexaphonic pick-up (which can extract pitch information from each string and transcribe it as MIDI notes), and MIDI software for guitar, like the Jam Origin MIDI Guitar 2 (which instead processes the signal from a guitar and then extracts the notes, either monophonically or polyphonically, depending on the user).

Within the Sound and Music Computing (SMC) and HCI research communities, there is a particular interest in exploring and developing DMIs (encompassing digital musical instruments, interfaces, and interactions). An example of a DMI emerging from the NIME community is the D-Box (Zappi & Mcpherson, 2014) (Figure 3), which is a “hackable”, circuit-bending inspired musical instrument, whose sound output can be manipulated by rewiring its internal circuit, which modifies the audio signal generated by software running on the Bela—a Linux-based maker platform (McPherson & Zappi, 2015). Other notable academically originated DMI examples are the reacTable (Jordà et al., 2005), and the Haken Continuum fingerboard (Haken & Eagan, 2010), both which became commercially successful. As

[6] Musical Instrument Digital Interface (MIDI) is a technical standard that describes a communications protocol, digital interface, and electrical connectors that connect a wide variety of electronic musical instruments, computers, and related audio devices for playing, editing, and recording music.
[7] Open Sound Control (OSC) is a protocol for networking sound synthesizers, computers, and other multimedia devices for purposes such as musical performance or show control.

described in the next section, multiple DMI projects have been developed in these communities in the form of augmentations to the guitar, as well as accessory devices or software to process the signal of the instrument.

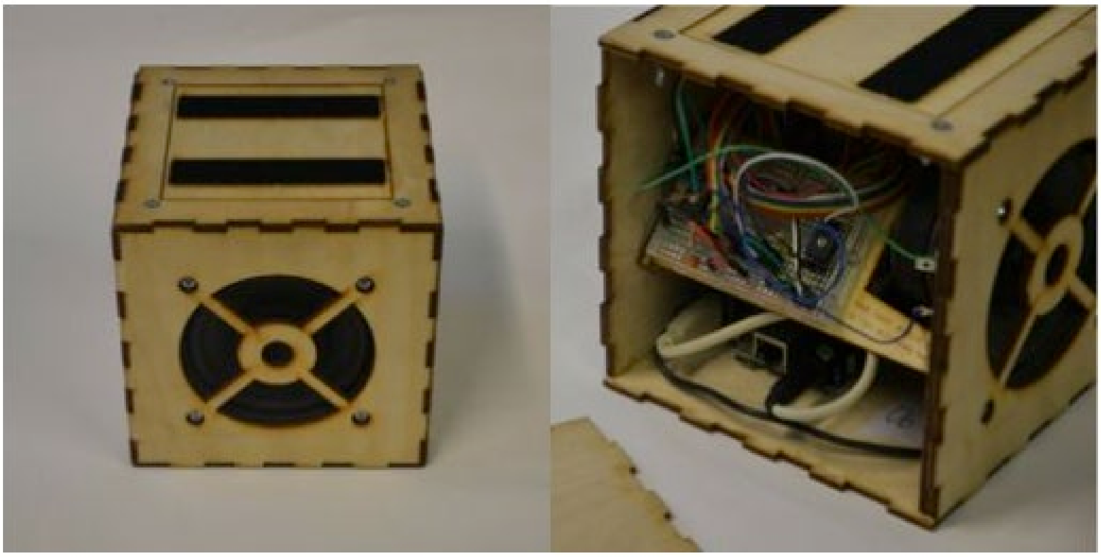


Figure 3. The D-Box.

2.2.2 Augmented Musical Instruments

As previously mentioned, DMIs are developed as self-contained software and hardware projects (Magnusson & Mendieta, 2007). In contrast, AMIs are built upon existing musical instruments, predominantly with the aim of extending their sonic capabilities (Miranda & Wanderley, 2006). However, musical instruments may also be augmented in other ways, as in the case of the Carolan Guitar (Benford et al., 2016) which embeds a digital layer of information associated with instrument and makes it accessible through fiducial patterns engraved onto its body. In this sense, a broader definition for AMIs would include traditional instruments that have been added to physically, electronically, or digitally to expand their qualities and capabilities. Nonetheless, the focus of this thesis lies on physical alteration and technological intervention aspects of augmentation.

AMIs can vary in terms of how invasive they are to the instrument and how much they transform it, and in terms of their design intent and rationale (Avila, Hazzard, et al., 2019). For example, there is a plethora of guitar accessory devices that are designed to prevent as much physical modification to the instrument as possible, hence providing a non-invasive augmentation to the instrument—involving minimal and/or reversible intervention.

According to Meneses et al., (2018) an example of such kind of augmentation would be connecting an electric guitar to an audio effects foot pedal, thus expanding the sonic capabilities of the instrument. Furthermore, Meneses (ibid) provides a review of recent guitar augmentation projects. Another notable non-invasive DMI for guitars emerging from the NIME community is the Magpick (Morreale et al., 2019) (Figure 4), an augmented guitar plectrum that uses electro-magnetic induction which interacts the guitar pick-ups, allowing the player to explore alternative expressive techniques and sound effects through gestural interactions with the plectrum. A similar implementation was developed by Vets et al., (2017). A commercially available device that has a similar sonic effect and non-invasive approach is the EBow, although it does not use the plectrum form factor as in the two previous examples.

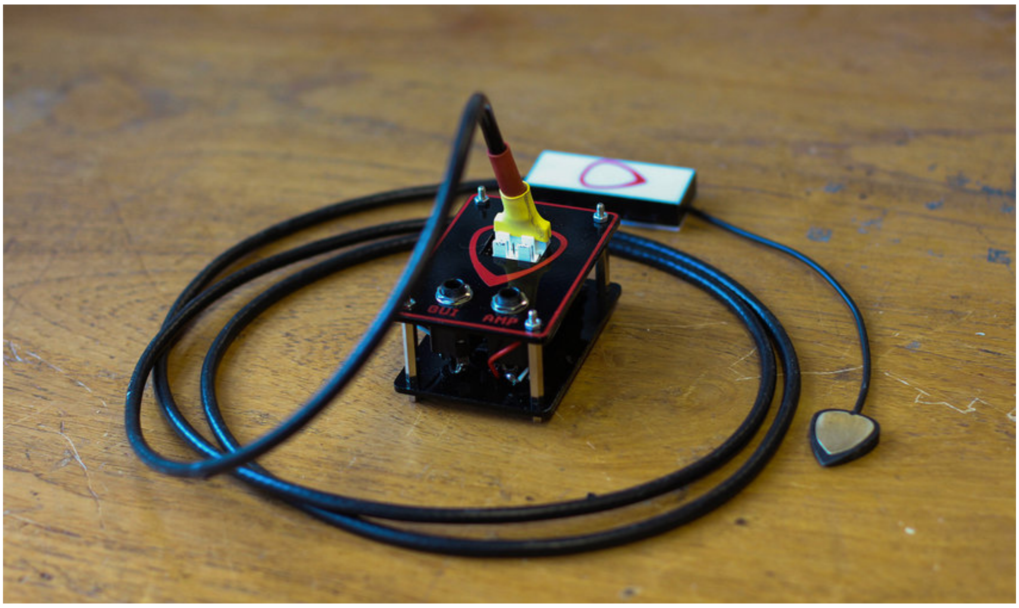


Figure 4. The Magpick.

Conversely, other augmentation approaches are much more invasive, and in some cases cause irreversible modifications to the instrument. For instance, the "kill switch" is a common alteration in electric guitars, which involves permanently drilling a hole to install a momentary button that toggles the audio signal off when pressed, creating interesting sound effects. Two popular guitarists that have explored performance techniques with this guitar modification are Tom Morello and Buckethead. Alternatively, the Fret Zealot[8] does not sonically augment the instrument, but instead provides visual information (e.g., finger positions) to the guitarist by using strips of LEDs which are adhesively attached to the fretboard.

[8] https://www.fretzealot.com/

Another dimension of augmentation is the degree of transformation that the intervention imbues on the instrument (Avila, Hazzard, et al., 2019), e.g., sonically, aesthetically, ergonomically, or technologically, among other enhancements. In correlation with invasiveness, some instruments are minimally or completely not invasive to the instrument, yet they transform the sound of the instrument significantly. A remarkable AMI that exemplifies this correlation is the Magnetic Resonator Piano (McPherson & Kim, 2010) (Figure 5) which is the result of temporarily placing a sensor bar in front of the keys of a grand piano and an array of electrically driven magnets inside of its soundboard to resonate its strings. Effectively, this augmentation transforms a grand piano into a new kind of piano with bespoke performance techniques, which has gathered a community of performers and composers over the years (McPherson & Kim, 2012).

Figure 5. The Magnetic Resonator Piano.

Moreover, transformative augmentation may also imply that the technological interventions made to an instrument find their way as essential and permanent design features embedded in enhanced versions of the instrument (Avila, Hazzard, et al., 2019). This is arguably the case with the electric guitar, where early electrical amplification mechanisms for the acoustic guitar—motivated by the necessity for louder guitars in orchestras (as mentioned in Section 2.2)—featured actuators and magnetic coils which resemble those of modern-day electric guitar pick-ups. Hence, although *"organologically"* speaking the acoustic guitar and the electric guitar are the same instrument, the electric guitar is the result of augmenting the acoustic guitar and transforming it into a new kind of instrument with additional capabilities and a different performative character. In this sense, an AMI arguably can transition from an instrument that is sonically extended by means of hardware and software enhancements (Miranda & Wanderley, 2006) to become a completely new kind of instrument (Avila, Hazzard, et al., 2019).

Thus, a wide range of innovative guitar designs have emerged throughout the years (Figure 6) to diversify the capabilities and expression of the instrument even further. For example, some guitar designs embed digital signal processing (DSP) capabilities into the instrument (e.g., Line 6 Variax guitar), which allow it to model several types of guitars and tunings. Others embed synthesis capabilities (e.g., the Roland GR-300 guitar), and infinite resonance (e.g., the Moog guitar). Furthermore, the Sensus guitar (Turchet & Barthet, 2019) is yet another guitar design that features DSP capabilities (such as effect modelling), actuators that use the resonance of the guitar to amplify its sound, multiple sensor inputs, like gyroscopic sensors (to sense the tilt of the instrument), as well as a series of capacitive touch sensors across the neck and the body of the guitar, and Internet and Bluetooth connectivity, making the instrument a sort of Internet of Things (IoT) device that can connect to other devices within a network.

Figure 6. Line 6 Variax, Roland GR-505, Moog and Sensus Guitars.

AMIs can also have specific design intents in addition to musical expression. For instance, some AMIs are designed to support novice learning, such as the ShIFT (Semi-haptic Interface for Flute Tutoring) system (Xia & Dannenberg, 2018), which features a series of servo motors that push the learner's fingers with the aim of correcting their note fingering. Alternatively, the Svampolin (Pardue et al., 2019) digitally corrects the pitch of the notes that learner plays in the violin by capturing the input from each string using electrodynamic pick-ups and processing them with ultra-low latency DSP (using Bela). Another design rationale that has been recently gathering momentum is performance accessibility. This subset of DMIs is often referred to as accessible DMIs or (ADMIs), which are concerned with supporting performers with physical or cognitive impairments. Two notable examples are Larsen's et al., Actuated Guitar (2014) and Harrison and McPherson's one-handed bass (2017), both of which use foot operated devices to drive actuators on the body of the instrument to strum and fret the strings, respectively (Figure 7).

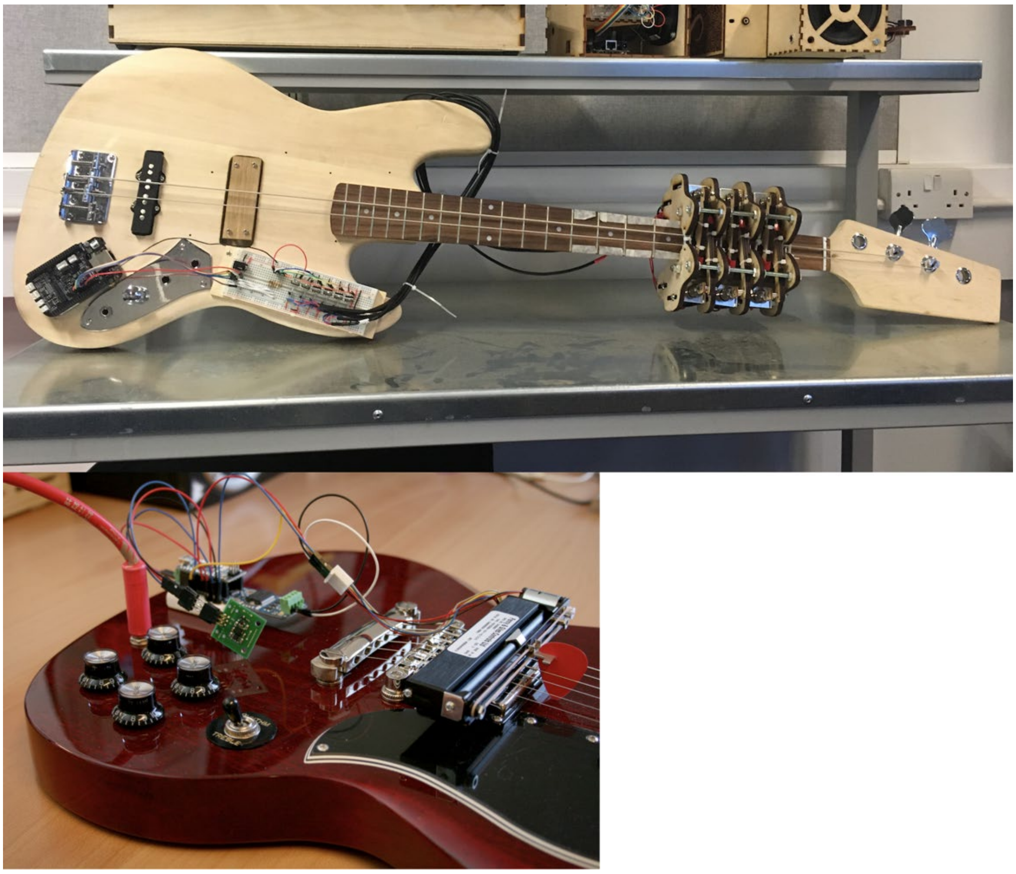


Figure 7. Harrison & McPherson's one-handed bass and Larsen et al., Actuated Guitar.

In this thesis, the design intent is to augment guitars (or their accompanying artefacts) to support performance preparation. Previous works such as those by MacConell et al. (2013)

and Newton and Marshall's (2011) have explored ways of augmenting the electric guitar to support mixed media performances, i.e., traditional instrument performance where added electronic performative elements are involved, such as when controlling a computer or a MIDI interface. In this type of performance setting, the performer constantly alternates between instrument playing and interface navigation. Hence, the aforementioned authors have approached this issue by supplementing the guitar with additional inputs to bridge the overhead of transitioning between both modes of interaction (MacConnell et al., 2013; Newton & Marshall, 2011).

2.2.3 Augmenting the Ecology

In HCI, the concept of artefact ecology emerged from Vyas and Dix's (2007) research for designing technologies for supporting embodied meeting practices in the workplace. These authors use the term to refer to:

> *"A system consisting of different digital and physical artefacts, people, their work practices and values and lays emphasis on the role artefacts play in embodiment, work coordination and supporting remote awareness."*

Similarly, Jung et al., (2008) propose the concept of "ecology of artifacts" to describe the interrelationships and dynamic interplays between different interactive artifacts in the "increasingly ubiquitous technology environment" in people's lives. Both conceptual frameworks are similar in that they are used to extract design implications for situated action when interacting with multiple artefacts (e.g., in work meetings (Vyas & Dix, 2007)), but they differ in that Jung's framework constrains the interrelationships to physical artefacts—although intangible aspects like informational properties or the artefacts, are mentioned (Jung et al., 2008)—whereas Vyas and Dix's extend their framework to also include people, their practices and values, with a particular focus on embodiment, coordination and remote awareness (Vyas & Dix, 2007).

Masu et al. (2019), adopted Jung's ecology of artefacts conceptual framework and extended it with parts of Morreale and Angeli's (2014), MINUET (Musical Interfaces for User Tracking) framework to develop the AARCA (Actors, Role, Context, Activity, Artefacts) framework, which they employ to analyse artefact ecologies in music performance settings. In electroacoustic music research, Waters (2007) employs the concept of "performance ecosystems" (which he attributes to John Bowers) to analyse and evaluate performance settings (encompassing the performer, the instrument, and the environment). Likewise, in their framework Rodger et al. (2020), consider ecologies, processes and specificities to evaluate DMIs.

The aim of these authors is to contest the user and device evaluation paradigm in HCI, arguing that "musicians are not users, but rather agents in musical ecologies". In these ecologies, constellations of processes emerging from the affordances of a singular instrument or the interplay between multiple instruments, with which actors interact with accordingly to their individual capacities and skilful behaviours. In this sense, both the instrument and the instrumentalist present different specificities which shape the processes in the ecology.

These ecological frameworks are similar in that the musicians, their activities and their performance settings are all considered for analysis, evaluation, and design implications—with a particular interest in mixed media performances with DMIs. However, they differ in their analytical scope, where for instance the AARCA framework (Masu et al., 2019) has defined the specific components of the ecology, whereas in Waters' (2007) and Rodger et al., (2020) frameworks the different components are more open to interpretation.

The ecological perspective of interaction with musical instruments that is employed in this thesis is mostly similar to the one outlined by Rodger et al. (ibid). Here, the focus lies in the different facets of embodied practice with guitar, but it is non-exclusive to performance settings (as it appears with the aforementioned ecological frameworks), thus encompassing more nuanced embodied activities, such as guitar building and modification—or in the specific case of this thesis, the ecology of performance preparation with guitar, i.e., ensemble rehearsals and individual instrumental practice.

It should be considered that there is a vast and ever-growing plethora of accessories, tools, resources, gizmos, gadgets, gimmicks, toys, software, services, add-ons and accompanying devices for guitars (among other physical, digital, tangible, and intangible artefacts). For example, one could consider the plectrum as an accessory that extends embodied guitar practice by facilitating string picking, thus allowing for particular techniques to be executed with it, such as sweep picking. This is also the case for other similar handheld accessories that have been invented for the guitar like the guitar slide or the E-bow.

Other tools are only meant to provide ancillary physical and cognitive support to guitarists, rather than being used in a performative sense. For example, although the clip-on guitar tuner does not serve any performative goal, it helps guitarists to tune the guitar (even in noisy environments) by harnessing the resonance of the body of the instrument. One may also consider the resources with which the musician prepares to perform such as YouTube videos, song books, handwritten lead sheets, personal notes, and scores (Masu, 2021), as part of the guitar ecology. Bespoke devices have also been created with this use case in mind, such as the Tascam CDGT (Figure 8), which was a Compact Disc (CD) player/audio interface/DSP unit that could slow down and loop audio tracks from a CD to facilitate their instrumental transcription, as well as add effects to a guitar signal. Several existing audio (and non-audio) technologies may also be used for this purpose, such as digital audio workstations, drum machines, loop pedals, mobile applications (Yousician), and metronomes, respectively. Bespoke software (e.g., Guitar Pro and MuseScore), services (e.g., Soundslice and TrueFire), and online communities (e.g., Ultimate Guitar) also play a part in this preparation ecology.

Figure 8. TASCAM CD GT-1.

2.3 Performance Preparation Practices with Guitar

The ubiquity of the guitar has made it an interesting and emergent subject across several fields of social study, such as ethnomusicology and ethnography, which consider the role of and relevance of the instrument in human activities (Dawe, 2013, 2017). Kevin Dawe (2017) notes that despite of the guitar’s social and cultural significance it has received little attention in the field of ethnomusicology, although the existing body of research in this area is rich.

Similarly, Lucy Green points out that there is a small but well-established body of literature on the social practices of popular musicians (Green, 2017). Other studies on the various activities of popular musicians address their music making and production activities (Benford et al., 2012; McGarry et al., 2017; McGrath et al., 2016; McGrath & Love, 2017), their participation in online communities and the impact that such spaces have on their music learning and practice (Green, 2017; Waldron, 2013b), as well as on the distribution and promotion of their music (Hoare et al., 2014; Hracs, 2012; Tolmie et al., 2013).

Analysing such phenomenologically situated interactions between people and digital technologies (Harrison et al., 2007) by observing them 'in the wild' (Chamberlain & Crabtree, 2020; Crabtree et al., 2013) can inform and motivate innovative design concepts and guidelines which take these 'real-life' findings into account (O'Hara & Brown, 2006) and potentially contribute to their subsequent adoption and sustained use (Hoare et al., 2014; Marquez-Borbon & Martinez Avila, 2018). Nonetheless, there is an absence of work that address the informal music learning practices of popular musicians and how these findings could be applied to music technology design

Hence, this project seeks to contribute to the body of ethnographic research on the individual and collaborative activities of popular musicians—especially those that are supported by technology—and expand current research on their informal learning practices and formation of communities of practice (CoPs). Further on, opportunities for design shall be explored in terms of technologically enhancing the interaction between the performer and their instrument (in this case, the guitar, or the bass) as well as with other musicians, considering how their collaborative practices may be supported.

2.3.1 Musicians Preparing to Perform

As previously mentioned, one of the aims of this thesis is to observe guitarists preparing to perform to inform the design of embodied interactions with guitar. However, given that there is a vast range of guitar traditions (Bennett & Dawe, 2020), and arguably, there are different embodied practices and ecologies in each of these traditions, the scope here is narrowed to the preparation activities of guitarists who may be considered "popular musicians" or "working musicians", as those were the kind of musicians that were mostly observed during the data collection in this thesis (see Chapter 4). There are many definitions of both terms, but here I draw upon Faulkner and Becker's (2009), Green's (2017), and Waldron's (2007) descriptions.

Faulkner and Becker (2009) describe working musicians as proficient performers who are skilled in a variety of styles and that perform at different sorts of venues (e.g., bars and dance clubs) and events (e.g., weddings and parties) for a living. Their definition emerges from their observational and participatory accounts of Jazz musicians who possess vast music repertoires and the ability to improvise or learn music in the spot by following the cues of other musicians in the group (ibid). Green (2017) describes popular musicians as performers of vernacular music (in this case, Western traditions from the US and the UK, which were the majority of those who she interviewed), who generally are self-taught and also learn by watching and imitating other musicians from recordings, from live events or from their peer groups.

Like Faulkner and Becker (2009), and Green (2017), Waldron also makes emphasis in the informal learning aspects of music preparation, such as copying music by ear (i.e., transcribing music with the instrument) and supporting preparation with online resources such as forums and online communities, mostly providing examples of the Irish Tradition (Waldron, 2007, 2013b). In this thesis, the focus lies on both working musicians and popular musicians who are proficient in popular music styles who are proficient and perform publicly in live venues on a regular basis, and hence are constantly learning and practicing new musical material.

Similarly, Benford et al. (2012), conducted an ethnographic study of 'Irish sessions' in which they observed how Irish folk musicians would spontaneously gather at pubs to play and improvise around traditional tunes on the spot, using supporting materials like notebooks, but avoiding sheet music or mobile devices to do so. However, the authors report that nevertheless, these musicians would in fact use online resources to support their practice and learning of Irish repertoire, but not would use them in the gatherings to keep the setting "traditional"—the authors also unpack design implications for supporting traditional music making, based on this situated discretion (ibid).

Repertoire learning is reported as an essential activity by working musicians and popular musicians by multiple authors (Ahmed et al., 2012; Benford et al., 2012; Faulkner & Becker, 2009; Green, 2017; McGrath et al., 2016), who detail how these musicians dedicate extensive amounts of time towards building and maintaining an evolving collection of performance material. Likewise, a musician's personal repertoire accounts for their musical proficiency and experience and it also facilitates performance with other musicians who share similar repertoires (Faulkner & Becker, 2009).

2.3.2 Informal Music Learning Practices

As previously mentioned, both popular musicians and working musicians often engage in informal music learning practices. As opposed to "formal learning", which is considered to be mostly prescribed in the classical tradition and a set curriculum (Green, 2017), popular music is often learnt in a more vernacular and oral manner (ibid). Nonetheless, all musicians alike spend significant amounts of time practicing with their instrument and rehearsing repertoire in ensembles (if they are part of one), as well as maintaining said repertoire (Faulkner & Becker, 2009). Green (2017) also assessed a series of informal music practices generally associated with playing popular music. She noted a reliance on music notation resources such as lead sheets and chord charts, as well as a widespread tendency to learn songs by listening and copying from recordings (i.e., "learning by ear") or by observing other musicians, as is also the case in other music communities such as traditional Irish music (Benford et al., 2012; Waldron, 2013b). Green (2017) also reports how musicians informally learn from each other during rehearsals.

To build a repertoire, guitarists should be sufficiently skilled to be able to reproduce songs in their primary instrument. To do so, they generally rely in skills such as reading and writing some sort of musical notation (e.g., tablature or lead sheets), listening, and playing along to recordings, or watching how other performer plays the song (in video or in person) (Avila, Greenhalgh, et al., 2019; Avila, Hazzard, et al., 2019; Faulkner & Becker, 2009; Green, 2017; Waldron, 2013a). In addition, they should also be able discern and memorise the structure of the song (e.g., chord progressions and harmonies) and be able to apply these abilities in performance (Green, 2017).

For instance, it is common for Irish music performers to gather in pubs with their instruments and play music in spontaneous 'Irish sessions' with other fellow musicians, joining in and out as the music is being played, by either listening and recalling the tunes from memory or learning them and playing them by "ear" in the spot (Benford et al., 2012). In other words, to be able participate in a session, Irish folk musicians must be able to play a tune sufficiently enough to avoid an inadequate performance (Benford et al., 2012; Faulkner & Becker, 2009).

In this context, however, it is not strictly necessary for performers to be able to produce exact copies of the traditional tunes but rather to be able to loosely imitate and adapt their improvisation to the stylistic components (Benford et al., 2012; Green, 2017).

Regarding learning songs by ear, Green (2017) proposes distinct levels of listening to music in terms of analytical effort, namely:

- **Purposive listening:** Paying attention to structural details of a song with the purpose of learning and putting them to use (i.e., a performance).
- **Attentive listening:** Listening to a song with the same attention to detail as with purposive learning but without any direct purpose (e.g., musical appreciation).
- **Distracted listening:** Not making any conscious effort to discern the structure of a song beyond simple enjoyment.

In these regards, the individual repertoire of each musician may consist of songs they know at various levels of detail, ranging from knowing the underlying harmonies or certain sections of a song (Faulkner & Becker, 2009), to knowing minute details such as the specific notes within melodies, as well as the timbral, textural and rhythmic qualities of the original recording (Green, 2017). Being able to play with other musicians, involves applying such skills into collaborative practices, for instance, rehearsing a list of songs together or jamming. Such collective activities usually involve some form of peer-directed learning (when one of the members of the band explicitly teaches something to his or her bandmates), or group learning (when learning within the band occurs implicitly as a consequence of the interactions between bandmates) (ibid). For instance, Jazz musicians can perform for extensive periods of time—sometimes without previous acquaintance or rehearsal with fellow performers—by means of combining their individual repertoires based on their shared repertoires, as well as their ability to improvise over songs by means of listening and adaptive playing (Faulkner & Becker, 2009). This latter process is also supported by making use of resources such as "fake books" (such as the Real Book[9] (Figure 9), which frequently offer a reservoir of songs written as lead sheets for performers to read and improvise along with.

[9] *The Real Book—Volume I*. Hal Leonard Corporation.

Figure 9. A page from the Real Book.

However, although a band rehearsal may be regarded as an organised activity with the collective aim of practicing songs, they could also be considered as a space for group creativity, e.g., free improvisation, jamming sessions, or collaborative composing. According to Green (2017), free improvisation may be differentiated from jamming as the former is much less structured, it occurs with limited 'pre-agreed components' and is modulated by subtle interactions between the performers (eye contact, or physical gestures) whereas jamming is improvisation based upon well-known harmonic and rhythmic patterns (e.g., 12-bar blues progression) which can be easily modulated (occasional chord substitutions and variations) without prior verbal agreement. Green argues that jamming is a key social convention and practice of popular music making, which allows groups of musicians to easily make music on the spot, even when unacquainted, sometimes leading to the formation of new bands (ibid).

2.3.3 The Role of Digital Technology in Supporting the Preparation Process

Besides using written resources (e.g., lead sheets or tablature) and audio recordings to learn songs and expand their repertoire, musicians nowadays also make extensive use of the Internet to search for such materials, as well as for more specialized content that provides them with explanations and demonstrations of how a song might be performed (Burns et al., 2017; Waldron, 2013b). They may find this information through audio-visual materials online such as YouTube videos (Burns et al., 2017; Waldron, 2013a). These videos may vary in their degree of information provided ranging from presenting the song in its original format—usually through the artist's video channel—to full-fledged lessons where each section of the song is explained and demonstrated in detail, in some cases even providing notation (Figure 10).

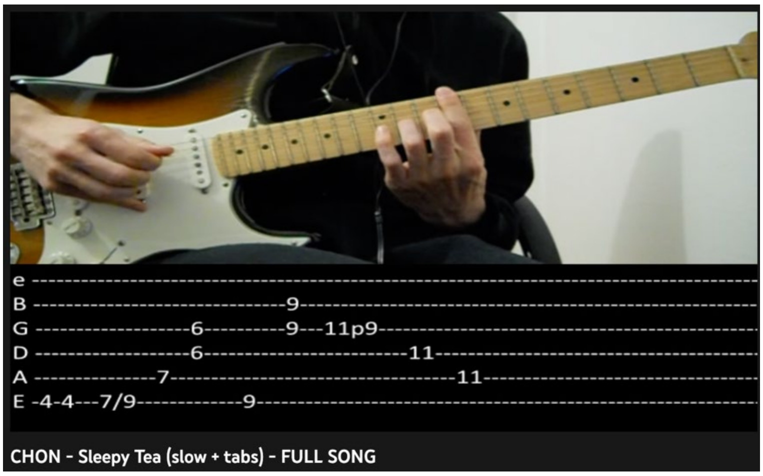


Figure 10. YouTube video tutorial by Nikola Gugoski.

Waldron aptly applies the term 'pedagogical syncretism' to describe how popular musicians make use of diverse kinds of resources (e.g., notation and YouTube videos) and learning modes (aural, visual and peer learning) and then merge them, resulting in a unique approach to vernacular music learning (Waldron, 2013b). Likewise, Faulkner and Becker (2009). point out that the ways these resources are nowadays distributed through the Internet allow contemporary musicians to listen and learn what they want, no longer depending on what music radio stations choose to broadcast, meaning that they can either choose to specialize in one or two genres of music or to have incredibly versatile repertoires.

In addition to being able to individually prepare by merging multiple audio-visual resources from the Internet, musicians also make use of online communities and social media to engage in discussion of musical topics with peers and are also able to ask them for evaluation and feedback on their individual performance (Burns et al., 2017; Hoare et al., 2014b; Waldron, 2009, 2013c).

In a series of ethnographic (and cyber-ethnographic) studies Waldron (2013b) examined how online communities formed around folk music genres, such as Bluegrass, Irish Traditional and Old-Time music, allowed for informal music learning to happen through social participation as described by Wenger's Communities of Practice theory (Wenger, 1999).

Moreover, other authors have pointed out the access to the knowledge, expertise, and support of like-minded individuals in a shared domain of interest among the benefits of joining an online community (Hoare et al., 2014; Kollock, 1998). For example, Ultimate Guitar[10] is a heavily UGC-driven online community, where its members have crowdsourced an extensive archive of tablatures and chord charts for guitar and bass—as well as drums and ukulele—over the years. Users of this website can access to multiple media formats of the same piece of music, ranging from tablatures represented in ASCII format (Figure 11), to interactive scores that facilitate key transposition, play MIDI sounds, and display multiple tracks corresponding to each instrument that is played in the song (similar to tablature editor software, Guitar Pro), as well as backing tracks and video lessons (often hosted in YouTube).

Moreover, some of these files offer supporting information about the song such as its key, tuning of the instrument, capo position (if there is one), strumming pattern, and even the level of difficulty of playing the song. Likewise, the forums on the website allow for users to further discuss details of the songs, such as alternative chord voicings, phrasings, or instrumentations. The emergence of such 'participatory culture' (Jenkins, 2009) involved in established online communities like YouTube and Ultimate Guitar evidences the need—for actively performing guitarists and bassists—to have more in-depth information and different representations (audio, video, and notation) about the songs they attempt to learn to expand their repertoires, as well as a space to share and discuss ideas between peers in and across bands (Chamberlain et al., 2015; Green, 2017; Hoare et al., 2014).

[10] https://www.ultimate-guitar.com/

```
E7sus4/B   Em7   Em7/A   D6    E7    D     Bm    D/F#  D9    Gm/D  A7/D  Gm11  A13
e|---0-----0-----0-----2-----0-----2-----2-----x-----5-----3-----0-----1-----2--
B|---3-----3-----3-----0-----3-----3-----3-----3-----5-----3-----2-----1-----2--
G|---2-----0-----0-----2-----1-----2-----4-----2-----5-----3-----0-----3-----0--
D|---x-----2-----2-----0-----2-----0-----4-----0-----0-----0-----0-----x-----2--
A|---2-----2-----0-----x-----2-----x-----2-----x-----x-----x-----x-----0-----0--
E|---x-----0-----x-----x-----0-----x-----x-----x-----x-----x-----x-----3-----x--
```

Figure 11. Tablature in ASCII format.

Digital technologies can also be employed to intervene and support the music learning and instrumental practice process. In this regard, Percival et al., (2007) and Burns et al., (2017) have identified that the in the absence of a teacher, the novice student may lack the ability to critically self-analyse their performance, and thus the student's individual practice time in-between lessons that could potentially benefit from technological intervention. In this sense, computer-assistance, in the form of automatic music transcription, note segmentation, pitch estimation and data visualisation, may be considered useful to help students judge their own performance. This approach, however, often aims to scaffold certain operational aspects of individual practice of novice musicians, such as technical exercises, which are often tedious and repetitive, and which may lead to frustration when playing the instrument (Percival et al., 2007).

Thus, some of these CAMITs rely on "gamification" (Deterding et al., 2011), i.e., adopting aspects of games (or in this case, videogames) to make an interactive experience more engaging—in this case, learning a musical instrument. A notable commercial example of a CAMIT that employs gamification to make the learning experience more appealing is Yousician (Figure 12). However, it should also be considered that while gamifying learning experiences can extrinsically stimulate motivation and engagement in the learner (Denis & Jouvelot, 2005) it can also result in vitiated learning habits, such as degenerate strategies[11].

[11] What is Degenerate Strategy? - Definition from Techopedia (www.techopedia.com). Retrieved 10 June 2022, from http://www.techopedia.com/definition/27042/degenerate-strategy

Figure 12. The Yousician Application.

Some CAMITs that have emerged from academia have also employed the online community model to develop music learning systems that support cooperative and self-learning environments (Burns et al., 2017; Ng & Nesi, 2008). For example, the “i-Maestro” project (K. Ng & Nesi, 2008), sought to provide a computer-assisted music-learning environment where students could connect with teachers and other students remotely. Moreover, this system also provided a series of tools for both providing and receiving feedback through notational systems augmented with interactive visualisations of sound and physical gesture, as well as gestural analysis of instrument performance with the support of sensors and computer vision.

Similarly, the “Novaxe” project (Burns et al., 2017) proposes an augmented notation system for guitar learning in-between lessons or self-learning, which aimed to cater for the multiple types of notations frequently used by guitarists (e.g., tablature, lead sheets, and chord sheets). With such system, the authors aim to build an online community of learners and teachers by providing a platform where scores may be imported, curated, and edited by its users. As a way of physically integrating learning experiences into the guitar, some manufacturers have developed ways for the guitar to interface with learning resources. For instance, Yousician listens to the instrument’s input through the mobile device’s microphone (as described in their advertisement). In the other hand, the aforementioned Fret Zealot uses LED strips that synchronously light up with a mobile application, thus showing finger positions of scales, chords or songs interactively (Figure 13 [Left]).

Other guitar concepts, like the gTar have built in mobile phone docks to insert the device into and synchronise an application with LEDs on the frets of the guitar (Figure 13 [Centre]). This design feature can also be observed in other instruments like the LUMI keyboard, which has been commercially successful in recent years (Figure 13 [Right]).

Figure 13. Fret Zealot, gTar, and LUMI.

Although these approaches are remarkable examples of how performance preparation can benefit from technological intervention, the majority approach the design process from a technologically deterministic standpoint, where the technology is developed with the expectation that guitarists will adopt it and integrate it into their existing practices and ecologies. In contrast, as previously mentioned, one of the aims of this thesis is to approach the design process in the opposite direction, by directly observing and enquiring musicians on their individual and collaborative activities.

This design approach has proven to offer significant insights in mapping out of people's organisational workflows (Ahmed et al., 2012; Chamberlain & Crabtree, 2016; McGarry et al., 2017), characterising their methods and roles of action (Booth & Gurevich, 2012; Green, 2017), the interrelationship between their individual and collective activities (Borgo, 2012; Schiavio et al., 2019), as well as informing the design of systems that are sensible to the needs of their intended users (Benford et al., 2016; Heinz & O'Modhrain, 2010; McGrath & Love, 2017).

2.4 Embodied Music Practices

In this thesis, embodied interactions with guitars are explored from both an embodied interaction perspective (Dourish, 2004b) and its outlook on interactions with music, namely, embodied musical interaction (Lesaffre et al., 2017; Tanaka, 2019). More specifically, this thesis focuses on embodied practices with guitar happening during performance preparation.

Firstly, one should consider that guitars are complex physical artefacts for making music, which require skilful twohanded use, and fine dexterity. However, when an artefact is integrated into a complex ecology of physical and digital tools and resources, complex embodied phenomena also emerge from the interplay between artefacts (Jung et al., 2008; Vyas & Dix, 2007), such as multitasking (Janssen et al., 2015), multi-object manual operations (Oulasvirta & Bergstrom-Lehtovirta, 2011), interruptions (Borst et al., 2015; Janssen et al., 2015), and encumbrances (Ng et al., 2014).

In the case of performance preparation with guitar, there are multiple artefacts that come into play besides the instrument, such as the resources that guitarists may use to support their practice—e.g., a music stands to prop their lead sheets or song books, or a computer to play media from, like YouTube videos or audio tracks—as well tools and devices, like metronomes, tuners, amplifiers, guitar pedals, and computers. Thus, as in other artefact ecologies, embodied phenomena are also expected to emerge during guitar performance preparation—especially when the guitar demands skilled manual operation, but so do other activities involved in the preparation activities, such as navigating media materials using a computer mouse or a keyboard.

2.4.1 Embodied Interaction

In HCI, there are different perspectives on embodied and bodily interactions. For instance, in his 1990s seminal work *“Where the Action Is”,* Paul Dourish (2004b) articulates the concept of embodied interaction as he speculates about tangible interactions through ecologies of physical computing artefacts which are orchestrated by social interactions. To ground his notion of embodied interaction, Dourish dissects the works of multiple phenomenological philosophers, such as Husserl, Merleau-Ponty, among others (ibid). For instance, he draws on Heidegger to ponder whether an interface is the principal object of attention or whether it becomes transparent during an interaction (Tanaka, 2019). Akin to this latter notion, Mark Weiser and John Seely Brown (1997) speculated about a “calm” technology paradigm, where interactions with computers would happen without constantly demanding the attention of the user. Like Dourish, Weiser (1991) also proposes an ecology of interconnected computing devices in the workplace, coining the concept of ubiquitous computing.

Alternatively, Don Ihde (1990) proposes a post-phenomenological view of the interrelations between humans, technologies, and the world. Ihde proposes four kinds of relations with technology (and physical artefacts alike), namely, embodiment, hermeneutic, alterity and background relations. From Ihde's perspective, Weiser's calm computing would be defined as "background" relations with technology, e.g., receiving a mobile phone notification signals the presence of computing happening in the background but does require direct engagement from the user. In turn, an embodiment relationship, i.e., a so-called unity between humans and technology directed at the world would be aptly represented by Dawe's (2017) description of musical instruments, i.e., tools that offer melodic, harmonic, and rhythmic resources not directly through the human body.

Following this perspective, Magnusson (2009) argues that in contrast to acoustic instruments' embodiment relations, DMIs afford hermeneutic relations instead—i.e., when a technology or tool is used to interpret information about the world (e.g., a metal detector)—especially when they are operated through more symbolic means—such as when "live coding"[12] (Knotts, 2020; Magnusson, 2014). Building upon Ihde's post-phenomenological work, Peter-Paul Verbeek (2015) proposes a theory of technological mediation in which he unpacks additional aspects of human-technology relations. As mediations with the world, these human-technology relations can be analysed in terms of extensions of humans, dialectics, or a hybrid of the latter two. As extensions, technologies are thus regarded as tools or instruments that facilitate or enable practices and experiences—as would be the case with musical instruments.

Another bodily aspect that Verbeek proposes for these relations are "contact points" between humans and technological artefacts. Latching on Dorrestijn's (2014) framework to categorize these contact points, Verbeek (2015) proposes that humans encounter technologies physically (i.e., bodily encounters with artefacts) and cognitively (i.e., interpreting the information these artefacts provide).

In the other hand, Kristina Höök advocates for a *non-dualistic* (Höök et al., 2021) view on technology design, proposing the soma design paradigm and method (Höök, 2018). In essence, soma design is grounded on Richard Shusterman's (2012) pragmatic philosophy of "somaesthetics"—a portmanteau of "soma" (a non-dualistic entity comprising of the body,

[12] "Live coding is an algorithmic performance practice at the intersection of generative art and laptop performance. Performances involve the programmer writing and editing programming code to produce creative outputs including music, visuals, and dance"

the mind, the self, and its emotions) and aesthetics, as in the practical ability to appreciate the world through human perception and engage with it (ibid). Thus, soma design encourages designers to hone their somaesthetic appreciation skills and sensibilities by engaging in bodily activities such as *Feldenkrais* (1972). By doing so, the designer is expected to gain tacit knowledge of a felt experience or harness their somatic connoisseurship of an existing experience (or somatically facilitate or communicate it to others) (Schiphorst, 2011) and combine these sensibilities with technological meta-materials (Windlin et al., 2019) to creatively orchestrate and design the interaction with technology, as well as shape the somaesthetics of the "interaction gestalt" (Lim et al., 2007).

Furthermore, Höök argues that Dourish's concept of embodiment (Dourish, 2004b) does not fully account for the physical body, nor did it provide any notions of aesthetic experiences as an ideal that designers could strive to design for (Höök, 2018). Lastly, one of Höök's most striking arguments is that human action cannot ever be disembodied, thus it does not make sense to propose embodied interaction as a specific subset of IxD (ibid).

2.4.2 Embodied Musical Interaction

As previously mentioned, due to musical instruments artefactual nature, there are also many phenomenological accounts of instrumental performance. For example, in *"The Ways of the Hand"* David Sudnow (2001) provides an auto-ethnographic account on his learning process of Jazz piano improvisation, in which he carefully describes the embodied process of positioning his fingers to make shapes and "grab places" on the keyboard to play chords, along with descriptions of the tactile, auditory, visual and proprioceptive qualities of this process, and how these become unconscious over time, as he improves (ibid). Similarly, in his work *"Thinking through the Cello",* Tim Ingold (2019), describes his sensations when playing the cello as "becoming" his playing, feeling the instrument resonate and his body actuating it (e.g., the pressure of the bow against the strings) in an act of correspondence between instrument and performer.

Employing this sort of phenomenological accounts of embodied experiences as a resource for design, Kristina Andersen (Andersen & Gibson, 2017) draws on the experiences of cello playing and electroacoustic composition to co-design an augmented cello through a series of *embodied ideation* (Wilde et al., 2017) and prototyping exercises. Remarkably, Andersen & Gibson (2017) focus on enabling sustained periods of flow and concentration in the experience of playing music, as well as intuitive modes of expression with augmented instruments, rather than on usability or efficiency issues—something that is similar to the augmentation aims with guitar in this thesis.

Holland et al. (2013) propose the study of Music Interaction, which draws upon principles of HCI but also proposes its own agenda as an independent field. In Music Interaction research, the human body, its motions, and its relationship with musical instruments have been extensively studied as resources for design. Like Verbeek's (2015) appraisal of technologies as extensions of humans, Luc Nijs (2017). quotes on performers' experiences of performing with their instrument perceiving them as an extension of their bodies. As previously mentioned, Magnusson (2009) calls to attention that this embodied relationship with traditional musical instrument is characterised by the sensory correspondence afforded by the instrument such as its resonance and vibrations. With this latter notion in mind, there have been attempts to imbue DMIs with this "acoustic feel" through haptic feedback via vibrotactile actuators (Marshall & Wanderley, 2011). Likewise, Otso Lähdeoja (2008) also proposes the notion of contact points to highlight the convergencies between musical instruments and performative gestures resulting in sound production, e.g., the hands strumming the strings or fretting the frets of the guitar.

Drawing on Dourish's embodied interaction ideas, Atau Tanaka (2019) puts forward the notion of embodied musical interactions proposing that people may establish bodily relations with music through instrumental performance and other embodied sonic experiences, such as mapping bodily gestures to expressive sonic output through motion capture (Han & Gold, 2014; Trail et al., 2012), using IMUs (Brown et al., 2018) or sonifying the body's bioelectrical signals to make music (Jensenius et al., 2017; Tanaka & Donnarumma, 2019).

Furthermore, motion capture is also employed to analyse the gestures of musicians during performance, leading to multiple classifications of "musical gestures" (Jensenius & Wanderley, 2010). In turn, these classifications have influenced the design of DMIs, such the harnessing of ancillary gestures—i.e., gestures that are not directly involved in producing sound during performance but that are close to performance gestures—to control expressive aspects of the guitar whilst minimising interruptions to performance (Lähdeoja, 2008; Morreale et al., 2019).

I draw upon Höök's soma design principles to inform the design of DMIs, harnessing performers' subjective bodily experiences and sensations during instrumental performance as a resource for design (Avila et al., 2020). Along with this work only a few other works have considered somaesthetics as a design framework for DMIs (Bomba & Dahlstedt, 2019; Hattwick et al., 2014; Magnusson & Mendieta, 2007; Tanaka & Donnarumma, 2019). In this light, guitar playing is an embodied practice which involves bodily movements upon and around the instrument, which are tightly interwoven with dexterity, musicality, and emotional expression, which are honed with years of physical practice and performance.

These movements range from the intricately complex and coordinated motions of the hands when playing the guitar to the expressive and communicative motions of the body when performing music with the instrument, as well as the so-called ancillary gestures (Lähdeoja et al., 2009) often involved in using peripheral devices during performance, such as pedals and computers. Arguably, experienced guitarists develop a sense of "correspondence" with their guitars, becoming one with the instrument as they perform, as well as a somatic connoisseurship of their instrument—e.g., its material, its resonance, and its feel.

2.5 Positioning of the Thesis

The literature reviewed here covers aspects of DMI and AMI design, observing how instrument augmentation can lead to innovations, especially in the case of guitars (Avila, Hazzard, et al., 2019). It is also noted that guitars are immersed in very extensive ecology of artefacts which is non-exclusive to physical and tangible accessories that can be attached to the guitar or peripherals that can interface with it, but also to intangible and digital artefacts, such as bespoke software and online resources and services. Interactions with this artefact ecology are observed through performance preparation practices with guitars and other instruments, particularly in the form of informal music learning practices, such as when Irish Folk musicians gather at pubs to improvise over Irish tunes with the support of specific printed resources (Benford et al., 2012) or when Rock musicians learn music from the vast plethora of resources available online (Waldron, 2013b).

Moreover, phenomenological accounts of musical instrument performance are also addressed, reporting on the sensorial and bodily experiences of playing the cello (Ingold, 2019; Nijs, 2017) and learning to improvise on the piano (Sudnow, 2001). Some authors have harnessed these sorts of accounts to inform the design of augmented musical instruments (Andersen & Gibson, 2017). From a DMI design point of view, some of these bodily gestures have been observed and analysed to inform the design of new sonic expressions (Lähdeoja, 2008; Morreale et al., 2019) and the bodily sensations felt with acoustic instruments have also been considered when designing instruments that take this embodied relation into account (Hattwick et al., 2014). Parts of the literature addressed here can also be positioned in terms of Kevin Dawe's proposition of the "guitarscape" (Dawe, 2017), i.e., the body of research related to the guitar phenomenon (including fields such as cultural studies, musicology, ethnography, among others).

As described by Dawe, the guitarscape is comprised of much of the landscapes proposed on Appadurai's model of global cultural flows (Appadurai, 1990), as well as other 'scapes' proposed by other authors and himself (e.g., the "sensescape"). This thesis, however, only focuses on certain elements of the guitarscape (Figure 14), namely:

- **The Ethnoscape.** In this context, it refers to how the Internet has facilitated the formation of a global online community of guitarists (and musicians in general), as well as the sharing and distribution of guitar-related resources, obtaining and providing feedback from and to the community, and contacting musicians to form groups (locally and globally), among other activities that involve the flow of guitarists across boundaries.
- **The Sensescape.** According to Dawe (2017), this relates to the use of the body in guitar performance, the sensual culture of the guitar (e.g., its 'feel' and 'touch'), and the general discussion on the body, the senses, and the mind relating to the guitar.
- **The Technoscape.** Here we focus on the flow of technology related with guitar, namely, the technological tools, resources, artefacts, and services that exist for guitars. In this thesis, we address both academic and commercial spheres of guitar innovation and the different guitar ecosystems that these technologies permeate.
- **The Mediascape.** In this case it refers to the dissemination of guitar-related information both in digital and physical formats. Thus, the guitar mediascape is not limited to the corpus of guitar-based music. It also encompasses information that ranges from musical notation for guitars (i.e., tablature), tutorial videos and interactive scores, to articles comparing guitar pickups, and guides on how to build guitars, to name a few examples.

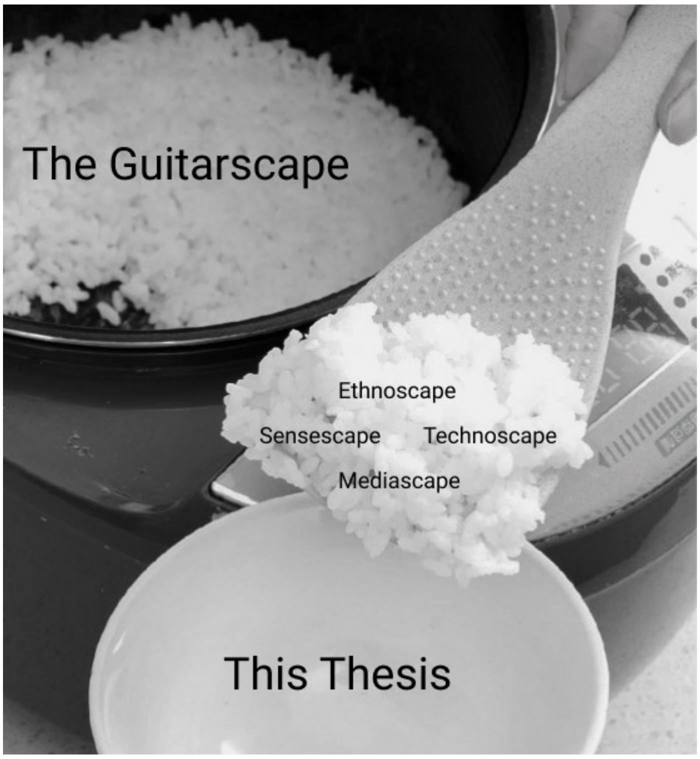


Figure 14. Positioning of this thesis.

However, it should be noted that this thesis does not attempt to provide a comprehensive cross-disciplinary overview of these areas but instead draw from their perspectives to inform the understanding and design of embodied interactions for guitars. Though embodied musical interaction is a prominent area of research within the study of music interaction, there are seldom any studies that consider the internal subjective experience of musical instrument playing as a resource for DMI design. Moreover, the majority of DMI and AMI designs that do take the body into account during the design process, generally place the focus on the sensor inputs, the gestural mappings, and the sonic outputs rather than the subjective bodily experience, based on somatic appreciation (Avila et al., 2020).

Although there are indeed works that harness the phenomenological accounts of musicians' experiences of instrumental performance to guide the augmentation of musical instruments (Andersen & Gibson, 2017) to enhance their sonic and expressive capabilities, there are seldom any studies that observe the existing preparation practices to inform the augmentation of musical instruments, nor the design of augmented guitars, in particular.

In the following chapter I present an overview of the methods employed in my thesis, namely, (1) the ethnographic methods which were employed to observe and analyse the performance preparation practices of guitarists and chart their artefact ecologies, (2) the participatory design methods that were utilised to gather feedback from guitarists on the design elements of guitar-specific technologies as well as their design input to support their instrumental practice activities, (3) the embodied ideation methods that informed the design of prototypes that considered the embodied experience of playing guitar, and lastly, (4) the evaluation methods used to evaluate the resulting research prototype that emerged from the design implications of the studies that preceded it.

Chapter 3
Methodology

3.1 Introduction

In this chapter, an overview of human-centred design processes is presented to introduce the methods employed in this thesis. The UK's Design Council "Double Diamond of Design[13]" (Figure 15), is presented as a reference framework to be compared with other design processes. Designer-oriented attitudes (Fallman, 2003) are also addressed to position my role as a designer in this particular design process. The designer's bodily perspective is also addressed from a soma design point of view (Höök et al., 2018).

Subsequently, each of the design methods employed in this thesis, namely, design ethnography, participatory design, soma design and user-centred evaluation methods are introduced through historical and design practice overviews, and their specific techniques and considerations of each method are also addressed. In this thesis, a user-centred (or human-centred) approach of IxD (Sharp et al., 2019) is employed, where a series of methods commonly used in HCI research are combined throughout the course of four studies, namely, an ethnographic study (Chapter 4), a participatory design study (Chapter 5), a soma design study and a subsequent user evaluation study (Chapter 6).

It should also be noted that due to the nature of the human-centred design methodology employed in this thesis, all of protocols of the studies conducted here had to be approved by the University of Nottingham's School of Computer Science ethics committee prior to collecting any data from the musicians' who participated in them. In addition, to collect data from a participant, they had to provide their informed consent after being presented with an information sheet detailing the objectives of each study and signing a consent form and a privacy notice explaining the use, storage, anonymisation and protection of their data. Although IxD processes can vary depending on the specific approach undertaken, they generally entail an iterative process where design ideas are constantly generated and developed. One way of visualising this process is with the Double Diamond of Design framework which consists of four stages, namely, Discover, Define, Develop and Deliver:

[13] https://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond

- **Discover.** Gathering insight about a problem to design for.
- **Define.** Narrowing the scope of the design problem.
- **Develop.** Developing solutions to a problem.
- **Deliver.** Producing a final product.

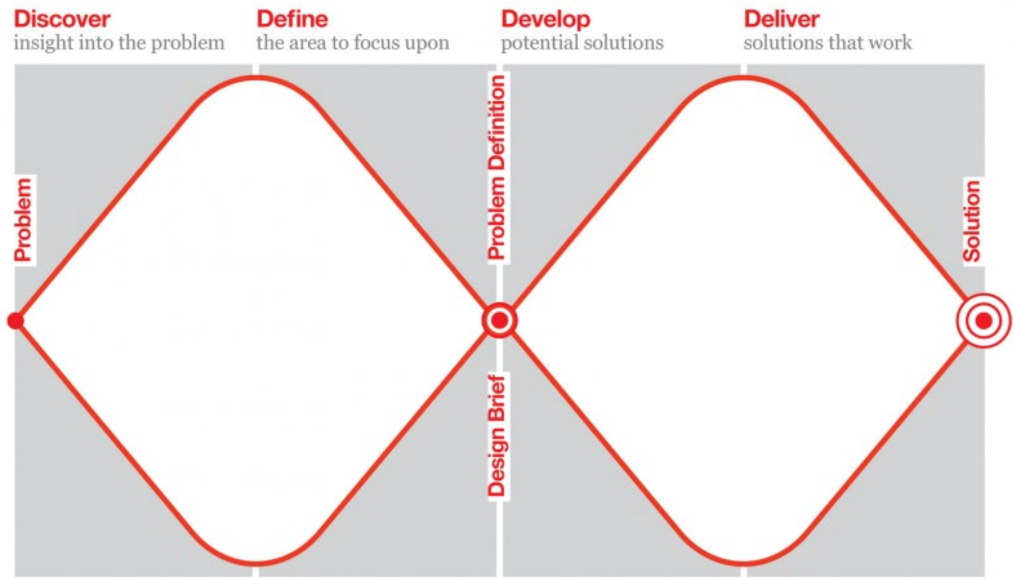


Figure 15. Double Diamond of Design.

However, not all IxD processes begin with problematization, nor do they all end with solutions (Blythe et al., 2016). Using the Double Diamond as a visual reference framework, some processes may begin with a problem then move to the development stage by creating a series of research prototypes to use as probes in order to go back to the discover stage and gather more insights about a particular problem (Gaver et al., 1999; Odom et al., 2016). Others may not begin with a problem at all, but rather with an exploration of a particular space—or aesthetic quality—and end in the development stage with a series of design experiments or "proto-experiences" (Höök et al., 2021; Svanæs & Solheim, 2016; Tsaknaki, 2021). Counterintuitively, others may actually employ ambiguity as a resource for the design process (Gaver et al., 2003).

In this regard, Daniel Fallman (2003) distinguishes between knowledge-generating design-oriented research and artefact-generating research-oriented design. Another remarkable aspect of the IxD process to consider that Fallman calls to attention is the design-oriented attitude of the designer during the process, and proposes three distinct designer accounts (Table 1), namely, the conservative, the pragmatic and the romantic, each with its own role for the designer, conceptualisation of the problem, aim of the product, methodological process, usage of terminology (knowledge employed and generated) and philosophical base (role model). Thus, from Fallman's point of view, the Double Diamond of Design process is conservative in nature, as its trajectory begins with the definition of a problem to be solved and then scoping its solution into a set of requirements for a product to be developed (ibid).

Table 1. Design-oriented designer accounts.

	Conservative Account	Pragmatic Account	Romantic Account
Designer	An information processor	A reflective, know-how bricoleur	A creative imaginative genius or artist
Problem	Ill-defined and unstructured; to be defined	Unique to the situation; to be set by the designer	Subordinate to the final product
Product	A result of the process	An outcome of the dialogue; integrated in the world	A functional piece of art
Process	A rational search process; fully transparent	A reflective conversation; a dialogue	Opaque; mystical
Knowledge	Guidelines; design methods; scientific laws	How each problem should be tackled; compound seeing; experience	Creativity; imagination; craft; drawing
Role model	Natural sciences; engineering; optimization theory	Bricolage; human sciences; sociology	Art; music; poetry drama

Table adapted from (Fallman, 2003).

Although the designer is—naturally—responsible for guiding the design process, a designer may also take different design stances according to their subjective bodily experience. Inspired by Merleau-Ponty (1979), Höök et al. (2021), propose a somatic approach to the designer role, distinguishing from first, second and third-person perspectives of the body while "being inside an experience". In this sense, a first-person perspective (Höök et al., 2018) entails the personal bodily experiences that an individual might feel and harness as input, e.g., turning muscle tension into sonic output (Tanaka, 2019); second-person perspective is being able to feel others' or transmit one's personal bodily experiences, through exercises such as kinaesthetic empathy (Françoise et al., 2017; Svanæs & Solheim, 2016); and a third-person perspective is to focus on the body as an "object in the world" (Svanæs & Barkhuus, 2020), e.g., "noting how one specific muscle acts as you are about to fall off the balance beam" (Höök et al., 2021). From a methodological standpoint, Petitmengin (2006) frames the second-person perspective as an interview method (Shear & Varela, 1999), that facilitates the gathering of first-person perspective insights to an interviewee who might not be able to consciously describe their subjective experience in detail.

3.2 Design Ethnography

In this thesis, an ethnomethodologically informed design ethnography approach (Crabtree et al., 2012) is adopted to gather field data, i.e., observing people's activities in their everyday environments, analysing them and writing up "thick descriptions" (Geertz, 2008) of their "taken for granted work practices" (Rogers, 2004). As its name implies, this methodological approach is based on ethnomethodology, a branch of sociology that was pioneered by Harold Garfinkel (2016). Likewise, other foundational aspects of this design method are derived from Harvey Sacks' "studies of work" (Sacks, 1992). However, its use in computing systems design was in fact pioneered by Lucy Suchman (1987) with her ground-breaking PhD work at Xerox PARC, resulting in "Plans and Situated Actions: The Problem of Human-Machine Communication".

Suchman's research was instrumental for HCI's "turn to the social", i.e., focusing on social activity rather than modelling interactions based on cognitive perspectives (Crabtree et al., 2012). Similarly, Johnathan Grudin's (1990) work was influential in observing how cognitive approaches did not take the real context of the users into account to date, this methodological approach is still widely employed in HCI and Computer-Supported Cooperative Work (CSCW) research and IxD.

Some notable works in music-oriented ethnography—as previously mentioned—are Sudnow's (2001) auto-ethnography of learning to improvise Jazz piano, Faulkner's and Becker's (2009) ethnography (and auto-ethnographies) of working musicians in the American Jazz scene Dawe's ethnomusicological and ethnographic works of the guitar phenomenon (Dawe, 2013, 2017), Green's (2017) ethnographic work on popular musicians' informal learning practices, as well as Georgina Born's (1995) ethnography of IRCAM's academic practices.

Within HCI and CSCW research with implications for music technology design, notable ethnographic works (or works that have implications for systems design) are Waldron's cyber-ethnographies of online communities of practicing musicians (Irish Folk and banjo players), exploring their use of UGC platforms such as YouTube and other specialised forums (Waldron, 2009, 2013b), Benford et al. (2012) study of Irish Folk musicians gathering to play sessions at pubs Ahmed et al. (2012) study of DJ's preparation work for live performances, Hoare et al. (2014), study of pro-amateur musicians producing and distributing their own music, McGarry et al. (2017) study of music producers' work practices and their use of metadata McGrath et al. studies of Grime artists' music production practices and usage of UGC platforms (McGrath et al., 2016; McGrath & Love, 2017), Chamberlain and Crabtree's (2016) studies of music social media (i.e., SoundCloud) and music acquisition and Booth's and Gurevich's (2012) ethnography of the Birmingham Laptop Ensemble.

3.2.1 Techniques and Considerations

Ethnographic work in this thesis was grounded in observational data collection, i.e., going to the places of practice of guitarists'—both at their individual home practice spaces and/or rehearsal spaces, accompanied by other musicians in their musical groups. Observations were captured using multimedia equipment such as video-cameras and audio recorders and were supported by note taking and photographing actions or supporting tools and resources used during the rehearsals (e.g., lead sheets).

Capturing this data is useful for assembling an ethnographic record of "vivid exhibits" which can then be operationalised by creating thick descriptions—i.e., an explication of how an activity is done—and consequently ethnographic vignettes that elaborate on particular phenomena observed, aided by photographs, quotes from the participants observed and detailed descriptions of their activities (Crabtree et al., 2012). Another technique that can be employed to unpack the sequential order of work using fieldnotes and other vivid exhibits is "horizontal and vertical slicing" (ibid), where these resources are used to map the sequential order of a practice divided into stages (horizontal axis), and the series of activities required to accomplish each stage (vertical axis), which lead to the completion of said practice (Figure 16).

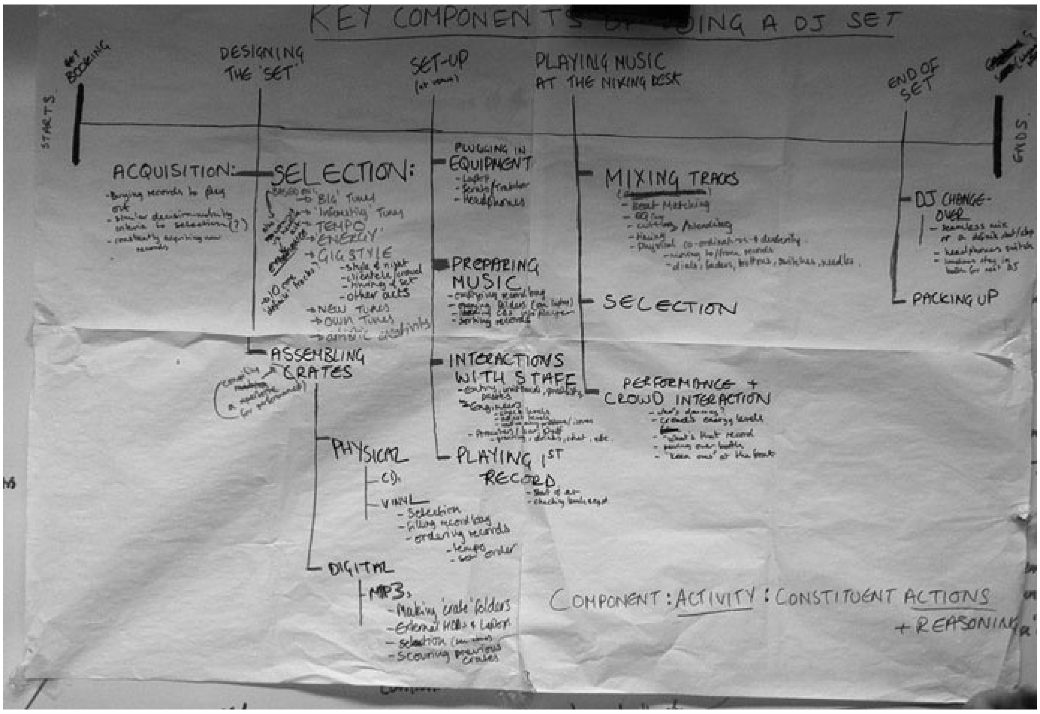


Figure 16. Horizontal and Vertical Slicing of a DJ's preparation of a set (Ahmed et al., 2012).

Observational data collection can also be supplemented with contextual enquiries—i.e., to ask people about their practices in their actual context where their activities happen (Holtzblatt et al., 2004)—as well as *a posteriori* (or *a priori*) semi-structured interviews, i.e., inquiring the participants about their practices outside of their places of practice loosely guided by a set of questions to conduct the interview in a conversational, interviewee-guided manner. Nonetheless, it should also be considered that the presence of an observer may invariably impact the ways that people conduct their practices, sometimes leading them to act differently as they would normally would when not being observed—i.e., the Hawthorne effect (Mayo, 2003).

To analyse ethnographic data different analytic techniques can be employed, such as thematic analysis (Braun & Clarke, 2006), which consists of coding data into patterns, emergent categories and themes (Saldaña, 2021) (see section 4.3), which can eventually lead to the construction of a grounded theory (Charmaz, 2006). Another technique is content analysis, which looks for various aspects of verbalisations and vivid exhibits, such as feelings, attitudes, artefacts and people, and the frequency with which particular themes or categories occur (Krippendorff, 2018). Similarly, sentiment analysis looks for emotional information within verbalisations (Sharp et al., 2019). Ultimately, unpacked ethnographic data can inform implications for design (Dourish, 2006), i.e., challenges and opportunities for technological intervention, as well as design rationales (Moran & Carroll, 2020), i.e., a justification for the decisions taken during a design process.

In this thesis, ethnographic methods were employed to collect ecologically valid data of guitarists preparing to perform, with a particular interest in observing their embodied practices with the guitar in the spaces where the action happens, as well as the tools, resources and artefacts they use to support them (Avila, Greenhalgh, et al., 2019). Thus, musicians were observed during performance preparation and interviewed on their practices. Observational data was then transcribed into thick descriptions and vivid exhibits. The resulting transcripts and accompanying images were then codified into themes and categories (Saldaña, 2021) and analysed using a thematic analysis approach (Braun & Clarke, 2006), which was supported by NVivo's transcript annotation tools (see Chapter 8). In Chapter 4 design implications derived from the ethnographic study are presented in Section 4.5.

3.3 Participatory Design

Participatory Design (PD) is an umbrella term that encompasses theory, techniques, methods, and design approaches that advocate for the active participation of end-users during the design process. Although most user-centred design (UCD) methods involve some level of input from users, what makes PD distinct from other methods is the higher decision-making agency and more direct creative involvement of the user (Simonsen, 2013), as well as the constant and iterative mutual learning between designer and user (Kensing & Madsen, 1992). Arguably, the nature of the users' participation should be genuine, i.e., not just token representation (Greenbaum & Kyng, 2020; Simonsen, 2013) and it is the responsibility of the designer to facilitate it (Lucero et al., 2012).

As detailed in Bjerknes et al. (1987) *"Computers and Democracy: A Scandinavian Challenge"* PD is rooted in cooperative design ideals, and has been cemented in major Scandinavian, British and North American research projects in the 70s and 80s (ibid) that, albeit each with their own cultural adaptations, were characterised by the close cooperation between workers and researchers in the understanding, decision-making, design, deployment, communication and democratisation of new technologies in the workplace. Nonetheless, cooperative design puts more emphasis in creating systems that support the cooperative nature of work which appears more akin to CSCW approaches.

In recent years, the term co-design has emerged as a synonym for PD. Sanders and Stappers (2008) argue that co-design is a novelty term currently used to describe what essentially has been referred to as PD over the last 50 years. They also propose that co-design can be considered as a specific instance of co-creation, i.e., broadly, any act of collective creativity. Thus, co-design specifically focuses on harnessing co-creation among designers and non-designers in the design process.

Furthermore, these authors differentiate UCD from PD based on the role of the user, wherein UCD the user is considered a passive subject that is either observed, interviewed, instructed to perform specific tasks or to evaluate product concepts generated by 'expert' designers; whereas PD considers users as partners who co-create and co-design with designers, and that participate in the generation of design ideas and in making design decisions.

In *"Designing with the User"* Suchman (1988) succinctly illustrates the essence of PD:

> *Our use of technology is, in large measure, the stuff of which our working lives are made; a resource with which we organize our relations to other people and through which we experience ourselves as powerful, competent, and productive human beings. The question is how, and by whom, should new technology be shaped. The answer, according to this book, is by those who will use it. As researchers and designers our job is to uncover,* ***with them****, the horizon of technological possibilities.*

We should note that although PD originated during a time when most industries were undergoing a process of 'computerization' (ibid), this design approach has evolved and matured over the years, extending beyond the workplace. Whether it is co-designing with autistic children (Spiel et al., 2016), coal miners (Bjerknes et al., 1987), or a community of guitarists, designers employing this approach generally seek to learn as much as possible about the users' points of view about their contexts, their organisational order, their activities, their internal politics and hierarchies and what they regard as important in each of these areas, and to teach the users how their contributions to the design process shape the technologies being made for them. In other words, the aim of co-design is to actively involve the users in the design process and harness their valuable domain knowledge to inform the design work that addresses them; thus, facilitating their participation is crucial for them to contribute productively to the process (Lucero et al., 2012).

Among some notable examples of music-oriented participatory design inspired research are Tanaka et al. (2019) co-design of a haptic-based audio editing device (the "Haptic Wave") with a group of visually impaired audio producers by collaborating with them over the course of two and a half years. To inform the initial stages of the design process the researchers prepared a haptic interface to enable the participants to 'feel' and subsequently discuss qualities of sound which are often presented in a visual medium, which then informed the second and final iteration of the prototype. The Haptic Wave was then used by six participants for five weeks, who then reported their experiences in a diary (ibid).

In another study, Newton and Marshall developed the "Augmentalist" toolkit to facilitate the process of prototyping and tinkering with sensor technology to musicians (Newton & Marshall, 2011). The toolkit simplified the process of mapping sensor input to audio output to enable a group of musicians without any experience of sensor technology (including guitarists and bassists, among others) to technologically intervene in their own instruments and allow the researchers to examine their design approaches (ibid).

Inspired by elements from the Magic Machines workshops outlined by Andersen and Wakkary (2019), Lepri and McPherson (2019) ran a series of workshops with musicians in which they were prompted to engage in *embodied making* processes to design and craft fictional musical instruments, with the aim of eliciting value-based design implications (Borning & Muller, 2012; Friedman, 1996) emerging from the instrumental concerns and musical values embodied in their low-fidelity hand-crafted instruments. In the field of ADMI design, Lucas et al., (2020) collaboratively designed a guitar-inspired instrument with a physically disabled musician and assessed his use for a period of two months.

3.3.1 Techniques and Considerations

In his presentation of the dialogue-labs method, Lucero et al. (2012) succinctly describes how different co-design techniques have been developed to tackle discrete stages of a design process, and how these can be combined within a design process (Figure 17).

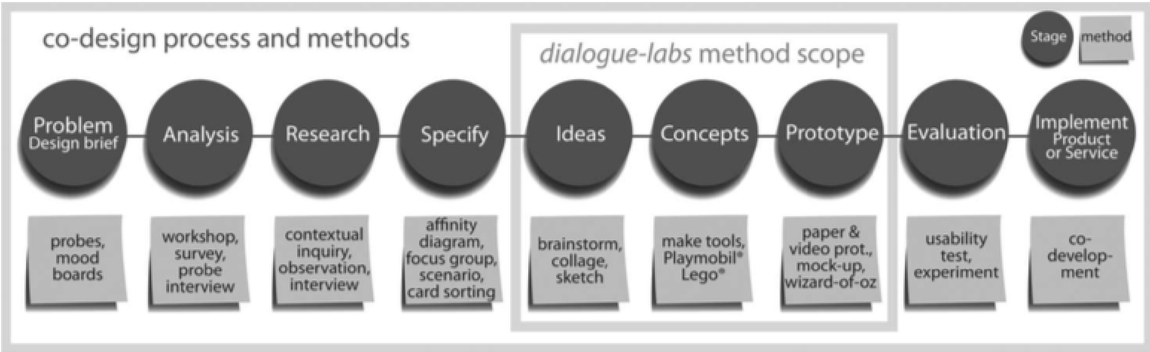


Figure 17. Stages and methods of a co-design process (Lucero et al., 2012).

Likewise, Dindler and Iversen (2007) dissect Johansson's "Staging, Evoking, and Enacting" framework (Johansson, 2005) into different design methods used for each stage of the design process where the "design situation, ideas for the future, and their consequences are negotiated" (Dindler & Iversen, 2007):

- **Staging.** This stage may involve ethnographic field data collection to produce accounts of people's current practices, or probe-based techniques (Gaver et al., 1999) which aim to explore particular contexts of practice which may not be accessible to observers.
- **Evoking.** This stage involves formulating possible futures deriving from existing practices (Johansson, 2005). For example, "Future Workshops" (Kensing & Madsen, 1992) can be considered an evoking method. In turn, these are divided into three phases:
    - **Critique Phase.** Drawing out specific issues of a current practice (e.g., brain-storming problems)
    - **Fantasy Phase.** Imagining potential interventions to the problem (e.g., sketching ideas)
    - **Implementation Phase.** Proposing ways of realistically achieving the interventions.

  "Generative Tools" (Sanders, 2000) may also be considered as an evoking technique, which consists of providing participants with toolkits, which feature predominantly visual and tangible components (as opposed to verbalisations), for people to express insights on their practices or ideas for future interventions (Figure 18).

- **Enacting.** This stage involves exploring design ideas through mock-ups and prototyping. Examples involve low-fidelity prototyping (Ehn & Kyng, 1991), and cooperative prototyping techniques (Bødker & Grønbæk, 1991).

Figure 18. Sander's Hospital Kit: An example of Generative Tools for staging, evoking and enacting design possibilities.

In this thesis, participatory-design-inspired and co-design techniques were employed to gather guitarists together to reflect on their embodied practices during performance preparation and to probe a series of research prototypes aimed at supporting them, with the aim of having guitarists critique, discuss and refine them (see Chapter 5).

3.4 Embodied Ideation Techniques

As previously mentioned, in Subsection 2.4.1 embodied interactions can be designed by taking the body and the subjective felt experiences of people into account as resources for design (Höök, 2018). As articulated by Wilde et al (2017), Embodied Design (ED) leverages these first-person perspectives (Höök et al., 2021) in the ideation, speculation, engagement, analysis, and embodied interaction design processes, and is grounded in phenomenology (Merleau-Ponty, 1979), pragmatic aesthetics (Shusterman, 2008), embodied cognition

(Varela et al., 2017), and embodied, embedded, and enacted mind principles (Clark, 1998; Gallagher, 2006; Kiverstein & Clark, 2009).

Thus, ED methods (Figure 19) can be remarkably diverse and idiosyncratic to the researcher-designers that develop them (Wilde et al., 2017), making it akin to a “romantic” approach to design (Fallman, 2003). Although all these methods place their focus in the body, they have different methodological approaches. For example, some designer-researchers ground their design techniques on Somaesthetics (Höök, 2018), while others draw upon methods from theatre and drama—e.g., techniques such as situated scenarios (Iacucci & Kuutti, 2002), “magic tools” (Brandt & Grunnet, 2000), as well as Schiphorst & Andersen's (2004) and Loke & Robertson's (2013) performance-based methods.

Figure 19. Participants enacting Tomico & Wilde's (2016) “Material Props in Context” ED Ideation method.

Furthermore, whilst there is a plethora of embodied ideation techniques, some notable techniques include kinaesthetic interaction (Fogtmann et al., 2008), “informance” (informative performance) (Buchenau & Suri, 2000; C. Burns et al., 1994), “embodied sketching” (Márquez Segura et al., 2016), and “bodystorming”. To build on these introspective activities, designers can also engage in active processes of bodily exploration which are supported by encounters with the tactile and kinaesthetic properties of materials (Höök et al., 2018) and technological encounters which may be enabled by mediating technological toolkits such as “soma bits” (Windlin et al., 2019).

In particular, such material encounters are enhanced by other grounded embodied ideation design practices, such as estrangement (Wilde et al., 2017), i.e., to turn familiar interactions upside-down, to “re-learn” how it is experienced, by questioning and deconstructing habitual movements and encompassing practices, in order to enable reflection on its tacit and intimate aspects (Bell et al., 2005; Koefoed Hansen & Kozel, 2007; Wilde, 2015), and potentially reveal new perspectives which may inform the embodied design process. Wilde et al., (2017) further explicate that estrangement relies on disrupting how a particular somatic experience is perceived. However, due to the tacit nature of these methods they argue that it is challenging to communicate and replicate them in a systematic manner, thus, they propose a framework aimed to facilitate the choice of methods based on their inherent values and outcomes. The framework per se, consists of four guiding concepts, namely:

- **Disrupt.** What physical or conceptual elements are added or taken away from the body or the action?
- **Destabilise.** What taken for granted interactions become conceptually or physically unstable through this disruption?
- **Emerge.** What is brought into awareness through this destabilisation?
- **Embody.** What interaction ideas or qualities become tangible or visible in the process?

Likewise, they provide a series of expected outcomes from embodied ideation methods, such as new material forms, new concepts, and new bodily behaviours. In this thesis, an opportunity emerged to engage in a soma design process, in which my first-person perspective as a guitarist was harnessed to develop more prototypes. In this process, embodied ideation techniques were employed to disrupt the habitual movements of guitarists during performance preparation with the aim of elicit alternative embodied interactions in this particular context of practice (see Subsection 6.3).

3.5 Evaluation Methods

Sharp et al. (2019) propose three categories for evaluation which vary depending on the setting of evaluation, involvement of the user and level of control of the researcher, namely:

- **Controlled settings directly involving users.** Users' activities are evaluated based on a series of hypotheses in a controlled laboratory setting, following an experimental protocol.
- **Natural settings directly involving users.** Users' activities are evaluated "in the wild" with minimum to no intervention from the researcher.

- **Any settings not involving users.** Users are not evaluated directly, though in some cases their input may be interpreted through a system's analytics. However, in many cases users are not involved in the process at all and instead consultants or researchers unpack usability aspects and problems of a system through interaction heuristics or models.

Furthermore, Sharp et al. (ibid) evaluate the pros and cons of each evaluation category, considering their ecological validity, i.e., how the setting in which an evaluation is conducted may influence its results. For example, modelling is quick but can miss unpredictability usability problems (thus having the lowest ecological validity). In turn, lab studies are good at revealing usability problems but poor at capturing the context of use, i.e., what happens in the "real world". In contrast, field studies have high ecological validity as they are good to observe users' activities in real settings (e.g., at participants' homes or public places).

Nonetheless, in the wild studies are time consuming (Rogers et al., 2013) and demanding in terms of the quality of the prototype to be deployed (Odom et al., 2016) or the input asked from participants. For example, data collection may rely on the participants recording and reflecting on how they use the product, by writing up their experiences in diaries, filling in online forms, and/or taking part in intermittent interviews. In some cases, to facilitate data collection, the context of use may be configured to record the users' activities in their natural setting, e.g., their homes (see the *Living Lab* method (Bergvall-Kareborn et al., 2009)).

In this thesis, after considering the observed practices of guitarists' as well as their verbal accounts on their activities and their existing ecologies, and the developed prototypes, a final prototype was developed which was then evaluated with guitarists in the context of performance preparation. In this thesis, evaluation methods with high ecological validity were prioritised. However, due to the impact of the COVID-19 pandemic, adaptions had to be made to the evaluation study design in compliance to the UK government's health regulations (see Section 6.5).

3.6 Summary

In this chapter, the methods employed in this thesis as well as examples of their specific techniques have been presented. An introductory overview of human-centred design processes is provided using the Double Diamond of Design as a base framework. Likewise, the distinct roles and perspectives that the designer can assume are also outlined. In this thesis, a pragmatic design approach (Fallman, 2003) is adopted, i.e., my role as a designer was to situate myself within guitarists' performance preparation spaces and consider their existing practices and the tools, resources and artefacts they use to support them in order to design artefacts to mediate with this existing ecology and iterate them as new meanings emerge from the iterative process of deploying the designs in the context of practice (Coyne & Snodgrass, 1991). Thus, this thesis uses a combination of methods to survey, chart and probe this ecology (Figure 20). Ultimately, in an ideal design process a product would be the expected outcome.

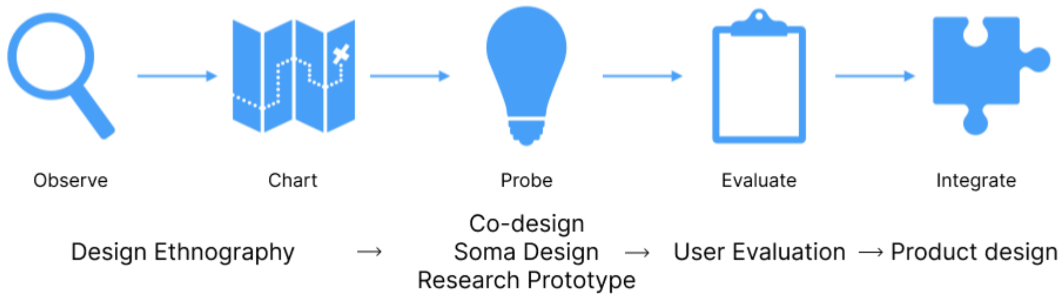


Figure 20. Design process in this thesis.

Chapter 4
A Study of Musicians Preparing to Perform

4.1 Overview and Recruitment

This chapter reports on an ethnographic fieldwork study with the principal aim of surveying guitarists' embodied performance preparation activities and the practicalities associated with the practice process by observing them while engaged in learning and practicing activities at home, or at rehearsal spaces with their bands, and enquiring them about how they accomplish these with the tools and resources involved in the process. For this study an ethnomethodologically inspired ethnographic approach to fieldwork was adopted, entailing data collection and qualitative analysis of field observations of participants' activities in their "everyday environments" (Crabtree et al., 2012).

Participants were recruited through close acquaintances and via a call for participation in social networking websites. Eventually, initial participants helped snowballing the study by inviting their acquaintances to participate. The recruitment criteria focused on participants over 18 years of age who played guitar or bass and that engaged in learning and practicing musical repertoire (i.e., original or 'cover' songs) individually or when rehearsing with a musical group on a regular basis. A total of 45 participants were recruited throughout the course of the fieldwork (Section 4.2).

There was a diverse range of musicians (i.e., guitarists, bassists, percussionists, vocalists, and multi-instrumentalists), performance traditions (e.g., Rock, Jazz, Doom Metal, Americana, Country, Pop, Soul, Funk, Reggae, and Folk, among others) and proficiency levels involved, ranging from proficient hobbyists to semi-professional and professional musicians who either performed original music, renditions of existing music or a combination of both at different kinds of venues (e.g., cafés, pubs, clubs, restaurants, etc.) and events (e.g., open mic or jam nights, festivals, birthday parties, weddings, and so on) as working musicians. They also performed in diverse types of ensembles (e.g., in tribute or function bands, or as soloists) and sometimes in multiple bands.

There were 10 participants in the study who identified as female and 31 who identified as male, and participants spanned an estimated age range of 19–64 years of age, where the average participant was above 30 years old.

4.2 Data Collection

Ethnographic fieldwork in this case specifically involved capturing observational data in the participants' normal practicing environment (i.e., home practicing spaces and rehearsal rooms), often supplemented with elements of contextual enquiry. Likewise, some participants took part in additional semi-structured interviews, which often took place outside of their contexts of practice, though not exclusively. The observational studies and interviews explored aspects of the guitarists' instrumental practices such as:

(1) Their experience and sustained practice with the instrument (e.g., how many years have they been playing the instrument, their training, their musical style, and their regular context of practice, i.e., alone or with others).
(2) Their individual and collaborative performance preparation processes (e.g., how often and for how long they practice, the objectives of the practice, i.e., improving technique or building and maintaining a repertoire).
(3) The tools and resources that accompany and support these processes (i.e., physical, and digital sources of musical material, such as books or the Internet; and physical and digital tools and materials, such as paper, metronomes, or specialised software).
(4) The practicalities and problems associated with these processes.

Audio and video recordings of these sessions were captured and subsequently reviewed, where key interactions, emerging patterns, themes, and accompanying verbalizations by participants, i.e., their comments and descriptions of their activities—as well as non-directed discussions amongst themselves (particularly during their group rehearsals).

In addition, field notes and pictures of relevant tools and resources were also captured, charted, and analysed in terms of interactional qualities whilst in use during embodied instrumental practicing activities, i.e., interacting with these tools and resources whilst having a guitar at hand.

The engagement of each participant throughout the study varied across each case, wherein some cases participants took part in all the data collection modalities of this study (i.e., individual interview, observation of their individual practice at home, and observation of rehearsal with their band), whilst in other cases they only took part in one or two of the modalities (see Table 2). Nonetheless, sufficient data was gathered in each of the data collection modalities in order to reach theoretical saturation (Flick, 2018).

The data collection was specifically focused on guitarists and bassists to collect a consistent corpus of rich observational and first-hand discussion data with a comparable group of instrumentalists practicing with remarkably similar chordophones. Nonetheless, as many of these musicians actively participated in group rehearsals with their wider ensembles, collaborative practices with other instrumentalists (e.g., percussionists and vocalists) were also observed and factored in the data collection and subsequent analysis (Section 4.3).

Table 2. Participants in the ethnographic study.

#	Interviews	Individual Practice	Group Rehearsal
1	P1 (Contextual)	P1 (+ Contextual Interview)	P1, P10, P28
2	P2	P2	P2, P29, P30
3	P3	P3	P4, P31, P32, P33, P34
4	P5	P5	P6, P35, P36
5	P7 (Contextual)	P7 (+ Contextual Interview)	P8, Px, Py, Pz
6	P8 (Contextual)	P8 (+ Contextual Interview)	P8, P37, Px
7	P9	P10 (+ Contextual Interview)	P9, P38
8	P11	P12 (+ Contextual Interview)	P11, P39, P40, P41
9	P13		P13, P42, P43, P44, P45
10	P14–P27		

Note: Participants involved in more than one data collection modality are highlighted in blue.

A total of 23 participants were interviewed, of which 14 exclusively participated in the interview modality of the study and not in observations of their individual practice or group rehearsal (P14–P27). Coincidentally, these 14 participants were interviewed outside of their context of practice (i.e., in the laboratory space, at local coffee shops, or remotely). The other 9 participants (P1, P2, P3, P5, P7, P8, P9, P11, and P13) were involved in interviews as well as in one or two of the other data collection modalities.

Some of these participants were contextually interviewed at their practicing space, followed by an observation of their individual practice (P1, P7, P8, P10, and P12) while others were preliminary interviewed outside of their practicing space and then scheduled for an observation of their practice or their rehearsal *in situ* (P2, P3, P5, P9, P11 and P13). A total of 8 individual practice sessions were observed. Many of these observations occurred at the participant's home practice spaces, except in two cases, where the practices took place in a practice room at the music faculty and a co-workspace (P7 and P8, respectively). A total of 9 band rehearsals were observed. Most band rehearsals occurred in rehearsal studio rooms, except in two cases, where the rehearsals took place at the participants' homes (P1, P10, and P28's trio, and P9, and P38's duo, respectively).

Prior to data collection, informed consent was obtained from each participant after they understood the purposes of the study, the use, storage, and eventual destruction of the data collected during their participation as well as their right to withdraw from the study at any time they wished to do so. For my safety during unaccompanied data collection outside of the University, measures had to be put in place to assess the risks regarding the location in which the interviews and observations were to take place, that is, whether the location to be visited was safe for both the participant and me, and any equipment I would bring along. Efforts were made to gather a diverse set of participants in consideration of multiculturality and gender parity, like reaching out to acquaintances in the UK's Mexican community and making special calls for participation aimed at women only.

4.3 Data Analysis

Prior to commencing the data analysis, it was necessary to prepare, organise and collate the data. Although most data were captured through interviews (n = 23), priority was given to those cases that were conducted in the context of practice (i.e., contextual interviews) or followed by an *in-situ* observation of practice. The underlying rationale of this prioritisation was the aim of gathering ecologically valid data in accordance with the premise of the ethnographic study's methodology. Nonetheless, to this effect, interviews served as an entry point to subsequent observational studies, allowing participants to build trust and familiarity with the aims of the study.

Hence, for purposes of data collation, non-contextual interviews that were not followed by an observation of preparation practices on site or that did not draw elements from the context of practice into the interview (e.g., bringing rehearsal materials to the interview for demonstration, as in the case of P14) were excluded from the data analysis (i.e., P15–P27). In the case of field data gathered from rehearsal observations, only 8 of the 9 sessions were considered in the analysis as consent for data collection could not be obtained from Py and Pz (see Table 2: Group Rehearsal, row 5). Likewise, I excluded myself (Px) from this data set.

Subsequently, audio and video data from observational studies were transcribed and analysed using an ethnographic approach by producing thick descriptions of the different activities of guitarists during individual practice and collaborative rehearsal. Then, as described by Crabtree et al. (2012) a series of *'vignettes'* were assembled to:

> *"(…) elaborate particular actions and interactions by combining small pieces of these descriptions of work and transcriptions of talk with photographs and other images to elaborate the setting, its work and organisation."*

From this point on in this chapter, the term vignette is employed as described by Crabtree in the statement above (ibid) and is used in reference to the illustration of observable actions and interactions underlying the preparation activities of guitarists. The curation of these vignettes was guided by the following items of analytical interest:

- The set-up and configuration of the practice/rehearsal environment.
- The use of support tools and resources (both digital and analogue).
- The preparation activities undertaken, supported by these tools and resources.
- Comments and responses to contextual enquiries.
- Socio-technical interactions amongst participants.
- Any other behaviours or events of interest.

Several observable distinct preparation activities emerged from this analysis. To succinctly report on the corpus of findings, a series of vignettes which most vividly illustrate each particular activity are presented in a summative manner. The vignettes are arranged in two parts, namely, (1) Individual Practice Activities, and (2) Collaborative Rehearsal Activities. While some of the vignettes elaborate on the description of activities in more detail, other vignettes more broadly highlight the occurrence of similar instances of an activity across the corpus of observations.

4.4 Findings

Each of the following vignettes illustrate specific aspects of individual and collaborative performance preparation by describing the activities of each participant (Table 3). To present the vignettes, a series of participant profiles are laid out to characterise the enaction of these activities (Table 4), by providing a brief description of the participant's experience with the instrument, their performance practices, and the preparation activities they were undertaking during the observational session.

Table 3. Ethnographic vignettes.

Individual Practice Activities	
Vignettes	Participants
Configuring the Space	Mike (P1), Paco (P3), Kelly (P5)
Sourcing and Auditing Resources	Mike (P1), Paco (P3), Victor (P7), Talos (P8), Arnie (P12)
Creating and Updating of Resources	Mike (P1), Troy (P2), Cindy (P14)
Fine-grained Preparation with Resources	Mike (P1), Paco (P3), Arnie (P12)
Archiving Resources	Mike (P1), Kelly (P5), Ivan (P9), Finn (P10)
Collaborative Rehearsal Activities	
Vignettes	Participants
Collective Decision-Making & Pre-rehearsal Preparation	Mike (P1), Kit (P11), Janice (P13)
Configuring the Space for Rehearsal	Troy (P2), Kit (P11), Janice (P13)
Paper Resources in Use	Mike (P1), Troy (P2), Kit (P11), Janice (P13)
Digital Resources in Use	Lila (P4), Kit (P11), Janice (P13)
Directing	Lila (P4), Kit (P11)

Direct quotes from the participant are also included when relevant, along with pictures of their activities and contexts of practice. For anonymity and legibility each participant has been assigned with a pseudonym.

Table 4. Participant profiles.

Name	Gender	Musical training	Primary instrument	Years playing	# Of bands	Band types	Musical styles
Mike	Male	Self-taught	Bass	~50	4	Function, Original	Rock, Jazz, Folk
Troy	Male	Self-taught	Bass	~30	1	Original	Folk, Rock, Prog
Paco	Male	Self-taught	Guitar	9	Solo	Covers	Blues, Rock
Lila	Female	N/A	Drums	N/A	1	Covers	Rock, Heavy Metal
Kelly	Female	Self-taught	Guitar	~30	Solo	Covers	Folk, Classical
Victor	Male	Classically trained	Guitar	4	Solo	Covers	Blues, Alternative
Talos	Male	Self-taught	Guitar	~10	Solo	Covers, Original	Rock, Metal
Ivan	Male	Self-taught	Guitar	~30	1	Covers, Original	Folk, Americana, Country
Finn	Male	Self-taught	Guitar	~30	1	Original	Blues, Americana, Folk, Country
Kit	Male	Self-taught	Guitar	43	2	Function, Covers, Original	Pop, Rock, Motown, Rock, Punk
Arnie	Male	Self-taught	Bass	22	1	Function	Alternative Rock, Funk
Janice	Female	Self-taught	Vocals	N/A	2	Tribute band	Rock, Pop
Cindy	Female	Self-taught	Bass	13	5	Covers	Hard, Classic and Glam Rock, Blues

4.4.1 Individual Practice Activities

The following vignettes describe performance preparation activities that were undertaken by musicians individually, i.e., in isolation from their band, and usually at home. Thus, the activities illustrated here reflect personal approaches to practice space configuration, and working through musical material supported by practicing resources, as well as their respective sourcing, auditioning, creation, updating and archival.

4.4.1.1 Configuring the Space

Mike performs his instrumental practice in an attic room in his home which is used as a general utility, office, and practice room (Figure 21). In the room there is a desktop computer set on a small desk along with a printer, blank sheets of paper, pencils and pens, and a wheeled office chair with no arm rests (not pictured).

Figure 21. Mike's home practicing set-up.

Next to the desk Mike has conveniently positioned his bass on a stand along with a small practice amplifier at its side, both within easy reach of his siting space within the desk area. The amplifier (to which is the bass is connected), is observed leaning back against a filing cabinet, also positioning the speaker controls within direct line of Mike's reach when sitting at the desk.

Similarly, **Paco** undertakes his instrumental practice sitting in an office chair at a desk in his bedroom, where he has placed a laptop computer along with blank sheets of paper and lead sheets with rudimentary instrumental exercises and reference information (e.g., the chord degrees in all twelve keys of the major scale), a portable guitar amplifier on top of the desk, to which he has connected his electric guitar to, and a wireless Bluetooth speaker synchronised to his laptop. When practicing with acoustic guitar he did not make use of the practice amplifier.

Conversely, **Kelly** did not use neither a computer nor an amplifier for her practice at any moment nor did she perform her instrumental practice in front of a desk. Instead, she positioned a small foot stool in front of a couch in her living room, where she sat during her acoustic guitar practice (Figure 22).

Figure 22. Kelly's home practicing set-up.

She also laid out a series of notebooks and diaries on top of her couch along with a couple of capos, a digital clip-on guitar tuner, and a small tube containing a fret and guitar string cleaning cloth and lubricant brush, allowing her to easily reach back for these tools and resources when needed, such as when tuning her instrument, changing musical keys (facilitated by the capo), quickly looking through her notes (i.e., lyrics, set list of songs, etc.), and when wrapping up her practice and cleaning up her guitar's fretboard and strings. To the right of her sitting stool, she also positioned a guitar stand on which she had her guitar within close reach.

4.4.1.2 Sourcing and Auditioning Resources

Mike's instrumental practice session began with him sitting down at his desk with his bass in traditional fashion (i.e., in a seated position, with the instrument against the body and resting on top of the legs). He started by reaching for his desktop computer's mouse to open his browser and then typing in YouTube's URL to search for a new song he was midway through learning for an upcoming concert, of which he still needed to learn the bass solo part:

"So, this is something I am already done a little bit of work on for the covers bands. So, it's just really getting confident with it. I've listened to this a few times. I've done some previous work on this one. There's a bass solo in the middle which I have not really learned. So, I'll play to that point and then have a listen"

When he found the official video of the song 'Smooth Operator' by Sade, he then proceeded to play along with the song coordinated with the bass parts. Subsequently, when the song arrived at the bass solo part, he stopped playing along to attentively listen to the audio and copy the notes in detail with his instrument, i.e., learning the material by 'ear' (this process of fine-grained preparation is described with more detail in section 4.4.1.4).

After a few cycles of listening and copying the notes, Mike drew the process to a halt, stating that instructional videos can be quite useful in these situations, upon which he proceeded to search for one of such videos on YouTube (YT) once again. His search resulted in sourcing and viewing a tutorial video that displayed a close-up view of a bass player's hands performing the song with music notation and tablature underneath, which were synchronized with the music being played:

"Here's a really good one which actually has the music [i.e., notation]. These are very helpful".

Mike then continued to learn and practice the bass solo along to this video (Figure 23).

Figure 23. Mike practicing a bass solo along with a tutorial video on YouTube.

Mike also described how in certain occasions his band would need to adapt the music to suit the singer's vocal range, so he would search for interactive musical notation resources, such as 'chord charts' that had an automatic 'transpose function', which allowed him to easily shift the chords to different tonal keys (Figure 24):

"So, these are the original chords: it's in 'D'… 'D minor', but there's a transpose function, so if we need to play the song in, say… 'C', we drop it down two semitones,

and there we've got the chords in a different key so that's quite useful, that's very useful in fact"

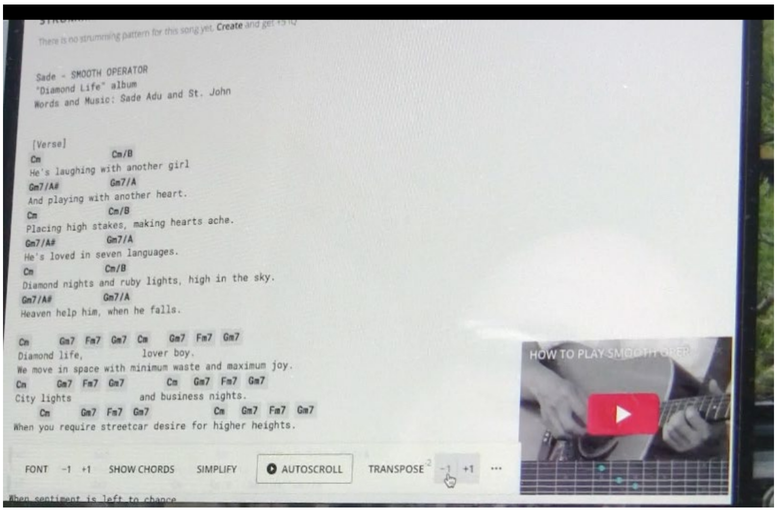


Figure 24. Using the transpose function in Ultimate Guitar.

However, although Mike mentioned the transpose function was useful, he also discussed how he still needed to spend a significant amount of time re-learning the song to adapt to a new key, and then described how it would also be useful to be able to do this with audio so he could play along the new version in a different key:

"(…) But then if you want to play along, you can't do that because the original song on YouTube or the record or the CD it's not in this key now. So that's when it would be good to transpose an entire song and listen to it in a different key. Which again you could do with Logic or Pro Tools or any other recording software. (…) But, you know, a lot of that software is really expensive. So, for me it wouldn't be worth investing that money in expensive sampling software, so I just have to put the hours in and do it manually"

Similarly, **Paco's** instrumental practice session commenced with him sitting down at his desk with his guitar held in traditional fashion. He also started off by doing an online search for cover versions of a song he wanted to learn for an upcoming open mic, using his laptop computer. Likewise, he navigated to the YT website and typed the title of the song he was looking for into the search bar.

To coordinate this activity while holding his instrument Paco would momentarily take both hands off the guitar while resting his right upper arm on top of the body of guitar reaching over to type on the laptop (Figure 25 [Left]). He then grasped the computer mouse to navigate the search results, choose a full band cover version of the song, open it in a separate browser tab and then start the video's playback. While listening to the recording Paco opened a separate tab and started looking for the chords and the lyrics of the song in the Ultimate Guitar (UG) website. He then turned back to the YT video, closed it, and said:

> *"This cover is good, but it sounds too 'full'. So, I would search something that resembles how I am going to be playing it".*

Followed by a subsequent browsing for alternate versions of the video amongst the previous search results (see Figure 25 [Right]).

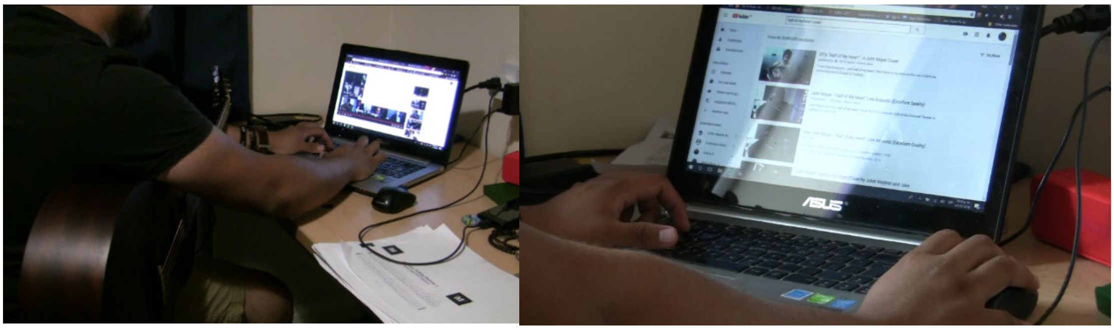


Figure 25. Paco searching and auditioning resources.

Throughout the process Paco continued to search and audition resources by playing and singing along with them, all while switching between being engaged with the instrument, navigating, and operating multiple resources on his laptop. In terms of his resource selection process, Paco paid attention in particular to the chord charts and lyrics that were rated higher by members of the UG community, though he would always check for consistency with the original material, as the content would vary across different versions. For example, in one instance, he noted that some of the chord symbols on a chord chart were not correctly positioned above of their corresponding lyrics:

> *"Something that happens a lot is that you see how chord changes are usually placed wrong, such as putting the chord changes a syllable before or a syllable after. So then when you start playing is when you realise that that is not how it goes."*

Paco then compared the UG chart with the music from the YT video, confirming his observations for points of error. Having made an assessment, he proceeded to play the song using the chart but with the adjustments he just had gleaned from the YT video. In contrast to Mike and Paco, **Victor** was not observed at his home practicing space. Instead, he was observed in a practice room in the music faculty where he set a portable guitar amplifier and his laptop on top of a high bench. He then strapped on his guitar and sat on the bench with his feet suspended on the air. His practice began by drawing out his mobile phone out of his pocket and browsing for two lists of songs he had previously written down in his notes, one containing songs that he already knew how to play, and another one with songs he wanted to learn:

> *"I've got a list of songs here that I do know. And songs that I have to learn. The last song I learnt was 'Money' by The Beatles"*

He then selected one of the songs from his 'to learn' list, 'Tighten Up' by the Black Keys, and then reached for his laptop computer to search for the guitar tablature on the UG website. To do this while sitting on top of the bench with his guitar on his lap he turned sideways to face the laptop and one-handedly typed the title of the song in the search bar of the website (Figure 26 [Left]). He then browsed the list of tablatures and selected one to practice with. Victor then started playing the guitar whilst reading from the tablature in his laptop screen. After a few attempts at reproducing the notated music in his instrument he then briefly said:

> *"OK, am I doing it right? Let me check. I have the song on my phone."*

And then once again drew his mobile phone out of his pocket to search and play the audio of the song from his music files, using both hands to hold and operate his phone. Victor then started the audio playback of the song and he put his phone to the side to listen to the music attentively to the parts of the song he wanted to play in his instrument. He then paused the audio and started playing some of the musical phrases he had just listened to, with his guitar. He then crossed his legs and rested his phone on the flat surface of his thigh while resting the guitar in his other thigh (Figure 26 [Right]). He then resumed the audio playback of the song and began to play along with his guitar.

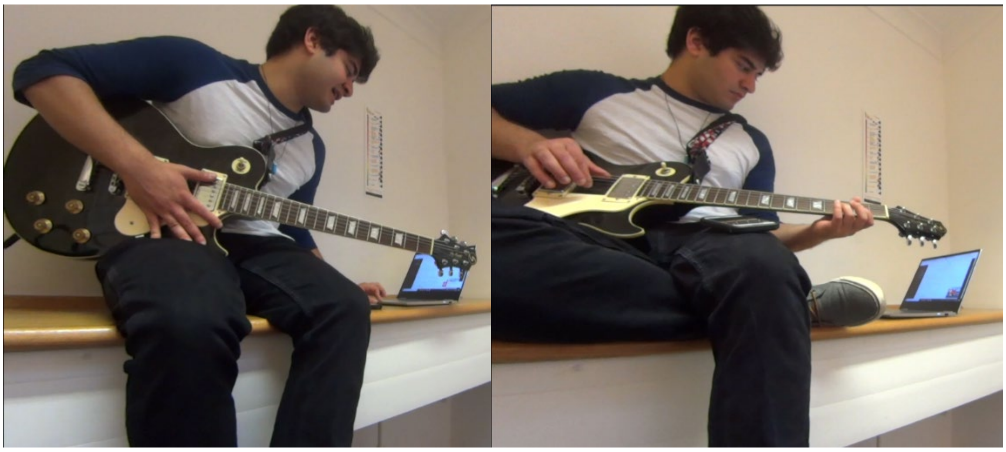


Figure 26. Victor searching for notated resources and playing to audio from his mobile phone.

Like Victor, **Talos** was also not observed in his home practicing space but rather a lounge space within a co-work office building where he would sometimes work until late at night. Talos explained that during the evenings the building was mostly empty, with a few people working after hours. He also mentioned that he would usually look for an empty lounge room to relax and play guitar during breaks. Talos commenced his practice by sitting on top of a cushioned area of the lounge and setting his laptop in front of him (Figure 27). He rested his acoustic guitar on his lap and against his body.

Like the other participants, he then opened a browser window, navigated to UG, and started searching for the tablatures of a song. Likewise, he auditioned the tablatures by reading, singing, and playing along with them. During the process, Talos would stop playing to clamp a guitar capo and occasionally re-adjust it to play the chords in a different key whilst also singing, as well as using UG's transpose function (see Figure 24), to find a suitable key for his vocal range.

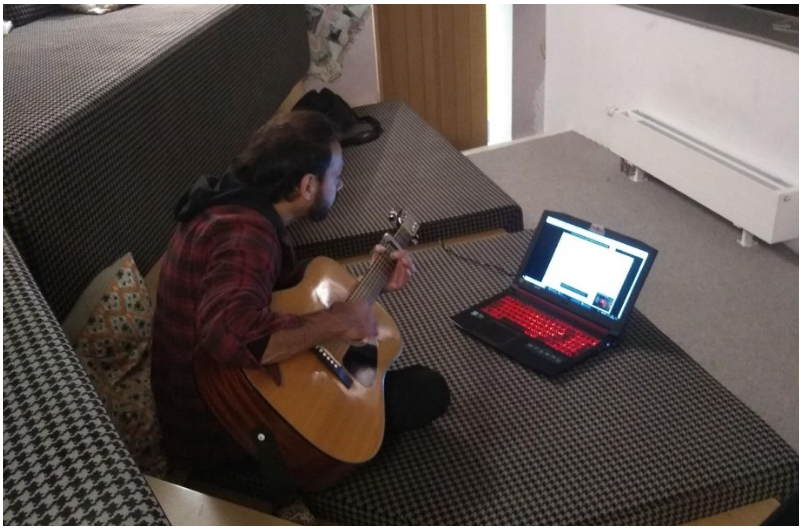


Figure 27. Talos playing along tablatures in UG.

After a few trials of adjusting the capo and transposing the chords in the tablature he then said:

> *"Yeah… Today I can sing it with the capo on the second fret. I'll make a note on my phone that today I have nailed it with the capo on the second fret."*

Talos then opened a separate tab in his browser, navigated to YT and searched for a tutorial of the song he was attempting to play. When he found and selected a video, he then started playback and started strumming the guitar strings along with the pattern being played by the

YT video instructor, but he did not fret the chords on the fretboard, focusing instead on the rhythm of his strumming hand, as he verbalized the strumming pattern:

"Down, down, down…"

When the video playback concluded Talos then proceeded to describe his resource sourcing and auditioning process in more detail by displaying the different online resources he would often go back to when practicing with his computer (Figure 28) as well as by providing anecdotal examples of previous engagements with them:

> *"If I couldn't find a song on UG, I'd go to Songsterr dot com. If I can't find a tutorial of someone doing it on YT, then UG or Chordify come quite handy. For example, [there was] a song by Chris Cornell I couldn't find a video of someone playing it on YouTube, so I went to UG. Still couldn't find it, so I went to Songsterr, and I found the chords, but I didn't know how to play it, so I had to go to Chordify to find the rhythm out and then play it. Songsterr will give you breakdowns -they will give you the bar- so for rhythm-based stuff is quite handy. So, before the change of chords, they will give you bar. In UG they won't give you that. It helps a lot with the changes."*

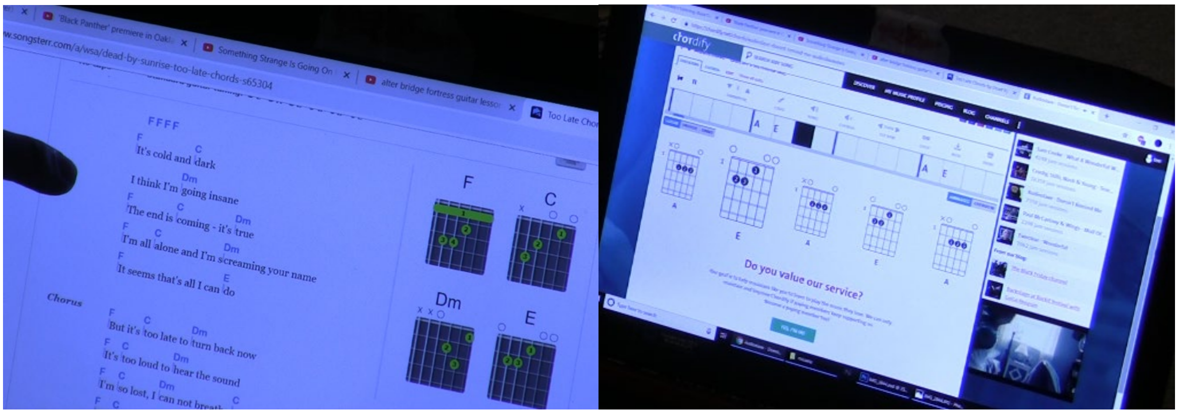


Figure 28. Talos displaying Songsterr and Chordify's interfaces.

> *"I use Chordify to get the rhythm out. It will show you the chord changes and when to change. And it shows the BPM. And it plays along the original, actually. To slow down the tempo you would have to buy it You can also order MIDI files [from Chordify] and see markers for song sections in Ableton Live. If everything else fails, I would go to Riff station… It is pretty much like Chordify but it's a paid app that you have to download. Unlike Chordify it will blur the next chord in the sequence."*

4.4.1.3 Creating and Updating of Resources

During **Mike's** practice session, he demonstrated how he would create a hand-written chord chart to support his practice process, by opening an audio file of an original song that a friend had sent to him via e-mail for him to practice for a subsequent rehearsal (see Section 4.4.2.1):

> *"So, this is an MP3 that the guitarist sent me this morning with some ideas [for a new song]. So, I have heard this before, but I've never tried to play along to it".*

As he was listening to the audio from that a friend had sent to him via e-mail he then said:

> *"So, I'll find the key first. I don't have the chords written out for this".*

He then proceeded to play along the audio for a few moments with his bass, and then he stopped the audio and said:

> *"So, what I would do with this one now is I would take it back to the very start and try just to write the chords".*

As he resumed the audio's playback and continued playing some the principal notes of the song with his bass, he then took off his right hand away from the instrument, reached for a sheet of scrap paper and moved his computer peripherals (keyboard and mouse) to the side to clear up some space to allow him to set the paper down on the desk.

As previously observed, he once again continued to one-handedly play his bass by fretting notes with his left hand, as he simultaneously reached for the computer mouse and held his right hand on top of it, allowing him to momentarily operate the media transport controls to cycle through short fragments of the audio recording, by pausing and moving play head back a few seconds in the audio's timeline (Figure 29 [Left]).

After a few attempts at playing the chord progression from the audio, Mike then moved his hand away from the mouse to grab a pen, and subsequently started writing down the chords of the progression on the piece of paper, whilst he continued to one-handled fret the notes in the bass with his left hand (Figure 29 [Right]).

Figure 29. Mike navigating a video and writing notation whilst playing one handed.

Once he noted the down the complete sequence of chords, he resumed playing the instrument with both hands and continued to rehearse the chord progression as he followed the chord chart he had just jotted down, whilst also listening to the song, to corroborate his transcription and adjust the sheet as necessary. He then said:

> *"So, then the next thing with this will be to actually rehearse together and make sure whatever I've thought in my head works with what the songwriter was thinking".*

In the case of **Troy**, by bringing his 'leads sheets' (i.e., sheets of paper containing varying levels of information depth and granularity, such as song titles and instrumental performance indications) to the interview, he demonstrated how he collaboratively iterated his personal musical ideas by involving his bandmates in the creative process. To narrate the process, he took out a handle of lead sheets from a folder and began to describe the iterative process of composing an original song with his band:

> *"So that's me on my own, writing the words 10 years ago or something (Figure 30 [Left]). Then I took it to a practice with Paul and John and we came up with that (Figure 30 [Centre]). And then, I went away and tidied it up (Figure 30 [Right])—this is a more methodical version of that (points to the previous sheet (Figure 30 [Centre]), that's just a jotting from a jam. So, I've come up with an idea, but we then jam that song, and it becomes this, from my original.*

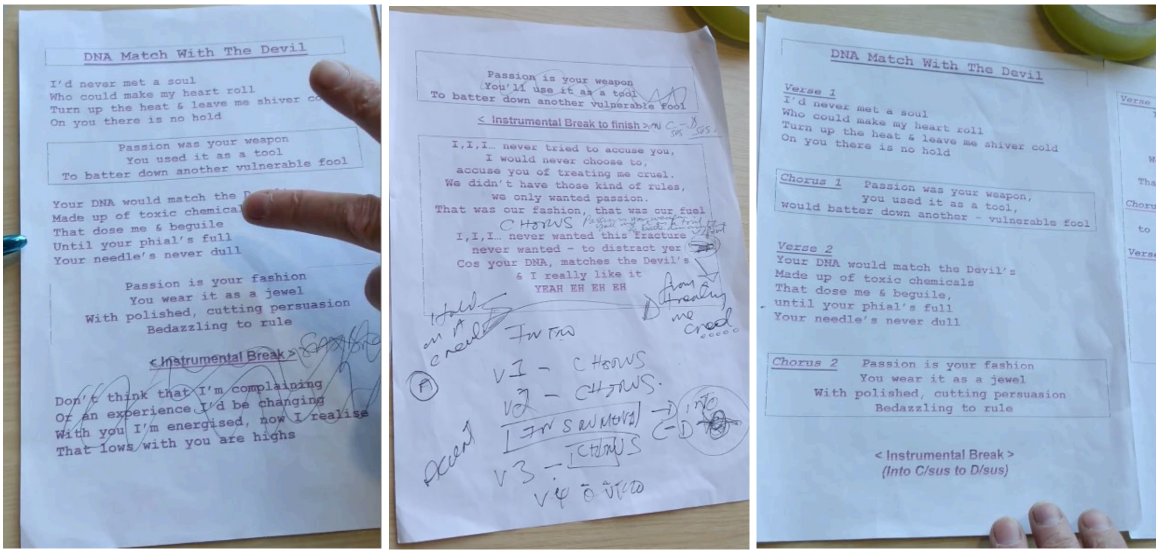


Figure 30. Troy's lead sheets demonstrating an iterative and collaborative composition process.

Similarly, **Cindy** demonstrated her use of word-processed and printed paper-based resources during an interview. In her case, she showed some of her lead sheets and set lists, i.e., sheets of paper with multiple titles of songs in the order they are meant to be performed during a live performance.

The amount of information she personally includes in her lead sheets illustrates how her needs change throughout her song-learning process. As described by Cindy, when initially approaching a new song, she generally includes much more in-depth scaffolding information to orient her practice and performance, e.g., section titles (chorus, solo, etc.), chords to be played (above the principal lyrics they were meant to be accompanying), number of measures, repeats, and diagonal lines next to each chord, indicating how many times each chord is meant to be played (Figure 31 [Left]).

As her familiarity with a song progresses, she consequently includes less indications in her lead sheets, e.g., only displaying the song titles and indicating the tonal key next to them, with occasional indications of sectional arrangements with corresponding repetitions (e.g., 'Verse Chorus x2'), but discarding chords and lyrics (Figure 31 [Centre]). At later stages, when she has become acquainted with the song's structure, her sheets only include the song titles indicating the order in which the songs are played throughout the show—as set lists (Figure 31 [Right]).

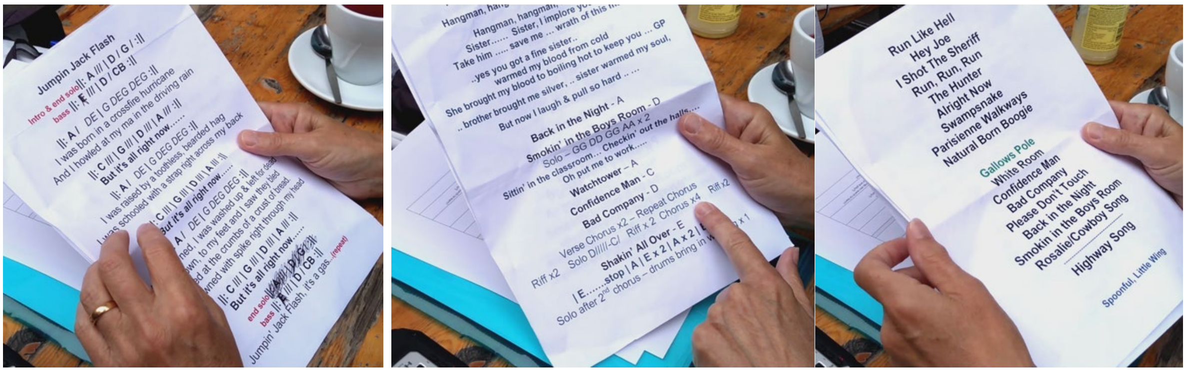


Figure 31. Cindy's lead sheets scaffolding her song-learning process.

4.4.1.4 Fine-grained Preparation

Mike's learning and practicing of intricate melodies with his bass—in this case, a bass solo—supported by interactive resources, highlighted physical challenges when working through a musical passage with the instrument while navigating the media playback of a YT video, by manually operating his computer's peripherals, i.e., keyboard and mouse:

> *"This is when it gets really annoying […]. The big problem with using a computer is having to manually rewind, fast forward, stop. […] What would be really good*

would be some way for me just to take that little piece and just keep cycling it. And I'm sure I could probably do it on GarageBand or something like that, but I've never really invested the time in trying to find out how to do that".

As Mike played along to a YT music video (Sade's 'Smooth Operator') at the beginning of his bass practice, he firstly recapped the parts of the song that he had previously learnt:

"So, I'm just making sure I've got the right chords, not the exact bass notes".

After playing for a few moments, he stopped plucking the strings of the bass, and took his right hand off the instrument to grab his computer mouse and adjust the video's volume. However, whilst making this adjustment Mike continued playing the principal notes of the song by tapping the strings on the fretboard with his left hand, allowing him to remain in synchronization with the song's rhythm and chord progression (Figure 32).

This hand switch over occurred over the span of a few seconds, and as soon as Mike made the volume adjustment, he swiftly returned his right hand to its original playing position, on top of the strings of the bass's body, to continue playing the instrument with both hands.

Figure 32. Mike operating a computer whilst having his bass at hand.

As previously mentioned, one of Mike's practice objectives was to learn the bass solo in the song. When the audio on the YT video reached the bass solo section, he stopped playing and began to attentively listen to the bass solo. What followed was a cyclic process of listening, attempting to mimic the notes by playing along to the audio with his bass, alternated with media navigation involving manual operation of his computer's peripherals with his right hand, i.e., stopping the playback, grabbing the mouse and positioning the cursor to the point in the timeline at the start of the section he was attempting to copy with the instrument, and resuming the audio playback to repeat the process. He would then proceed to do this for several rounds, progressively learning multiple isolated fragments of the solo in this fashion:

> *"What would be really good would be some way for me just to take that little piece and just keep cycling it. And I'm sure I could probably do it on GarageBand or something like that, but I've never really invested the time in trying to find out how to do that".*

At one point during this process, he accidentally started the media playback of a different YT video on the website. This meant having to abruptly stop his instrumental transcription process to fully focus on the computer to navigate back to the previous video and browsing once again for the fragment in the song he was previously practicing along to. During the entire process, his gaze would frequently switch between his left hand, monitoring his hand placement on the bass's fretboard and his computer screen focusing on the media playback on the video.

Another aspect of the practice that was observed was Mike's assessment of how much accuracy he had to achieve when transcribing the solo in his bass. In this case, Mike stated that some prominent parts of a song—such as this particular bass solo—would require a high-fidelity reproduction in the instrument, as the audience would certainly expect these musical phrases to sound as close as possible to its original rendition:

> *"Yeah, so, some parts of a song will be very broadly brushed. But there might be one little piece which is very well-known. So, it's worthwhile spending a little time to get that bit as people expect to hear it".*

During **Paco's** practice session, one of his main activities was to rehearse songs that involved playing the guitar whilst also singing. Having previously sourced the necessary support resources to practice with, Paco then proceeded to simultaneously listen to the audio from a YT video, whilst also reading the lyrics with UG, which corresponded to the song from the audio, having each resource in its own browser tab.

As Paco sang along the lyrics, he also played the accompanying guitar chords annotated on top of the lyrics, in sync with the audio from the video. Throughout the process, Paco continuously shifted between simultaneous guitar playing and singing, and occasionally stopping to navigate the resources in the browser using his computer keyboard to operate the transport controls in the YT media player or his mouse to scroll up the lyrics in UG, to align it with the song's audio. Expressing his desire for a device that could automatically scroll the song's lyrics, he then said:

"If I had more budget to buy a teleprompter that would be cool"

Like Mike and Paco, **Arnie** was also learning and practicing a set of cover songs on the bass, though in this case, he was learning songs from a list sent by a prospective new singer for his band, to sing during his audition. However, in contrast with Mike and Paco, Arnie was practicing through a song he was already acquainted with ("Uptown Funk" by Bruno Mars).

Thus, through his practice Arnie demonstrated substantially less switching between playing his bass and navigating the YT video that he was using to support his practice, only stopping to attentively listen and loop through the "breakdown" section of the song for a couple of times. To loop around the section, he positioned the cursor over a specific point of the YT video's timeline which he then used as a "bookmark", allowing him to quickly restart the playback from that point (i.e., the breakdown section) by just clicking the mouse.

Arnie described his song learning process as "layered", as he learns the general structure of the song first and then he *"builds the individual parts up".* Like Mike, he also mentioned that learning and reproducing musical phrases accurately was a crucial part of his process:

> *"People don't necessarily notice when you do it, but they tend to notice when you don't".*

4.4.1.5 Archiving Resources

Towards the end of his bass practice **Mike** took a moment to describe how he collected and archived different resources, by showing me one of his personal binders containing many sheets of paper, with hand-written and printed chord charts, scores, lyrics, and notes to support his music learning, practicing and rehearsal, dating back years (Figure 33):

> *"I have files of tons of stuff going back years. I've got chord charts, words, lyrics; all from different bands I've played with".*

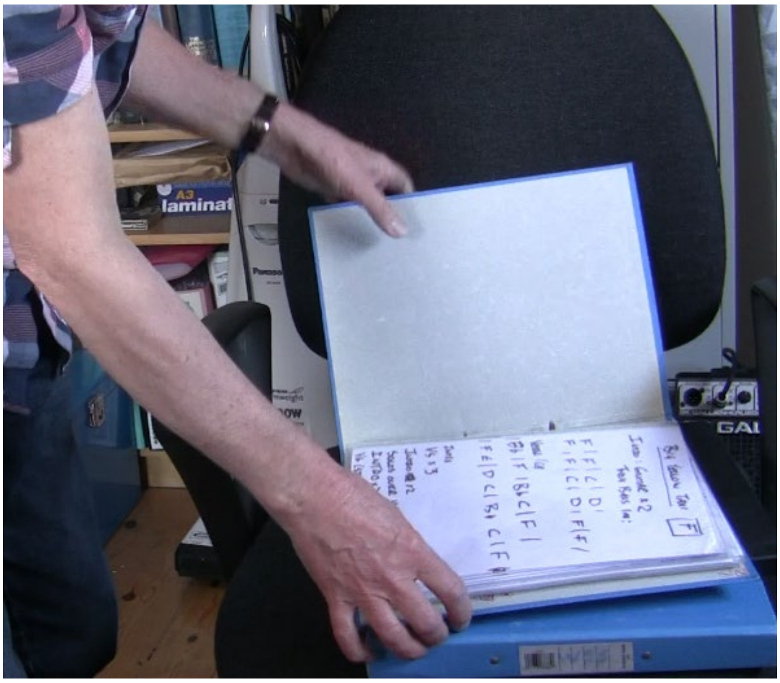


Figure 33. Mike’s archive of resources.

Mike further explained that he initially uses resources to scaffold his song learning but only retains those resources that are “ready” for archival, i.e., more consolidated versions of the resource, with all the necessary information and clarified details. As described by Mike his reasoning for this is to have an organised archive of resources to use as personal reference during rehearsals, but also to lookup when revisiting materials from his repertory after an extended period of time. Furthermore, he also mentioned this resource would be useful in case someone needed to deputize for him, on a short notice, in case he could not perform.

Kelly, on the other hand, has multiple notebooks to keep records of various aspects of her instrumental performance (Figure 34).

One of her notebooks, which she referred to as her catalogue, mainly featured lists of songs from her repertoire, grouped by genre (e.g., blues, instrumentals songs, etc.) or utility (e.g., songs she wants to learn, her duo songs, her original songs, and her current repertoire). Her lists contain annotations for individual songs or groups of songs, such as their tonal keys, guitar tunings (e.g., DADGAD), and indications of which fret should the capo be placed on in each song. She explained that she uses this notebook to look up songs from her repertoire, to decide what to play in different performance contexts and venues. She also has another notebook in which she writes down all the set lists from gigs that she has performed across the years in different venues and her residencies.

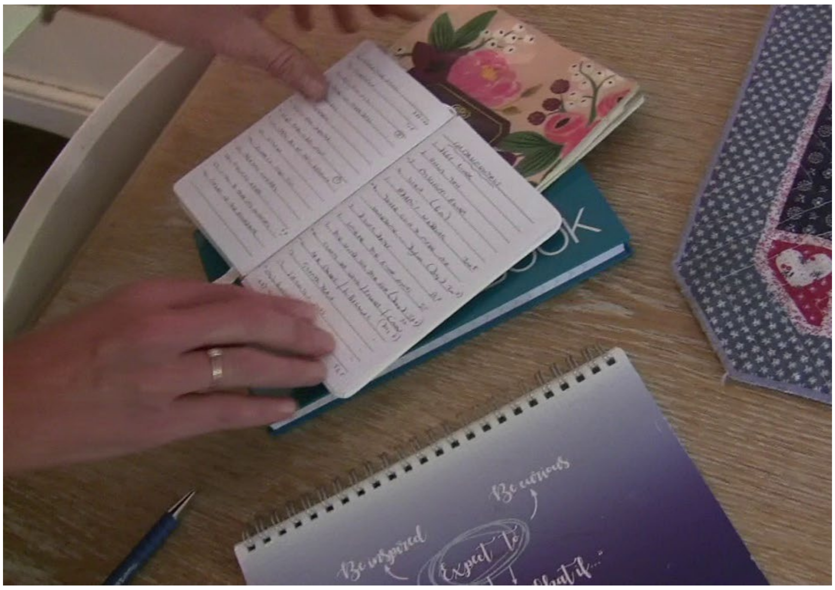


Figure 34. Kelly’s notebooks.

Kelly mentioned she mainly employs this notebook to ‘shuffle’ her set lists around, to avoid playing the same songs gig after gig. Kelly also uses yet another notebook to keep a log of her instrumental practice, grouping her practice routines by set lists of songs, arranged by guitar tuning and the approximate duration of each routine, and another one to make scribbles of set lists in the fly, with some annotations, and rip pages out to take with her to gigs, using the other notebooks as reference.

Like Mike, **Ivan** keeps a folder with sheets of paper containing different types of resources related with his band. Among the resources he keeps are lead sheets and lyrics, but he also keeps other utilitarian resources, such as a stage specification for his band, i.e., a document to be handed out to a sound engineer at a live music venue, detailing the audio equipment requirements for each member, as well as their spatial arrangement on stage for live performances (Figure 35 [Left]).

On the other hand, Melvin—who plays with Ivan in his band—uses a notebook (Figure 35 [Right]), containing his hand-written notes, as a medium for archiving, browsing, and referencing the body of resources he uses to support his instrumental practice (similar to Kelly).

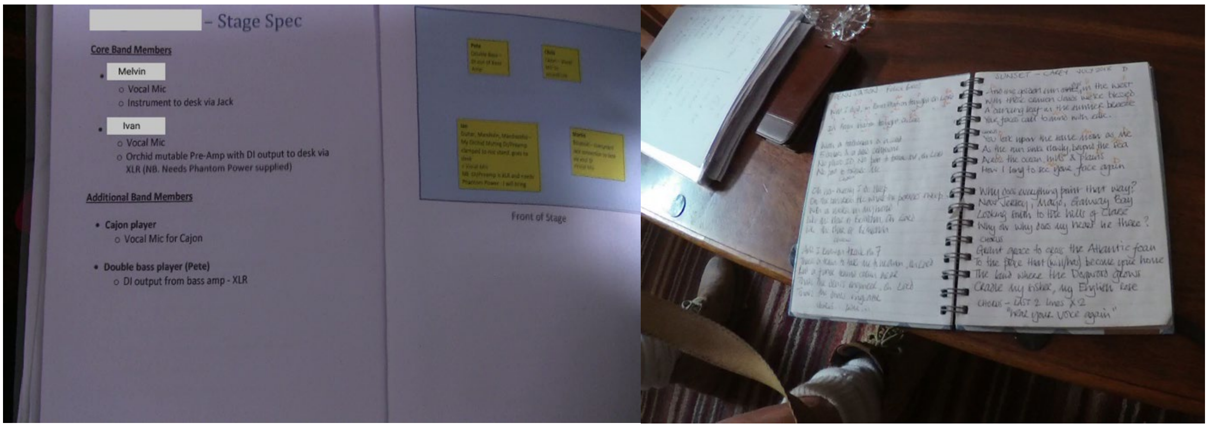


Figure 35. Ivan's folder and Melvin's notebook.

Likewise, **Finn** uses a notebook to write "lyrical sketches" and songs. He also keeps a backlog of resources containing various kinds of resources and lyrical ideas, which he uses as a reference to compose his songs. Once a composition feels like it is finished, he types it up and stores it in a box, occasionally making annotations on top of the lyrics:

> *"I always keep a notebook for lyrics, and I also keep a backlog of little phrases, a chorus, or a verse or a middle 8, or something and I use that when I've got no new ideas, I'll go back and work on something that didn't get finished or that I wasn't happy with. When something feels like it's finished, especially lyrics, I type them up. And sometimes, but not always jot down the chords above the lyrics. I've now got a large box of lyrics. I get a lot of satisfaction out of writing."*

In contrast to the previously mentioned participants, however, Finn does not primarily archive notated resources (e.g., tablature or musical scores). Instead, he tries to remember the chord progressions in his head, and then makes audio recordings with his friends (or with his Dictaphone) to keep a record of his music:

> *"I have one of those little Dictaphone machines, I don't use it very much, but every now and then if I don't have much time, I can just hum a tune into there or play a guitar part, but that's very rare. Normally I like it forming in my mind rather than externally."*

When asked to show his backlog of files he seemed reticent to do so, as this appeared to be a very intimate collection of writings and physical recordings dating back decades:

> *"I'd rather not. That would be a bit like sharing a personal diary. It is not as organised as a filing system; it doesn't work like that. I've got lots of folders with songs, lyrics, and chords over the years, and they go back to the 1980s. I [also] have got handwritten things that go back before that. And I'm a little bit superstitious, I'd be really uncomfortable [to show] some painful audio recordings, cassette tapes, reel to reel stuff, and stuff in the computer. That would be a bit too far."*

4.4.2 Collaborative Rehearsal Activities

The following vignettes describe collaborative performance preparation activities that were undertaken by musicians in groups, i.e., band rehearsals at rehearsal studio rooms. Thus, the activities described here reflect cooperative and socio-technical approaches to preparation, illustrated by collective decision-making and peer-learning practices, such as the direction of musical and performative proceedings by lead members, and the sharing of physical and digital resources at rehearsal spaces and through online file sharing services, as well as the configuration of rehearsal spaces.

4.4.2.1 Collective Decision-Making and Pre-rehearsal Preparation

In one of **Mike's** bands (the one that Finn leads), they collectively generate musical ideas and plan for upcoming rehearsals, discussing their individual preparatory work within the collective and sharing associated resources to work with in between rehearsals:

> *"When we rehearse as a band we may come up with some ideas: 'Oh shall we try this song'. Instead of doing it there and then we'll go home, maybe record those songs, send out an mp3 or a YouTube link for other people to listen to and feedback".*

In the case of one of **Kit's** bands (the one in which he plays bass, sings, and leads), remote pre-rehearsal preparations and decision-making are often undertaken with a bespoke Facebook group that him and his bandmates have designated to discuss band matters and objectives, such as the songs they plan to rehearse during upcoming rehearsals and whether particular songs need further improvement before being performed live:

> *"We'll very often have an exchange with each other. We have our own Facebook group. We'll say stuff like: 'tonight we're gonna learn this song and we need to do this or let's look at this again'… there's a certain amount of objective setting".*

Janice described how she and her band would use Google Drive to share resources and discuss them prior to rehearsals:

> *"We have a Google drive, so we basically sometimes upload music to that. Occasionally, it has been used in the past to drop chord sheets and they've been corrected because someone has said 'this isn't the right chord'".*

Furthermore, she also mentioned how her band would also use a WhatsApp group chat to communicate:

> *"There's a chat that we talk about [things about rehearsals]; find videos of David Bowie doing it live on the web, and then say 'this is a good ending to the song' so*

everybody will go on and practice that particular ending. We use WhatsApp basically".

4.4.2.2 Configuring the Space for Rehearsal

Troy's band gathers at a rehearsal room on a regular basis. This room is available in an hourly basis, and it includes equipment, such as a public-address (PA) system, a mixer, microphones, stands, guitar amplifiers, and a drum kit. In addition, the band members bring their own instrumental equipment, e.g., cymbals, electric guitars, effects pedals, among other tools and resources. Both Troy and the band's guitarist, James, sit to the sides of Petros, the band's drummer.

Each band member's personal space allows them to easily access their instrumental equipment, such as amplifiers, pedalboards, and other musical instruments, as well as their personal tools and resources, such as microphone stands, tuners, power leads, extension cords, and their lead sheets. The band members position themselves in a 'triangle' formation, in such a way that they can see and speak to each other during rehearsal (Figure 36).

Prior to starting to rehearse their music, each band member sets up their own equipment, i.e., positioning, powering up and testing their audio equipment for volume levels, tuning up their instruments, and laying out their lead sheets. Each band member requires different amounts of time to configure and spatially arrange their equipment, hence, some of them start warming up by playing their instruments.

Figure 36. Troy's band in rehearsal.

Similarly, **Kit's band** rehearses in a hired rehearsal room, with included facilities (e.g., PA, microphones, mixers, amplifiers, stands, etc.), and likewise the band members bring their own instrumental equipment (i.e., cymbals, two electric guitars with effect pedal boards and amplifiers, a bass guitar and bass amplifier, and an electronic keyboard). In this case, the band also positions themselves in a triangle formation, with the guitarists, Marvin, and Stuart to the sides of John, the drummer, and Kit in the front and centre, coordinating and directing the band (see Subsection 4.4.2.5).

This formation allows them to face into the centre of the room and Kit, as well as each other and their audio equipment and instruments. They also take a moment to set up their own 'stations', arranging their equipment, instruments, and resources, each taking differing amounts of time during the positioning, powering up and configuration process. This again results in some of the band members engaging in other preparation activities, for instance, Marvin began tuning his guitar and testing out his effects pedals, while Kit tested the sound of the PA system by speaking into the microphone and playing the keyboard, occasionally adjusting the sound levels.

Janice's band also plays in a rented rehearsal room, similar to that of Troy's band. As in the other rehearsal spaces, facilities include amplifiers, PAs, microphones, and mixer, but the band members also bring their own instruments and equipment, i.e., electric guitars, bass guitar, effects pedal boards, as well as other tools and resources, such as power leads, extension cords, and lead sheets. In this case, the band members position themselves in a semi-circle formation (Figure 37), where Janice (singer) and Molly (lead guitarist and back-up singer) face each other, then to Janice's and Molly's right, stand Arthur (bass player) and Anthony (rhythm guitarist), respectively, and at the centre Peter in the drums. Likewise, the band members each set up their own equipment and instruments, and they also engage in pre-rehearsal activities set up. These activities appeared to be consistent, and part of an established routine across bands and individual musicians during rehearsals.

Figure 37. Janice's band in rehearsal.

4.4.2.3 Paper Resources in Use

Following the configuration of the rehearsal space, the set-up of equipment, and accompanying pre-rehearsal activities, e.g., warming up and sound checks, **Troy** took out his lead sheets from a suitcase which he uses to transport other tools and equipment such as, power leads, extension cords, his multi-effects stomp box and saxophone. He then closed the suitcase and laid out the folders containing the lead sheets on top of it.

He browsed through the lead sheets, took one of them and then laid it out on top of his pedalboard, as a make-shift music stand (Figure 38 [Left]). The lead sheet features word-processed lyrics with hand-written annotations on top, such as chord changes, and song sections (Figure 38 [Right]). Troy uses the lead sheet to support his performance during the rehearsal.

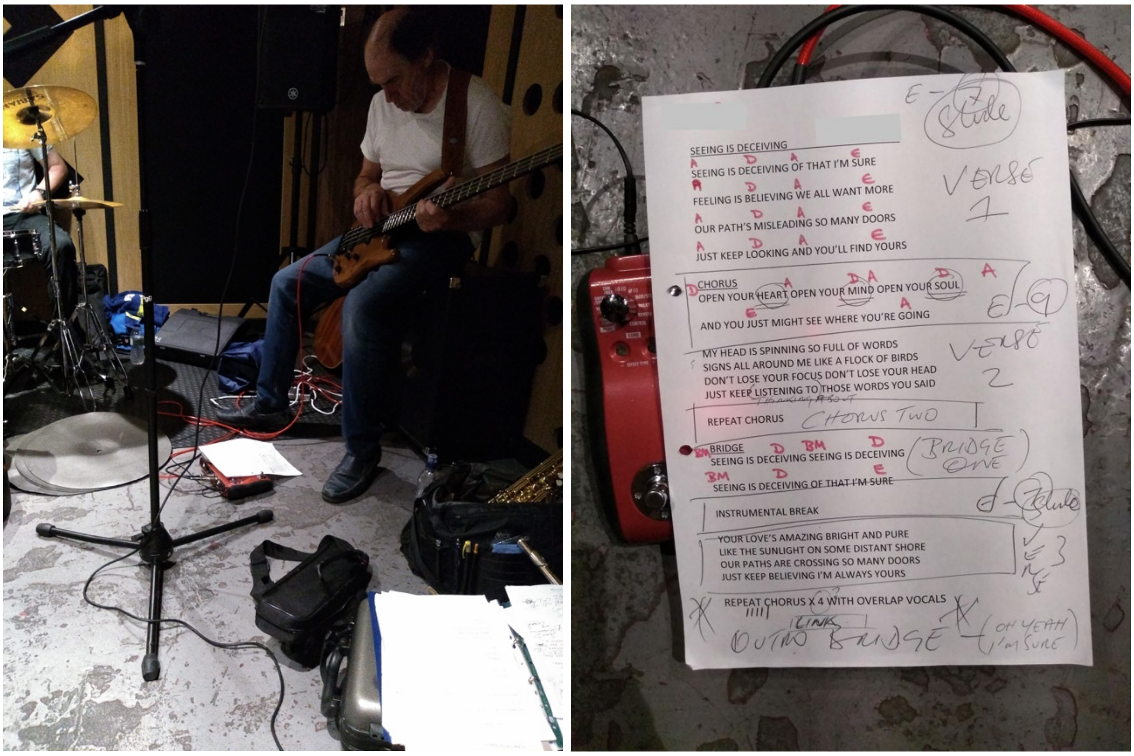


Figure 38. Troy playing along his lead sheet during rehearsal.

Similarly, following initial equipment configuration, **Kit** took out a folder from his backpack, which contained printed copies of the setlist of songs for the rehearsal, and started handing out the copies to each of the band members. As he handed one of the copies to Marvin, the latter mentioned he had brought his own, and then proceeded to compare it to his own lead sheets, and then discarded it—placing it on the floor—as Kit continued to distribute copies to the other band members. Besides showing the rehearsal's set-list, Marvin's lead sheets also featured the chord changes of each song, next to their titles (Figure 42).

Furthermore, Marvin subsequently took hold of a small table which already was in the rehearsal room, and he moved it closer to his rehearsal area—i.e., where he had set up his pedalboard and amplifier—to lay out his lead sheets on top of it (Figure 39 [Left]), along with his plectrum and a pen. Similarly, John the drummer also grabbed a stool in the room and placed it next to his drum kit, to use it as a stand for his set-list. Stuart, on the other hand, took a different approach to managing his lead sheets, and did not take them out at the beginning the rehearsal—unlike Marvin and John. Instead he reached out for his lead sheet only when playing a particular song in the set. Like Troy, he placed his lead sheet on top of his pedalboard (Figure 39 [Right]).

Figure 39. Marvin and Stuart using lead sheets during rehearsal.

As mentioned in 4.4.2.2, while configuring the space, musicians often draw their lead sheets to support their instrumental performance during rehearsal. In the case of **Janice's band**, Anthony took out a couple of handwritten lead sheets from his guitar case and he laid them out on the floor, next to his pedalboard. One of his lead sheets features idiosyncratic notes, such as numbers and chord changes, without any indication of song titles, whilst the other features a detailed tablature, notating a series of arpeggios and chords note by note.

4.4.2.4 Digital Resources in Use

During rehearsals, musicians were observed referring to different digital resources to support their rehearsal activities, as well as repair collective mistakes, in regards of song structure, lyrics, among other instrumental and musical aspects. For instance, in **Lila's band**, the band's vocalist, Diego, was observed using his mobile phone to read the lyrics from the song he was singing.

In the case of **Kit's band,** the band was observed struggling to play a cover song they were rehearsing. The band members appeared to have trouble remembering the structure of the song and were falling out of sync during the introduction part. To resolve this confusion, Marvin, still with electric guitar strapped to his body, reached out for his mobile phone lying on the table and searched the web for the song they were rehearsing. Upon finding a recording of the song online, he then held his mobile phone near a microphone to amplify the sound through the PAs in the rehearsal room, for everyone to hear (Figure 40). As they listened to introduction part of the song for a couple of seconds they synchronously hummed and bobbed their heads along the tune, signalling a collective agreement.

Figure 40. Marvin playing a recording for the band during the rehearsal.

A similar recall of digital resources was observed in **Janice's** band during rehearsal. At one point during a break in-between song, Anthony, the guitar player, asked the band:

"What's next then, what else are we doing?"

Subsequently, Janice took out her mobile phone to search for a setlist she had prepared for the rehearsal. As she read the set list out loud into the microphone for everyone to hear through the PAs, the band collectively discussed the order of the setlist, and whether they needed to shuffle it around to elicit a particular response from their audience:

"How about 'Rebel Rebel' first, and then 'John', and then 'Queen Bitch'? I don't think 'Rebel' is as energetic. 'Rebel Rebel' to 'Ashes to ashes' would be a build-up."

Like Diego, Janice also used her mobile phone to read the lyrics of a song to support her singing during the rehearsal (Figure 41). At another juncture during the rehearsal, Anthony asked Arthur—the bass player—to look up the chords for a song that they were rehearsing at that moment in the 'Ultimate Guitar: Chords and Tabs' app that the latter had in his tablet, which was propped on a music stand. Consequently, Arthur looked for the charts for the song in question for Anthony. Once he found it, he lent the stand with the tablet for Anthony to play along with when rehearsing that specific song (Figure 41).

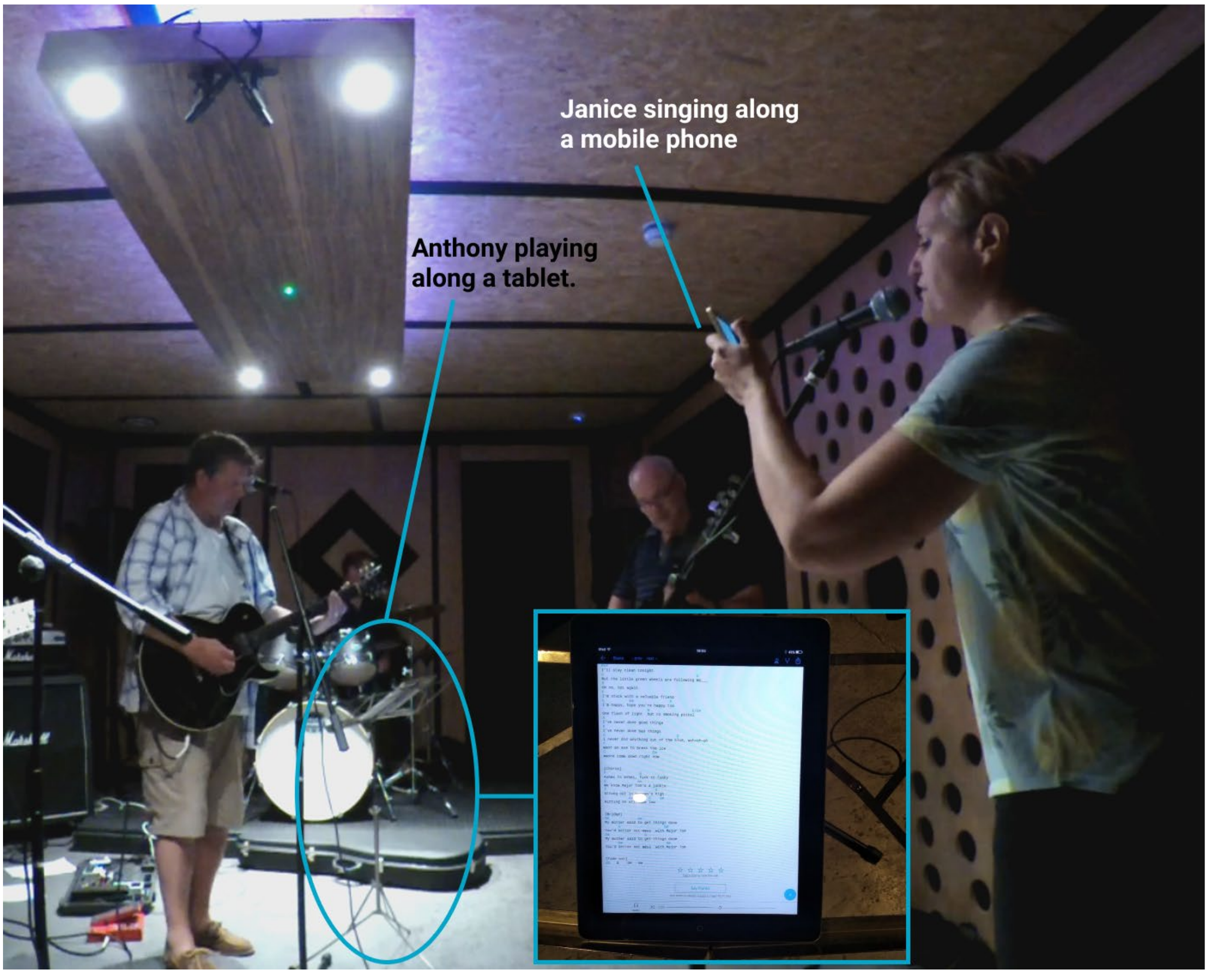


Figure 41. Band members using diverse digital resources during rehearsal.

4.4.2.5 Directing

As mentioned before, when bands rehearse songs, they often stop playing when mistakes occur. During these breaks, band members were observed to engage in different activities to remediate such mistakes, such as discussing and clarifying the points of error as well as looking up reference material to corroborate. For instance, in **Lila's band** one of the guitarists, appeared to be having trouble with playing his part on time, thus the band had to stop every time he made a mistake to redo the part.

Although the mistake was subtle it appeared to be crucial to play the part as close as possible to the original. Hence, the lead singer—who had initially noticed the error—was observed supporting the guitarist by signalling the beats with his hand, for the guitarist to play the part in time.

In **Kit's band**, he was primarily observed assuming the role of director in the band, as he engaged in multiple directing activities, such as signalling sectional transitions in the songs by calling out indications into the microphone to instruct the others during performance (e.g., "Just bass and drums") (Figure 42 [Left]), or by instructing which sections needed to be played again for corrections (e.g., "Let's go from the top").

Kit was also observed teaching others by borrowing instruments from other band members to demonstrate how the instrumental parts were performed in the instrument ought to be played or by revising other member's lead sheets. At one point during the rehearsal, Kit noted that Marvin was playing the chord progression from 'Dear Prudence' incorrectly.

Hence, Kit borrowed Stuart's guitar and moved closer to Marvin to demonstrate and vocalise the correct sequence of chords for Marvin, while he reproduced it in his own instrument, playing along with Kit. Marvin then requested Kit to dictate the chords, so that he could amend his lead sheet (Figure 42 [Right]).

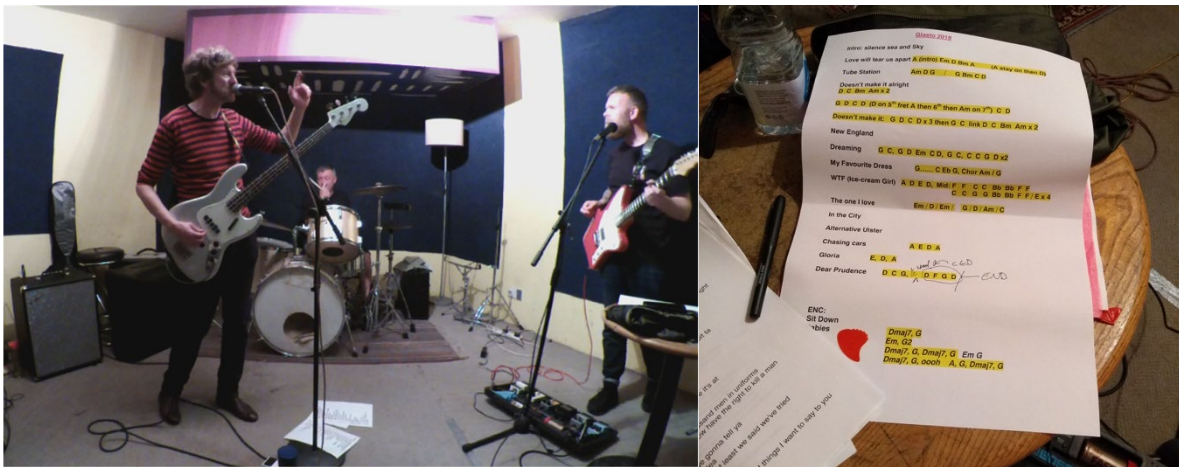


Figure 42. Kit directing and Marvin's annotated set-list.

4.5 Discussion

The previously presented ethnographic vignettes provide a detailed report of the diversity of performance preparation activities that guitarists engage with, as well as the practicalities and problems associated with these activities, which involve collaboration with other musicians and extensive use of support resources and tools. It should be noted that those who participated in the study represent a very specific type of semi-professional musical practice with the guitar in a particular locale. This practice may be similar in many other places, cultures, and styles of music (although potentially with nuanced variations), but it may be the case that other instrumental performance traditions and practices will have their own distinct preparation activities, using different tools and resources from the ones observed in this ethnographic study.

As observed in both the individual practice and collaborative rehearsal contexts, there are multiple aspects of these performance preparation activities with the guitar that illustrate the embodied, social, and technologically mediated nature of playing the instrument. For instance, it is evident from vignettes that the guitar is rarely used in complete isolation, but rather as part of a complex ecology involving other musicians, specialised artefacts (i.e., tools, resources, technologies, and equipment), and dedicated spaces for musical practice. In the case of performance preparation, supporting media resources play a salient role during preparation at home and in the rehearsal space.

As observed in each of the vignettes, these support resources are varied in content (the kind of musical information presented), medium (through which the information is presented, e.g., computer, piece of paper, another musician teaching the song, etc.) and purpose (scaffold the learning process, support the performance, or communicate information to other musicians).

These mainly include distinct types of musical information—with various degrees of specificity—that guitarists use to support their practice, such as audio recordings from a particular song, instruction, and demonstration of how it is played, and musical notation detailing the chords, tempo, articulation and accompanying lyrics, among other details. Some of these supported resources were employed in digital form, e.g., videos recordings, from live performances and tutorial videos (Mike, Paco, Talos, and Arnie), audio recordings (Paco, Vikram, Diego, Marvin, and Mike), tablature notation (Paco, Mike, Cindy, and Vikram), interactive score players (Talos), and lyrics (Paco, Talos, Cindy, Diego, and Janice).

These resources originate from various sources, such as UGC platforms like YouTube, Ultimate Guitar, Chordify and Songsterr, to bespoke music streaming services like Spotify or specialised software like Riff Station, or recordings made by other band mates and sent over email. Hence, the resources range from official versions to unofficial covers, which are mostly created by individual musicians, and shared amongst bands or through global online communities. Thus, different versions of a particular resource can exist, and can vary in type of information and level of detailed provided.

These digital resources were mostly sourced, browsed, reproduced, and navigated, using desktop and laptop computers, and mobile devices, such as tablets and phones, each with their respective inputs, i.e., peripheral devices, such as mouse and keyboard, and tactile input via touch screens in mobile devices.

On the other hand, physical resources can vary from physical audio formats like reel-to-reel or cassette tapes (Finn), to paper-based informational resources containing lyrics (Kelly, Melvin, and Finn), hand-written and typed lead sheets (Mike, Cindy, Troy, Anthony, and Stuart), and set lists (Cindy, Victor, Talos, and Lila's, Kit's, and Janice's bands). Paper-based resources were prominently observed in both individual and group contexts, highlighting the convenience, reliability, portability, archiving and support for annotation of paper, even when digital resources with similar qualities and capabilities were present (Janice's band).

Upon unpacking and analysing multiple individual practice and collaborative rehearsal sessions, it can be observed that these preparation activities are closely intertwined and are encompassed within a broader process of group preparation for performance. This process begins with individual practice where the emphasis is on becoming acquainted with the musical material to be performed, which may have been previously decided between a musical group or an individual musician, who directs the band or plays as a solo performer.

Familiarization with this material involves diverse levels of learning, ranging from more general aspects of a song, like its form and structure, to the more detailed, such as particular musical phrases or lyrical verses. At this stage, resources to support this process may be sourced from online resources (or alternatively, song books, e.g. The Real Book) or created by musicians (especially when the song has not been transcribed yet).

Resources also vary in purpose depending on the stage of the learning and practicing process, where initial familiarization is often facilitated by detailed resources or handwritten annotations with plenty of information, such as chords, notes, measures, and lyrics (e.g., Troy and Cindy's lead sheets), or by just listening to the audio of a song, when practicing over an already familiar piece for the sake of retention (Mike and Arnie).

Then during rehearsals, it appeared that the general expectation was that musicians should have learned their individual parts in isolation prior to getting together, to focus in other more high-level aspects of the performance, like coordinating performative aspects of particular songs, such as fine-tuning particular phrases (Lila's band) or chord progressions (Kit's band), or collectively deciding the order of the songs (Janice's band). However, there were instances were musicians had to quickly learn parts of a song and correct them in the spot (e.g., Kit teaching Stuart the correct sequence of chords).

In particular, band rehearsals revealed the highly social nature of performance preparation, as many of the individual musicians that were interviewed or that were observed rehearsing with their bands, reported how they would engage in many collective decision making activities before meeting in the rehearsal room, such as coordinating aspects of their performance via social networking and file sharing platforms, e.g. email (Mike), Facebook (Kit's band), Google Drive and WhatsApp (Janice's band), like songs they wanted to learn and perform—as well as whether the song should be adapted to be played in a different style—the order of the songs during performance.

Likewise, during rehearsals, musicians engage in collaborative activities when they get together, like directing (Kit and Lila's bands), peer-to-peer teaching (Kit's band), sharing physical and digital resources (Kit, Lila, and Janice's bands), and simply just listening and looking at what everyone else plays, synchronously and co-located. Remarkably, when coordination breaks, frustration is visible across band members and immediate remediation is sought after, such as reaching consensus by recurring to "reference" material (Kit and Lila's bands) or teaching each other the "correct" version of the song they are attempting to play (Kit's band).

Moreover, user-generated informational resources created by online communities of musicians which are shared in platforms that allow for feedback, discussion, and rating (such as YouTube, Ultimate Guitar and other UGC websites) are another marked example of how musicians are actively involved with a wider global community of practice to which they draw upon for material created from other members not personally known. Across these findings there are clear examples of socio-technical processes amongst musicians in bands, embodied practices involving a sustained practice with a musical instrument and extensive use of tools and resources to support preparation with the guitar.

These findings also reflect challenges and opportunities for the design of interactive technologies that can support these processes, practices and mediate the interaction with other elements of this particular ecology involving guitarists (and other musicians they interact with), guitars (and other supporting tools, resources and technologies), and contexts of practice (such as individual practice and rehearsal rooms).

Given the predominance of support resources across the different embodied practices and artefact ecologies (Vyas & Dix, 2007) of guitarists observed during their performance preparation activities, a salient design intervention opportunity for guitar technology and augmentation lies in enhancing the interaction between the practicing guitarist and said resources, e.g., their creation, access and use during performance preparation—especially when the guitarist is engaged in rehearsal with the instrument at hand.

In particular there are three main areas of design intervention to explore, namely, (1) supporting encumbered interactions—such as when embodied instrumental performance is physically disrupted when switching modes of interaction between guitar and support resources; (2) contextual interactions—which can be determined by specific places, and other particular situational elements like specific people and artefacts—and, (3) connected interactions—which imply the networking between multiple devices in the guitar ecology.

4.5.1 Supporting Encumbered Interaction

Encumbered instrumental activities were observed across several instances of performance preparation, particularly when navigating digital support resources using peripheral devices, such as computer keyboards, mice (Paco, Arnie and Mike) or touchscreens (Janice, Diego, Anthony and Marvin), which demand fine-grained manual operation and attention, forcing guitarists to momentarily stop playing the instrument, or to quickly shift back and forth between both modes of interaction (i.e., interaction with devices and instrumental performance).

While some participants, like Mike, managed to simultaneously engage—to some extent—with both activities by playing the instrument one-handed and navigating the digital resource with the other available hand, though in Mike's case, this strategy led to incurring into navigation problems, and only playing principal notes with the bass rather than detailed articulation only accessible with both his hands, rendering this particular adaptation usable only for specific situations during practice, e.g., making annotations to a lead sheet.

In this sense, it should be considered that while the focus of instrumental practice lies in playing the instrument—in this case, the guitar—interaction with resources also takes a considerable amount of time and imposes additional physical effort and coordination from guitarists.

There are broader strategies that could be explored to approach this interaction challenge. A possible intervention implies ameliorating the transition between modes of interaction. This might be achieved by reducing the overhead between playing the instrument and navigating interactive resources by augmenting the guitar with additional inputs that interface with the resources, transforming the guitar into a peripheral device for media navigation.

There are existing technologies that can potentially achieve this, such as the *Sensus Guitar* (Turchet & Barthet, 2019) (Figure 43 [Left]), which features a range of built in sensors and inputs distributed in the neck and body of the guitar, such as an inertial measurement unit (IMU), a set of capacitive touch inputs the guitar and an ultrasonic sensor, which are used to modulate audio parameters and effects by tilting the body of the guitar, or by sliding and tapping the touch inputs with the hand, or by waving the hand on top of the ultrasonic sensor. Similarly, the Guitar Wing (Figure 43 [Centre]) and the ACPAD (Figure 43 [Right]) are MIDI controller devices which can be attached or clipped onto the guitar's body and that feature a range of touch inputs that can control audio effects or send MIDI messages to trigger other actions.

Figure 43. The Sensus Guitar, the Guitar Wing and the ACPAD's in-instrument touch inputs.

These control inputs could facilitate some of the preparation activities described in the vignettes previously presented. For example, the touch sensors could be harnessed as media transport controls which could facilitate Mike, Paco, and Arnie's fine-grained track navigation, i.e., playing, pausing, and scrubbing the playback backwards and forwards when practicing particular sections of a song.

Although this type of interface still requires the hand to momentarily stop playing the instrument to operate its inputs, the distance between instrument and media controls can be dramatically reduced with this approach. Eventually, after continued use of these devices, more streamlined hand gestures between guitar and inputs may potentially be developed, such as when guitarists make swift volume or tone adjustments by quickly turning the knobs on the guitar during performances. Built in guitar inputs such as knobs and pickup selectors have been established over several decades, with the invention of the electric guitar, and are familiar design elements of the instrument.

Alternatively, other "hands-free" interaction modalities could be explored to allow the guitarist to keep their hands engaged in instrumental performance with the guitar as much as possible. Again, considering existing technologies, the most obvious response would be guitar effects pedals, which are generally used to trigger audio effects on and off, as well as to modulate a signal's volume or filter it—such as with the Cry Baby Wah's sweeping mechanism.

Other MIDI-compliant pedals (Figure 44) can also be used to trigger events in a computer or communicate with other MIDI devices and can even do so wirelessly if the hardware features networking capabilities (e.g., Bluetooth, Wi-Fi, etc.). This latter kind of pedals could also be used for fine-grained track navigation albeit with physical constraints—e.g., only being able to use one foot at a time to control the device when standing up.

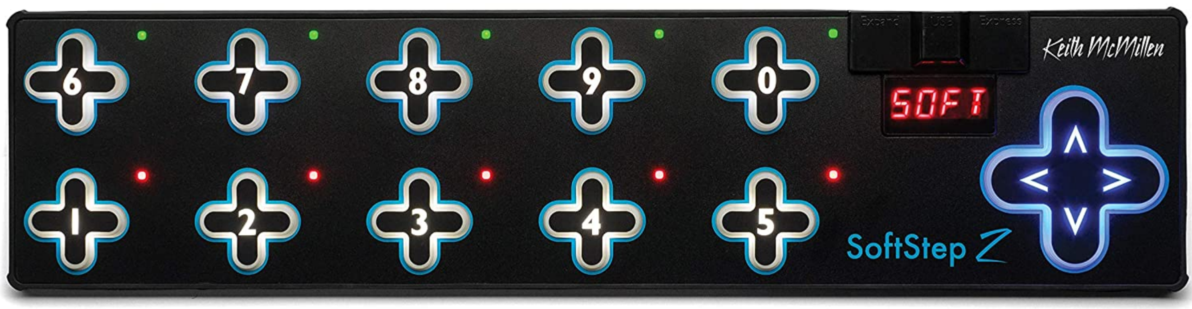


Figure 44. The Keith McMillen SoftStep 2 MIDI keyboard foot controller.

Furthermore, other available inputs that could be harnessed from the guitarist/guitar apparatus for media control are the guitarist's voice (a common approach with *Voice User Interfaces*, i.e., VUIs), and the sound that the instrument makes (both interaction modalities involving audio as input), as well as the physical gestures that could be enacted with the instrument—e.g. tilting the guitar to scroll the lyrics of a song (Paco) (Lähdeoja, 2008; Turchet & Barthet, 2019)—or with the body, such as moving the head and the arms (Newton & Marshall, 2011), or the eyes (i.e., the direction of the gaze (Vamvakousis & Ramirez, 2016)).

These bodily movements could be tracked using motion capture technology (Microsoft Kinect or Leap Motion), an IMU, an eye-tracker, or a radar-based gesture tracking device (Google Soli). In the case of using VUIs, spoken commands and utterances could be used to browse resources online (Paco, Victor, and Talos) or to navigate media resources to specific points within a YouTube video (Chang et al., 2019). Likewise, musical phrases performed with the instrument could be used in a similar fashion, where specific sequences of notes could trigger particular actions (Greenhalgh et al., 2016).

Nonetheless, the underlying design of these technological interventions, should carefully consider the existing embodied practices of guitarists during performance preparation, since the inputs proposed above require bodily actions that are to some extent involved in expressive and communicative gestures (Jensenius & Wanderley, 2010) with the instrument and the body during musical performance, e.g., making expressive bodily gestures like bobbing the head back and forth to the rhythm of the music (Kit's band) or striking a pose with the guitar; or communicative gestures like indicating the tempo of the music to other musicians in the band (Lila's band) or giving directions by making hand signals. Similarly, voice commands may not be a practical choice if the musician is engaged in singing.

4.5.2 Supporting Contextual Interaction

As previously mentioned, the assemblage of tools, resources, and musicians in the context of performance preparation with guitar—and their interrelations, during the course of embodied practices—alludes to what Vyas and Dix (2007) refer to as an "artefact ecology". Likewise, it also draws attention to the three main significant elements of the context of practice proposed in Dey et al. (2001) framework for the design of context-aware applications, namely, people, things, and places.

In this case, the significant people in this particular "environment" are the musicians involved in the music-making activities (i.e., the people), the significant things they use, such as their guitars (and other instruments); their musical equipment (i.e., amplifiers and pedalboards); their computing devices (i.e., personal computers and mobile devices), and the various support resources they access with these devices (e.g., YouTube videos), as well as the paper-based resources they make and share amongst themselves, and the significant places where these activities happen, such as their personal practice, and shared rehearsal spaces.

Following Dey's framework (ibid), there are several contextual interventions that could be explored. One such approach would be to automatically conjure support resources when specific musicians are present in particular contexts of practice. These resources could be conjured based on temporal and geographical aspects, considering that a practicing musician is regularly present at practice spaces, generally using the same resources for a period of time, e.g., learning a list of songs for a particular show. Hence, one temporal aspect of the context of practice to be considered, is the historical use of support resources by a musician which may provide information as to what musical materials they have been recently working with.

In the case of individual practice at home, Mike could use such a context-aware technology to recall a playlist of videos, music tracks or scores based on his last individual practice session at home. In contrast, when Mike gathers with his bandmates in the rehearsal room, the support resources to be recalled by this technology might instead be tailored to the band's current work-in-progress repertoire, which is likely to be rehearsed when they get together—even if Mike's own personal repertoire is slightly different.

Another temporal aspect to be considered are the musicians' plans for future performances which, as observed, significantly influenced the course of action during rehearsals. For example, in Paco's and Mike's individual practices as well as in Janice's and Kit's band rehearsals, the songs to be practiced were decided based on upcoming events and venues, considering the kinds of audiences they were expecting to play for and the duration of the show or their allocated timeslot in a wider line-up.

Furthermore, the order of the songs, and song alternatives—e.g., encores and reserves to be played in case of contingencies (Figure 45)—were pre-decided prior to forthcoming performances as a response to the anticipated situational factors previously mentioned. In this sense, most preparation activities presented in the findings illustrate this sense of continuity, i.e., of musical material being worked up and refined across sessions.

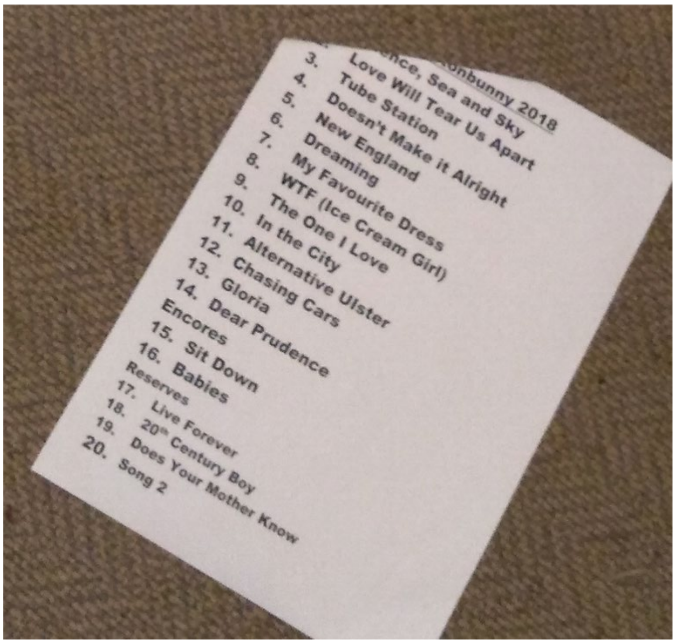


Figure 45. Kit's set list with song alternatives.

The "things" in the ecology could also determine these contextual interactions, e.g., if a collection of musical instruments belonging to a particular set of musicians is present in a room, a context-aware system would provide suggestions of the music to be rehearsed with such instruments. For example, in Troy's band performance he was observed switching between multiple instruments, i.e., bass, flute and saxophone, thus, if one these instruments were not present, then the context-aware system would not highlight songs employing them.

Besides facilitating the recall of resources, adapting the interaction with them according to the context of practice is another aspect of preparation that could be enhanced with context-aware computing. Musicians were observed interacting with resources in multiple ways. For instance, during individual practice, interactions with digital resources ranged from sourcing, browsing and auditioning resources, to fine-grained operation of media.

The latter type of interaction is marked with a focus on transport controls in order to coordinate the actions (Chang et al., 2019; Tuncer et al., 2021) with both the media resource and the guitar, i.e., constantly pause and reproduce the media during the transcription of a musical piece with the instrument. Hence, while this interaction could be supported by a simpler interface that limits the time spent operating the transport controls, resource browsing and auditing of media resources could still be supported by a more complex interface, akin to media library navigation. Similar adaptive interfaces are proposed for mobile interactions, were simplified interfaces are presented for when the user is in motion (i.e., walking), as opposed to when stationary (Kane et al., 2008).

4.5.3 Supporting Connected Interaction

As previously mentioned, contextual interactions can be determined by the 'things' in the context of practice. However, things can also be connected to communicate and coordinate with each other—even in the absence of human input—as IoT devices. With this in mind, Turchet et al., (2018), propose an Internet of Musical Things (IoMusT), in which different elements of a musical performance ecology are interconnected (Figure 46), i.e., musical instruments and equipment, musicians and audiences.

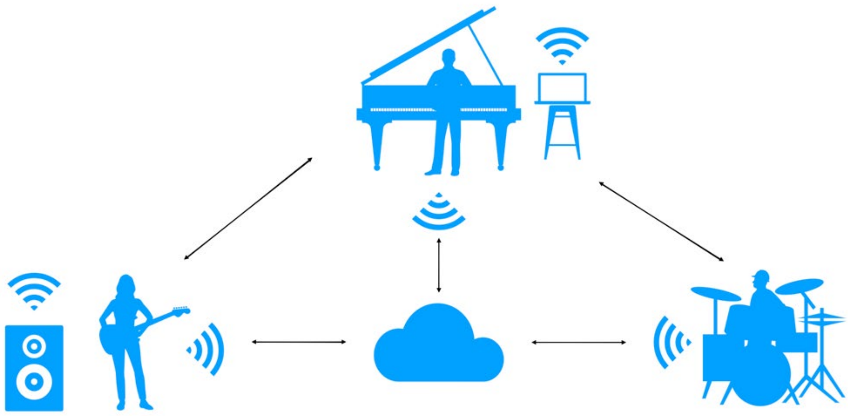


Figure 46. The Internet of Musical Things.

In this musical IoT, musical instruments are conceived as "smart" devices (Turchet, 2019), which can potentially store digital resources or facilitate their access with the instrument. Moreover, these Smart Musical Instruments (SMIs) may share digital resources with other SMIs, IoMusT and standard IoT devices, and collect contextual data (e.g. presence and proximity of other IoMusT devices) to facilitate contextual interactions and intelligently collate relevant information of individual and collaborative preparation activities, such as shared repertoires, as well as reference versions of the songs and their metadata (such as the duration of the piece, and its tempo, key and time signature, structure, sections, chords, notes, lyrics, etc.). SMIs may also connect with other devices in the network, like computing and mobile devices—or any device with networking capabilities, for that matter—forming extended user interfaces, as demonstrated in ubiquitous computing and IoT approaches (Brudy et al., 2019; Newman et al., 2002).

Thus, with this approach, a guitar could be paired with a mobile device such as a tablet or mobile phone, to display the media in the device's screen and receiving wireless input from the instrument to navigate the media. Yet another approach could be to harness the instrument as token to access digital resources belonging to the owner of the instrument, as demonstrated with the Carolan Guitar (Benford et al., 2015) (Figure 47), which is engraved with fiducial markers around its body that can be scanned with a mobile device to access digital content.

With this approach, distinct members of a band could each use their instruments to access their personal digital resources without having to physically store them in the actual instrument, as opposed to an SMI which would require access to either internal or external data storage devices, or a particular data base in the cloud for that end (Turchet et al., 2020).

Figure 47. The Carolan Guitar.

4.6 Conclusion

In this chapter, initial ethnographic explorations within a wider design process have been reported. Ethnomethodologically inspired ethnographic studies were conducted with the aim of obtaining ecologically valid data of guitarists preparing to perform with their own instruments and their own support resources. Gathering data in this fashion was motivated by the lack of HCI, NIME and IxD studies employing ethnographic methods to inform the design of new technologies for guitar in the context of performance preparation, as most existing approaches have predominantly focused on augmenting the sonic capabilities of the instrument for it to explore new forms of musical expression.

Hence, in this study, the various preparation activities of a group of approximately 45 musicians from a community of practice were documented in interviews and observational studies. This group of musicians is constituted by different musical bands and solo guitar projects, thus the findings presented in the chapter, although focused on instrumental preparation activities with the guitar, also document the interrelation between guitarists and other instrumentalists, as well as their use of technology to support their collaborative activities in each of their musical groups.

In this sense, findings are structured in individual and collaborative preparation activities. Individual practice was mostly observed at home spaces, with a few exceptions, and it was marked by a substantial use of physical and digital support resources, i.e., paper-based resources like chord charts and lead sheets, and online materials like YouTube videos and digital scores. In turn these resources also shaped critical aspects of the personal practice process of guitarists such as the physical arrangement of their practice spaces, as well as their embodied practices with the instrument, which were significantly influenced by the use of media resources, as guitarists were frequently observed switching back and forth between playing the instrument and then quickly turning their action to media navigation, which would occasionally disrupt the flow of practice.

Guitarists also demonstrated their preferences for particular support resources according to their needs, as well as developing strategies for making their own (e.g., hand-written or typed), and archiving these for future use and reference. Collaborative practice in the other hand, illustrated the coordination of individuals rehearsing with different instruments, as well as the use of paper-based and digital support resources during rehearsal, often prepared prior to each session.

Moreover, musicians in bands reported on their collaboratively organised pre-rehearsal activities—e.g., deciding what songs to play at an upcoming gig—by using social media, messaging, and file sharing platforms. Band rehearsals were also marked by informal music learning practices (Green, 2017), such as peer-directed learning, e.g., when one of the members of the band explicitly teaches something to their bandmates), and group learning, e.g., when learning within the band occurs implicitly as a consequence of the interactions between bandmates (ibid).

Given the diversity of practices and goals of the musicians observed and interviewed, a focal perspective was necessitated to conduct a concrete analysis of a determinate performance preparation practice. Hence, the focus of the analysis laid on the activities that characterise working musicians who purposefully prepare for performances on a regular basis, often getting remuneration for their services as music performers at gigs and festivals. For this reason, most of the data collected that was collated for thematic analysis involves musicians working on cover songs—rather than original songs.

Likewise, the richest vignettes emerging from the analysis, in terms of embodied practices with the instrument, were those that illustrated musicians interacting with physical and digital tools and resources whilst having the instrument at hand. In contrast, other preparation practices captured during initial data collection were excluded from the analysis, particularly those in which musicians were not observed engaging with additional resources whatsoever to support the practice, such as when musicians simply ran through their set list without any issues to repair (e.g., musical performance mistakes), or during other musical processes, such as live performance, composition, or improvisation.

As raised in the discussion, the vignettes curated from the thematic analysis illustrate the interrelation between embodied musical practices and the use of technologies supporting the preparation process. Thus, these findings are useful in providing implications for designing (Dourish, 2006) technological interventions for the guitar, and guitar playing, in the context of performance preparation. Three main design exploration areas are proposed based on the findings of the ethnographic study, namely, (1) supporting encumbered interactions, (2) contextual interactions, and (3) connected interactions.

A series of technological interventions are proposed for each of these areas. Focusing on the embodied interaction with the instrument and the encumbrances that emerge during the use of additional support resources, proposed interventions explore ways of facilitating the access to resources and their fine-grained navigation when the instrument is at hand, such as by augmenting the guitar with additional inputs and sensors to access and operate the resources, as well as by thinking of alternate devices that could support encumbered interactions, such as pedals or voice user interfaces.

Furthermore, support for contextual interactions is suggested to harness the primary elements of the context of practice as situational cues for context-aware computing systems, such as detecting the presence of specific musicians and artefacts involved in preparation activities and the locations where these activities happen. These contextual interactions are also further enhanced by supporting connected interactions, i.e., embedding the aforementioned elements of context of practice with networking and IoMusT capabilities which make them “discoverable” and “smart”, so that they can connect and communicate with other instruments and other devices, so as to, allow musicians to create, discover, access, recall, share and navigate resources, but also to allow the smart devices to store historical and geographical data to make inferences about the context—and its elements—to make decisions without human intervention.

4.6.1 Next Steps on the Design Process

These design interventions may accommodate both the individual and collaborative preparation activities of guitarists. However, given the broadness of the proposed scope of intervention—and the limited time and resources for this thesis project—it is necessary to focus on one design challenge at a time. Henceforth, this thesis project primarily focuses on supporting unencumbered interactions during individual instrument practice, especially when using additional resources, as the rationale for design interventions, studies and discussion presented in the subsequent chapters.

Chapter 5
The “Augmenting Guitars” Workshops

5.1 Overview and Recruitment

This chapter reports on a series of four workshops with guitarists and bassists evaluating and discussing five technological interventions aimed at supporting unencumbered interactions with the guitar during instrumental performance preparation, particularly when using secondary resources such as interactive media, which when accessed with a computing device requires the manual operation of peripheral controls (e.g., keyboard, mouse, touch screen, etc.) in order to be navigated—as discussed in Chapter 4.

The aim these workshops was to have guitarists engage with five distinct controllers for guitars each prototyping a specific interaction modality for interfacing with media resources which are generally employed during performance preparation with guitar when using a computing device—such as audio and video resources—and to have them critically reflect on each of the modalities in terms of whether these would suit their existing performance preparation practices.

Moreover, participants values, attitudes, and concerns regarding the technological intervention of their embodied practices with the instrument and their existing preparation ecologies, namely their practice spaces, tools, and resources, were surveyed. Specific issues related to the temporary and permanent physical modification of their guitars when technologically augmenting them, were also discussed.

The methodology of this study is inspired by participatory design (PD) principles and techniques (Lucero et al., 2012; Suchman, 1988), where the design of research prototypes has been informed by ecologically valid data (ethnographic study), and are then subsequently evaluated by the experts of the domain (Sanders, 2001), to further iterate proposed design interventions. In essence, these prototypes are meant to be provocative prototypes (or “provotypes”) for participatory innovation (Boer & Donovan, 2012).

For this study participants from the previous ethnographic study were once again contacted and a call for participation was distributed across several Facebook groups for recruitment. This resulted in, once again, recruiting Troy, Paco, Talos, Kelly, Ivan, Kit, Mike, and Jamie who also participated in the ethnographic study. The recruitment criteria specified that participants should be active guitar or bass performers, though casual players who wished to participate were not excluded from selection. A total of 20 participants were recruited and distributed across four separate two-hour workshops—each with 4 to 6 participants attending at a time (Table 5).

Table 5. Participants in the participatory design study.

Workshop 1	Workshop 2	Workshop 3	Workshop 4
Troy (P2)	Kelly (P5)	Ivan (P9)	Mike (P1)
Paco (P3)	Jose (P48)	Kit (P11)	Jamie (P15)
Talos (P8)	Maria (P49)	Marc (P53)	Krist (P56)
Serj (P46)	Danna (P50)	Cyril (P54)	Evelyn (P57)
Callum (P47)	Pixie (P51)	Charles (P55)	
	Greg (P52)		

Note: Participants involved in the previous ethnographic study are highlighted in blue.

In this case only guitarists and bassists participated in the study—in contrast to the previous study where other instrumentalists were also observed—and their instrumental proficiency levels ranged from hobbyists to professional performers of original music and covers. Nonetheless, most participants primarily played guitar (i.e., only 2 participants reported playing bass as their main instrument, although some participants played both bass and guitar, and others played several chordophones).

Although many of the participants performed in bands, the focus of this study was on their individual preparation practices, particularly those involving the use of digital media resources to support the learning and practice of musical repertoire, and the associated encumbrances emerging from their use. Furthermore, participants were encouraged to bring their own instruments to the workshop, although these were not compulsorily required to participate. In this study, the ratio between participants identifying as female and was 1:3, and most participants were above 30 years old.

The rationale for designing the research prototypes and the characteristics of each individual interaction modality is described in the next section (5.2), followed by subsequent sections describing the design of the workshops where the prototypes were deployed (5.3), data collection methods and analysis (5.4), findings (5.5) and discussion (5.6) of the study's results, which shed light on the values and attitudes of guitarists towards technological interventions in the context of instrumental practice, as well as the tensions involved in adopting or rejecting such technologies in their current practices and artefact ecologies.

5.2 Prototypes

Results and implications from the preceding ethnographic study reported in Chapter 4 charted three potential design challenges to be explored in terms of guitar augmentation and technological intervention, namely supporting encumbered, contextual, and connected interactions. To narrow the scope of intervention, the subsequent design work is oriented towards further investigating ways of supporting encumbered interactions emerging from the simultaneous use of time-based media resources (e.g., YouTube videos, audio tracks, etc.) and guitar playing during performance preparation practices.

To explore the space of potential design interventions in this area, a series of prototypes—high and low fidelity—were developed to investigate different interaction modalities aimed at preventing guitarists from physically interrupting their instrumental performance when practicing along media, i.e., stop playing guitar to operate media controls. The prototypes were employed to elicit exploration, reflection and inspiration from participants and myself within a co-design process. The prototypes employed the following technological augmentation and intervention approaches:

1. Augmentations made to the guitar, i.e., by harnessing the guitar as a controller by doing gestures with the instrument, or by using combinations of musical notes as input (like how voice commands with voice user interfaces, i.e., VUIs), or by supplementing the existing controls on guitars (e.g., volume knobs) with additional media controls mounted on the body of the guitar, i.e., near the locus of interaction.
2. Augmentations made to existing artefacts associated with the performance preparation context, which were previously characterised during field work (Avila, Greenhalgh, et al., 2019), e.g., individual stomp-boxes or multi-effects ones (with multiple foot switches).
3. Potential technologies that would leave the hands free to play during guitar performance preparation, where the hands are actively occupied with the instrument, but also constantly transition to manually navigating interactive media resources on a computer, e.g., VUIs.

The latter two proposed intervention approaches also commonly explore harnessing other physical inputs from the guitarist's body—alternative to their hands—such as the feet (i.e., pedals) or the voice (i.e., VUIs), as proposed in Chapter 4. Specifically, five interaction modalities for interacting with an audio track—a common digital media resource in guitar preparation practices—whilst having a guitar at hand, were prototyped, namely, (1) touch controls mounted on the surface of the guitar, (2) foot switches on a stomp box, (3) voice commands with a VUI (4), musical phrases (sequences of notes) as input (using Muzicodes (Greenhalgh et al., 2016)), and (5) gestural interactions.

Although these modalities of interaction are different, the functionality provided to navigate media resources remains consistent across prototypes, i.e., they were designed to trigger a standard set of media controls either via the MIDI and OSC, or system events to allow users to navigate the same audio track with a computer running Ableton Live, a DAW that facilitates the assignment of MIDI messages and keystroke events to control actions, such as transport controls, navigation and annotation, among other media actions to interact with the track.

In the DAW, the track (Figure 48 [Left]) is visualized as a soundwave which has been divided into sections annotated with labels—i.e., 'Intro', 'Verse', 'Chorus', 'Solo' and 'Outro', according to the song's sections in the track (Figure 48 [Right]). The aim with this apparatus was to facilitate the navigation of the same audio track across the five interaction modalities, using a consistent set of controls mapped to each the prototypes' inputs, to enable them to play, pause, rewind, and fast forward the track, to set a bookmark on the track, to navigate to the previous or the next bookmark, or to jump directly to one of the track's bookmarks.

Although the DAW's interface may not necessarily resemble that of an interactive online resource such as a YouTube video player, it is expected that the interactions prototyped here may be easily extended to such digital resources. Over the following subsections, each prototype's individual interaction modality is thoroughly described.

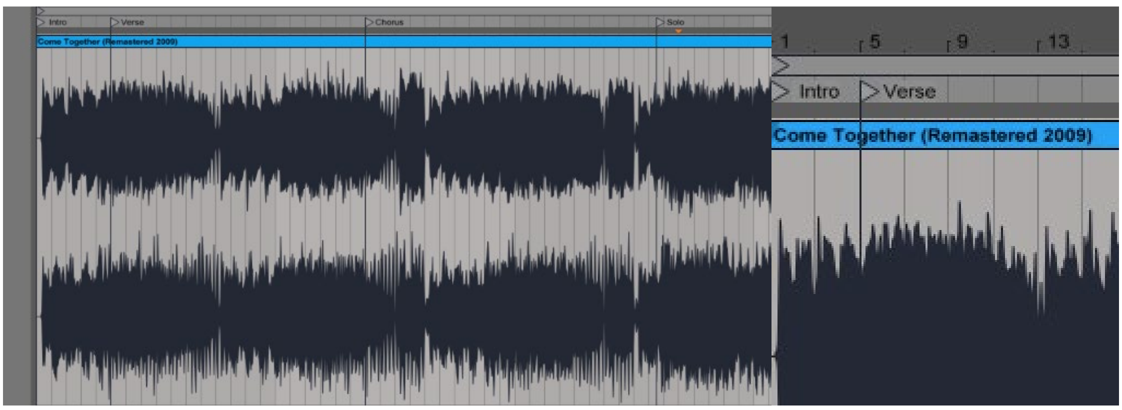


Figure 48. Audio track and close-up of section markers.

5.2.1 Touch Controls

This prototype aims to supplement the guitar with additional media controls localized on its body, to reduce the overhead of transitioning between playing the guitar and navigating media resources with a computer, which would be typically controlled with peripheral devices, e.g., a mouse or a keyboard. To rapidly prototype a set of proximal controls, a simple graphical user interface (GUI) was designed with TouchOSC. This middleware provides basic layouts for skeuomorphic control inputs generally used in electronic musical instruments' interfaces (i.e., buttons, toggles, knobs, faders, etc.), thus allowing for the design of custom interactive touch controls that can be displayed on any mobile device. The prototype's custom GUI consists of two rows of buttons (Figure 49 [Right]).

The upper row has five buttons for navigating to the beginning of each section marker and the lower row has six buttons with transport controls. The GUI is presented on a mobile phone which is fixed to the front of an electric guitar with masking tape (Figure 49 [Left]). In this case, the inputs are mapped to MIDI messages which trigger control actions in Live's DAW and are sent over Wi-Fi using virtual MIDI ports in the host computer. Hence, by touching the screen of the mobile phone—using the GUI provided—the guitarist can operate transport controls to navigate the audio track in the DAW by reaching directly towards the body of the instrument. The labels and mappings of each touch control are presented in Table 6.

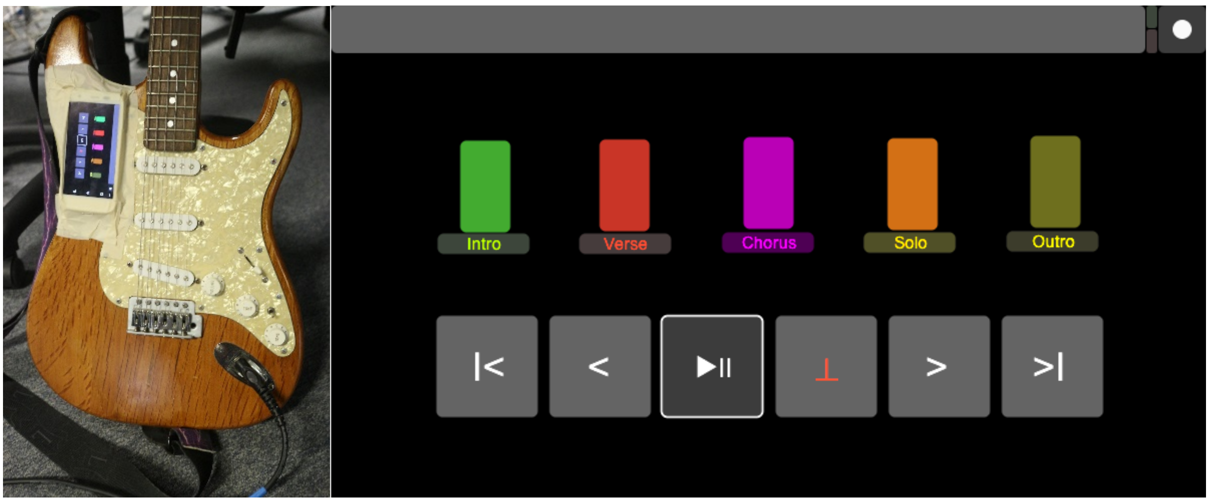


Figure 49. Touch controller on an electric guitar and close-up of the GUI.

Table 6. TouchOSC GUI labels, key events, MIDI mappings, and actions for each button.

Label	Intro	Verse	Chorus	Solo	Outro	I<	<	⏵II	⊥	>	>I
Mapping	A	S	D	F	G	CC 1	LEFT	SPACE	CC 3	RIGHT	CC 2
Action	To Intro	To Verse	To Chorus	To Solo	To Outro	Previous locator	Move left	Play, Pause	Add locator	Move right	Next locator

Note: CC1 and CC2 are MIDI control change messages. The rest of the mappings are key bindings.

5.2.2 Foot Controller

This prototype explores the use of foot switches on a stomp box as peripheral media controls. Pedals are built in some musical instruments such as pianos, pedal steel guitars and harps (among others), and are used for expression control, such as sustaining or attenuating the sound of the instrument. However, in the case of some digital musical instruments, i.e., electronic piano keyboards, and electrically amplified instruments, i.e., electric guitars, pedals often feature as separate peripheral devices.

In the case of the electric guitar, pedals—also known as "stomp boxes"—are generally used in musical performance to control the expressivity of the audio signal (e.g., filtering, modulation, or gain volume), to trigger audio effects (i.e., as an on and off switch), or to trigger other media actions, including the operation of transport controls for media navigation. To prototype this interaction modality, an Apogee GiO MIDI foot controller was employed (Figure 50 [Top]). The stomp box can be connected to any Apple personal computer via USB and is intended to be used with Apple's DAWs, i.e., GarageBand and Logic. The stomp box features two rows of foot switches.

The upper row has five squared foot switches with underlying LED lights which are used for triggering transport controls and recording with the DAW. The lower row has five circular foot switches to assign to virtual pedals and two triangular foot switches to navigate pedal pre-sets, when using the DAW. The number of inputs in this stomp box allowed for mapping the same media actions as in the first prototype, with a similar spatial layout, although in this case, the interaction involves using the feet to press the foot switches rather than touching a screen. In this case, the stomp box sends MIDI messages to Live's DAW via USB and are then re-routed to other media actions.

To achieve this, OSCulator was employed to re-map each of the foots switches' original bindings to trigger the media actions previously defined in Live's DAW, as this middleware facilitates the re-routing of MIDI or OSC inputs to various other outputs, such as MIDI, OSC, and key events, among other outputs (see Table 6 and Table 7 for a comparison). The foot switches have also been re-labelled to indicate their new actions (Figure 50 [Bottom]).

Figure 50. Original layout of the GiO foot controller and customized layout.

Table 7. GiO's mappings re-routed to abstract media actions.

Original Label	o	I<	<<	>>	▶ II	N/A	N/A	N/A	N/A	N/A	Next
Original Mapping	CC20	CC24	CC22	CC23	CC21	CC25	CC26	CC27	CC28	CC29	CC30
New Label	Intro	Verse	Chorus	Solo	Outro	I<	<	▶ II	⊥	>	>I
Re-routed Mapping	A	S	D	F	G	CC 1	LEFT	SPACE	CC 3	RIGHT	CC 2
Action	To Intro	To Verse	To Chorus	To Solo	To Outro	Previous locator	Move left	Play, Pause	Add locator	Move right	Next locator

Note: N/A stands for label-less foot switches.

5.2.3 Voice Commands

This prototype explores the use of voice commands to navigate media when playing the guitar, in order to leave the hands frees to play. To prototype this interaction modality, a rudimentary VUI was developed to run on laptop using the native accessibility features of Mac OS and Automator—an Apple application that automates system tasks and allows for making custom dictation commands (i.e., voice commands that trigger actions).

In this case, single word commands were defined, which closely corresponded to the previously defined labels for each section marker and transport controls to trigger media actions. Then, using Automator, a set of AppleScripts were defined to trigger specific key stroke system events when the voice commands were uttered. These commands were then mapped to navigation and transport controls in Live's DAW (Table 8).

Table 8. VUI commands, mappings, and actions.

Voice Command	Intro	Verse	Chorus	Solo	Outro	Last	Left	Play/ Stop	Mark	Right	Next
Mapping	A	S	D	F	G	H	LEFT	SPACE	J	RIGHT	K
Action	To Intro	To Verse	To Chorus	To Solo	To Outro	Previous locator	Move left	Play, Pause	Add locator	Move right	Next locator

In order to avoid false positives when using the VUI prototype—e.g., voice commands being triggered with the audio bleeding from the music track—a vocal microphone was connected to the laptop using an audio interface. With this audio setup, voice commands could only be triggered when speaking closely to the microphone (Figure 51).

Figure 51. Guitarist using voice commands to navigate the track.

5.2.4 Musical Notes

This prototype explores the use of musical notes as input to trigger media actions for musicians to navigate a track by playing music with their instruments rather than through interaction with a separate device. To achieve this, the Muzicodes system (Greenhalgh et al., 2016) was used, which can extract features from an audio signal or a MIDI message (e.g., pitch, velocity, duration, etc.), facilitating the detection of particular sequences of notes and their codification to act as triggers for predefined actions (e.g., URLs, MIDI or OSC messages, etc.) when performed with a musical instrument. For the prototype, a set of melodic phrases (consisting of sequences of four or five musical notes) were defined to trigger the abstract media controls. These musical phrases closely resembled melodic extracts from the audio track displayed in Live's DAW, to trigger the section bookmarks that corresponded to such melodies when the participants performed them with their guitar. Conversely, to trigger transport controls, a set of two-note phrases were defined (Figure 52).

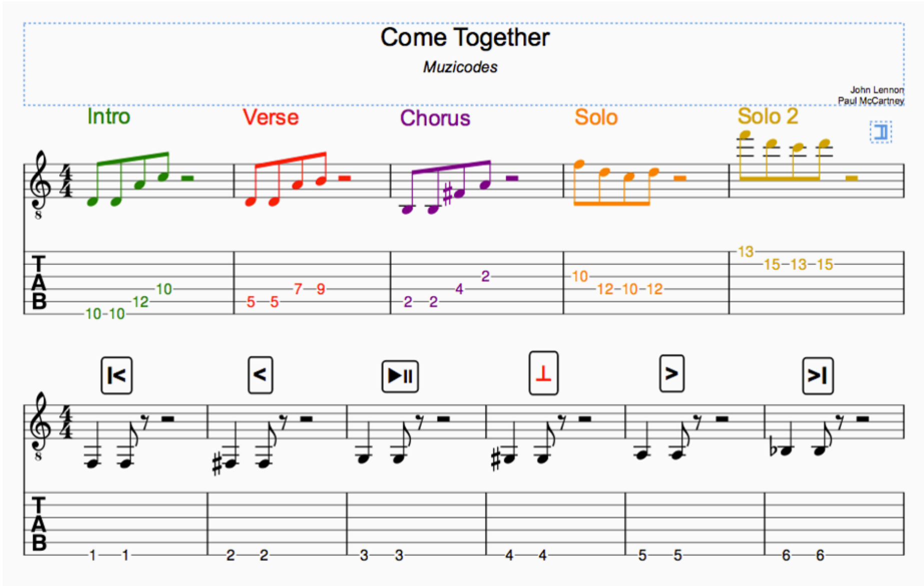


Figure 52. Musical phrases used to trigger media actions with Muzicodes.

The musical phrases were to be performed with an electric guitar connected to a laptop through an audio interface, and then converted to MIDI notes using Jam Origin's MIDI Guitar 2. These MIDI notes from the guitar would in turn trigger raw MIDI note (formatted as hexadecimal strings) and OSC messages (via UDP[14]) in Muzicodes, which were then again re-routed with OSCulator to trigger the previously defined mappings in Live's DAW. The whole communication pipeline is broken in down in Table 9.

Table 9. Muzicodes to OSCulator to Live's DAW pipeline.

Musical Notes	D3,D3, A3,C4	D3,D3, A3,B3	B2,B2, F#3,A3	F4,D4, C4,D4	F5,D5, C5,D5	F2,F2	F#2, F#2	G2,G2	G#2, G#2	A2,A2	A#2, A#2
Output	933A7F (MIDI)	943A7F (MIDI)	953A7F (MIDI)	963A7F (MIDI)	973A7F (MIDI)	Last (OSC)	Left (OSC)	PlayStop (OSC)	Mark (OSC)	Right (OSC)	Next (OSC)
Re-routed Mapping	A	S	D	F	G	CC 1	LEFT	SPACE	CC 3	RIGHT	CC 2
Action	To Intro	To Verse	To Chorus	To Solo	To Outro	Previous locator	Move left	Play, Pause	Add locator	Move right	Next locator

Note: OSC messages were sent using UDP addresses, e.g., "osc.udp://127.0.0.1:8000/Next".

[14] In computer networking, the User Datagram Protocol (UDP) is used to send messages to other hosts on an Internet Protocol (IP) network.

The musical codes were presented as musical notation and tablature on a sheet of paper, which was set on a music stand for the participants to play along with (Figure 53 [Top]). Moreover, the neck of the guitar was labelled with the transport control symbols so that guitarists could also easily remember the fret position of each control (Figure 53 [Bottom]).

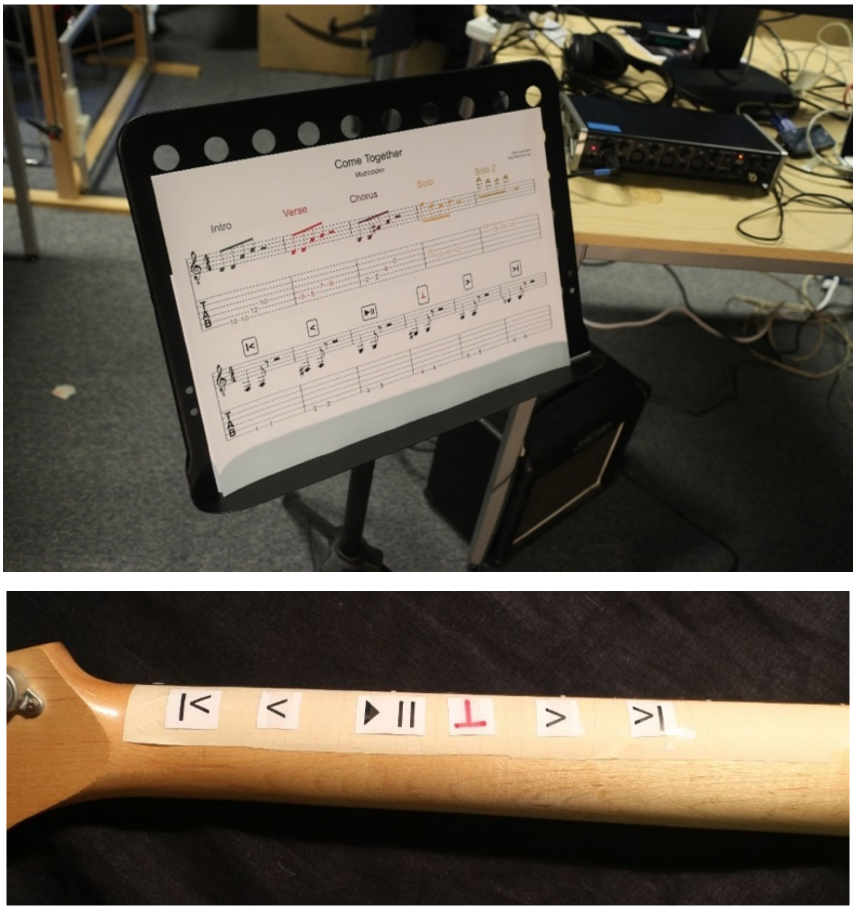


Figure 53. Muzicodes presented with sheet music and transport control labels on guitar neck.

Furthermore, due to Muzicodes's functionality one can define codes that can be flexibly triggered, i.e., with absolute or relative pitches or durations—see Greenhalgh et al. (2016) for an in-depth description. In this case, codes were defined using musical notes with absolute pitches but relative durations—i.e., notes only had to be played in the right octave range (e.g., "D3, D3, A3, C4") irrespective of the rhythm or duration of the notes.

5.2.5 Gestural Controls

Physical gestures were also proposed as an interaction modality to navigate media, although in contrast with the previous four prototypes—which were presented as high-fidelity interactive devices for each specific interaction modality—gesture-based media controls were explored by having participants engage in embodied ideation activities with mock-up cardboard guitars (further described in Section 5.3.1), such as embodied sketching (Márquez Segura et al., 2016), and bodystorming (Buchenau & Suri, 2000).

In this activity, participants were asked to speculate about gestures with the guitar that could trigger the same media controls as with the previous prototypes, and to enact them using the cardboard guitar props (Figure 54). Moreover, they were also asked to ideate ways of alternatively triggering these media controls with bodily gestures or wearable devices.

Figure 54. Embodied ideation during bodystorming activity.

5.3 Workshop Design

The design of the workshops conducted in this study was inspired by the *Future Technology Workshop* method (Vavoula & Sharples, 2007), which gathers people with everyday knowledge and experience of a particular domain (in this case, performance preparation with guitars) and engages them in a series of design activities to envision and design relations between current and future interactive technologies in said domain.

In this case, a series of generative tools (Sanders, 2000) were employed, such as embodied ideation (Márquez Segura et al., 2016; Schleicher et al., 2010), and other participatory design techniques, for participants to collaboratively envision, ideate, sketch, design and enact use scenarios. These co-design activities gravitated around the prototypes, with the aim of having guitarists opportunistically explore and evaluate (i.e., discuss, reflect, critique, and refine) their interactive design elements and affordances, in regards of the potential utility that each technological intervention would provide to their specific preparation practices.

Moreover, the workshops also had elements of value-sensitive design (Borning & Muller, 2012; Friedman, 1996), as one of the particular aims of this study was to survey the values and attitudes of participants towards the technological interventions of their guitars and elements of their context of practice, namely, pedalboards, microphones, computers, and DAWs. The goal of the workshops was to obtain qualitative feedback from guitarists early in the design process before designing more complex prototypes. Each workshop ran for approximately two hours, and its activities were guided by a pre-defined agenda set by me. Up next, the materials used in the workshop, as well as the general order of events and design activities are described in more detail.

5.3.1 Workshop Materials

To elicit ideation, reflection, and discussion from the participants after getting introduced to the prototypes and using them, participants were presented with a series of materials to work with, such as a set of guitar-shaped props, which used by participants during the *design* activities of the workshop, as well as sheets of paper, post-its and pens to make sketches or write down their ideas throughout the workshop (Figure 55).

There were two types of guitar props, namely, (1) a set of life-sized hand-cut cardboard guitars, that were used in a bodystorming activity (further described in Subsection 5.3.2), in which the participants were asked to think of gestural mappings that could trigger the same media controls presented with the high-fidelity prototypes and then enact them using these props, and (2) a set of acrylic guitars which were used as whiteboards on which participants could sketch their ideas for additional controls that could be mounted on guitars. These latter props allowed guitarists to showcase and share their ideas with the other guitarists as well as discuss aspects of positioning, size, and layout of inputs, as well as demonstrate how they would interact with these controls on a real-sized guitar-shaped prop (as described in Subsection 5.3.2).

Figure 55. Guitar-shaped props and stationery supplies used during the workshop.

5.3.2 Workshop Procedure

The workshops were structured in three stages (Figure 56), namely, (1) an introduction, where I presented myself to the participants, as well as the aims of the workshop, and the topics to be discussed; (2) a series of co-design rounds, where the participants tested the prototypes, reflected on them, and refined them through a series of design activities, and (3) a concluding discussion to wrap up the workshop by asking a series of reflective questions. In the following subsection the workshop's stages are described in further detail.

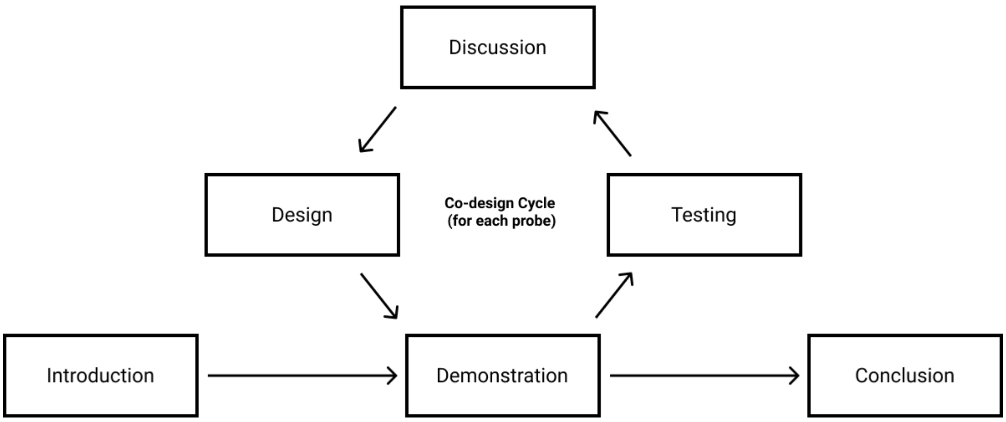


Figure 56. Workshop structure.

5.3.2.1 Introduction Stage

In this stage the participants and I introduced ourselves. I then presented the aims of the workshop, namely, (1) to overview and reflect on guitar and bass practice using computers,

(2) to discuss and evaluate a series of prototypes for supporting encumbered interactions, and (3) to refine the prototypes by doing some hands-on interaction design activities.

Moreover, the participants were introduced to the problem of encumbered interaction (i.e., the interaction design challenge to be tackled by the prototypes) through a *user story* (Righi et al., 2017) presented with a video snippet extracted from the previously captured ethnographic data. In the video a bassist can be observed sitting down in front of his personal computer (PC) trying to practice a song by watching a YouTube video whilst having his bass at hand and playing along with the audio, only stopping to navigate through video using the computer mouse and keyboard.

After the video was finished the participants were presented with three frames of the video in which the bassist can be clearly seen in different poses, namely, (1) typing on his keyboard whilst having the bass in his lap, (2) handling his mouse and (3) playing the bass (Figure 57). These frames were shown to signal the transitioning between playing the instrument along a media resource in the computer and interacting with the computer to navigate said media, highlighting the cumbersomeness of this particular practice. After looking at the frames, participants were then briefly enquired on their familiarity with this activity and on their personal approach to guitar practice using supporting media resources (e.g., videos, audio tracks, guitar tablatures, or others).

Figure 57. Frames from the video shown to participants.

Notated musical resources, such as tablature, lead sheets and lyrics with chords, were also addressed in terms of presentation and granularity of information, and how they are generally segmented into sections. This latter notion was introduced with the aim to familiarise the participants with the underlying interaction scheme which they would engage with across all the prototypes.

This consisted of navigating an audio track by using transport controls (e.g., 'play,' 'pause,' etc.) and jumping to specific section bookmarks (i.e., 'verse,' 'chorus,' etc.). After the prototypes' main interaction scheme (audio track navigation) and abstract media controls were presented (i.e., transport controls and section bookmarks), the workshop transitioned onto the co-design stage.

5.3.2.2 Co-design stage

In this stage, the participants engaged in a co-design cycle involving four activities with each of the prototypes, namely, (1) Demonstration, (2) Testing, (3) Discussion and (4) Design. In the **Demonstration** activity in each cycle, I firstly introduced the commercially available equivalent of each prototype to survey whether participants were familiar with a similar input modality.

For instance, when introducing the touch controller prototype, I presented a picture of an electric guitar's volume and tone knobs and the pickup selector mounted in the instrument and then subsequently presented a picture of the prototype mounted in the instrument featuring a similar interaction paradigm (in-instrument controls).

In the case of the foot controller prototype, a picture a multi-effects floorboard (i.e., a Boss ME-80) featuring a series of foot pedals was shown, and for the voice commands a picture of an intelligent personal assistant (i.e., an Amazon Alexa Echo Dot) was shown. However, in the case of the musical notes prototype, which do not have many widespread technological equivalents, a description of the general functionality of the system was provided, which was equated to a voice assistant that uses musical notes instead of voice commands.

Likewise, with the gestural controls prototype, which were more speculative, a series of provocative questions were asked such as, "What if we could navigate this track by moving the guitar or the body?" and "What if we wore something? (e.g., a glove, a ring, a special shoe?)." Moreover, examples of gestural technologies were also discussed (e.g., Microsoft

Kinect, and Nintendo Wii). After introducing a prototype, I would then demonstrate to the participants how to navigate the track using the prototype's particular interaction modality.

Then, in the **Testing** activity, participants were prompted to test out the prototypes. On average, two participants would volunteer to test out a prototype during each co-design cycle, whilst the others observed. At least one participant tried each of the interaction modalities. The prototype testing stage would then be followed by a **Discussion** activity, in which participants would be asked to share their experience with the others and this would prompt a guided group discussion about the interaction with the prototype, which was mediated and driven by critical enquiries from myself, prompting the participants to critically reflect on various aspects of the interaction with prototypes, such as whether they would use the technology in their daily practice, the positive and negative aspects of the interaction modality, and whether they envisioned other alternative applications for the technology beyond using it for performance preparation at the home practice setting.

Furthermore, in the case of the touch and foot controller prototypes, additional questions were asked in regards of their specific interaction modality, as these were more physically tangible prototypes—in contrast with the voice commands, musical notes, and gesture controls prototypes, which were either more abstract or speculative.

Hence, for the touch controller prototype, questions like: "What do you think about the position of the controls?;" "What fingers did you use to operate it?" and "Would you like this to be embedded in a guitar or as a separate accessory?" were asked, whereas for the pedal-based prototype, questions like: "What do you think about the position of the pedals?" or "Did you use both feet?" were asked.

After discussing a prototype, participants were the instructed to refine and expand on it by engaging in a specific **Design** activity related with that specific prototype. In the case of the touch controller prototype, participants were prompted to sketch their ideas for alternative guitar-mounted controls on the acrylic guitars that were provided, using them as whiteboards (Figure 58). Participants were also given the option to alternatively stick sticky notes on their instrument (in the case they had brought it to the workshop) or in the cardboard guitars to sketch their interface ideas, if they wished to do so. For the foot switches prototype, participants were instructed to draw their designs on sheets of paper.

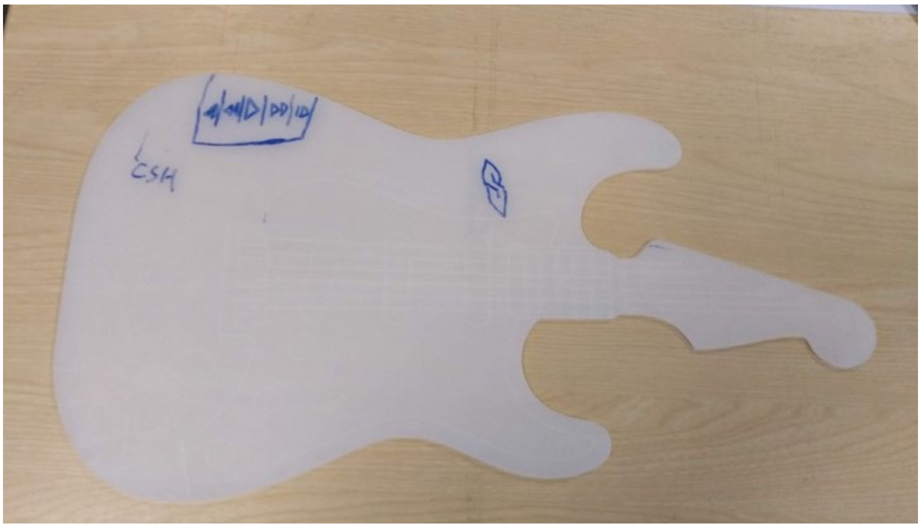


Figure 58. A participant’s sketch on an acrylic guitar.

After the participants finished sketching their designs individually, they were then instructed to show and tell their designs to the group. Furthermore, I encouraged participants to comment on each other’s designs and enquired whether they would modify their designs after looking at the other design ideas from other participants, or if they would adopt aspects of each other’s designs.

Due to the non-tangible nature of the interaction modalities presented in the remaining prototypes, i.e., voice commands and musical notes, participants were instead instructed to brainstorm, write down and discuss as a group what words or musical phrases they would use to trigger the media controls to navigate the audio track. For gestural controls, however, participants were instructed to think and discuss how they could employ bodily gestures with the instrument, with their body or with wearable technology (e.g., a glove, a ring, a shoe, etc.) to navigate the audio track.

To this end, participants were provided with a set of cardboard guitars to facilitate their embodied ideation process, that is, to discuss their ideas by moving around with the guitar props, or by moving the props around. Participants would also discuss their ideas collaboratively, whilst enacting the gestural controls that would trigger the media actions to navigate the audio, thus demonstrating their ideas to each other through *‘bodystormed’* embodied sketches (i.e., the ephemeral bodily movements enacted with the cardboard guitars).

5.3.2.3 Wrap-up Stage

After the co-design stage, there was a wrap-up discussion to conclude the workshop, in which participants were enquired with a series of critical questions to address whether they considered that these technological interventions supported their personal preparation practices and whether these technologies could be integrated with their musical instruments, equipment, and within their context of practice in general.

They were also asked which of these interventions they preferred the most, whether they would spend time learning how to use it to eventually adopt it as part of their equipment, whether they would add additional design elements and functionality to the current prototypes, and whether they would like to see different interactive control elements from the prototypes combined in a single design.

Furthermore, participants were asked whether they would prefer these interventions to be presented as temporary augmentations to the guitar or as separate devices that could be used in conjunction with media or whether they preferred the technologies to be embedded in the instrument (as a novel technology). Participants were also asked whether they would replace their current instruments with these new instruments.

Specifically, participants were presented with three different approaches to intervening guitars, namely, temporary interventions (e.g., clamping a capo or clipping a tuner, i.e., something that can be attached or removed from the instrument), permanent interventions (e.g., drilling a hole to install more inputs, i.e., irreversibly modifying the instrument), and integrated interventions (i.e., designing a new kind of guitar integrating the technology in the design, e.g., the Sensus Guitar or the Fusion Guitar[15]), in order to survey their attitudes towards these different approaches to the technological intervention of the instrument. The aim with this discussion was to examine any concluding thoughts in terms of impressions, challenges and responses regarding the design elements and interaction techniques demonstrated with the prototypes presented to the guitarists and bassists.

[15] https://fusionguitars.com/

5.4 Data Collection and Analysis

As detailed in the sections above, the workshops involved a series of co-design activities in which participants tested and reflected upon a series of interaction modalities prototyped by me. They also generated design ideas that supported their subsequent discussions on these interaction modalities and the prototype's design elements guided by the researcher's enquiry.

To collect data and outputs from these activities, video, and audio recordings, as well as photographs were captured during each of the four sessions, which took place in the laboratory space at the University of Nottingham. The space was arranged to facilitate the conduction of the workshop, the testing of prototypes by the participants, as well as their group discussions. The testing area was also arranged so that it would resemble a practice space, akin to Schleicher et al. (Schleicher et al., 2010) "strong prototyping" technique. The participant outputs that were collected were the following:

(1) Transcripts of verbal responses to usability queries on the prototypes.
(2) Transcripts of verbalisations amongst participants (discussions).
(3) Photographs of sketches (sheets of paper and acrylic guitars).
(4) Videos and photographs of embodied sketches (acrylic and cardboard guitars).

These outputs were then curated and prepared for subsequent analysis. For instance, utterances by me and social exchanges between participants (e.g., introductions and off topic conversations) were excluded from the transcriptions. Furthermore, photographs and videos of participants' designs and embodied sketches were only considered for analysis when they supported their verbalisations.

The transcriptions and supporting photographs were then codified into emerging codes and categories (Saldaña, 2021) using the NVivo software. After an initial pass of open coding, the data was then axially and selectively coded according to the emerging themes and broad categories (ibid), using a content analysis approach—focusing on utterances of feelings and attitudes towards the prototypes, and the frequency of category occurrences (Krippendorff, 2018).

5.5 Findings

The findings from the workshop are collated and reported in terms of the most salient impressions and considerations of each interaction modality (i.e., touch controls, foot switches, voice commands, musical notes, and gestural controls) across the four workshops. As mentioned before, only a set of participants hands-on tested each of the research prototypes, so the reported first impressions after using the touch controller are based only on the input of these participants. However, general discussions and critical reflections of the prototype are based on the input of the whole group.

These reflections encompass aspects of the interaction with each individual prototype, and speculation of its usage in the context of performance preparation, as well as its incorporation within existing practices to support encumbered interactions. Then, a summary of the wrap-up discussions across the four workshops, which reflected on the issues of the technological interventions to the guitar and their integration with other equipment in the context of practice are presented.

5.5.1 Touch Controller

In general, participants appeared to positively react to the prototype, making favourable remarks after using it for the first time during the workshop. However, in the subsequent group discussions, participants addressed more specific aspects of the embodied interaction with the device, namely, its affordances, i.e., its inputs and their visibility, and the form factor, footprint, and positioning of the device on the instrument.

Moreover, they identified a series of interaction challenges when speculating about the use of this device in their regular guitar practice. Addressing the **support of encumbered interactions** when testing this prototype, Mike, Kelly, and Krist pointed out that the prototype was helpful for ameliorating the switching of modes of interaction between the guitar and the computer, by allowing them to keep their hands in the instrument (Mike), and avoiding repetitive tasks with the computer, such as navigating to a particular section of an audio track over and over, to transcribe it on the instrument (Kelly and Krist):

> *"I would certainly use something that would mean I wouldn't have to move my hands away from the instrument to a mouse or to a keyboard. That's a huge benefit for me." (Mike)*
>
> *"If it's only one little bit you want to keep going back to and you just stick it in, it's just a way to stop going like that [makes an encumbered pose]." (Kelly)*

"That's really cool. If you got a song that has loads of sections. And you need to roll over and over one section." (Krist)

In addition to supporting encumbered interactions, Pixie also suggested that this interaction modality could also prevent potential injuries during performance preparation:

"I get quite a lot of joint pain and when I am practicing it gets worse. And I've really struggled with this whole clicking things and pausing. So, I think that could potentially save injury caused by stressful, straining movements when doing it over and over. I think above and beyond it is a really useful way of streamlining your practice and taking distractions out." (Pixie)

Callum and Ivan mentioned that although useful, the device would probably only be used temporarily in a performance preparation context, e.g., the home practice space:

"For home practice is brilliant but not much else. It saves a lot of time when you are constantly reaching to get things changed, it's so efficient." (Callum)

"The idea is great, but the prototype is halfway, rather than something you would use all the time." (Ivan)

Regarding the **interaction with the prototype's touchscreen**, Kit, Evelyn, and Charles reported issues such as getting distracted when having to look down to see the controls (Figure 59 Subsequently, a series of design-oriented responses to this particular interaction challenge emerged during the discussion and during the design activity with the whiteboard guitars (see Subsection 5.5.1.1):

"It's quite distracting at first, I don't know how quickly you would get used to that. You kinda have to bend over to look at it from above." (Kit)

"I felt like I had to bend over to have a look." (Evelyn)

"You also have to learn where the buttons are." (Charles)

Figure 59. Guitarist using the touch controls.

Although some participants reported it would be simple to learn the layout of the controls, other suggested **simpler interaction modes** or interfaces altogether (e.g., pedals):

> *“It all seems quite well thought out, quite simple to know what the symbols are.” (Callum)*
>
> *“Yeah, because in the end it just becomes automatic. You don’t need to look at it when you get used to it.” (Paco)*
>
> *“I would reduce the amount of buttons and controls that you have. I would have something like ‘tap’–‘go back,’ ‘double tap’–‘go forward,’ so it's a simpler interaction.” (Cyril)*
>
> *“When it's stuck in the guitar, you're still doing this [looks down to touch his guitar] instead of this [makes encumbered pose], not a big advance. If it were a set of pedals, that would be useful, because you could still play, and get used to where they are.” (Ivan)*

Paco, Marc, Mike, Evelyn, and Krist also discussed and expressed concerns about the **positioning of the device** on the body of the guitar and pointed out a couple of issues, such as whether the device (as it was located) would be too invasive to impede particular bodily practices with the guitar, i.e., **disrupting the flow** of performance:

> *“You would have to really careful of where the device is actually going to be set up on the guitar. I mean, if you are learning something that requires more movement of your wrist or requires a more aggressive or lively attack on the guitar, you might actually press a button unwillingly. Perhaps you could find a way to ‘unlock’ it with a double tap, so you don’t accidentally set it up.” (Paco)*
>
> *“Will it obstruct the strings while you are playing? Or will it morph into the guitar? Unless it was like a tuner, but you would still have to go on top of the guitar to do it.” (Marc)*

In particular, Mike, Evelyn and Krist discussed how the positioning of the device could potentially affect some playing styles on the guitar (as pointed out by Paco) but not the bass:

> *— “For me, as a bass player, that's a natural position [below the strings].” (Mike)*
>
> *— “But (…) when you're playing, you're gonna keep hitting the controller if it's down there.” (Evelyn)*
>
> *— “No, not really.” (Mike)*
>
> *— “As a rhythm guitarist you would.” (Evelyn)*
>
> *— “As a bass player you're resting up there. For you [Mike] actually it makes sense that is below, rather than above the strings, because there's risk you would hit it because of where your hand is resting.” (Krist)*

Following up on the discussions about the positioning of the device on the instrument, I enquired participants whether they would prefer a device that could be temporarily attached to the guitar, or a device that would be permanently embedded within it. In this case, most of the participants seemed to be inclined towards a **temporary intervention** for varied reasons, such as, accommodating different playing styles:

> *"If it were detachable, you could click it on here [points towards top of his bass]. Then, if you were playing a different style, you could click it on here [points towards bottom of his bass]. It's just individual styles really." (Troy)*
>
> *"I wouldn't like to have it embedded in a guitar. I'd like to position it where it suits me best." (Mike)*
>
> *"As many musicians as I know, everyone has different practices, and they're so different in so many ways. So, I think to get the most mass appeal out of it, it would probably benefit from being adjustable, adaptable, so you could put it in any of these places if that's doable. And if the strap is one of those options you can play about with and find what really works for you, rather, than only having options, x, y, and z." (Pixie)*

Using the device across different instruments:

> *"If you played the bass and the guitar you could use it for both." (Jamie)*
>
> *"(…) and move from instrument to instrument." (Mike)*

And overall, not wanting a bespoke guitar for practice, but rather have an accessory that could be used during home practice:

> *"If it were something that you could use at home, could you have that as a nice clip on? Slot it onto the guitar and not damage any of the paintwork, and then when you go into a gig, you just take it off. But whether you would want to develop something as a performance tool that had all of that built onto it. That was just used at home as a learning thing. Maybe a younger generation of guitarist will embrace an instrument that came with all of that on it as permanent feature." (Kit)*
>
> *"I'd probably go for something attachable like a tuner. You would be able put it on and take it off and take it off. If you've only got one guitar you wouldn't like that [device] stuck to the guitar for all the time." (Callum)*
>
> *"It would be nice for it to be something that just sits (…) same as the tuner that you clip onto the headstock of the guitar (…) rather than have to be installed like a guitar synth." (Krist)*

Furthermore, Evelyn and Jamie noted several potential caveats of a guitar that would have this sort of technology embedded into it:

> *— "I presume you would like to build a guitar that has that stuff in it." (Evelyn)*

> — *"But you wouldn't be able to break it because it would all go wrong." (Jamie)*
>
> — *"This is part of your practice, not part of your performance. You wouldn't want it embedded because you wouldn't want it when you're performing." (Evelyn)*
>
> — *"Yeah, and there's different risks, like going to a festival." (Jamie)*
>
> — *"Or lending your guitar to someone else." (Evelyn)*

However, according to Paco, Troy, Kelly, Kit, and Greg the temporary intervention approach also presented issues, namely, not having enough **space on the body of the guitar** to overlay the additional controls (i.e., considering the different shapes of guitars):

> *"I'd probably use it on an acoustic where I have all this space that I could use (…) With an electric (…) unless you have a Les Paul or something really bulky that you can put it maybe on this area [touches the 'lower' body of the guitar]. With a Strat, no, I don't see any space really where I could put it on." (Paco)*
>
> *"It also depends on whether it's an acoustic guitar and you've got a different [guitar] body." (Troy)*

And the overall invasiveness of the device in terms of potentially **damaging the instrument** or **affecting its resonance** (in the case of acoustic guitars):

> *"If it's something that is going to be inserted or clipped on there could be all sorts of issues about scratching the instrument." (Kelly)*
>
> *"For someone like me who owns some retro guitars and that's why I like them, I wouldn't like to put something like that on it." (Kit)*
>
> *"These folks are all doing acoustic stuff, and regardless of what you put on the guitar, if it's acoustic it's gonna be changing it." (Greg)*

Alternatively, Troy, Talos and Evelyn suggested how this device would also be **useful for other situations** where musicians are working with a computer whilst having an instrument at hand, namely when producing and recording musical tracks:

> *"If you write your own stuff and you've got your own track in there—if you do this in sections, for example, and just want to move to that section rather than whizzing through the whole track to get to the bit you wanna play—I think it could be useful for that." (Troy)*
>
> *"It's pretty handy if you want to do inserts. Let's say for example you are making a song and you want to add a specific layer—maybe a mute crunchy guitar, and then maybe adding another layer (…), [like] an overdrive— (…) you can carry on going back into that position and keep on doing it instead of reaching out for the mouse or the keyboard—it kills a lot of time" (Talos)*

> *"Maybe when people are recording? Maybe that could be a way of stopping little sections that didn't go quite right, so they could re-practice that and slot it into the soundwave." (Evelyn)*

Furthermore, Evelyn, Krist, Mike and Jamie discussed whether this technological intervention would **clash with their existing preparation practices**, e.g., requiring them to learn how to use production software (likely because the prototype was presented with Live's DAW) and set up the track with it (i.e., break it up into sections), thus taking up practice time:

> — *"The con is that you have to upload the soundtrack in there, and then you have to break it into the sections." (Evelyn)*
>
> — *"You need to know about audio editing." (Krist)*
>
> — *"Yeah, I don't know how to use audio editing software. I don't like it." (Evelyn)*
>
> — *"I just want to learn the song; I don't want to learn to be a music editor." (Mike)*
>
> — *"I'm not afraid of the editing, because you can see where the breaks are in the song, in the waves." (Jamie)*
>
> — *"Yeah, but how do you get that on there on the first place." (Evelyn)*

Likewise, Greg and Cyril made similar comments during previous workshop sessions:

> *"That looks really cool but doesn't make any sense to me [Ableton's interface]. Most musicians aren't sound techs." (Greg)*
>
> *"This soundwave is not showing me much, maybe if I know the song really well, but not now." (Cyril)*

There were also some expressed concerns of whether the device would or would not work with **other elements of their practice context:**

> *"Does it only work if you have Ableton Live?" (Serj)*
>
> *"Would you have to download this program [Ableton] to use it?" (Maria)*
>
> *"Is it only to control the software or could you also control a video?" (Charles)*

5.5.1.1 Design Activity: Whiteboard Guitars

During this design activity the participants used the whiteboard guitars as a support to visually and bodily address their previously discussed issues regarding the positioning of the controller device on the instrument and its affordances, considering their existing bodily practices with the guitar and the physical integrity of the instrument.

Alternatively, in some cases, participants used the cardboard guitars and sticky notes to demonstrate their designs, as well as sheets of paper to draw them. In relation to accommodating their embodied instrumental practices, several aspects were considered, such as, positioning the device within **easy reach of their hands** (Charles), and to **accommodate their different performance styles** (Talos, Paco and Mike):

> *"I thought I could do a thinner controller and I would place it here because I think my hand is here when I'm playing, so maybe it's more accessible there." (Charles)*

> *"I tend to do [makes strumming gesture] that a lot. So that's why I've put it on here [lower body of the guitar]. It's like something you can attach, just like a monkey tripod." (Talos)*

> *"Probably it's me being old fashioned but I wouldn't mess up a lot with the guitar. So, it would be something here just to tap the bottom [demonstrates with the prop guitar] (Figure 60), because it would make it so easy. (…) It could be [used] with any of my fingers that I want to be using, even if I'm playing with a pick or fingerpicking (…). I believe it's really unusual for people to attack in this direction so probably something like this would be useful, because even if you are sweep picking many people go this way, not many people go this way." (Paco)*

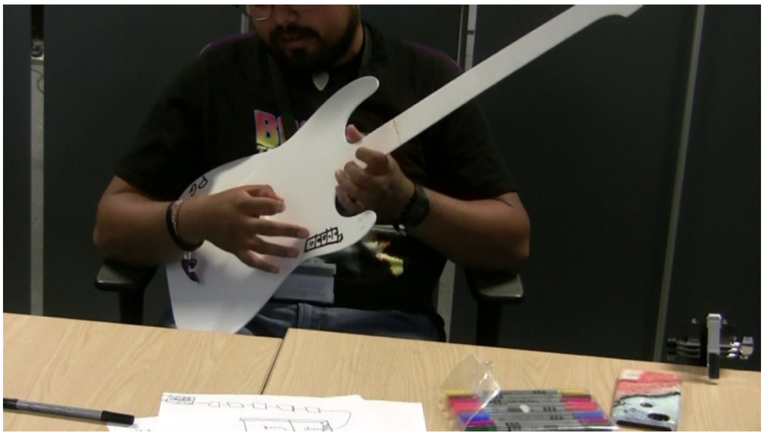


Figure 60. Paco demonstrating his interface design.

> *"Because of the way I play as a bass player, the natural position would be towards the bottom of the instrument, out of the way of the strings. It needs to be unintrusive and easily movable from position to position on the guitar or bass to suit a player's style or the type of instrument really." (Mike)*

Furthermore, also to the end of unobtrusively accommodating embodied instrumental practices, the **different shapes of guitars and their existing and familiar affordances** (e.g., the position of volume and tone controllers in acoustic and electric guitars) were also taken into consideration when addressing the positioning of the controller device (Callum):

> *"I usually tend to go that way rather than up here, so I've put it up here. I wouldn't have it built in, I'll have it like a strap, like something you could clip on so you could adjust the size to depending on which instrument you were playing. It's pretty straightforward and it should be something easily connected." (Callum)*

Pixie, Kelly, Danna, and Jose discussed the nuanced differences between the shape of an acoustic guitar and an electric guitar and their corresponding affordances:

> — *"Because I am an acoustic player, I think something in line with the pre-amp would be really useful [Figure 61], because it is a place you are already used to looking at and you are used to interacting with I think that's potentially a good idea." (Pixie)*

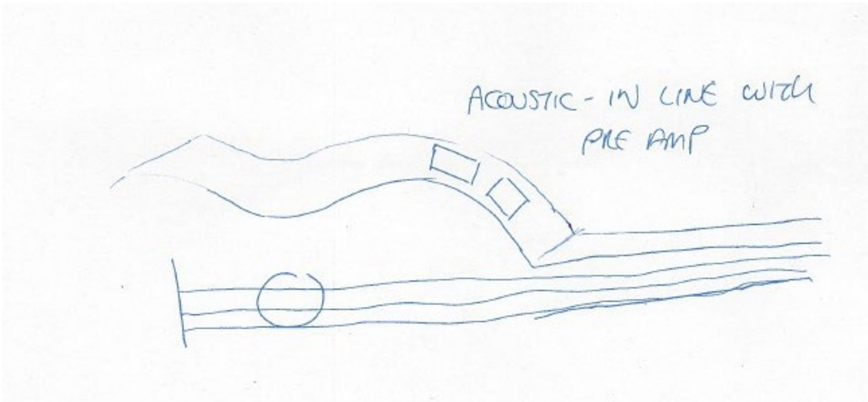


Figure 61. Pixie's augmented guitar sketch.

> — *"Well, I just figured that (…) in an acoustic you got space there (…) [also points towards the side of the guitar, like Pixie] for an acoustic player, it's already been designed where the adjustments are. [Same] in an electric guitar [volume and tone knobs]. [So, I have] just stuck them in the same place, so you'll find it easier to move from there to there [from guitar to computer]" (Kelly)*

> — *"In an acoustic I would do the same, it's really comfortable in there [same area as Pixie and Kelly]." (Danna)*

> — *"I think the same, this is the best part to put a device or buttons [on an electric] because this part is where you play so it could, be an **obstruction**." (Jose)*

In addition to obstructions in terms of the **physical disruption of performance**, Jamie, Krist and Evelyn also addressed the issue of the controls' visibility and the distractions from performance caused by having to attend to the instrument-mounted device:

> — *"I don't really play electric guitar, so I just used my assumption. I think the phone one is intrusive and distracts you from what you're doing. So, I would make something smaller and easier to touch and positioned here [Figure 62 (Left)] so you could keep playing. And then you would be able to move it. And then if you have an acoustic guitar, maybe you could put it right there [on the side of the guitar] because I think people are more used to twiddling with things there anyway [Figure 62 (Right)] and it's easier to look at." (Jamie)*

> — *"Is right under your **eyes** isn't it." (Krist)*

— "I'd like that you [Jamie] are thinking about the different shapes of guitars. That is really important in any kind of portable design that goes in different positions where you would put it." (Evelyn)

Figure 62. Jamie's controller designs on different guitars.

Alternatively, to address the issue of the **controller's visibility** Danna, Pixie and Maria discussed the idea of having physical inputs rather than touch controls:

— "Instead of a screen I would do it with buttons. Because you don't have to be looking at them, you just have to feel them. (…) You can get used to the feeling of them. And I think it's more comfortable than to be looking at them and observing where to put the fingers. Kinda like old phones with buttons, where you knew where each button was." (Danna)

— "And you had the little dot in the middle to know where the centre is. I like the idea of raised buttons because then you get used to the idea of where things are. And that's perhaps preferable than a flat screen for me. You could incorporate the same idea of having it in line with the pre-amp on the side with the physical buttons, and it becomes touch familiarity and muscle memory. Everyone was used to the old phones with the buttons, you didn't have to think about after a while, especially with the little nobbles when you know you are in the middle one, something like that it was just easy to just feel it." (Pixie)

— "Actually, I pretended to have [physical] buttons here down on the edge of the guitar below so you would just press the button you need, or a portable screen that you can attach." (Maria)

In the other hand, Kit proposed a recessed display that could be angled so it was more visible for the player, and which could be either embedded or attached to the guitar:

"I had two separate ideas. One is if you want to have an entirely new guitar to do this job, you could think it could go well with something like the modelling guitars and then you added this as an extra feature. So, I was thinking on the way you had the mobile taped to your guitar. Obviously, you have this thing of looking over like this. So, if you were to have this as a permanent thing you could recess the display into the guitar a bit, so it's angled up to the player. But then I thought that's a very

> *expensive thing to develop a guitar that is going to do that.* ***Many people are not gonna want to do that.*** *I was also thinking of the placement of it, because as someone pointed out, it could get in the way of your strumming - particularly if you are a big strummer, you're gonna be whacking that. And also, it can't go here because of your elbow. So as an add-on you could have something that is shaped like a prism rather than flat, so that the display is angled towards you." (Kit)*

Yet another way of ameliorating distractions that was proposed by participants, was to make the interaction with the controller simpler by reducing the number of inputs and assigning more functions to single inputs:

> *"So basically, one tap is to pause it, one tap to play and double tap to go back, (…) two taps could be something like go to the previous section. Because normally you're only learning one section at a time - you're not jumping between solo, verse, and chorus. So maybe one tapping button could be more convenient." (Cyril)*
>
> *"I also think that three buttons could work, these two would be to go to the next or the previous sections but if you hold them then you can go forward or backwards and then the central button if you press it, it plays and pauses, but if you double that then you can make a mark with that same button." (Charles)*
>
> *"You don't want to over-complicate it too much or else you just would be confused most of the time. So, it's just simply play stop, next track, last track (…)" (Serj)*

Nonetheless, participants also expressed their concerns regarding how **invasive**, or destructive will it be to attach or embed the controller device onto the instrument:

> *"The best scenario would be to have a device that you could put on the guitar with a sticker, so not to damage the guitar, not to make it invasive." (Cyril)*
>
> *"The obvious problem with that is cutting holes in your guitar is not something you do willingly, isn't it?" (Pixie)*
>
> *"It's gonna change the tone as well, isn't it? if you attach it. I don't know, everything that is going to add bulk to an acoustic guitar isn't a good thing, isn't it?" (Kelly)*
>
> *"Maybe something shaped like your phone, a box, 3D, with the buttons in it. Put it on the strap so it sits right here. It's right there [Figure 63 (Left)], or here on the strap [Figure 63 (Right)], either one. And that way it's not touching your guitar. Perhaps this one [Figure 63 (Right)] I wouldn't like it because I got a beard, and if you have really long hair, you wouldn't like that one [Figure 63 (Left)]. But if it attaches onto the strap, I can put it in here or here and do whichever one is gonna make me happier." (Greg)*

Figure 63. Greg bodystorming where he would position the device.

5.5.2 Foot Controller

In the case of the foot switches prototype (Figure 64), participants tended to compare it with the previous prototype, i.e., the touch controller. This often resulted in participants favouring the foot switches over the touch controls, albeit with some exceptions. Contrasting comparisons were generally accompanied with a previously identified interaction challenge from the touch controls, thus supporting their preference for the foot switches.

The interaction challenges when using the touch controller that were addressed included the issue of disrupting the embodied instrumental practices with the guitar, the issue of the visibility of the inputs and the distractions it caused, and the invasiveness of the device when attached to or embedded into the instrument. However, other arguments in favour of the touch controller were also revisited such as its mobility and portability.

Furthermore, other specific affordances of the foot switches were discussed, such as the number of inputs on the floorboard, its compatibility with other pedals and how it would be integrated in other performance practices along with other equipment.

Figure 64. Participant using the foot controller.

Regarding the **support of encumbered interactions** Callum, Mike, Danna, Jamie, Greg, and Pixie expressed their preference for the foot controller due to similar reasons, such as not having to interrupt their performance with the instrument to manually operate them:

> *"I love this. I would probably think is better than the phone, because you can still play and change it with your feet. When you have got the strapped phone on the guitar, you are still interrupting your playing to reach over for it." (Callum)*
>
> *"Yeah, that's not gonna get in the way of your playing. I'm not used to pedals (…) [but] having said that, the foot pedal as everybody said looks really easy, intuitive to use, so I wouldn't definitely be tempted to have a go." (Mike)*
>
> *"I prefer to use the pedal I think because you are free here [moves hands] and you don't have to look at anything else, just the monitor sometimes." (Danna)*
>
> *"I can see that being really handy. Because you're hands-free completely." (Jamie)*

Not having to distract themselves from practice by looking down to use them:

> *"I prefer the foot one due to visual problems, so I don't keep changing glasses so that I can see down there [to in-instrument controls]." (Greg)*
>
> *"And you don't have to crank your neck all the time [to look down]". (Pixie)*
>
> *"If all of your concentration is in playing the guitar the last thing you need to concentrate is on why is that button so small." (Jamie)*

Their existing familiarity with pedals:

> *"I already use foot pedals when I play anyway, so it's easier to switch to a new pedal if you are used to that idea." (Greg)*

And ultimately not having to attach or embed an invasive device into the guitar:

> *"And I also feel like I wouldn't like to have something on the guitar. I don't know if it would be sponged up or how would you put it on there, but if it's on the floor is not on the guitar. Is not gonna change the tone of what I'm playing." (Greg)*

In contrast, arguments in favour of the touch controller addressed its **mobility and portability**, although Jamie pointed out this sort of device would probably mostly be used in a home practice context, so mobility will not be an issue with the pedal:

> *"I prefer the phone, because this one [the pedal] you have to connect it to the computer, and the other one could be wireless." (Jose)*
>
> *"Could you get the phone to make the sounds, so you wouldn't need the speakers in the computer? That could make it even more wireless." (Greg)*
>
> *"(…) I don't think it's something that you need to move around too much though. If it's just for personal practice, I don't see any need to take it to band practice, so it wouldn't be necessary to be the most mobile thing." (Jamie)*

Nonetheless, participants also pointed out a series of potential embodied interaction challenges with the prototype pedal, such as whether having too many inputs on the pedal would cause physical disruption or a distraction from the instrumental practice (something that was also mentioned in the pedal design activity in Subsection 5.5.2.1):

> *"There are too many buttons I'd say. Perhaps, three, maximum four might be handy. You see, people are lazy, and when it takes extra effort to get used to it, it might repel them." (Cyril)*
>
> *"If you had a song that only had one solo, would those [foot switches] be out of use?" (Marc)*

Similarly, Serj suggested that media navigation using the foot controller should not require too much physical effort:

> *"So maybe if you program it so that you only press it and directs you straight away to the next part. Because it may be quite time consuming to do this all the time [taps repeatedly on the floor] but other than that I'd definitely use it." (Serj)*

For the same reason when other participants suggested additional functionality to the pedal like looping, Jamie pointed out this could also cause distractions from instrumental practice:

> *"I don't know if I would like to over-complicate it with a loop pedal. You would have to use it easily, because with the current one you still got your freedom, you just have these little bits of concentration with your feet, so your concentration is better in your music than it is on your feet, isn't it?" (Jamie)*

Another concern that participants expressed was whether the device would require extensive prior configuration before using it in practice:

> *"So yeah, I would worry more about the interaction—like once this is setup it's brilliant, but how much would it take to set everything up—like do I need the program?" (Paco)*

> *"So, you would have to add your own edit points? So, you would have to put some prep into it, to add the new points into it, on each new song." (Kit)*
>
> *"It would be good to have that pre-set." (Marc)*

Participants also discussed the compatibility of the pedal with their existing practices and equipment. In particular, Paco and Callum discussed how this pedal would interact with other pedals in a live performance, beyond the instrumental practice context:

> *— "I would prefer to buy something that I can use live rather than to practice. And also, like, the connectivity of this with a pedalboard—how they interact. Maybe make it smaller, so it can go into my pedalboard. Because then you can use this for other things like playing live. Maybe for backing tracks." (Paco)*
>
> *— "Yeah, if it's something more compact, then it can go on your pedalboard like you said. Also, the sense of universality to it. You can use if for live sets or electro-acoustic or bass, you can still just plug it in and do the same things with it. I'd say the pedal works better for that, rather than the phone." (Callum)*

Similarly, Ivan proposed different modes of usage for the pedal to accommodate different instrumental practices:

> *"You could have one mode to control effects, another for practice. You could have different interfaces for different things." (Ivan)*

In the specific context of performance preparation, participants also discussed whether the device could be used with other resources:

> *"Do I need the program [Ableton Live]? Or can I use it over Spotify? And then, would you need the actual file of the song? Because sometimes some people look at videos of other people playing the song instead of the official one. It all depends on how easy it is to set up and what can you pair with that because if you need the recording software or a really high-quality recording of the song, maybe it becomes more of an effort or more expensive that you need to buy. So maybe you have to think how you can pair this with other interfaces like YouTube, Spotify, Apple Music, and stuff like that." (Paco)*
>
> *"Will it be something that you could use in conjunction with YouTube videos?" (Kit)*
>
> *"It's a good idea, for instance, if on YouTube you could add your own markers and then navigate them." (Cyril)*
>
> *"It would be quite useful to take the track from the video and put your markers in." (Ivan)*

5.5.2.1 Design Activity: Drawing Pedals

During this design activity participants used sheets of paper to draw and showcase their fictional pedals as a way to discuss their design ideas and refinements to the pedal prototype previously used. These ideas generally responded to issues they pointed out with the prototype, such as the affordances of the device (the visibility, size, and number of foot switches), and how these could be refined to support their instrumental practices. Other participants further expanded the functionality of the pedal to accommodate live performance practices. Addressing the visibility of the inputs Jamie, Evelyn and Kit discussed a series of design ideas:

> *— "For the pedal I would prefer something that is very colourful and visible. So, for example if you look down to the pedal you can quickly see which button, you're gonna hit. It makes it easier for you." (Jamie)*
>
> *— "I like the bold colours suggestion." (Evelyn)*
>
> *— "Maybe the button of the section you are on starts flashing." (Kit)*

Participants also discussed the layout of the inputs, the size of the pedal and its material:

> *"Perhaps I would change the transport controls to the back and the sections in the front. I would also have the solos in the ends as a rhythm guitarist I might not be focusing quite a lot on the solos." (Evelyn)*
>
> *"I like the idea of the foot pedal, but just make them slightly bigger for people who have giant feet like mine." (Greg)*
>
> *"And probably I'd make it of robust material because I can get quite animated and if I hit it quite hard, I wouldn't like it to break. I wouldn't like it to be a delicate piece of kit." (Jamie)*

In regard of the number of foot switches on the prototype pedal, most participants were inclined to simplify the interface by reducing the number of inputs:

> *"I think you could get away with just three buttons on a foot controller. The three buttons would be a play-stop button, and a previous and next section button. But the setup would be in the computer first. I don't see the advantage of setting it up with guitar controls, because it's not the right interface. (...) you should use the right tools to do the right things." (Ivan)*
>
> *"My idea works with a pedalboard, if we assume we're working with YouTube videos rather than software like Guitar Pro, we should also have three buttons, so you double tap on one and you record your sample of a section than tap it again and that records it. If you tap it, one more time then you go to the first tap on the section and those labels could be labelled however you want." (Cyril)*
>
> *"Mine is a pedal in which you pop an SD card in and then you load your stuff on it and then you split up your sections. And you have a section up, a section down, and a restart button, and also a tuner (Figure 65)." (Marc)*

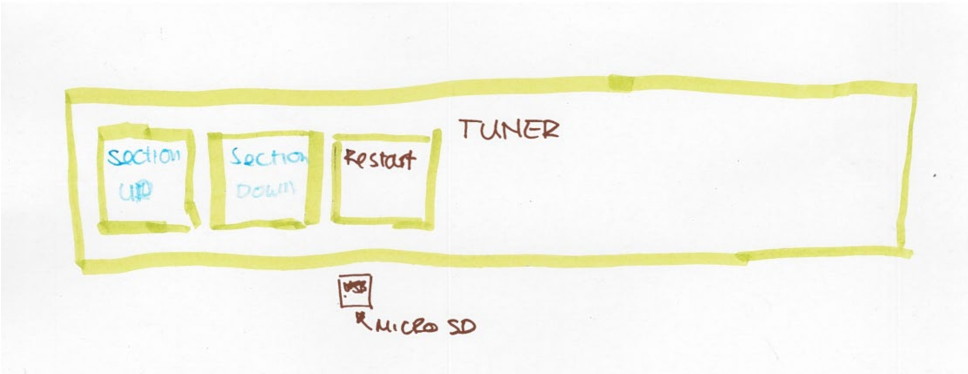


Figure 65. Marc's simplified pedal.

In this sense, Kit and Marc pointed out in conversation that a simpler interface would ameliorate potential disruption or distraction from instrumental preparation:

> *"I think one idea that is coming up from everybody's designs is wanting to keep it simple (three buttons, one button)." (Kit)*

> *"Just because you got a lot to think about already, trying to learn the song. That can be hard enough." (Marc)*

Other participants further expanded the functionality of the prototype to be used with their existing media resources and to accommodate their live performance practices, and to integrate the device within their musical equipment and computing devices:

> *"Maybe you can add a few more buttons, but for a live setting I would do [something] more practical. I would have a play button, which is going to play your track. You should be able to play anything in your library, and of course it has to come with a USB or MIDI entry because that's how you can actually control what's in there, on your device, maybe a tablet you would use for this if you do it live, and if you do it in your house it's just your computer (Figure 66)." (Paco)*

> *"It would be something you could easily fit in. You can put it anywhere on the pedalboard really." (Callum)*

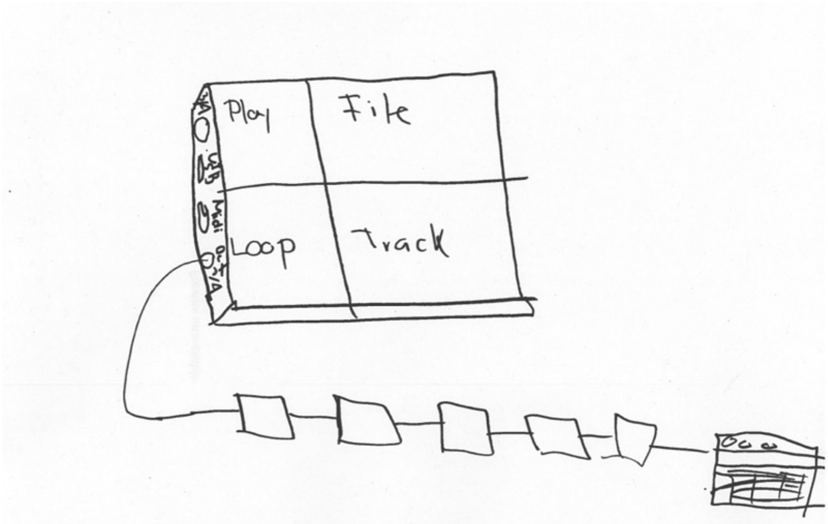


Figure 66. Paco's pedal with expanded functionality.

5.5.3 Voice Commands

Although voice commands could be appraised as an interaction modality that could allow for hands-free instrumental practice, as the device would only require them to utter a single-word voice command—such as 'play' or 'stop'—to trigger a media action, participants pointed out a series of potential issues with the device that could disrupt their practice with the instrument and discussed ways of overcoming them. Participants also expressed concerns of whether the device would require extensive pre-configuration.

Moreover, participants discussed how the device would fit within their current performance preparation practices, tools, and resources, such as when using this device with their preferred software or during band practice. Although most participants were familiar with how this technology could be used in other contexts, such as when driving a car, a portion of the participants associated the use of this technology as something more suitable for younger players, and generally not as something that they would consider as part of their context of practice.

When addressing how the device would be used during practice, participants pointed a series of caveats with this interaction modality which could potentially disrupt their preparation activities. For example, Evelyn, Maria, and Pixie were concerned the device would involuntarily trigger media actions when they were singing or speaking to band mates:

> *"I think no [I wouldn't use it]. Because I sing and play so I wouldn't want to have to keep saying play and stop and be singing at the same time. Whereas the foot thing wouldn't intrude like that." (Evelyn)*

“Do we have to make sure that the word we're saying is not included in the song?” (Maria)

“I don't like things listening to me. You see, you spoke, and it did something. I really don't like it. I don't have a Smart TV at home because I don't like these things listening to me. That would be my main objection. Another issue is that I know three different people called Mark, so every time I would speak to them it would put new sections! That might be problematic!” (Pixie)

Alternatively, Charles, Marc and Kit discussed how they could overcome this issue by employing a keyword to wake up the device to listen for voice command:

— “I see some negative aspects, if you are also singing and then you say stop, you would lose the music.” (Charles)

— “If "stop" is in the lyrics, yeah.” (Marc)

— “It depends on the reach of the microphone I suppose.” (Kit)

— “Maybe if you add a keyword so that the mic knows that it has to listen to the command. Like with Alexa. And that way you can avoid the problem when singing unless the song includes the keyword as well.” (Charles)

Likewise, Greg mentioned a similar approach in previous workshop session:

“I would actually say, stop verse 1, stop verse 2 - so it stops what is doing and gets to the next one. I would have a two-word command, not a single word command, so it's less likely to be triggered by mistake, for example if you were practicing ‘Stop in the name of love.’" (Greg)

In conversation, Mike and Evelyn discussed one potential caveat of employing longer utterances to trigger the media action, i.e., the VUI not understanding the user’s accent:

— “I wouldn't say left and right.” (Evelyn)

—"Maybe forwards and backwards.” (Mike)

—"I guess back to, and then you could combine it with, back to... intro or back to chorus. If you make longer sentences you are running with the risk of the variety of accents, and the machine not understanding.” (Evelyn)

Furthermore, Paco, Evelyn and Mike expressed concerns about how time-consuming the device would be to setup prior to practicing and whether it would be necessary to have specialist knowledge of audio software or additional equipment to be able to use it:

“I would use this if it was already there. If I didn’t have to assign any scripts or commands, if somebody had invested time already to do this for me.” (Paco)

“The other possible con would be if you have to have this microphone to isolate the voice. And if you have to set it up to do so. That's gonna be annoying for people who just wants to get to play the music, not setup lots of things.” (Evelyn)

"But then you would have to define what each section is (...) and again you would have to be quite skilful at operating garage band or whatever." (Mike)

Paco also enquired whether it would be compatible with other media resources and software tools, whilst Kelly asked if the device would interfere with other VUIs, if present:

"That's a really good idea if you could use it with any kind of software that plays music, or if you have like that app that has a license to use all the music, or you build it like an add-on or plug-in for any other platform. So, you could be in Spotify and say: 'Come Together Solo' and it comes in on that section." (Paco)

"What if you already had Alexa? Would it interfere with it maybe?" (Kelly)

Considering the use of the device in a rehearsal context with a full band, Troy enquired how the device would respond when collaboratively composing songs with his band mates and naming song sections in the fly, followed by supporting remarks from Paco and Callum:

— "So how would it work with something that doesn't follow the 'verse, verse, chorus' usual thing? We have this discussion when we're writing songs, like, 'is that the bridge, pre-chorus, or whatever'? Or I might call it, the 'lead guitar' or 'the muted synth bit,' I reckon. So, it's just that, how would it know what those signify upon being triggered?" (Troy)

— "Also, some songs don't have a chorus." (Paco)

— "Or are instrumental." (Troy)

— "Yeah, exactly." (Paco)

— "Yeah, depending on the song it can get quite complicated." (Callum)

Remarkably, although most of the participants were familiar with the technology and its use in other contexts, Cyril, Ivan, Jamie, and Evelyn appeared to regard voice commands as a technological novelty that would be more easily accepted by younger generations:

"I used to have a VUI in my car, and when you pressed a button, it would listen to you. And I would say call, and then it would ask me whom, to confirm. So, if you secure it nicely it might work, especially with younger generations who are better with technologies." (Cyril)

"I don't use any of that technology at home myself, but I know a lot of people that do. They might be into it, and I think a lot of people would like that." (Kit)

"I think that's a thrill, but I think people would like it, particularly if it has a key word like Alexa, that could rule out a lot of problems. Once you have it developed it could be a good selling point for a younger generation. Older people might still go for a manual thing, but it would be nice to have a VUI as part of the package." (Ivan)

"Maybe younger people would be more willing to engage with this kind of stuff." (Jamie)

"Yeah, when you wheel out new technology you can create a niche for it. So younger people might think they have to have this." (Evelyn)

5.5.4 Musical Notes

One of the particularities of employing musical notes as a control input to navigate media using the prototype presented in the workshop is that interaction with the system implies playing distinct musical phrases to navigate to specific parts of an audio track (so as to loop around that same fragment of the song) and playing discrete two-note phrases to trigger transport controls—as previously described in Section 5.2.4.

However, to play the musical phrases participants were required to firstly get acquainted with the notes that comprised them, thus a sheet of paper with a score and tablature was presented for musicians to read the notes and perform them (Figure 53). This initial requirement resulted in participants identifying a series of caveats of using this interaction modality during performance preparation, such as demanding proficiency with sight-reading prior to use the device or having to be acquainted with the song already—prior to learning it.

Participants also observed that this approach to media navigation imposed a series of impracticalities to performance preparation, like those in the VUI prototype, in relation to how media actions could be accidentally triggered when loosely playing the instrument in the context of practice.

Likewise, participants also considered that to use the device they would first need to spend a significant amount of time learning how to use it and set it up. However, some participants were also amused by the game-like qualities of this interaction modality, i.e., triggering bespoke actions by playing customisable musical phrases with their instrument, and proposed alternative use cases for this technology. Regarding learning to play the codes before being able to use the interface, Talos, Marc and Evelyn appeared to have the impression that a knowledge of music theory or sight-reading was required to use the prototype:

"But then it requires music theory, doesn't it?" (Talos)

"I don't use tab I just go by ear so it might not be great for me." (Marc)

"And obviously you got to be a very proficient reader of music and tabs." (Evelyn)

Similarly, Evelyn, Kit and Greg also pointed out some fundamental problems with the interaction design of the prototype when used in the context of performance preparation, namely, having to know the song before learning it (Evelyn and Kit), and learning to play the wrong notes to avoid repeatedly triggering the media actions (Greg):

> *"Also, if you already can break the thing down in that way, I'm not sure that you need it, because you already know it. You don't need this practice technology then. This seems very much for proficient players." (Evelyn)*
>
> *"I think there's a basic problem with it, if you're using Muzicodes to learn or navigate a song, then you have to play a Muzicode from a song that you don't necessarily know yet." (Kit)*
>
> *"I can see a negative side of it, it's teaching to play the wrong bit. Especially for someone being new. It's got to be the wrong notes, otherwise you would activate it over and over." (Greg)*

In relation to avoiding unwanted media control triggering, Pixie, Mike, and Evelyn also pointed out how this particular issue would potentially disrupt the instrumental practice:

> *"If it's only a bit different from something in the song and you make a mess up there and then you trigger it when you don't want it too, I can see that being annoying." (Pixie)*
>
> *"What happens if the sequences of notes that indicates it to start or stop position and then you played that somewhere down the line is just going to go back, that's gonna be annoying." (Mike)*
>
> *"I think one of the cons is that that sequence of notes could be somewhere else so you may do the looping when you don't want to." (Evelyn)*

Moreover, Kit, Charles, Ivan, and Marc concluded that although the two-note musical phrases assigned to trigger transport controls could potentially facilitate media navigation by playing the instrument, they were nonetheless also prone to disrupting the instrumental practice:

> *— "Using the note pairs to move a section I think that's pretty nice to hit the guitar twice and move between stuff. I think that works pretty well. But not sure about using the musical codes as such." (Kit)*
>
> *— "The basic controls I like them, just 'doob,' 'doob' and you play." (Charles)*
>
> *— "Because that'd be standard through anything." (Ivan)*
>
> *—"But maybe if the song also includes that you would stop the recording." (Charles)*
>
> *— "Also, when you are learning the song would you start hitting it twice and integrating it into the actual song because you're used to learning it that way? I don't know. If you happen to hit something else, it is just gonna do what you don't want it to do?" (Marc)*

— "It could get very frustrating. To me that's just another voice command. But just more complicated, because you have to think about it, rather than say the word." (Ivan)

In this sense Paco speculated possible ways of bypassing the system temporarily so that it would stop listening for musical codes when not needed:

"Maybe you should assign a signal to stop that process, so you avoid by any chance playing the notes you programmed it for." (Paco)

Another issue with the system that was contemplated was whether the system would be able to discern when musicians performed fast, complex, or loose musical phrases, or whether the entire system would fail if there were slight changes in the instrument's tuning:

"I like the idea. You could use it for practice and for live performance. The only struggle is that you would have to be precise when you are actually entering the code. It could be a little out of tune or something. That's something to consider." (Serj)

"If the singer weren't feeling quite great that day and you went an octave higher you could set the whole thing to go haywire, it would get confused. (…) For sure for prog or metal it won't work because the system will go haywire. Because there are so many notes." (Talos)

"It's filled with problems, if the guitar is slightly out of tune, it's not gonna work." (Ivan)

Yet another impediment to instrumental practice that participants discussed was the potentially lengthy setup of the device, especially when needing to assign particular musical phrases to trigger specific media actions, and learning how to use it:

"It seems like a very lengthy way (…) it involves too much effort on the part of the user, doesn't it? I mean if this is supposed to be advancing technology and you want to cut out as much human input as you can." (Kelly)

"I get really put off by having to learn to use new technology if it seems particularly complicated" (Pixie)

"I think is good but is kinda tricky (…) complicated to set it up." (Maria)

"I see there's definitely a use for performance as well. But it just takes some setting up and getting it prepped really." (Krist)

"This is a good idea; you just need to work on the lag (…) and make it really user friendly to set up the codes. Because if I need to spend 30 minutes setting all the sections in a song maybe I would prefer something that I could just tap, and it would work." (Paco)

Kit and Ivan also concluded that having to set up different musical codes for every new song they wanted to learn would be time-consuming and effortful:

> *— "Would you be having to change that Muzicode for every single song you're learning then?" (Kit)*
>
> *— "You would have to tie a Muzicode with a mark." (Ivan)*
>
> *— "Every time, yeah... You would have to build a set of Muzicodes for every song you'll learn." (Kit)*
>
> *— "Unless you have a standard set of marks, and a standard set of Muzicodes. Which wouldn't work." (Ivan)*
>
> *— "Yeah, for example if "Come Together" was the Muzicode for every other song you took on. But you would have to use the Muzicodes of another song!" (Kit)*
>
> *— "You can spend ages setting it up, learn the song and never use it again." (Ivan)*
>
> *— "I like it, it's fun. But like they say [Ivan and Kit], maybe it's a lot of work just to learn a song." (Charles)*

In relation to this issue Talos and Paco discussed ways of assigning musical codes to media actions more smoothly with the aid of a pedal:

> *—"Maybe a pedal that when you press it makes the system listen for a Muzicode for you to set it up, and also mutes the sound of the guitar whilst it is talking to the software." (Talos)*
>
> *— "Yeah, instead of having a MIDI converter and a laptop you could have stomp box to record your inputs directly with your guitar lead, and then connect it to a computer with USB." (Paco)*

Regarding other potential applications of this technology in the context of music-related practices, participants suggested a series of use cases during live performance. However, other participants pointed that a pedal could potentially achieve comparable results:

> *"You could trigger like extra layers, like MIDI sequences or something." (Krist)*
>
> *"I think perhaps using it in performance. Like people do with pedals. So, this method of triggering it with notes to get it to loop back to a certain point might be very useful. And also like you mention if you could trigger a video that would also be very good for a performance aspect. They could use this and maybe not a foot pedal. The thing with the foot pedal is that you can build up lots of stuff. Not sure if this can do that." (Evelyn)*
>
> *"(…) because of the inherent repetition in music, for me, thinking about these things I've written, given that I do some of the multimedia elements as well (…) there's often times in which I would like to highlight this section, with lights. Is very likely that the bit I want to trigger is a repetition from something, somewhere else in*

the song anyway. So, I think in that case, I'm more inclined to just look at a pedal operation for whatever that was, because I got immediate, 'bang!' is on, and 'bang!' is off, something that would not accidentally trigger it." (Pixie)

Alternatively other participants suggested use cases more inclined towards instructional games or gimmicks that added play value to the context of practice:

— "There's probably some added value in terms of being a fun feature rather than say the words. If you make your own up it could be quite fun, but would it be more practical? Play value really." (Kit)

— "Yeah, it's always necessary." (Marc)

— "Practice can be a bit boring." (Ivan)

— "Yeah, that's true." (Kit)

Pixie and Kelly discussed the positive and negative aspects of a game that would use musical notes as input, such as pandering to young learners but potentially introducing degenerate strategies into the instrumental learning experience:

— "I get really frustrated by things like rock band and guitar hero. But I could see some potential to use Muzicodes to create a game, where you actually have to learn the tab to control the game. That might be a way to target it for younger people learning, that could be really useful. If it were a game in which you had to play the right notes rather than just pushing a button. Potentially that could be interesting." (Pixie)

— "But it does take away from the object of the exercise, which is just to learn music. Because you could always put any kind of interface between it. From A to get to B. But another thing is that if they are too busy concentrating on winning and not learning the song." (Kelly)

— "I don't think, necessarily for learning a song, but for learning where the notes are. So, something like that, where you are enjoying the experience, but is kinda like sneaking the knowledge as well, it might be useful. Everyone learns differently, I think I might benefit from that." (Pixie)

5.5.4.1 Design Activity: Thinking of Musical Codes

When thinking about how they would design their own musical codes participants came up with ideas such as mnemonic devices, which also evidenced that some level of prior skill with the system was required to cleverly design musical codes that would be long and unique enough to be differentiated to not get triggered all the time:

"If I could make my own Muzicode I'll just fit it into that [plays a melodic phrase that resembles notes in the chorus of 'Come Together']. If I know this is 'B,' 'A,' 'G,' 'A,' that for me would be something I could remember, like 'baga'." (Troy)

“For example, if my song starts with an arpeggio my signal is going to be a chord with those notes so my fingers can be in the shape of the notes I will be playing.” (Paco)

“I do like that idea, is all personalized for the player really. It [defining a Muzicode] does depend on the player and in the piece itself. If it’s something simple [a short phrase] it might end up getting mixed with a whole bunch of other tunes. But I don’t know, making it simple, make it unique? Can you do both? Probably can, it would depend in the tune itself, on the player’s playing style and on their personal preference. There shouldn’t be like a standard Muzicode for every single player that uses Muzicodes, you should have freedom to make your own. I think that’s an advantage that Muzicodes might have because you can assign different phrases to different sections.” (Callum)

“I would introduce it in song writing and I would probably use three notes to trigger the section I would like to practice. Two notes I don't think would quite do it, it would be too easy to have them trigger by coincidence that may occur in the song. Or maybe I could use some sort of hammer on or something that I know would be a certain call or action that would recall things.” (Jamie)

5.5.5 Gestural Controls

As previously mentioned, gesture-based controls were not developed into a functioning prototype as with the other interaction modalities. Instead, guitarists were prompted to think about, enact and discuss gestural mappings to trigger the media actions presented across the other prototypes, during a bodystorming activity using the cardboard guitars props provided (Figure 54). This activity also prompted participants to speculate how they would employ this interaction modality during performance preparation and to reflect on the issues related with the technology, in the subsequent group discussion.

The aspects of gesture controls that participants discussed involved the different modalities of gestural interactions, such as gesture recognition at multiple levels, ranging from gesturing with the instrument or having the instrument recognize gestural inputs (e.g., tapping or sliding the fingers on the body of the instrument), as well as motion capture and wearables. They also discussed the possibility of having false positive media triggering across these modalities and speculated ways of bypassing them (as with the voice commands and musical notes modalities).

Participants also suggested alternative applications for this technology, such as controlling digital audio effects or to encourage people to move more when performing. When discussing ways of gesturing with the guitar to navigate media, Marc, and Ivan discussed what the requirements of the technology would be, especially when some performers might move a lot during practice, whereas Cyril pointed out that such an interaction modality would be frustrating for those who do not like moving too much when playing the instrument:

> — *"Logically speaking if you would like to go, it would be pushing away from you and to stop you would pull it back. Section up will be tilt it up, …down. It would have to be rudimentary normal stuff like up, down, away, forwards." (Marc)*
>
> — *"In terms of the technology it might be a sensor on the guitar and then you just move it." (Ivan)*
>
> — *"You would have to have a strong strap just to make sure you don't have any mishaps." (Marc)*
>
> — *"You would have to consider the sensitivity of how much you have to do it to activate it. How much calibration can you do? Because some people move a lot." (Ivan)*
>
> — *"And if you don't move too much it's going to be really annoying to make those movements." (Cyril)*

In contrast, Paco, Serj and Callum pointed out that doing so could potentially be disrupting to embodied instrumental practices as it would limit the mobility of guitarists to some extent, if the technology were to be constantly recognizing all of their gestures:

> — *"You can think of many gestures, but this would limit the applicability of practicing. And even during practice I would find it annoying, because maybe you're rehearsing a new solo, or a new song and you just really like it and keep on moving to the beat of the track. Unless there is a gesture to set it on and off because nobody is like a statue when they are practicing at home. No one stays still. I don't know [maybe] someone calls you [he turns his head back], and then the whole practice is gone." (Paco)*
>
> — *"Yeah, sometimes when you really get into it, you're just like [bobs his head]." (Serj)*
>
> — *"Yeah, 'cause lots could go down. Say you take your guitar off and then it's all just like balls up. I don't think is just very practical either way." (Callum)*

Along the same lines Pixie, Greg and Kelly also made similar remarks. In particular, Pixie suggested that using bodily gestures with the guitar to trigger media actions during practice would possibly limit her performance movements:

> — *"For me that would mean that I would have to have that only being used in a practice guitar because I move about a fair bit when I'm performing. But I like to practice with a guitar I'm performing with. So, I couldn't say, this is a learner's thing guitar, but any movement I do with the guitar I'm likely to make it in stage anyway, so it would totally take out being able to do it." (Pixie)*

— "You move a lot when you practice, and if you're going to make yourself sit still. If you did that [makes movement with whiteboard guitar] and then you would change something." (Greg)

— "It interferes with your playing, doesn't it?" (Kelly)

— "If you dropped your pick and then you had to pick it up and puts the chorus on again. I can see it being frustrating." (Pixie)

Alternatively, a set of standardized touch gestures with the hand to be recognized by the instrument were suggested by multiple participants (e.g., tap, double-tap, slide, etc.):

"It would have to be a set of movements, that did it or something that you could customize for you. Maybe having something that you just hit. Like tap for start and double tap for stop." (Ivan)

For example, in conversation, Evelyn, Krist, Mike, and Jamie discussed a series of advantages that in-instrument touch gestures had over gestures that would require moving the whole instrument, such as being less prone to unwanted triggering of media actions, as well as being more clearly defined as set of standard hand gestures rather than whole body gestures, thus being less disruptive to embodied practice:

— "So, you could tap it to stop and strum to start." (Evelyn)

— "Yeah, that could be interesting because there's no risk of mistaking a note or something." (Krist)

— "Yeah, you could do all sorts of things in different parts." (Evelyn)

— "Or even slide to go back or slide to go forwards (Figure 67) (Mike)

— "And if you swipe a little bit [on the neck of the guitar] maybe you go to the chorus and if you swipe more maybe you go back to the intro and then swipe forward and then you go to the end. I want this to happen." (Evelyn)

— "I think the movement thing would distract you less from your practice. But tapping on a guitar, that could work on any guitar, electric or an acoustic. The only thing that you need to remember is the set movement. And I move quite a lot when I play so it would be very easy just to do that, for me." (Jamie)

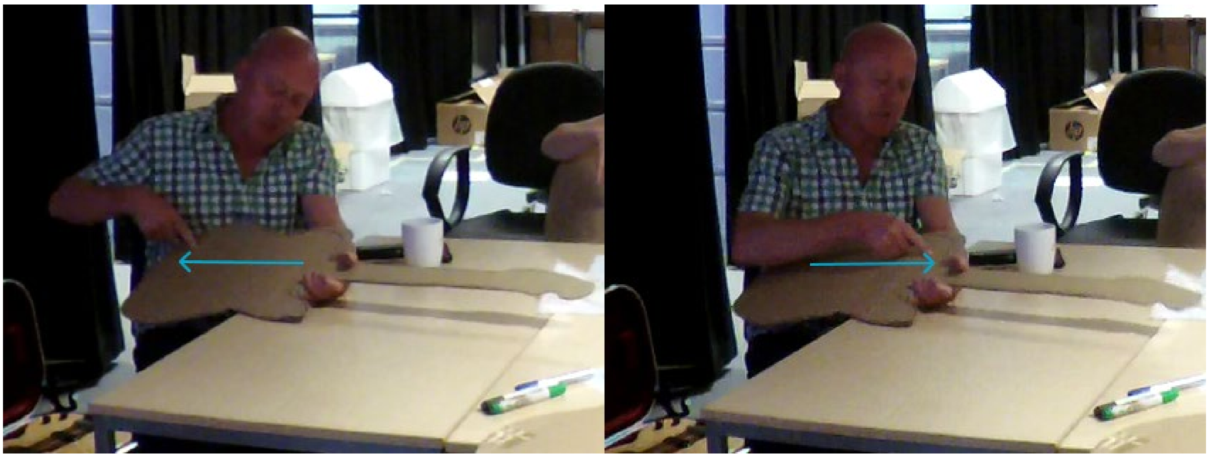


Figure 67. Mike demonstrating his gestural control ideas.

Another advantage that this group of participants discussed was that having the instrument recognizing the gestures would require less equipment, as opposed to using a fully-fledged motion capture system (e.g., Nintendo Wii), a foot controller (i.e., a pedal), or a microphone, to use with the VUI previously discussed. In this sense, having to engage with too much equipment simultaneously was regarded as disruptive to instrumental practice:

> — *"It's probably easy for gestures to be misunderstood or misinterpreted. I think that'd be quite a complex bit of programming." (Mike)*
>
> — *"But there's stuff like the Nintendo Wii, they are accurate on how they work." (Jamie)*
>
> — *"There's lots of kit though. You have the Wiimotes with sensors. They all connect to each other; they're all monitoring each other. Could you do all that without all the kit? Because you need to minimize variables and moving parts, because you're already focusing on doing stuff. You can't have confusing moving parts - making sure that's responding to that while you're trying to sing and play at the same time." (Krist)*
>
> — *"It has to be as simple as possible. I already got the bass, I got an amp, I got the computer, I am singing, I've got a mouse, I've got a keyboard, it's already too much stuff. I just wanna learn a new song." (Mike)*
>
> — *"I think the tapping is quite neat, I mean your guitar is plugged in, so it's gonna notice that. And with the funny gesture is gonna misinterpret that, it might not get what your intention is. Whereas one, two, three taps, they are quite clearly defined, and obviously you could turn them into commands. And that would negate the need for a foot switch I suppose. I like the tapping on the guitar is less risky. There's less moving parts. Less variables." (Krist)*
>
> — *"The pros are that, from what we all have been saying it sounds like you have to have an agreed set of actions that most guitar players would be happy with so maybe taps or some kind of movements. And they would have to be very natural*

and related to how people play anyway so you can slide up and down to make certain things happen. And related to that pro is that you don't have any other behaviour that you need to do like, a pedal underneath or setting up a microphone or stuff like that." (Evelyn)

Likewise, another group of participants (Kit, Ivan, and Marc) also pointed out how motion capture approaches (e.g., Xbox Kinect or camera-based motion capture) could impede bodily movements during practice:

— "With Xbox and things like this you've had stuff that captures gesture for a long time haven't you. It would be quite nice to put your headstock down and that moves to another point. But what if it's something you'll naturally do with the guitar and then you accidentally jump a section. [Maybe] it could also be a camera in the computer that watches it, rather than something in the guitar." (Kit)

— "I think I wouldn't use a camera to capture the gestures. You could have many problems; you couldn't move to far away or maybe someone walks in front of you." (Ivan)

— "You would have to set an area." (Marc)

Furthermore, Ivan, Pixie, Marc, Jamie, and Evelyn also suggested the possibility of using wearables to control media actions using several types of bodily inputs, e.g., eyes and hands:

"I work at [an Aerospace Company] and we have been making some eye tracking helmets for pilots. And they can activate things with their eyeballs. That sort of concept might be better than gestures." (Ivan)

"Eyes! that's an option, so I could just move it back by flicking it. I think it would take a while to get used to it wouldn't it?" (Pixie)

"Or like a secret glove." (Marc)

"Maybe with a glove or ring that detects when you make a significant movement." (Jamie)

In regards of ways of bypassing unwanted media action triggering, participants proposed a series of approaches, such as using a pedal to momentarily capture the gestures or relying on a system that could learn their personal gestures with high fidelity (e.g., an artificial intelligence):

"Maybe if you had a button and then pressed the button and made the movement." (Charles)

"And it could get used to your own personal movement." (Marc)

"If I knew that would pick my particular gesture so it might be that or whatever we programmed in. I think that would be really cool." (Troy)

In conversation, Talos, Troy, Callum and Paco also discussed these approaches and their challenges, as well as other previous issues, such as requiring too much equipment to capture bodily gestures and processing them into meaningful media actions:

> *— "Maybe a stomp pedal, you can press it whilst you move up the head." (Talos)*
>
> *— "Touching something." (Trevor)*
>
> *— "But how'd it know about the head?" (Callum)*
>
> *— "You'd need Google glass." (Talos)*
>
> *— "And how would the machine know which gesture is a meaningful instruction? I don't know?" (Trevor)*
>
> *— "Google glass? Again, that just seems like adding too much something when it can be so simple like…" (Callum)*
>
> *— "Yeah, I don't think gestures would be practical." (Paco)*
>
> *— "When you got something so simple like a finger touch or a foot stomp, seems like just adding things that don't really need to be there." (Callum)*
>
> *—"And if the machine knew what you want to do there would be problems." (Paco)*
>
> *— "Yeah, just like artificial intelligence." (Callum)*
>
> *— "Terminator." (Talos)*

This group of participants also expressed their reticence for gestural controls, and their preference for more familiar artefacts and interactions from their specific context of musical practice, such as guitar pedals:

> *— "Imagine this appears in the market tomorrow. Like the two options. I would definitely go for something I can just attach or detach, and just press." (Paco)*
>
> *— "We're not really into the gesture thing, I think. But it's gonna be a really cool thing in the future. On a personal level I would buy something like this if it's connected to your neck or your eyes. If you can train your mind to do gestures to move files, cause Google glass it's gonna be a new thing isn't it?" (Talos)*
>
> *— "Maybe guitar or bass wouldn't be like the best places to experiment this first. First it should work with so many other things, and then you could implement that in these instruments, because in the end people uses stomp boxes, we've had that for many many years." (Paco)*
>
> *— "Yeah, if it ain't broken don't fix it." (Callum)*
>
> *— "Because even the digital multi-effects they use the same principle that you need to stomp. Like you do all the programming at home or whatever but at the end when you use it you just stomp it. So, I believe that interaction should be to make sure you are actually actioning whatever you are using. That's why we like what*

> *we can touch or whatever because we know it works. And probably gesturing needs to be proven useful for other things first." (Paco)*

Lastly, some participants suggested other possible applications for gestural controls, such as performative exertion and musical expression:

> *"And it would also help people who don't have good stage movements. It will help them loosen up. It's not very engaging when you someone being static in a rock show." (Marc)*
>
> *"Perhaps it could help you move around a bit more. Play standing up and practice your stage presence." (Kit)*
>
> *"You could use it to control a whammy by tilting the neck up and down." (Cyril)*

5.5.6 Workshop Wrap-up

In the last part of the workshop participants were enquired about the prototypes in general, especially in regards of how much would they support their current practices. Participants responded by discussing which prototypes they would prefer, in terms of how they would use them in their current preparation activities, and with their current tools and resources. For instance, Troy and Paco discussed how the voice commands would be useful for them during their music-related activities. While Troy described how he would use the VUI during the pre-recording stages of his music production activities, Paco focused on whether he could use it with his existing tools and resources (e.g., Spotify or YouTube):

> *"So, if I had the track and I could say 'flute section', because currently I have to move it along with a mouse. So, I could see that [VUI] working for me to practice something for pre-recording, especially if it could be programmed to my own speak." (Troy)*
>
> *"The voice commands would be really helpful for me, as long as it is easy to use, even if you have to set it up yourself. Realistically, I would really like one of these things if it could work with all existing platforms in music, because you wouldn't need to install Pro Tools or anything like that. Some songs that are in YouTube aren't in Spotify, or the other way around. With your own songs maybe, you just have the file, and even sometimes you don't have the master file where it was recorded, only the guy that recorded it that has Pro Tools has it. So, if it could be compatible with anything that would be great." (Paco)*

In contrast, Serj and Callum expressed their preference for using musical notes (Muzicodes) as input over voice commands during practice and performance. For instance, Serj pointed out that since he lives with four of his siblings, resulting in a noisy home environment which would make it harder for the VUI to work properly. Furthermore, Callum also pointed out that he would prefer to use pedals in the live performance context and Muzicodes for "other things"—perhaps alluding to performance preparation or other musical activities:

> *"I really like the Muzicodes idea. The idea that you can just make a little phrase and then transition to something that you want to do. And the flexibility behind it that you can use outside of practice as well. I would say the VUI is quite good as well, but it depends, because when I practice, I am at home in my house and I have four other siblings and it gets really loud, so they might come in and say something and just mess everything up, so it wouldn't work as efficiently as a Muzicode." (Serj)*

> *"My personal favourite is, for live performance, the stomp box, it's really effective you don't need to use your hands, you can keep playing. And for other things I would use Muzicodes. Because with the VUI you do need a mic and it feels like you have to setup a home studio, with the Muzicodes is so simple, the only downside is if your guitar is out of tune. You could have separate bits for separate parts to avoid confusion." (Callum)*

On the other hand, Pixie discussed that she does not generally engage in music transcription (i.e., learning music by copying it off from musical tracks or videos with their musical instrument), but rather primarily focuses on making original music, thus, the technological intervention presented throughout the workshops would only support a small portion of her overall musical practice. Hence, she pointed out that the touch controller would be the most useful for her (especially if it were compatible with YouTube), due to factors such as her physical conditions (e.g., wear and tear in her joints), and her personal aversion for VUIs:

> *"I think this would only support a small part of what I am doing. I primarily do original music, but in the occasions that I wanted to learn covers - being able to use it in conjunction with YouTube would be really helpful. I would really like to minimize wear and tear in my joints, particularly in my elbow, wrist, and shoulder. So, if I weren't such a technophobe I would prefer the voice commands, but I just don't like objects listening to me. Taking that into account, I think that the phone is the most user friendly for me." (Pixie)*

Remarkably, Kelly pointed that although pedals could be something that she could potentially use during practice she would rather not use any of the proposed technological interventions, but keep using her existing tools and resources, i.e., her tablet. In particular issues such as having to set up additional equipment or figuring out how to use modern technologies in this context, were decisive factors for her rejection of the proposed interventions.

> *"I think for me the pedal one is the most immediately usable, but it still means you got to be sat somewhere where you can plug everything in. I mean, at the moment if I wanted to listen to something on a tablet and then just hit play and then go*

> *back to it, that's probably more straightforward than messing around with a pedal or attaching something to my acoustic guitar, which I wouldn't want to do. I wouldn't say that the voice commands would support what I am doing, because I gotta figure them out. And the musical notes are just like out there. It's complicated, not immediately practical. I think there's value in the whole idea of going back to sections but is all prescribed. I don't see things in terms of verse and chorus. You almost don't need that; all you need is your marker." (Kelly)*

In relation to learning how to use the proposed technologies, Pixie, Marc, and Ivan discussed that the tool should be simple enough to be easily learned to be used and not detract them from its main purpose, i.e., to support performance preparation:

> *"For me, it would be down to how quickly I could get a basic functionality out of it in ten minutes. I can understand anything takes time to get familiarized with it." (Pixie)*

> *"I'd learn how to use the voice one. Guitars are somewhat lazy, not lazy but it's just ease (...) you want to be thinking about other stuff as well." (Marc)*

> *"You don't want to be concentrating on the tool. You want to be concentrating on the practice. The tool's gotta be a support thing. It's not gonna be the main deal." (Ivan)*

Moreover, participants also proposed combining multiple of the technologies presented with the prototypes or to use the technologies in conjunction. For example, Maria proposed combining the touch controls with voice commands, whilst Ivan proposed combining the foot switches with voice commands:

> *"(…) And it could also have the choice of voice command, because with the phone you can do so many things. You can take them everywhere; you don't need a big pedal thing to carry with you." (Maria)*

> *"The floor pedals combined with the voice may be the most useful. I think you should keep the buttons as simple as possible and make them configurable." (Ivan)*

On the other hand, Kelly, Mike and Krist proposed cross-device interactions between the touch and the foot controller:

> *"You could have the phone as an accompaniment for the pedal. Because otherwise if you got a tool for one particular instrument that's only got one function, that you could only use it for that. Or have a technological set, where one person could use the pedal and another one the phone on the Ukulele, I don't know." (Kelly)*

> *"Or even a combination of a foot pedal and a tap. Tap on the guitar for the very basic stuff like stop, start, pause, and a foot pedal for the most complex stuff like fast forward, rewind, reverb, chorus, delay." (Mike)*

> *"Combining tap on the guitar with a footswitch. So, tapping into the pedal twice for the intro, and things like that, having different levels of looping." (Krist)*

Participants were also enquired about the different intervention approaches to guitar augmentation, namely, temporarily attaching a device on their guitar, permanently modifying their guitar to host the technology, or acquiring a bespoke guitar purposefully built with the technology embedded within it.

As also discussed in the guitar augmentation sketching activity described in Subsection 5.5.1.1, most participants were inclined for temporary intervention approaches (e.g., accessory devices, like clip-on guitar tuners) for reasons such as preserving and valuing the material integrity and identity of the guitar. For example, Kelly once again mentioned not wanting to change the tone of her guitar or damaging it. Likewise, Mike, Jose and Cyril made similar comments:

> *"I wouldn't like to put Velcro or sticky stuff on my guitar, because it would change the tone of it." (Kelly)*

> *"I would certainly try the pedal. And the instrument mounted thing if it's not gonna damage your instrument." (Mike)*

> *"I really like the phone one, because nowadays everything has a screen, and I think that for beginners that would be attractive, but maybe not stick it, just attach it temporarily." (Jose)*

> *"I'm really conscious about the wood of my guitar, I don't want to cut it. Maybe something that can be sticked into it and be easily removed without leaving goo behind." (Cyril)*

Others mentioned that they would only permanently modify guitars that they regarded as less valuable:

> *"I would do something on a guitar I wasn't too fuzzed about. Obviously if it was an expensive one, I would like to keep it as I bought it originally." (Marc)*

> *"I wouldn't replace any of my 7 or 8 guitars, but I know which of them I could potentially modify to integrate this." (Pixie)*

In particular, Paco, Troy, Ivan, Greg and Krist pointed out that that a guitar with such features would be potentially and expensive and not necessarily cost-effective if its solely purpose was to support performance preparation:

> *"If you could add these things into Variax guitar I wouldn't mind because that's a guitar that already has everything in it. But I wouldn't buy a guitar just because it has this [prototypes' features]. If I were going to get it would be something*

temporary that I just need to practice, because if I'm gonna practice for a live gig, it's likely that I am also gonna practice with a guitar that I'm gonna use on that gig. So, if you have multiple guitars for multiple songs, you could just clip it on and off. So, if you buy a guitar with that in it [embedded], and it's gonna have a poor resell value for having it, and if you have a lot of guitars, then why would you have a practice guitar if you are gonna use something else live?" (Paco)

"Also, it would be a cost. Someone who is just beginning may not know if they will carry on playing." (Troy)

"I doubt anybody would buy a separate guitar just to be able to practice. I think that's the strength of the temporary." (Ivan)

"The embedded one, I think that would be useful for busking, but I wouldn't play it because it's ugly. But maybe you could have it on a school to teach with it, and where no one is going to see it. But, spending so much money in something I'm just gonna practice on... I want to practice with something I will be actually playing on stage. That's a negative side of it." (Greg)

"I like the idea of a very special guitar being built particularly for that. But certainly, it's gonna be expensive." (Krist)

Participants also referred to the guitar as a valued material possession and made remarks that alluded to the guitar, and other associated musical equipment, as traditional artefacts that guitarists preferred to preserve as they were:

"You would have to consider that people sometimes have multiple guitars and would like to practice with them. My preference would be to have something temporary that you could move around. Another point to consider is you got a lot of people that have invested a lot of money in guitars that they've got." (Ivan)

"I wouldn't take the essence away of what you are doing which is playing guitar. If you wanted to get a separate guitar that did all of those things on its own, that's one thing but. People are not going to want to change the guitar. Guitars have stayed the same for a long time." (Marc)

"Guitar players are quite conservative people. It's been 70 years since transistors where invented and people still value valves, vacuum tubes." (Cyril)

5.6 Discussion

The findings from the workshops provide interaction design insights from a group of guitarists on the affordances of each of the interaction modalities presented throughout a series of prototypes for supporting encumbered interactions during individual performance preparation (i.e., touch controller, foot controller, VUI, musical notes, and gesture controls). Their reflections and critiques shed light on their values and attitudes towards these technological interventions in the context of performance preparation.

In addition to participants' discussions, their design input, namely sketches (and embodied sketches), as well as their speculation of use cases for each prototype were critical for understanding how this group of guitarists characterised each interaction modality in terms of accommodating their existing preparation practices and co-existing with their equipment, and why they preferred some modalities over others. Moreover, the idea of acrylic and cardboard guitars during the workshops can be considered as an expansion to the embodied sketching method proposed by Márquez Segura et al. (2016) where props that resemble the artefact to be augmented are utilised to elicit embodied ideation from participants.

Furthermore, participants also reflected on the augmentation of the guitar by means of permanently modifying the instrument to feature the technology (e.g., by drilling a hole in it), or temporarily attaching an accessory on it for the same purpose, as well as on the prospect of a new kind of guitar that would have the technologies built into it.

It should be noted, however, that this group of guitarists only represented a subset of guitar performance styles with their own specific repertoire and instrumental preparation needs, albeit all involving some form of interactive media to support the process. Although participants were not explicitly asked about the style of music they played, it could be roughly inferred based on their comments.

Even though some of the guitarists practiced similar performance styles, their use of tools and resources, and their affinity for some of the prototypes was varied, potentially due to several factors, such as age, access and familiarity to certain technologies and their personal approaches to performance preparation. It should also be noted that the prototypes focused in supporting a very specific use case involving encumbered interactions, which was transcribing and practicing music material by navigating interactive media, such as audio tracks and YouTube videos using a computer.

Hence, the underlying abstract controls for playback transport and section navigation where consistent across prototypes and they were all compatible with the same media resource, an audio track displayed in a DAW. Conversely, we should also consider that the abstract media navigation controls mappings for all the prototyped interaction modalities were constrained to Ableton Live DAW's affordances. Hence, the participants had to "scrub" through the music track to navigate it backwards and forwards and had to use pre-set markers to jump to pre-set parts of the track (e.g., intro, chorus, and verse).

Thus, support for these navigation modalities was inspired by findings from the ethnography, such as observations of participants' fine-grained navigation of videos by pausing the playback and returning to a previous frame in the timeline by pressing the left arrow key (←) or when "bookmarking" a place in the timeline by hovering the mouse cursor on top. However, other media navigation activities by participants were not supported due to design scope challenges, such as enabling participants to directly jump to anywhere in the DAW's track, as they would by hovering the mouse cursor over it.

5.6.1 On the Prototypes

In the case of the **touch controller**, the design goal was to localize a set of media controls on the instruments body to reducing the manual transitioning between instrument and media controls, which are often located nearer to the computer than to the instrument. In this sense, participants pointed out that this interaction modality was in fact convenient for keeping their hands and their focus on the instrument, as well as avoiding the repetitive task of switching between playing and navigating the media with existing peripheral controls (e.g., mouse and keyboard).

For one participant (Pixie) this prototype also seemed helpful for preventing physical injuries or ameliorating strain in her shoulders. Furthermore, participants also speculated that this device could be useful in other similar encumbered situations with guitars, such as when recording music. However, since the prototype was presented with a mobile phone, several participants pointed out that having to look at a smaller touch screen attached to the guitar to control the media was distracting, provoking a discussion about the embodied interaction with this particular touch device and its affordances.

For example, participants pointed out that they were still be disrupting their instrumental practice if they had to attend to the additional controls, especially since these were numerous (11 inputs in total) and presented with a graphical interface on a touch screen. Although the original intent of the prototype was to demonstrate the concept of media controls in the instrument, the participants' feedback on the interaction with the touch screen also revealed meaningful insights about this interaction modality.

Regarding how the device was mounted on the guitar it was notable that participants were concerned about whether the device would be too physically invasive in terms of damaging their guitar when mounted (i.e., scratching or leaving adhesive residues behind when attached) or changing its resonance given the added weight of the device when mounted on top of the guitar (especially with acoustic guitars).

Likewise, participants discussed the size and positioning of the device on the guitar in relation to accommodating different playing styles of guitarists as well as the different body shapes of guitars. For example, Paco mentioned that having the device attached right above the string could possible obstruct livelier and more aggressive playing styles. Likewise, participants pointed out that not all guitars had space available on their bodies for a device to be mounted nor they would want to mount it on especially valuable guitars.

During the subsequent design activities participants provided a series of responses to the interaction challenge of visual disruptions when having to look down to use the device's touch screen. One response was to use physical buttons with tactile cues on them—as in Braille—instead of a touch screen to facilitate non-visual interactions with the controls. Another response was to reduce the number of inputs in the device and to assign more actions to single inputs, to simplify the interface, by double or triple tapping an input to trigger distinct actions, accordingly—as seen in some types of headphone controls (Figure 68).

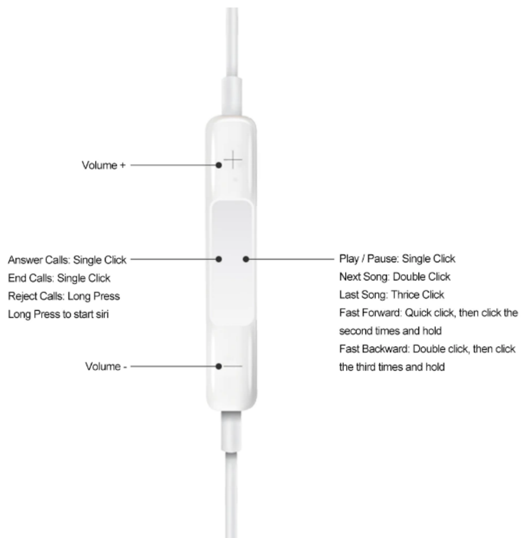


Figure 68. Apple headphone controls.

In response to concerns of how the device was mounted on the guitar, participants suggested more compact or detachable and accessory-like interventions which could be flexibly positioned on any part of the guitar according to the guitarist's preferences in terms of their playing style, as well as across different types of guitars, like a clip-on guitar tuner. Alternatively, an accessory device like the Guitar Wing could also be explored in this context of use, as the device can be clamped onto the guitar, it features a range of physical buttons, and it can wirelessly interact with a DAW via MIDI (Figure 43).

On the other hand, in the case of the **foot switches'** interaction modality, the goal was to obtain participants' insights of using foot controllers to navigate media—a mode of use that is feasible with many existing MIDI-based foot controllers (Figure 44. In this sense, for many participants, this appeared to be a remarkably familiar approach for triggering actions and keeping the hands free to play especially to those who already used pedals in their regular preparation and performance practices to trigger audio effects.

Some participants also pointed out that these devices are quite common in performance settings and have been around for several years. In terms of supporting encumbered interactions when operating media resources participants deemed pedals as potentially reliable pieces of technology for the context of performance preparation, given that they would only require the user to press a foot switch to trigger a specific media action. In terms of the affordances of this particular device, although participants favoured the tactile and aural feedback that the clicking of a foot switch affords when stomped, several participants mentioned that a set of eleven footswitches for media control would also draw significant attention away from the instrument, as they would also need to look down at the floorboard to interact with its inputs.

Furthermore, regarding the embodied interaction with the device, participants also raised the issue of how having to constantly press foot switches with the feet would be a physically tedious and time-consuming activity. Hence, during the design activity many participants proposed more compact pedals with a much smaller number of foot switches.

For example, some designs assigned two distinct foot switches for respectively going forwards and backwards on the track with a constant press of a switch, and another switch for toggling between play and stop. Other designs also discarded the bespoke foot switches for track sections, mentioning that in many cases they would work in one section at a time. In this sense, other designs proposed a foot switch for going back to the beginning of the track, and another foot switch to set an anchor point to loop back to.

In addition, participants also suggested having more peripherally visible and easily locatable foot switches by means of blinking lights on the switch or by having bigger switches which could be more easily felt with the feet. Both of these approaches can be observed in pedals such as the Line 6 Helix Stomp (Figure 69 [Left]) which features light-up rings around the foot switches, or pedals using Mooer foot switch toppers (Figure 69 [Right]), which according to Andertons Music Co.[16] (a predominant UK music equipment retailer), make foot switches easier to reach and locate in some situations:

"Some guys are using them for the 'hard to reach' foot switches which might otherwise require a tactically aimed big toe to successfully engage without disturbing anything else."

Figure 69. Approaches to facilitate foot switch location.

There are similar learnability issues with the foot switches modality, as with the touch controller, in the sense that the former also impose a series of physical and cognitive demands on the performer. Given that the feet lack the articulation and fine-motor capabilities of the hands, the inputs in pedals are generally restricted to foot switches or rocking pedals that allow for discrete gross-motor control.

Thus, although the disposition and affordances of pedals compensate for a lack of fine-motor skill with the feet, they still demand some prior physical preparation (mainly coordination and body-weight distribution) from performers to achieve skilful operation. Likewise, the greater the number of inputs in a pedal, the more coordination and visual attention it will demand, and unless the guitarist is sitting down, the interaction is limited to one foot. As reported by performers, such physical demand is comparable to playing a separate musical instrument during performance (Furniss & Dudas, 2014; Pestova, 2008).

[16] https://www.andertons.co.uk/

Voice commands were also an interaction modality aimed at exploring hands-free media navigation, which was evaluated and discussed during the workshops. Although most commercial VUIs enable hands-free interactions, media navigation with these devices is often restricted to remote control actions, such as play and pause. Hence, the prototype presented to guitarists explored additional media actions such as moving the play head forwards and backwards and navigating sections (as with the previous prototypes).

In this sense, while participants expressed that a VUI would be convenient for navigating media, this interaction modality posed significant caveats which would render it as impractical and inconvenient in the context of performance preparation. Apart from considering that playing an instrument and speaking at the same time is already challenging, participants remarkably pointed out that the VUI would interfere with other music-related activities during rehearsal, namely, singing, listening to music while practicing and talking to other band members during rehearsal, given that it will potentially not allow them to say any of the 11 words that would trigger the voice commands (e.g., “play”, “stop”, etc.), especially when some of these utterances are very likely to occur in all of these situations.

In addition, VUIs are also generally prone to react to words that sound like reserved voice commands. Hence, when participants discussed ways of tackling this issue, they generally suggested having a keyword like “Alexa” or employing longer utterances (e.g., “go to the solo”), or using a separate device like a pedal to conditionally toggle the “listening” of the device on and off. Nonetheless, even if the VUI were to be significantly robust at reliably triggering media actions, the fundamental problem with this kind of technology is that the uttering a voice command is not as immediate as pressing a button.

For instance, Chang et al., (Chang et al., 2019) have previously pointed out that navigating interactive media actively (such as in how-to videos to learn musical pieces) with VUIs required their participants to introduce delays in order to sequence multiple commands (e.g. pause, then rewind) to achieve the same task that a single click would achieve (hover the mouse to point earlier in the timeline and click), given that they would anticipate that the system would need to take some time to process their voice command in addition to the time it takes them to produce the utterance.

Furthermore, these authors mention that technical challenges like audio separation when users are already engaging in a noisy task (e.g., playing an instrument along to a musical track or a group of musicians playing their instruments together) could possibly undermine interactions with VUIs—a problem that was also noted by the participants of this study. Hence, although voice commands are convenient for passive interactions with music media, they are problematic for active media navigation.

A similar problem was observed with how **musical notes** were used as control inputs in the prototype presented to participants, given that the interaction with the system implied playing distinct musical phrases, consisting of four or five notes, to navigate to specific parts of an audio track (so as to loop around that same fragment of the song) as well as playing discrete two-note phrases to trigger transport controls. Although aligning media control with instrumental performance posits the advantage of latching onto already existing skills of the guitarist, restricting notes from the playable range of the guitar to be used as inputs is severely limiting in the context of preparation—just as it is limiting to restrict the words that a singer can sing.

However, what perhaps makes the use of musical notes as input even more challenging and counterintuitive than voice commands in this context is that they are required to be proficiently executed, i.e., playing the exact sequence of notes at a consistent tempo with certain loudness and intonation (the system would not recognize an out of tune guitar, an issue that is frequently observed with pitch tracking systems).

Thus, making mistakes (which is part of the rehearsal process) also means failing to navigate the media, thus rendering the interaction with the system somewhat counterproductive to performance preparation. Furthermore, the inherent repetition of musical phrases in a song would require the notes employed in the musical phrases to be bound to media actions to be slightly different than those in the actual song to avoid persistent false positive media action triggering. Thus, as pointed out by participants this particular issue would require them to play the “wrong notes” to navigate to specific sections of the track, and ultimately hampering the rehearsal of a musical piece.

Likewise, the fact that Muzicodes (i.e., the system with which this prototype was developed) requires a clever design of recognizable and unique musical phrases to be mapped to media actions for each new musical piece to be rehearsed, implies that guitarists need to become acquainted with the song beforehand, which would render the system useless in the context of learning a song for the first time, unless this process was automatized for the user.

Yet, one could also argue that given that Muzicodes also allows to factor in some tolerance to performance mistakes, that is, by configuring the system to trigger an action when at least a minimal portion of the notes have been performed correctly, this also introduces a problem of redundancy where a single musical phrase could trigger more than one action when performed. For these reasons, participants also suggested similar approaches to mitigate unwanted media control tiggering for this prototype, e.g., using a pedal to turn the system's note tracking off when not needed.

Even if consistent, short, and discrete musical phrases were to be used to trigger actions (such as playing two-note phrases), the issue of removing notes from the playable range of their instrument would persist. Nonetheless, it is notable how participants favoured these shorter note sequences due to the immediacy with which they triggered the media actions.

This was also a remarkable insight with **gestural controls,** as participants favoured more discrete gestures like tapping, flicking, and swiping with the fingers on the body of the guitar, rather than moving the whole guitar (e.g., swaying the neck up and down), or their whole body to trigger media controls. According to participants, these latter two approaches, i.e., tracking the continuous movement of the guitar or the body, which could be either implemented with motion sensors or motion capture, would invariably have unwanted media action triggering issues if their bodily movements were to be constantly monitored.

For some participants this either implied that they would have to be overtly stiff or unnecessarily active during their practice. They also pointed out that it would be frustrating if the system failed to recognize their movements, making them tediously repeat them. Hence, once again, design refinements also revolved around ways turning the motion capture system—or the motion sensors—on and off to avoid such mishaps (as also suggested with the voice commands and musical notes interaction modalities).

Conversely, the discrete gestures on the body of the guitar, which could be implemented with capacitive touch, resemble those that can be done on a mobile phone or a track pad, which in turn are closer to some of the gestures that participants could do with the touch controls prototype (i.e., tapping the touch screen with the finger), which was firstly introduced in the workshops. The difference between these in-instrument gestures and the touch controls, however, is that the guitarist would not need to look down to locate the buttons on the touch screen but rather just make a touch gesture on the body of the guitar.

In this sense, this approach would also localize the interaction within the guitar, harnessing gestures that although ancillary to guitar performance, are commonly observed with some of the physical inputs observed on the electric guitar, such as flicking a pickup selector switch or tapping on a kill-switch. To implement this, it should be considered whether the whole surface of the guitar would be capacitive or whether a capacitive surface would need to be attached on the body of the guitar (Gong et al., 2012), which again calls previously discussed considerations of device placement and positioning to attention, bearing in mind the different playing styles of guitarists, and their willingness to attach devices to their guitars.

In general, the interaction modalities that were deemed as most problematic, in terms of disrupting the flow of embodied instrumental practice, were those that were most prone to have a Midas touch problem (i.e. accidental triggering) that may emerge from a system that is constantly listening or looking for inputs to match to actions (Brown et al., 2018), i.e., the voice commands, the musical notes as input and gestural controls that involved the movement of the whole body or the instrument.

Participants appeared to be drawn to media controls that were more immediately responsive to their input, such as touch controls and foot switches, as well as musical notes when playing short two-notes phrases or touch gestures on the body of the instrument. Considering the problem of encumbered interaction when peripherally reaching out to navigate media with a computer when having the instrument at hand, they were also drawn to the prototypes that localised the interaction closer to the instrument, such as the touch controller, the instrument's musical notes as input, and the in-instrument gestures.

Nonetheless, as noted by participants, careful consideration is necessitated in terms of the number of inputs that these interfaces should have, and in case where physical inputs are involved (i.e., buttons or foot switches), these should also be visible and reachable, to avoid drawing too much attention towards the actual tool instead of supporting the practice. Another consideration to take into account is that, to some extent, all the interaction modalities proposed require the musician to develop a skill parallel to guitar playing.

However, what differentiates each modality in terms of the physical and cognitive demand when learning to use them—and thus how much each disrupt embodied instrumental performance—is how much does the musician need to engage their body and how much they need to shift their attention to use each device. In this sense, while the touch controls and the foot switches required little physical effort, they required the guitarist to heavily shift their attention to the interface.

Similarly, while in-instrument gestures would also not require much physical effort, neither would they require much visual attention from the musician. In contrast, whole body gestures would indeed require both the physical and mental effort form the musician, while voice commands and musical notes would be more cognitively demanding.

There were also other general participant concerns across prototypes, namely, how long will it take to configure them to be used in performance preparation—i.e., setting up the musical material to be practiced using the device, as well as setting the equipment necessary to use within their context of practice—and how long will it take to learn how to use it. In addition, participants also pointed out that it was important for these technological interventions to interface with the media tools and resources they use during instrumental practice.

5.6.2 Augmenting Guitars for Performance Preparation

As previously mentioned, during the wrap-up discussion at the end of each workshop, participants' attitudes towards three different approaches to technologically intervening guitars were surveyed, namely, temporary interventions (i.e., temporarily attaching a technological device on the body of the guitar, e.g., a clip-on guitar tuner), permanent interventions (i.e., permanently modifying the guitar to feature the technology, e.g., drilling a hole to fit a kill switch), and embedded interventions (e.g., designing a new kind of guitar integrating the technology in the design).

Unsurprisingly, most participants expressed having material and sentimental value over some of the guitars they owned, thus they preferred non-invasive, temporary interventions to the guitar for practical and aesthetic reasons. Hence, when presented with the touch controller—which were the only interaction modality that was mounted on the instrument—one of the key issues pointed out by most participants was whether a mounting the device would damage the guitar when mounted (i.e., scratching or leaving adhesive residues behind), or in the case of acoustic guitar players, whether the added weight of a mounted device would change the tone of the instrument.

Thus, most participants suggested compact and detachable interventions which could be flexibly positioned on any part of the guitar according to the guitarist's preferences, as well as across different types of guitars. When presented with the idea of a bespoke guitar that could integrate the technologies to interact with media resources (browsing, navigation, control, and feedback) within the design of the instrument (Figure 70), many participants deemed this concept as impractical since having to acquire a separate guitar solely to support practice would not be cost effective or aesthetically appealing for many guitarists.

Furthermore, guitarists often use the same guitar they want to perform with during practice, as particular guitars are often selected to perform specific musical pieces, due to the nuanced timbral qualities that each individual guitar features.

Figure 70. gTar and Fusion guitar featuring mobile phone docks.

Moreover, the touch controller modality revealed that although supplementing a guitar with additional inputs to control media by attaching a device onto its body could be helpful to narrow the bridge between media navigation and instrumental performance, this approach still demanded some degree of fine-grained manual operation, which in terms of cost efficiency would potentially not pose a significant improvement in comparison with more conventional methods, like using a keyboard and a mouse, or bespoke desktop based device for supporting guitar practice, such as the Tascam GB-10, or the more recent Boss Pocket GT (Figure 71)—which also supports practice with YouTube videos—especially if the device were to be used for practice only, as well as if it had to be irreversibly attached onto the guitar's body, potentially damaging it and altering its visual aesthetic or acoustic resonance, as well potentially not fitting all kinds of guitar shapes and dimensions.

Figure 71. Tascam and Boss' guitar training devices.

5.7 Conclusion

In this chapter, the rationale, design, and results from four workshops with 20 guitarists were reported. The principal aim of the workshops was to present guitarists frequently involved in performance preparation with the instrument with five interaction modalities for supporting encumbered interactions when navigating media resources during performance preparation, namely, touch controls on the instrument, foot switches on a pedal, voice commands with a VUI, musical notes as input with Muzicodes and gestural controls, and to have them evaluate, critically reflect on and discuss each modality with other guitarists in terms of using them during instrumental practice with their existing tools and resources.

To achieve this, the workshops were structured three in stages, namely, an introduction stage, a co-design stage, and a wrap-up stage. During the introduction stage, participants were presented with the workshop goals and an outline of activities. For the co-design stage, I drew upon multiple techniques from participatory design methods, such as generative tools (i.e., sketching) and embodied ideation techniques (i.e., bodystorming and embodied sketching), for guitarists to actively engage in activities that would facilitate the communication of their design ideas and critique of the prototypes presented to them.

Hence, during this stage, participants were firstly presented with a particular interaction modality, then they tested it out, and then to evaluate it they were asked to verbally discuss it and refine it by engaging in a series of design activities such as sketching their own guitar-mounted interfaces using the acrylic (“whiteboard”) guitars and their own pedal-based interfaces with sheets of paper, as well as speculating about their own voice commands or combinations of musical notes to trigger media inputs, and bodystorming gestural controls with cardboard guitars.

More than having participants improve the design of the prototypes, the underlying aim of these activities was to elicit their reasoning on the affordances and interaction techniques of the prototypes presented, and their insights on how these could be improved to better accommodate their preparation practices. For the wrap-up stages, participants discussed all the interaction modalities previously presented, and they were also asked about their insights on augmenting guitars to support performance preparation by temporarily attaching a device into the guitar for this end, or physically altering the guitar to feature the technology or having new kinds of guitars that would have the technology embedded in them.

The aim with this inquiry was to elicit insights on their values and attitudes towards the technological intervention of their instruments. Findings from the workshop revealed that guitarists were drawn to interaction modalities that allowed to keep their focus as much as possible in the instrument by making the interaction with the media resources as streamlined as possible to avoid any physical disruption or mental distraction from the embodied instrumental practice.

Thus, modalities such as touch controls, in-instrument gesture controls and foot switches were preferred due to their immediacy, in contrast with other modalities such as whole-body motions, gesturing with the whole instrument, voice commands or musical notes as input, which were regarded as prone to false positive triggering of media actions or as disruptive to other interaction channels already in use during performance preparation, like moving the body or the instrument along to the music, singing, and playing the instrument.

However, the touch and the foot controller were also deemed as disruptive to practice to some extent, as they demanded substantial periods of visual fixation, due to the numerous inputs they presented and the way the interfaces were laid—i.e., the touch controls were presented on a touchscreen, and the foot switches on a pedal which was laid out on the floor, so in both cases the user had to look down to locate the inputs.

In addition, another concern from guitarists about the touch controller was how invasive would they be if presented over a device that would have to be mounted on top of the guitar, i.e., whether the device would potentially damage the instrument when mounted, or whether it would affect is resonance (in the case of acoustic guitars), as well as how obstructive would the mounted device be to their embodied practices, i.e., whether its positioning on the instrument would cause the hand to bump into it.

These concerns were also touched upon when discussing the different guitar augmentation approaches during the wrap-up discussion and shed light on the values of this particular group of participants—representative of a community of practicing guitar performers—towards their instrument (and other related musical equipment), and how these fit within their preparation practices. In this sense, the guitar was described as an artefact that should not be tampered with too much (or not at all), for aesthetic and acoustic reasons. Furthermore, for some participants, their guitars were not just regarded as tools for music making but also as valuable artefacts, which in some cases can be substantially expensive.

For this reason, some participants were also drawn to pedals, not only because they were not physically mounted on top of the guitar, but also because they were familiar artefacts from their practice and performance ecologies. It was notable that several guitarists from this group were resistant to having their guitars modified and their preparation practices changed. However, the study also revealed further implications and considerations for designing for guitars in this particular context of practice.

In the next chapter, soma design is explored as an alternative ideation and prototyping approach to design interventions for supporting encumbered interactions during performance preparation. This approach harnesses the bodily and somatic appreciation of subjective experiences as a resource for design. Conversely, existing preconceptions of an experiences are also perturbed through embodied ideation techniques, such as estrangement (Wilde et al., 2017) and material encounters, in order to re-focus the attention on the body but also to explore and generate novel interactions within familiar design spaces, artefact ecologies, and existing embodied practices.

Chapter 6
The Stretchy Strap

6.1 Introduction

This chapter reports on the design and evaluation of the Stretchy Strap, a guitar strap augmented with elastic fabrics, electronic components, and conductive threads and yarns (Avila et al., 2022). The concept of the Stretchy Strap emerged during a soma design workshop and was further developed into a stretch-based, wearable controller to support performance preparation with interactive media. The design rationale behind the strap is also grounded in the findings of the ethnographic studies described in Chapter 4 and the findings of the workshop studies described in Chapter 5, and is further explained in Section 6.2.

In this study, the Stretchy Strap is characterised as a research prototype to elicit feedback from guitarists on their experience with the artefact. Hence, the strap prototype was deployed in a user study in which 10 proficient guitarists used it to learn and practice a song using SoundSlice, an online platform that allows users to synchronize YouTube videos with interactive music scores.

The aim of the study was to assess guitarists' experience with the Stretchy Strap when using it in their context of performance preparation, i.e., at their home-practice spaces, utilising their own guitars and support resources.

Due to the COVID-19 pandemic and ensuing social distancing and reduced gatherings' measures, the study protocol was modified so that rather than deploying the strap "in the wild" at participants' homes employing a *living lab* (Bergvall-Kareborn et al., 2009) method—i.e., conditioning their homes to capture data for the study—my home-practicing space was adapted instead to conduct the study. Thus, participants were asked to visit my home and bring their own guitars to practice a song using SoundSlice whilst wearing the Stretchy Strap to navigate the song.

Participants were interviewed before and after using the strap, and they were asked about their preparation practices involving media and how the strap affected this process, respectively. Then, transcripts from the interviews were codified into emerging codes and themes using a content analysis approach as in Chapter 5 (Section 5.4). Likewise, as in previous studies, former participants were once again asked to participate—further details of the recruitment criteria and evaluation of the Stretchy Strap are provided in Section 6.5, followed by evaluation findings (6.6) and general discussion (6.7).

6.2 Implications of the Ethnographic and Co-design Studies

As previously mentioned, the design of the Stretchy Strap is grounded on findings from previous studies. In this sense, the functionality of the strap responds to the problem of encumbered interaction during performance preparation. The design decision of using a guitar strap as a controller was influenced by a combination of the findings of the co-design studies (Chapter 5) and the soma design explorations.

In Chapter 4, a series of individual and collaborative performance preparation activities were described. It was also evident from the findings that many of these activities were supported by digital media resources. The specific preparation activity that the Stretchy Strap supports in this case is musical transcription using digital media, which in this thesis is characterised as the process in which an individual guitarist actively engages with musical material, by either carefully listening to an audio track, reading musical notation, or watching a demonstration of how the material is performed with the instrument—or a combination of these activities—with the goal of reproducing musical pieces with the instrument.

During the process, the guitarist constantly interprets the material and attempts to replicate the sounds on the guitar for several times until sufficiently reproducing the piece according to their performance needs. This process is mediated by support tools, such as media players that facilitate the navigation and pace control of the material, either by providing transport controls, playback speed adjustment and looping capabilities (Figure 72). In this case, the Stretchy Strap supports the navigation of a multimedia track in SoundSlice, featuring and interactive score synchronized with a YouTube video playing, using bodily gestures that trigger a set of media control actions (see Figure 84).

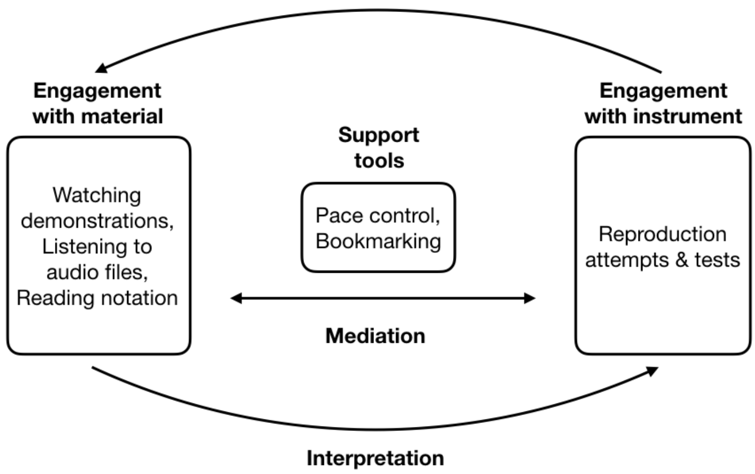


Figure 72. The instrumental music transcription process.

Through co-design activities such as drawing on acrylic guitars (as whiteboards), bodystorming with cardboard guitars, and testing out a series of media controller prototypes for guitar, the participatory-design-inspired workshops provided insights on the participants' reasoning about the affordances of different interaction modalities for media control and their impact on the interleaving bodily actions involved between guitar playing and fine-grained track navigation, as well as their attitudes towards augmenting through guitars through physical and technological interventions. Some of the findings of the workshop uncovered that this sample of participants (n = 20 guitarists):

- Preferred control modalities that were more immediately near the instrument and that allowed them to avoid physical disruption from playing the instrument.
- Rejected invasive and/or non-reversible physical interventions of the instrument due to the material value that the participants placed on their instruments, as well as how these interventions obstructed their bodily interactions with the instrument.
- Considered that a bespoke guitar with embedded technologies to control media was inconvenient, due to aesthetic and practical reasons, such as wanting to rehearse musical material and perform with the same guitar—i.e., one they would be familiar with.
- Favoured media control modalities that offered familiar affordances—such as pedals—due to their ease of use (offering immediate response), and for being part of the "usual" ecology of devices used in their guitar practice.

In this sense, the Stretchy Strap has various characteristics that are aligned with these values, such as being a familiar artefact of the “guitar” ecology—as it is an ubiquitous guitar accessory—it can be attached to and removed from the guitar in a non-invasive manner (and thus, it can be used across multiple owned guitars), it rests suspended closely to the body, and its media controls are immediately responsive to bodily motions that are close to the standard playing position and the instrument per se. With these factors in mind, the guitar strap was taken forward as an artefact to be explored and digitally augmented to support guitarists’ preparation practices involving fine-grained media navigation.

6.3 Soma Design Explorations

The form factor of the stretchy strap, originated from the series of material encounters with elastic and soft materials during the soma design workshops, whilst also exploring a series of bodily movements and sensations emerging from the *interaction gestalt* (Lim et al., 2007) occurring between body, guitar, and strap.

As described in Chapter 3 (Section 3.4), the soma design method is grounded in Shusterman’s (2012) theory of *Somaesthetics* and it draws from the notion that the soma is a holistic subjectivity that non-dualistically encompasses body, mind, felt experiences and social engagement (Shusterman, 2012), and that the soma should be attuned through bodily exercises, explorations, and reflection so that designers may actively develop a somaesthetic appreciation practice, which is more first-person-oriented, experiential and aesthetically felt, rather than symbolic or language-oriented, as with other more prevalent interaction design methods (Höök, 2018).

In this sense, the soma design explorations with guitar investigated ecological, aesthetic, material, and embodied aspects of preparation practices with guitar by engaging in bodily exploration and reflection activities with the body, guitar, and other materials. There were two soma design workshops where the felt experience of guitar playing was explored. The first workshop was more generally concerned on four different interaction design projects, while the second workshop solely focus on the guitar. The workshop proceedings are now described in further detail.

6.3.1 The First Soma Design Workshop

The first workshop was hosted in the Mixed Reality Laboratory (MRL) and organised and orchestrated by the Soma Design Group (SDG) from KTH (The Royal Institute of Technology in Stockholm), and it lasted two days. The workshop had 14 participants from the MRL and the SDG, consisting of PhDs, post-doctorate, and senior researchers with backgrounds in soma design and interaction design. During the workshop, a series of soma design methods were applied to four interaction design projects from the MRL that had some relation to the bodily experiences of balance and proprioception.

These projects involved (1) a Virtual Reality (VR) balance beam, (2) a VR flying harness, (3) an augmented guitar and (4) augmented prosthetics for dancers. Whilst the VR-oriented experiences were already developed into functional prototypes, the other two projects were still in the ideation stage. Nonetheless, the workshop activities allowed for further embodied ideation, material explorations and prototyping with all the projects. The participants worked in four separate groups, each focusing in one design project (Table 10).

Table 10. Design projects by participant groups.

Design project	Description
Flying Harness	VR human flying experience, made with stage harness hanging from scaffolding frame. VR experience was a simple point-to-fly interaction around a city.
Balance Beam	VR experience of walking a balance beam, made using a real balance beam (scaffolding pole) on the floor and a position- matched virtual beam. Included a rotational sensory misalignment to make balancing harder.
Augmented Guitar	Acoustic guitar augmented with computer recognisable patterns. Computers and audio interfaces for sound manipulation.
Prosthetics	More concept than ready-made design, this was the notion of 3D printing personalised prostheses for dancers. Example prostheses were brought along as inspiration.

Note: Table taken from (Höök et al., 2021).

The augmented guitar group consisted of two MRL members (my supervisor and I), and two SDG members. The MRL members were proficient with guitar playing, whilst the SDG members were only partially familiar with the instrument. Thus, the design ideation activities were guided by the guitarists from the MRL group whilst the soma design activities were guided by the SDG members—as they also orchestrated the workshop activities, which they curated prior to the workshop, by exploring the felt experience of balance and proprioception through *Feldenkrais* (Feldenkrais, 1972) and contact improvisation sessions (Figure 73). These bodily explorations (and others) were eventually featured during the two-day workshop. The workshop activities are described in detail in Table 11.

Figure 73. Soma designers engaging in contact improvisation activities.

Table 11. First soma design workshop proceedings.

Activity	Description
Day 1	
Introduction	Participants were introduced to the soma design methods.
Body Scan	A soma design practitioner guided participants through an activity where they directed their focus and attention towards specific bodily or sensory sensations through a series of guiding questions, whilst they lay down on mats on the floor, with their eyes closed.
Body sheets	To reflect on the participants' bodily experience during the body scan, participants illustrated their bodily sensations using body sheets (Figure 74). They then shared their reflections with their groups.
Familiarising with design projects	Participants were introduced to each of the four design projects and had a chance to choose which group they wanted to join based on their interests.
Feldenkrais exercises on Balance	A Feldenkrais practitioner guided participants through an activity where they directed their focus and attention towards the quality of the movement, bodily sensations and emotions associated with the experience of balance, by performing extremely slow movements and reflecting on the mechanics of habitual movements.
Soma Bits (Windlin et al., 2019) and Shapes	A set of semi-finished pieces of technology were employed to allow participants to touch and feel the affordances of different actuators, such as vibration, heat, or inflation/deflation (Figure 75). These bits were combined with a mix of materials, such as stretchy yoga bands, soft cushions and ready-made shapes that could be attached to body or used as platforms to step on (Figure 75).
Design work with prototypes	The groups used the soma bits and shapes to engage in embodied ideation activities with each design project.
Day 2	
Feldenkrais exercises on Balance	Participants engaged with these exercises once again to re-sensitise their soma for the day's design activities.
Body sheets	Once again participants used body sheets to reflect on their bodily experience—this time during the Feldenkrais exercise—and shared it with the other participants in their group.
Bio-sensing	Participants were briefly introduced to a toolkit of Bitalino biosensing sensors, including EKG, EEG and EMG sensors. Participants then used the sensors to engage in further embodied ideation explorations.
Contact Improvisation	Two soma design practitioners guided participants through this bodily activity in which groups of two participants engaged in activities of feeling the weight of another person's arm or leg by holding it in one's hands, or by exploring leading and following movements, building up a non-verbal communication between them, in order to feel one's body in relationship to others by using the fundamentals of sharing weight, touch, and movement awareness.
Design work	Participants finalised their prototypes and prepared a demonstrator.
Sharing the design work	Participants displayed their demonstrators to the group.
Conclusion	The group shared their final reflections on the whole soma design process.

Note: Table based on (Höök et al., 2021).

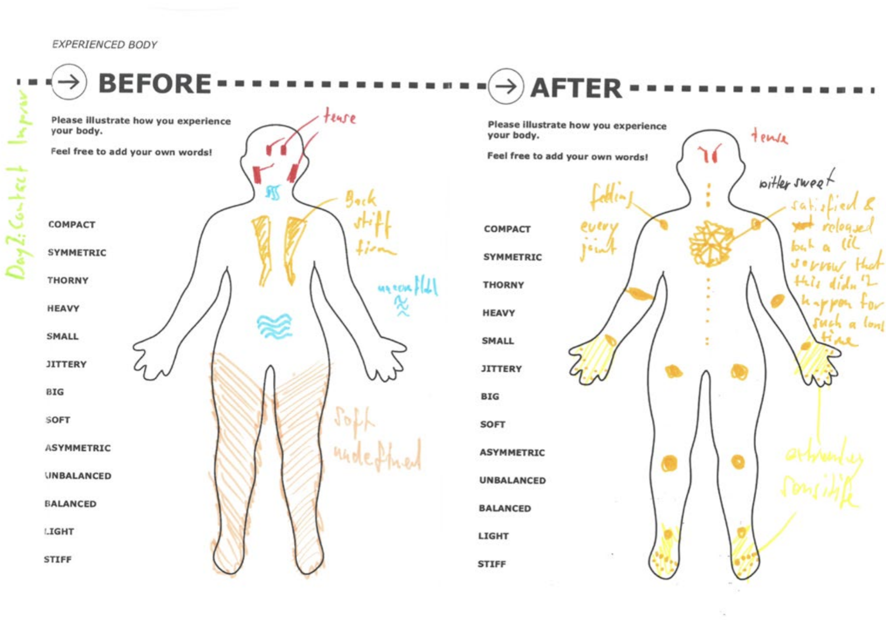


Figure 74. An example of a body sheet before and after a contact improvisation session.

Figure 75. Soft shapes, sensors, and actuators making part of the Soma Bits kit.

Whilst the whole group of participants engaged with most of these activities, some activities were more specific to each group's design project. For instance, in the case of the augmented guitar group, during the soma bits and shapes activity on the first day, members of the SDG and the Feldenkrais practitioner started feeling, touching, and placing soft soma shapes across the various parts of the body involved in keeping balance when playing guitar while standing up to maintain a performance posture and ground the guitarist to the floor, i.e., the calves, ankles, shoulders, neck, and back.

Likewise, the SDG members placed soma bits such as vibrating actuators and heat pads in different points of contact between guitar and body such as the chest, forearms, wrists, and hands. Furthermore, during this stage of the workshop one of the participants of the MRL used one of the elastic yoga bands brought by the SDG group to use it as a makeshift stretchy guitar strap to keep the guitar in place while standing up.

This material exploration playfully introduced unexpected affordances when engaging the elastic qualities of the material such as pushing the guitar down or away from the body, tugging the guitar neck down swaying it around through performative bodily motions. Consequently, guitarists in the team suggested using this stretchy interaction technique to modulate effects or generate sounds, as well as control media.

Another material exploration during this activity involved using two of the bigger soma shapes, which resembled cushy platforms. Once again—guided by notions of the guitar ecology and guitar playing—the MRL members of the team suggested using these cushy boards as a soft pedalboard. The team stacked the boards on top of each other, creating a sort of seesaw, on which the guitarist would stand on top of, and balance their body back and forth to interact with the soft pedalboard. The team also added vibration soma bits to the boards to simulate haptic feedback, as well as other materials like rubber balls which were mimicked soft buttons or sliders. Some of the design ideas that emerged from this material engagement were:

- A deformable effects pedalboard for the guitar, which would control the expression of an audio effect by balancing and swaying on top of it.
- Navigating media by stroking a soft slider (made of rubber balls underneath the surface of the board) with the foot.
- Providing performance cues (such as tempo or rhythm) with haptic feedback through the feet.

In the second day of design activities the augmented guitar team prepared a demonstrator in which both the stretchy strap and the cushy pedalboard were presented through a Wizard of Oz performance, in which one of the guitarists wore the strap and stood on top of the boards whilst playing guitar and pretending to control the expression of an audio effect by balancing the board back and forth and stretching the strap, whilst the other guitarist controlled the actual audio effect with his laptop computer (Figure 76).

Figure 76. Wizard of Oz performance with the Stretchy Strap and the Cushy Pedals.

6.3.2 The Second Soma Design Workshop

The second workshop was hosted at the Interaction Lab (MIDDLA) in KTH, and the proceedings were once again guided by the SDG, although the goal of exclusively focusing on guitars and building upon the previous workshop's design work and its reflections about guitar augmentation and designing for guitars utilising the soma design method (J. M. Avila et al., 2020) was proposed by the MRL members of the augmented guitar group.

This workshop was also two days long and had 10 participants: two from the MRL (My supervisor and I), seven from the SDG, and one from the Augmented Instruments Lab (AIL) from Queen Mary University of London (QMUL). Participants this time encompassed master's degree students, PhDs, post-doctoral and senior researchers with backgrounds in soma design, interaction design and musical interaction. In this case, the soma design explorations were focused on the felt experience of "tension and release" thematically involved in guitar playing in various facets, namely, the physical and mental tension during performance, and tension and release both in music and in the elastic material of the Stretchy Strap—as the workshop was mainly focused on further developing this design concept. The structure of the second workshop was similar to the first one, where both days began with bodily explorations followed by discussion in groups aided by body sheets, as well as subsequent design and prototyping activities, and concluding plenary discussions to reflect on design ideas and outputs.

However, in this particular workshop, a Feldenkrais practitioner with expertise in guitar playing and soma design was invited to guide bespoke bodily exercises that addressed the various parts of the body involved in the tension and release when playing guitar, such as the arms, palms, and fingers, but also those involved in breathing, such as the abdomen, ribs, and pelvis—following the notion that breath control is an essential bodily skill to attune for instrumental performance. The exercises were conducted individually and in pairs.

The latter were helpful in understanding shared physical control in subsequent design ideations. Moreover, the Feldenkrais practitioner was an active participant during the entire workshop, as a skilled guitarist. Also, in contrast with the previous workshop, there was an active effort to alleviate the "expertise gap" between guitarists and non-guitarists, and soma designers and non-soma designers in this workshop.

Hence, the cohort was divided into two teams with a "balanced" mix of guitarists and non-guitarists. Moreover, a series of somatic facilitation experiments were conducted so that non-guitarists could experience guitar playing, like a proficient player would. Firstly, a guitar was passed around the participants for them to hold, touch and tinker with to become comfortable and familiar with the instrument.

Then, different facilitation approaches were explored, for instance, a guitar was set on an open tuning so that non-guitarists could play simple chords by just strumming the strings, with the intent to allow them to focus on the motion of playing. Another approach involved having two people sharing a guitar, where a guitarist would fret the notes or chords in the fretboard and the non-guitarist would strum the strings (Figure 77 [Right]), this time to allow them to feel part of the performance of more complex melodies. An inversed version of this experiment involved taping a non-guitarist's hand on top of the guitarist's hand, which would then play melodies and scales, allowing the former to feel the sensation of the "playing hand" through the movements of the latter (Figure 77 [Left]).

Figure 77. Somatic facilitation experiments.

Conversely, Soma Bits and other materials were employed to "defamiliarize" the guitarists' experience of guitar playing. For example, vibrating actuators were taped to a guitarist's fingers to disrupt their digitation (Figure 78 [Left])—the guitarist reported the vibrations made his hand feel numb or "drunk". Another experiment involved muting the strings of the guitar with a stretchy yoga band, making the guitarist focus more on their bodily movements with the guitar rather than sound production with the instrument (Figure 78 [Centre]). A similar effect was achieved when using an inflatable cushion underneath the bridge of the guitar (Figure 78 [Right]).

Figure 78. Material explorations with Soma bits and other materials.

The subsequent design activities also involved using these inflatable Soma Bits and the stretchy yoga bands. One team explored placing the inflatable cushions on different parts of a Yamaha "silent guitar," such as the bridge (as previously mentioned), the neck, the back of the guitar and beneath the guitar strap. As this guitar has an open frame, it facilitated the attachment of the different inflatable cushions across the guitar. The other team expanded on the concept of the Stretchy Strap by attaching an additional strap around the waist and placing inflatable cushions both across the shoulder strap and waist strap. From these embodied design ideation processes, two design concepts emerged:

- A "breathing" guitar that would autonomously shift shape by inflating and deflating according to the breathing patterns of the player, to help them control their breath during performance or to comfort them. Another design intent of this shapeshifting guitar would be to have the neck deform to obstruct certain areas of the fretboard, thus pushing the guitarist to get out of their comfort zone and improvise around other areas of the guitar neck (Figure 79 [Left]).
- A "breathing" stretchy strap that would be affixed to the body by wrapping it around the waist and belly, and the around the neck and shoulders of the guitarist, featuring inflatable cushions in between these points of contact, thus fostering a more intimate—"hugging"—sensation, between player and instrument (Figure 79 [Right]). Moreover, this strap would allow for bodily movements in both the vertical and horizontal planes to control the expression of the sound output in nuanced ways. The inflatable cushion between belly and guitar would also act as a sensor/actuator; responding to the breathing of guitarist, allowing them to interact with it through squeezing (like a bagpipe).

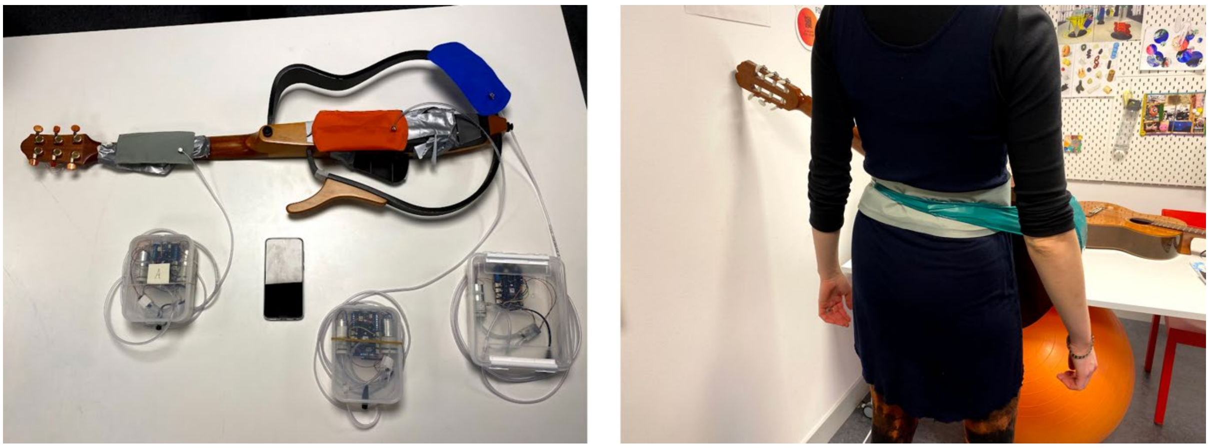


Figure 79. Augmented guitar concepts.

There were not any Wizard of Oz demonstrations at the end of this workshop. Instead, the designs were reflected upon by the whole group in plenary discussion. Although design generation was productive in both workshops—with five design concepts effectively emerging from the different material engagements, bodily explorations, and embodied ideations amongst participants—subsequent design work was focused in just one of the concepts, the stretchy strap from the first workshop.

6.3.3 Towards a Functional Prototype

In between both soma design workshops, the stretchy strap concept was also further explored during a two-day “absurd” musical instrument making hackathon at Queen Mary University of London (QMUL) (Lepri et al., 2020). During this hackathon, both mentorship on electronic textiles (e-textiles) by Hannah Perner-Wilson from Kobakant[17], and mentorship on the Bela platform (McPherson & Zappi, 2015) were available. Thus, considering the elastic affordances of the first strap mock-up (i.e., the yoga band), the design explorations in this event were oriented towards e-textiles and their integration with Bela. At the end of the hackathon a functional prototype was developed (Figure 80 [Left]), which utilised piezo sensors as exciters for a Karplus-Strong physical model and the stretch of an e-textile stress-gauge-like sensor (Figure 80 [Right]) to modulate the pitch of this signal.

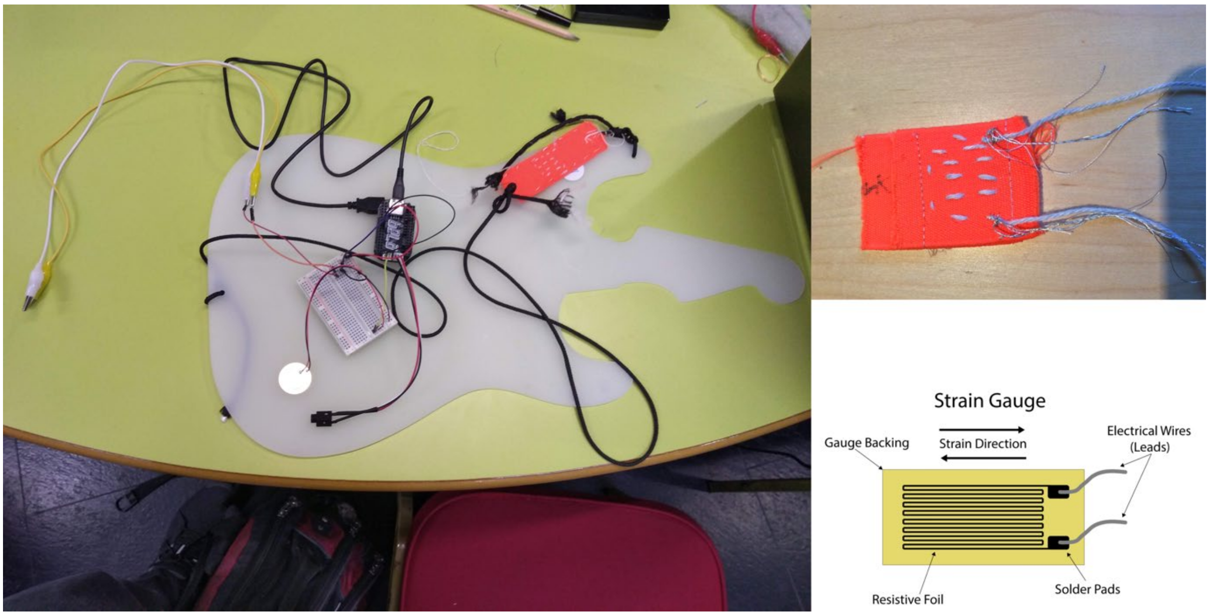


Figure 80. First Stretchy Strap functional iteration.

After the second soma design workshop, the Stretchy Strap design was refined at an academic visit also at QMUL, in which I manufactured various kinds of stretch sensors (and other e-textile sensors), exploring various sewing and electronics integration techniques—as well as utilising several types of yarns and fabrics Figure).

[17] https://www.kobakant.at/DIY/

Figure 81. Stretchy Strap sensor iterations.

Nonetheless, after several iterations the original stress-gauge design was again replicated for the final Stretchy Strap prototype. Moreover, recent works in the field of e-textiles design that explore stretch-based interaction techniques applied to the navigation of media (Olwal et al., 2020; Vogl et al., 2017) were considered during the development of this prototype, determining its abstract media controls and corresponding e-textile sensor inputs.

Likewise, recent studies that report that textile-based sensors can be smoothly integrated into everyday objects and imbue them with interactive qualities (Vogl et al., 2017)—as it is the aim with augmenting the guitar strap—and that stretch-based inputs are especially suitable to support micro-gestures (Olwal et al., 2020; Wolf et al., 2011), i.e., interactions that require less than four seconds to initiate and complete, and are usually intended to minimize visual, manual, and mental attention in contexts were imprecise interactions are prone to happen, such as in guitar practices with media, were also considered.

Ultimately, this academic visit led to the development of a media controller based on a guitar strap augmented with e-textiles. This controller was then employed as a research prototype to investigate how it would support guitarists' interactions with media during performance preparation with the guitar (Section 6.5). The manufacturing of the Stretchy Strap is now described in detail in the next section.

6.4 Manufacturing the Stretchy Strap

The Stretchy Strap consists of three hand-made electronic textile stretch sensors made with 2-way stretch elastic ribbing, which is hand-stitched with stainless steel conductive yarn (80% polyester and 20% stainless steel). The stitch pattern is a running stitch which zigzags across the width of the elastic fabric. This allows for the conductive fibres of the yarn to be compressed when the fabric is stretched. To increase the compression of the fibres and the tension of the elastic fabric material, a 10 cm piece of elastic fabric is looped around the plastic ends of the strap and then machine-sewn to the ends of a guitar strap (Figure 82 [Left]).

This also ensures that the stretch sensor is strong enough to hold the weight of an electric guitar but also to be stretched when downward tension is applied and to return to its original position when let go. To connect the stretch sensors to electronic components the ends of the yarn are overstitched with silver-plated nylon thread. The silver threads are then looped around solder tags and tinned with solder. The conductive yarn forms one half of a voltage divider circuit (Figure 82 [Right]).

The fixed resistor is chosen to balance the nominal resistance of the thread, and the capacitor provides lowpass filtering for noise reduction. The output of the voltage divider is sampled by a 16-bit analogue-to-digital converter on a Bela embedded computer (McPherson & Zappi, 2015) which runs a script that maps sensor readings to actions.

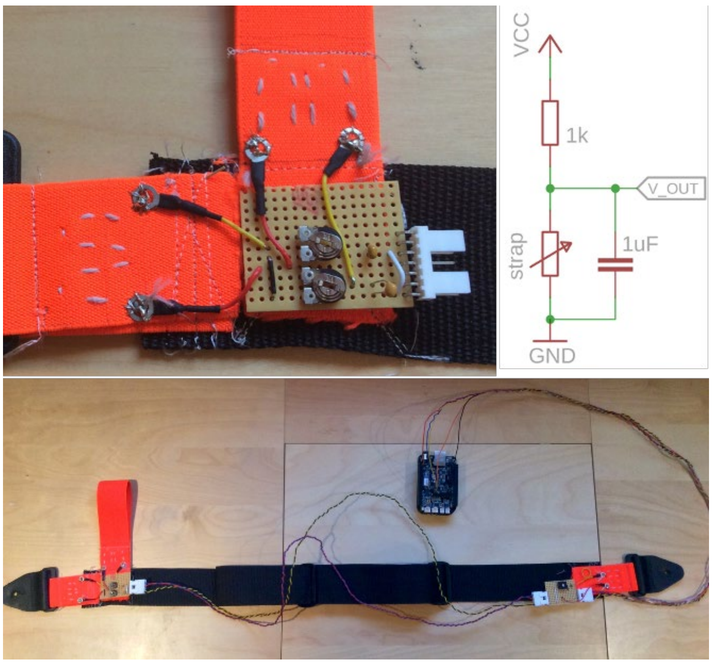


Figure 82. The Stretchy Strap. Close-up of sensors and its circuit diagram.

To use the Stretchy strap as a media controller a combination of technologies are employed. To read and process the sensor data a Bela mini is used, running a Pure Data script to map the continuous stretch sensor values to discrete MIDI messages by using sensor thresholds. These messages are sent to the host machine over USB.

To host and run the media we used the SoundSlice platform[18], which synchronises YouTube videos with interactive music notation in the web browser. By embedding the SoundSlice player in a bespoke website and using their API and the Web MIDI API, incoming MIDI messages from the Stretchy Strap were mapped to media controls to navigate an interactive score synchronised with a music video (Figure 83).

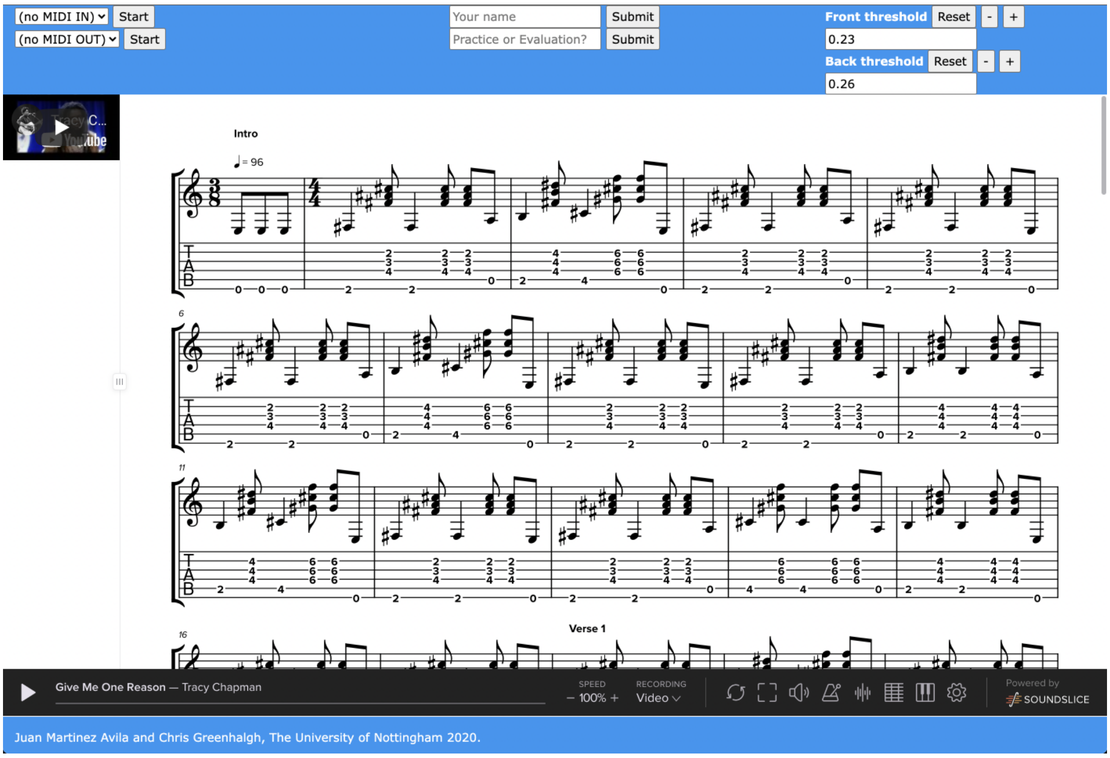


Figure 83. Embedding SoundSlice in a bespoke website.

This website also featured inputs for assigning MIDI inputs and outputs, entering the participant's name, and calibrating the stretch sensors' thresholds with outgoing MIDI messages. It also featured logging capabilities in the background for recording the control actions of guitarists when using the strap[19]. The Stretchy Strap's media control actions are triggered by engaging in subtle movements with the guitar which gently stretch the textile

[18] https://www.soundslice.com/
[19] https://github.com/psxjpm/Strap

sensors in the guitar strap. For example, tugging the neck of the guitar downwards toggles between play and pause, pushing down on the lower bout of the guitar with the forearm rewinds the playback and pulling on the rip cord on the side sets loops (Figure 84).

Figure 84. Stretchy Strap media controls.

The stretches which are more ready at hand (i.e., pulling down the neck and pushing down the lower bout of the guitar), are mapped to more critical and actions like play, pause and rewind. Whereas the rip cord is mapped to a secondary action which can be used when the guitarist stops playing, such as setting playback loops. It should be noted that as with the prototypes designed for the co-design workshops, the Stretchy Strap's interaction techniques were negotiated between the inputs available in the strap per se (i.e., three stretch inputs) and the available navigation controls in SoundSlice (i.e., play, pause, set loop, etc).

6.5 Evaluating the Strap

To evaluate the Stretchy Strap in use during performance preparation with SoundSlice, a group of 10 guitarists was recruited gather feedback on their experience with the strap. Again, participants from previous studies were contacted, of which Paco, Charles, Mike, and Kit participated once again. Recruited participants used their own guitars in the study (except for one participant) and were informed they would be asked to practise a song during the study using SoundSlice, but that they were not required to learn the song beforehand, and were not expected to perfectly perform it during the study, but rather just to engage with the media as they typically would and to focus on the experience of using the Stretchy Strap to support its navigation. The evaluation study consisted of four stages:

1. The study commenced with a brief background interview in which participants were asked about their instrumental practice and personal experience with the guitar and their everyday use of media resources to support their performance preparation. The aim of this interview was to survey the participants' experiences with encumbered interactions in the practice setting.
2. Following the interview participants were introduced to the Stretchy Strap and were asked to strap it on to their guitar. Before beginning to practice the song with the strap participants received a brief tutorial regards the strap's mappings and engaged in a brief orientation round using it to trigger the SoundSlice transport controls.
3. After familiarising themselves with it for a few minutes, participants were then instructed to practice along with the song and navigate the media using the strap. Participants were free to use the Stretchy Strap as long as they wanted over the course of this stage of the study (Figure 85).
4. The study was concluded with a semi-structured interview in which we captured participants' experiences of using the Stretchy Strap. Questions explored issues such as (a) using the strap as a media controller (i.e., the responsiveness of the controls, the mapping of the inputs, number of inputs, and other potential alternative inputs), (b) the bodily experience with the strap (i.e., ergonomic aspects, comfort and whether using the strap allowed to focus more on playing the instrument), (c) comparing the Stretchy Strap with the equipment they would regularly use to support their practice (e.g., mouse, or laptop trackpad), or during performance (e.g., guitar pedals), and (d) whether they envisioned the strap as part of their practice ecology, along with their instrument and practice resources.

Figure 85. Participant using the Stretchy Strap.

6.6 Evaluation Findings

The data reported here reflects only on the findings from the coding and content analysis of interview transcripts. Logging data and other data outputs in the study (i.e., video recordings and screen capture) were not considered for analysis. At the beginning of the study, i.e., the background interview prior to using the Stretchy Strap, the challenge of encumbrance was highlighted and confirmed by participants who reported experiencing a break in the flow of performance when needing to attend to digital media resources whilst playing their instrument.

For example, Samuel reported he would often find himself reaching over it to use the computer trying not to bang the guitar on the table. He describes this as having a barrier between the instrument and the computer. Andrew mentioned that even though using a mouse to control the playback of a track does not take much effort, it becomes annoying over time, when one must do the same operation repeatedly. Mike reported that having to repeatedly let go of the instrument to use a keyboard was a pain. Kit on the other hand said that it was difficult to return to a specific point in a song with accuracy when scrubbing the play back with the YouTube interface on a phone:

"Sometimes you can pull back too far, sometimes you can't find the right bit again."

Similarly, Gene mentioned that setting things on a screen is time-consuming and 'fiddly' and that dealing with time-based media can be tedious for having to pause and go back to a part in the playback (or having to scroll up and down a screen), whereas:

“With paper-based media everything is at hand, and you can go at your own pace.”

Pablo mentioned that when starting to play a new song for the first time, he would expect to initially make some mistakes, however he said that having to break the flow of performance—as soon as he set into it—to navigate the media would be one of the most frustrating things during practice. Participants also noted they would frequently repeat specific sections of a media track by manually pausing and rewinding to locate their segment of interest. For example, Kit reported the following:

“If I get stuck, I can just rewind and watch the same bit over and over again till I nail it.”

Likewise, Parker said it is quite common for him to want to get back to a particular point and re-listen certain bits over and over. More specifically, some participants mentioned that they wanted to focus their practice time playing the instrument rather than configuring equipment or media resources to support the rehearsal process:

“That's the fun performance bit for me (…) to just play the song and try and play all the way through even if I've made some cock ups (…) and have the band experience (…) fantasy part of playing.”

For instance, Gene mentioned that he only has limited time to play music and that sometimes using this software would lead to spend hours ‘fiddling’ with computers, that’s why he would prefer to use a songbook (as he would also get frustrated of having to do everything by ear).

Subsequently, the interviews that followed an extended engagement with the Stretchy Strap revealed several distinct themes regarding the bodily interactions with the strap and its usage for media control. Most participants found the strap intuitive, responsive, and simple to use. In the first instance, the strap feels familiar:

“It's just a kind of everyday part of playing the guitar.” (Pablo)

“It is still part of the guitar you are going to play with the strap most people you know even if you even if when you practice you don't put your strap on you are potentially practice into for performance and at some point, you're going to strap on, you know. It's just a kind of everyday part of playing the guitar.” (Gene)

Regarding the interaction with the strap when in use, Kit stated:

“I’s quite intuitive, tactile, and physical. You can quickly get the feel for how to do it.”

Pablo also mentioned that after using the strap for almost an hour, it became more intuitive to navigate media with it, although challenging in the beginning:

> *"I think they were distracting at first [the bodily actions] (…) [But] even within the duration of 50 minutes or so I was playing there it started to feel more natural (…) I was more likely to do it automatically without thinking about my transition."*

Gene observes that this simplicity and absence of a configuration process enabled him to just get on with the desired activity, stating:

> *"I have limited time to sit down I don't want to be configuring equipment, setting up pedals and stuff like that."*

Participants reported that the Stretchy Strap felt like it was part of the instrument:

> *"It feels like it is more part of holding the guitar, more like guitar playing." (Kit)*
>
> *"It felt like I was controlling it with my instrument." (Pablo)*
>
> *"Very easy to learn, movement is very natural, not anything that you wouldn't normally do. You don't have to take your hands out of the instrument." (Mike)*
>
> *"You don't have to move your hands away from the instrument to control the interface" (Charles)*
>
> *"It is quite intuitive [the way that the inputs are mapped]. You can quickly get the feel for how to do it. It's quite tactile and physical, you don't need to use a display to control it. It feels like it is more part of the guitar—part of holding the guitar. More like guitar playing rather than having to dance around, as with pedals." (Kit)*

Pablo also observed how it was:

> *"Closer to being part of the movements, the actions, the activities, that process of playing"*

Similarly, Paco asserted that:

> *"I think it's more natural just to learn a movement than to learn a combination of buttons. I think that people would be looking more often at the layout of the buttons while they are learning (e.g., with keyboard or pedal). Even after they have used it for a while probably will need to make sure that they are pressing the right one and this feels more natural to do especially if you are used to play with the strap."*

Pablo also elaborated on how different elements of the practice space feel like part of the performance and the instrument, whereas others do not:

> *"The computer does not feel like part of the instrument. The computer feels like part of the logistics, and I think amps kind of feel a bit like that, but pedals feel more like the performance—once they're set up you just go and turn it on or turn*

> *it off, changing the effect. They feel more like part of the performance because you can do it while performing."*

Moreover, participants indicated that the strap's closeness to the guitar enabled them to maintain a better focus and flow with the instrument, in contrast to their experience of using other modalities such as foot pedals. For example:

> *"When you are using pedals, you are in a different realm of control. When I'm practicing, I want to get into grips with what's happening on the fret board." (Gene)*

Pablo observes that:

> *"[pedals are] kind of peripheral to your guitar, and the strap feels like it's closer to your guitar (…) this feels more like you could sort of like flow into the action."*

Kit identified a similar experience:

> *"You haven't got to lean forward to stop and tap things and upset your balance with the guitar. You can keep the guitar in the right kind of pose and yeah it just helps you to carry on with it without breaking up that experience"*

In addition to the guitar, maintaining a focus on the SoundSlice UI while controlling it was also highlighted:

> *"After a little while with using the strap, I didn't have to take my eyes off the screen at all, you know, I could just like stop, start again and carry on, so it was actually helpful with focusing on what you're mentally doing" (Kit).*

Participants also talked through the interaction with the strap discussing its input configuration, limitations, and possible adaptations. Regarding the Strap's controls, Andrew stated that play and pause were the critical real-time functions to prioritise:

> *"In the computer I think that the play and pause are the ones that cause the most interruptions, so maybe it's important to have them close to the body."*

However, the rip cord interaction was not considered a real-time control action, as it required the player to take a hand away from performing on the instrument:

> *"I could never do that while playing because I'd have to take the hand off to pull it. It has a very different feel as an action to the other two, it's more deliberate. It's not an action that you do in flow, this control action is more suited to, some form of break period […] like moving to the next song, or back to the beginning of this one." (Pablo)*

> *"Because if you're in the middle of playing and you want to put the marker you've almost got think ahead to where you want to put that marker to be able to reach up and grab it. I quite like the play and pause it was 'cause it's using it quite a lot and I think but then actually you could keep your fingers." (Samuel)*

> *"One particular action the marker was that a bit awkward maybe at some point that you had to sort of take your hand away from the strings and then sort of grab on this thing. I think it's got a slight physical overhead which would mean that I wouldn't do it all the time I would probably only do it if I was fairly sure." (Parker)*

It was also suggested that discrete controls, such as play and pause, are effective for the nature of the strap's control interactions, but when fine-grained or continuous control was required (like rewinding), other modalities may serve better. For example, Parker goes on to suggest:

> *"If I wanted to make something fine grained, I'm just going to get on with the mouse I think."*
>
> *"The mouse would perhaps still be better for peaking forwards or navigating backwards." (Paco)*
>
> *"Could do scrolling with the mouse and rest of the learning process with the strap. Play and pause are the ones that cause the most interruptions, so maybe it's important to have them close to the body." (Andrew)*
>
> *"If you were in a rush to learn something maybe a keyboard would be more useful if you were unfamiliar with the strap." (Charles)*

When asked about adding additional inputs to the Stretchy Strap participants said:

> *"You should keep inputs under 5." (Charles)*
>
> *"If you're trying to give it an identity of its own and it's a different way of using technology to rehearse and then you start adding Keyboard type buttons to it then people are going well, I'll rather just do this (on a keyboard) rather than go for the strap." (Kit)*
>
> *"More than four would be too much to think about while you are concentrating on playing and learning. For me that's kind of stepping back… taking your hands off and pressing stop back forward yeah so, I would prefer to keep my hands on the on the strings, on the neck as much as possible so we know this kind of movement is for me far better than taking the hand away." (Mike)*

In general, there was a collective desire to "*keep it simple*," a thought echoed by Andrew, and Parker:

> *"I probably only would use play, pause and perhaps rewind on it, and not have lots of controls that I wouldn't be sure quite what was really going on." (Parker)*

Besides its minor sensor calibration issues, participants also pointed out other issues of the Stretchy Strap, such as ergonomic, learnability and aesthetic issues highlighting its limitations as a controller in particular use cases, such as fine-grained navigation. For example, having to push on the body of the guitar to rewind was deemed as a tedious action. Instead, a preferred mapping for this control input was to reset the media play head to the beginning of the track, as suggested by Pablo (and other participants):

> *"I would like it to go back to the beginning [triggering that action with the input]. This is annoying, I can go back quite slowly with my elbow on this for a bit [continuously pushing to rewind], but you know that's not going to help, so I'd just get the mouse instead."*

Another ergonomic issue that was pointed was the balance between pushing and pulling the elastic parts of the strap:

> *"So, pushing down is easy… but pulling it when my hand's already in that position, and I've gotta pull it down, that feels weird. (…) when I'm sitting down my body is taking the weight of the guitar (…) so I'm sitting down and I'm doing this and it's probably leaning back on me, so all my guitars weight is supported here on the body." (Pablo)*

Furthermore, Andrew mentioned two particularities of the strap, firstly, that holding a chord and tugging down the neck to actuate the strap demanded some skill, and that the angle of tugging would invariably change as the hand moved further down the neck. Andrew also mentioned that it would be useful to have haptic feedback with the rip cord input to know how hard to pull and get it right every time. Regarding aesthetic aspects Kit mentioned that:

> *"Guitarists can be very snobby with the material of their straps. Using this on stage, it's gotta look right."*

In general participants described a positive bodily experience using Stretchy Strap, as it enabled them to keep the flow of guitar playing a priority and the controller felt like part of the instrument and the performance. The proximity of the controller to the body and the instrument, along with the subtle movement of the neck of the guitar (to stretch the strap), removed the need to lunge forward to attend to other peripheral controls, such as a computer or a pedalboard, which interrupts flow.

The controls of the strap were considered most suited to real-time controls of play and pause and the rip cord for transport actions that take place in breaks between performances, whereas 'fine-grained' or continuous control might be better suited to other peripheral controllers.

6.7 Discussion

The discussion in this chapter is divided into two parts, namely, (1) the soma design discussion, unpacking insights from this design process, where no research participants were involved, and (2) the Stretchy Strap evaluation discussion, unpacking insights from the evaluation of the final Stretchy Strap with guitarists.

6.7.1 Soma Design Discussion

As previously mentioned, the Stretchy Strap is a design idea that emerged from serendipitously conducted soma design activities in this research project. It is notable that this concept did not emerge from the co-design activities with guitarists, which rather than providing innovative design concepts, revealed values and attitudes towards guitars, their augmentation, and the use of other associated devices to support embodied practices during instrumental preparation.

Reflecting on why this might be the case, one might firstly consider that encumbered interaction is in essence a body-centred problem, hence it calls out for design methods that place the focus on the body, such as soma design. One of the principal aims of soma design is to inform how one can flow with experiences, one's body, and the artefacts one designs (Höök, 2018; Höök et al., 2018). This led me and the designers involved in the soma design process to focus on their "whole body" experience when playing the guitar, and not just on the hands.

Thus, the focus during the process was drawn towards other aspects of the bodily experience during guitar playing such as holding and carrying the guitar, and one's posture and movement when playing it. In this sense, the attention shifted away from the fingers, hands and arms towards the torso, shoulders, and legs as potential sites for interactive interventions.

Another potential benefit of soma design in this case was the extended engagement with embodied ideation such as *slowstorming* (Höök, 2018) and *estrangement* (Wilde et al., 2017) which respectively aided the designers in the process of slowly zooming in their attention into particular embodied interactions during the design process, and to *defamiliarize* the experience of playing the guitar to guitarists, disrupting their preconceptions an opening the ideation process to unfamiliar design possibilities.

In particular, the soma bits toolkit, with its focus on soft and deformable materials, led the designers away from only considering the possibilities of conventional ‘hard’ materials such as switches, dials, foot pedals and of course the guitar itself. It was the playful exploration of the elastic materials in the soma bits toolkit —i.e., using one of the elastic yoga bands to use it as a makeshift strap—which directly inspired the idea of having a stretchy guitar strap, thus defamiliarizing the function of conventional guitar straps and introducing new affordances.

Likewise, the stretchy strap defamiliarized the guitarists’ habitual ways of holding and playing the guitar, while the cushy pedalboard defamiliarized the postures associated with performance. The Stretchy Strap, in particular, directly impacted the “interface” to the guitar—changing the way the instrument and player are connected, and thus altering a deeply embedded relationship and its associated internalized sensations.

Nonetheless, moving with a guitar connected to the body via elastic straps subsequently proved to be a surprisingly natural and expressive experience and stimulated thinking about how these bodily movements could address encumbered interaction with external media. The soma workshops were also notable for involving people who were experts in soma design but who were not proficient with guitar playing. Arguably, these participants did not arrive with the familiar baggage of expectations and assumptions about guitars and their ecology that the guitarists in the group had and instead drove the focus of the design process more onto the body.

Among the soma designers were also Feldenkrais practitioners who expertly led introspective bodily exercises. Interestingly, in one of the sessions, a participant of the workshop acted as a “somatic mediator,” being the Feldenkrais expert, soma designer and a guitarist. Thus, this participant’s design input mediated the diversity of design ideas coming from the different participants in the group (guitarists and non-guitarists).

There were also somatic facilitation experiments, like setting up the guitar in an open tuning or sharing a guitar between guitarists and a non-guitarists, which were key in allowing non-guitarists to partially experience key sensations related to guitar playing from a first-person perspective. Moreover, rather than trying to convey years of guitar playing experience through these exercises, the point was to allow non-guitarists to contribute their insights to the design process during the workshop.

These experiments also put the guitar at the forefront of the ideation process. This contrasts with the co-design workshops where participants were experienced guitarists and whose responses towards different design interventions to the guitar expressed a degree of conservatism. Experienced musicians who are knowledgeable about, if not obsessed by, guitars may be concerned with the overloading of their embodied instrumental practice when having to attend to additional control inputs, as well as damaging the physical integrity of the instrument or altering its cultural identity—by making the instrument look less appealing during performance—when technologically intervening it.

Soma practitioners on the other hand were frankly much less interested in guitars than they were with human bodies and the bodily experience, which led the design process in a new direction. Furthermore, reflecting on digital musical instrument design, a notable aspect of the soma design process was the focus on embodied sensations during guitar playing over making sounds, playing music with the instrument, or the technology behind the musical interaction (Avila et al., 2020; Marquez-Borbon & Martinez Avila, 2018). Lastly, playing the guitar is also very much as *aesthetic* matter in the sense that it needs to both feel good to the player and often look good to the audience too.

While the traditional focus on ergonomic design as part of human factors can help address body-centric issues such as motor performance, stress and fatigue, soma design deliberately encourages an aesthetic appreciation of bodily experience and so was an ideal fit for this design endeavour. It is no coincidence that, according to those who tested it, the Stretchy Strap feels good to move with and can also encourage performative movements.

6.7.2 Stretchy Strap Evaluation Discussion

The findings from the interviews prior the Stretchy Strap evaluation confirmed participants' experiences with encumbered interactions during guitar practice with computer media. For instance, many of the participants addressed how the use of media while playing the instrument would cause a break in their flow of practice, due to the physical and cognitive demands imposed by media navigation, such as shifting the hands to operate the mouse or keyboard and paying close attention to the interface used to play and navigate the media.

This constant physical and mental shift was described as tedious and annoying by several participants. After participants used the Stretchy Strap, they reported that this interaction modality ameliorates media-induced encumbrances, like repetitively letting go off the instrument to push a space bar on a keyboard to play and pause a track. In comparison to other guitar augmentations and interaction modalities that were explored during the co-design activities (Chapter 5, Section 5.2), the Stretchy Strap appears to demand less form the guitar player in terms of taking the hands off the instrument.

For example, when additional controls mounted on the body of the guitar were presented to guitarists during the co-design workshops, participants reported that too many control inputs could either overload the hands or the eyes, i.e., taking time and attention to “faff” around with too many extra controls rather than play the instrument, and having to move their hands from playing position to control-operating position. Thus, placing controls physically proximal to the instrument is different from making them convenient to use, especially when these may overload the core modalities of interaction involved in playing the instrument (Donovan & McPherson, 2014) and when there are limits as to how many parameters a musician can control (Levitin et al., 2002).

In contrast, the play/pause gesture (tugging down the guitar neck) using the strap was described as intuitive, responsive, and simple to use, with participants’ comments alluding to how the bodily actions to control the media made the strap to be perceived as being part of the instrument and allowing them to keep the flow of practice. The computer was reported as not perceived as part of the performative flow of rehearsal, but rather as the organisation of the preparation activity, i.e., what happens in between sprints of guitar playing. Thus, guitar playing feels performative, whilst operating media with the computer feels more like activity management. In this regard pedals were also regarded as part of the performance but at the same time separate from guitar playing (e.g., on a “different realm of control”).

Arguably, both operating controls on a guitar (like the volume knob) and sweeping a continuous expression control like a Wah pedal can, with practice, become part of the flow of performance. Moreover, there is also the question of how close to the locus of interaction should the media controls be, if they are too close, they can interfere with the instrumental technique, but if they are too far, they may be imposing a physical overhead on reaching the controls.

The Stretchy Strap potentially feels like “part of the instrument” since it partially prevents an undesired overloading of the hands or the fingers, which are crucial bodily inputs involved in guitar playing, especially when controlling it does not require moving the hand away from the instrument. Furthermore, the advantage of this approach is its physical proximity to the guitar while not obstructing the locus of a specific performance technique.

However, it should be considered that the other motions with the strap, i.e., pushing down the body of the strap to rewind and pulling the rip cord to set a marker do require momentarily letting go of the playing position, although keeping the interaction in proximity to the instrument. Thus, participants described that using the rip cord input required them to think ahead where they wanted to stop the audio playback to set a loop, and that the strap's rewind input was tedious to use, i.e., having to push down on the body of the guitar continuously to move back the play head in SoundSlice.

In this sense, while the strap is perceived to support that some parts of the rehearsal happen more closely to the 'flow' of performance, it also proves to be impractical to other more logistical parts of the rehearsal, like selecting what excerpt of the audio track is to be practiced. Reflecting on these contrasts one may consider two modes of interaction with media happening during this particular guitar practice activity.

One is (1) the "inner loop", which involves the "real-time" activity of constantly looping around a specific part of a song, i.e., by playing, pausing, and rewinding. This mode is characterised by participants as the one that is more drastically interrupted when having to shift from guitar playing to media navigation. In this sense, the inner loop is supported by the play/pause gesture with the strap. The other one is (2) the "outer loop", which involves the less "time-critical" activity of stopping instrumental performance to browse and select another fragment to engage with in real time.

Thus, multiple participants mentioned that other input modalities may be more suitable for outer loop activities, such as using a mouse to simply set the start of a loop in a particular region of an audio track or to hover on top of the timeline and selecting where to return the playback, rather than manually rewinding it. Moreover, as mentioned before both the rip cord and the rewind actions require the guitarist to momentarily remove their hand from the instrument.

Hence, the strap facilitates an essential part of the instrumental practice process, that is, ameliorating the constant repetition of the inner loop to some extent, by reducing the physical overhead involved in switching between playing instrument and operating media controls on a computer, by locating the associated control actions involved in the process nearer to the instrument without obstructing the bodily actions involved in performance.

Originally, in the Stretchy Strap, there was an attempt to centralise all “critical” media controls within the strap, in order to allow the guitarist to control the media actions whilst not taking their hands away (or too far away) from the instrument. However, after the evaluation, it was notable that only the play/pause input supported encumbered interaction, while the rewind and marker inputs potentially aggravated it. Hence, not every aspect of the practice needs to be unencumbered as logistical aspects will invariably happen outside the flow of performance.

The Stretchy Strap also felt “familiar,” as reported by participants. Possibly this impression results from augmenting a familiar artefact from the guitar ecology, i.e., the guitar strap, and the harnessing of its fundamental characteristics, i.e., to connect the guitar to the body and keep it in place—allowing guitarists to keep using the instrument while in motion or standing up—and augmenting it to become a media controlling device to support guitar practice. In this regard, a remarkable feature of the Stretchy Strap is its non-invasiveness to the physicality of the guitar—i.e., the guitar itself does not need to be modified to be used in conjunction with the strap.

Lastly, it shall be noted that the Stretchy Strap encapsulates the different design considerations that were pinpointed during the different stages of this research project, such as tackling the problem of encumbered interaction by presenting a control modality that does not overload the core instrumental techniques of the guitar (to some extent), which is a familiar object of the guitar ecology that does not invasively augment the instrument—hence taking into account its aesthetic, material and sentimental value, and which enhances the embodied experience and flow of guitar practice.

6.8 Conclusion

In this chapter, details of the design of the Stretchy Strap are described in terms of the textile and electronics materials employed and the textile and electronics techniques used to manufacture it, but also how the design rationale is grounded on the distinctive design considerations that emerged during previous studies. In this sense the Stretchy Strap has emerged from a relatively complex design process which has combined prototyping and co-design workshops with soma design, guided by findings of the ethnographic studies.

Notably, the strap is an unusual and innovative response to the challenge of encumbered interaction which was not considered prior to the soma design exercise. The different iterations of the strap are also described, ranging from an elastic yoga band mock up used in a Wizard of Oz demonstration, to fully fledged prototype. The deployment of the Strap for evaluation is also described, including the modifications made to the evaluation study in consideration of the COVID-19 pandemic.

The findings of the evaluation report on the interviews prior and after the evaluation of the strap. These confirmed aspects of encumbrance during guitar practice with computer media, as well as how the strap tackles these encumbrances. In particular, user feedback highlighted that the Stretchy Strap supported the repetitive aspects of guitar practice with media, or the so-called inner loop of this activity, involving the constant playing, pausing, and rewinding of a few seconds of playback to focus on a particular segment of an audio track. It was also noted that the strap felt familiar, and as part of the instrument and the performance—as opposed to other more “logistical” elements of the practice space, such as the computer—and that I was intuitive and easy to use.

However, it was also noted that some of the bodily gestures of the strap were not as supportive for unencumbered media control as originally intended with the interaction design of the device (and its media mappings). For example, the rewind input felt tedious, and the set loop marker input required some premeditation to be used, as reported by participants. Some participants also observed that the strap was prone to some ergonomic issues emerging from the guitarist’s posture or the position of their hands.

Lastly, the discussion presents a series of design insights emerging from the evaluation of the strap, namely the notion of an inner loop of a bodily practice, which in the case of performance preparation with guitar using interactive media involves the repetitive activities that characterise the performative “flow” of the guitar practice and an outer loop which involves the more reflective and logistic part of guitar practice, such as stopping to select a new fragment of a song. In the following chapter the overall design process is reflected on to answer the research questions initially posited as well as to provide considerations for designing embodied interactions for guitar.

Chapter 7
General Conclusion

7.1 Overview

Digital technologies underpin and support many every day and specialist activities. Considering typical popular musicians as a prime example, they are usually surrounded by an ecology of physical and digital artefacts, including their instrument(s), accompanying sound equipment, and a range of tools and resources used to support preparation and performance. Playing an instrument is a profoundly physical endeavour, and to perform on one to any level of competence a substantial degree of dextrous skill is generally required. Conversely, although listening to music with a media player might seem like a passive activity (e.g., when doing so during a car ride), repeatedly listening to a particular fragment on an audio track to transcribe it with the guitar demands intensive manual operation of the media controls, regardless of the interface with which they are presented, e.g., with physical or digital inputs.

The work presented in this thesis focuses on the embodied practices of guitarists whilst preparing for performances (as working musicians), and who for the most part, are learning and rehearsing new performance material with the support of digital media (e.g., videos and music from online services such as YouTube or Ultimate-Guitar). To survey these embodied preparation practices in the context where they occur, as well as to chart the resources involved in the process, an ethnographic study was initially conducted to gather ecologically valid data by observing guitarists engaging in learning and practicing activities at home, and at rehearsal spaces with their bands, and by enquiring them about how they accomplish these activities through semi-structured interviews.

To gather field data, audio and video recordings were captured during observational sessions and interviews. The data was analysed using an ethnographic approach by producing thick descriptions of the different activities of each musician and then unpacking a series of emerging themes. Based on these findings a series of challenges and opportunities for design were identified, namely, supporting (1) encumbered, (2) contextual, and (3) connected interactions (Avila, Greenhalgh, et al., 2019). These design opportunities accommodate both the individual and collaborative preparation activities of guitarists, however, to narrow the scope of design, the focus of this thesis primarily lay on supporting unencumbered interactions during individual instrument practice, especially when using additional resources, as the rationale of subsequent design interventions presented here.

Consequently, a series of provocative prototypes (or *provotypes*) for participatory innovation (Boer & Donovan, 2012) were developed and deployed during a series of participatory-design-inspired workshops in which a group of guitarists tested out four media navigation controllers whilst having a guitar at hand, and also engaged with low-fidelity prototypes such as cardboard and acrylic guitars during a series of co-design activities such as *bodystorming* (Schleicher et al., 2010) and paper sketching (Fallman, 2003)—as well as *embodied sketching* (Márquez Segura et al., 2016). The aim of these workshops was to extract tacit knowledge and elicit critical reflections from guitarists on technological interventions to the guitar and its ecology, as they engaged and responded to the interactional qualities of the prototypes during use, as well as during group discussion and design activities (such as sketching alternate versions of the prototypes provided or discussing alternative interactions with them).

Thus, the co-design workshops were helpful for obtaining a deeper understanding of the concerns and attitudes of guitarists towards the intervention of their embodied performance preparation practices with guitars and the tools and resources they use to support them, based on their ideation, insights and critiques emerging from the interaction with the prototypes which reflected critical design tensions, such as preserving the aesthetic and familiarity of existing artefacts in contrast to how much the technology would support their practices and integrate with their existing tools and resources. These workshops were followed by two additional *soma design* workshops where a range of embodied ideation techniques (Wilde et al., 2017) with guitars and other associated artefacts, such as pedals and straps were further explored. In contrast with the co-design workshops the agency of design shifted from guitarists/non-designers providing their feedback and expertise on the matter, to guitarists/expert designers (my supervisor and I) harnessing their first-person perspective and somatic experience of guitar playing as a resource for design (Höök, 2018; Höök et al., 2018).

In this sense, previously co-produced findings were complemented by perturbing and defamiliarizing pre-conceptions of familiar artefacts from the guitar ecology by engaging in a series of material encounters, in which the form, function and affordances of guitar effects pedals and guitar straps were subverted, by making them stretchy, squishy, inflatable, and rumbly (Avila et al., 2020; Tennent et al., 2021). The result of these workshops was the ideation of a series of deformable interfaces for the guitar based on existing elements of the guitar ecology, as well as the enactment of future uses for these technologies (Avila et al., 2020). One of these designs—the Stretchy Strap—was henceforth taken forward and continuously iterated into an embodied media controller using e-textiles. This research prototype was then deployed into a home practice space with the intent of observing whether this digitally augmented artefact with a familiar form but with new and unfamiliar affordances could potentially remedy the encumbered interactions that were observed in the context of practice and evaluated with 10 individual guitarists.

This fourth study culminated the design process which began with surveying an existing guitar ecology, then probing and perturbing it with technological interventions, and then observed the remediating impact of the Stretchy Strap intervention in that specific ecology. Based on the reflection of the overall process, considerations for the design of embodied interactions for guitar are provided, namely, (1) considering the instrument (its shape, material, and cultural identity), (2) considering the embodied practices with the instrument (the body, soma, and existing expert skilled practices with the instrument), (3) considering the practice ecology (i.e., the tools and resources involved during preparation and how these are laid out and configured in the practice space).

7.2 Revisiting the Research Questions

At the beginning of this thesis, three research questions were presented for investigating the embodied nature of guitarists' preparation practices, the scope of the design space for intervening in these practices, and the potential ways these interventions can be designed, i.e.,

1. What are the embodied practices of guitarists preparing to perform?
2. What is the nature of the design space of embodied interaction with guitars?
3. How can we design embodied interactions for guitarists preparing to perform?

The methodologies and design techniques employed across the four studies aimed to address these questions, through the observation and enquiry of participants' accounts of their embodied practices and the use of specific interaction modalities to support it, as well as the first-person reflection of the somatic experience of playing guitar and interaction with other artefacts of the guitar ecology, such as guitar straps and effects pedals, and an evaluation of an artefact designed to control media through bodily interactions (i.e., the Stretchy Strap), potentially allowed them to remediate existing issues emerging from the clash between the embodied nature of guitar playing and its alternation with navigating media controls using a computer's peripherals, such as encumbered interactions and interruptions. In the following subsubsections each research question is answered in further detail.

7.2.1 What are the embodied practices of guitarists preparing to perform?

As previously mentioned, the ethnographic study involved directly observing guitarists preparing to perform at home and at rehearsal rooms and contextually enquiring them about their practices. The field data corpus that was generated from this study was then unpacked into a series of embodied instrumental preparation activities that were observed across participants. As proposed before, these activities may be analysed and described using Dey et al. (2001) "People, Places and Things" framework. For example, guitarists in the study were often in coordination with other guitarists and musicians when making collective decisions in and out of rehearsal sessions. During rehearsals, participants would decide the order of their set-list, coordinate their musical arrangements, engage in informal music learning practices, such as directing and teaching each other musical phrases, and on some occasions, they would also improvise as a form of entertainment or as a compositional device. These sorts of socially driven activities were heavily supported by bodily gestures, such as pointing or signalling musical movement.

Embodied preparation activities were also impacted by the configuration of spaces. For instance, in the case of individual preparation, most guitarists laid out their home practice spaces to have their tools and resources at close reach to their bodies, e.g., their amplifier or effects pedal would be near their sitting area and they would often have a surface to lay out printed or hand-written materials (tablature or lead sheets), as well as their computer or mobile devices to browse video or audio resources from—often keeping the instrument strapped to their body or sitting on their lap. In the case of rehearsals with other musicians, physical resources, such as paper resources and digital resources, like tablets or mobile phones, were laid on music stands, on the floor or on top of pedalboards (or tables if there were any around). Moreover, musicians positioned themselves in specific formations to be able to see each other and communicate through physical gestures or by talking face to face in between breaks.

Perhaps the most salient observations of embodied activities occurred when musicians interacted with physical and digital resources whilst having their instrument at hand. This complex bodily interplay between resource handling and navigation, and instrumental performance was observed across a series of preparation activities. While there was a consistent alternation between interactions with instrument and resources across the activities, some of them required more focus on the resources, while others require more focus on the instrument, and some were arguably in between the two states.

For example, when browsing for online resources and auditing which ones were best for the practice, guitarists were observed mostly focusing on operating their computers (or mobile device) with both hands over the peripherals (i.e., when scrolling or browsing a website with the mouse or typing a song title with the keyboard). Although in most cases, the instrument would be at the guitarist's lap even if not being attended to. However, after media resource was selected for practice, then the guitarist would physically engage with the media and the instrument in diverse ways, depending on the presentation of the media or what the media was being used for.

Moreover, if the guitarist were engaged in transcribing the music with their instrument, they would often be observed repeatedly looping around specific excerpts of a musical track to hear (and in some cases, read) the notes (from a video or an audio player, either online, e.g., on YouTube, or from a native media player on their computer) and subsequently attempt to copy them with their instrument. To loop a section of a track, guitarists would need to engage in fine-grained manual operation of media controls, either via key commands (e.g., space bar to play and pause) or through a GUI (i.e., clicking on a particular section of the timeline to navigate to a specific part of a song). This process was further complicated when transcribing music on paper. In one instance, a bassist was observed listening to a track from an email attachment, which he then subsequently transcribed with his bass and then to a piece of paper, marking down the chord changes with a pen, as he played them on his bass.

In another instance, a guitarist rehearsing to play guitar and sing at a show was observed momentarily scrolling a webpage to read lyrics and tablature from a website whilst having the instrument at hand. This is equivalent to having to turn pages for an exceptionally long score.

For this reason, some orchestras employ page-turners to assist musicians with manual page turning of scores with multiple sheets music, so that they can keep focusing on playing their instruments. Likewise, mechanical, and digital page-turning devices have been developed to support this process, and instances of these devices can also be synchronised to mobile applications.

Another embodied activity that also involved interactions with media but in which the focus mostly lay on instrumental performance where run-throughs of musical pieces. In this case, guitarists were observed playing through a whole song accompanied with a media resource as a "backing track" to play along with, to test that they were able to perform it on their instrument. In this sense, the embodied practices of guitarists preparing to perform supported by interactive media are characterised by varying degrees of interleaving bodily interactions with the musical instrument and the media.

Hence, (1) the media used to prepare for performance, (2) the peripherals used to navigate it, and (3) the purpose of its usage determines the physical interaction (and the impairments) to be supported during instrumental practice. For example, if a guitarist uses a video tutorial of a song to listen to the music and see how it is played, and they use a laptop computer's keyboard and trackpad to navigate this media in order to loop over a particular section so as to transcribe it in the instrument, the embodied interaction would be completely different if they instead used a webpage with tablature and used a mobile phone's touch screen to navigate the content when also attempting to transcribe the piece.

7.2.2 What is the nature of the design space of embodied interaction with guitars?

The co-design study confirmed observations from the ethnographic studies, such as that guitarists generally possessed an existing array of tools and resources to support their practice—which was curated over the years—and a knowledge of the ecology of artefacts they could also potentially use for this purpose. As mentioned before, the guitar is a continuously evolving instrument, not only in terms of the music that is created with it, but as an artefact that has been in constant transformation over time. However, as the guitar is adapted to the exigencies of its surroundings, it also drives the creation of new artefacts which brings to attention that the guitar is seldom used alone, but rather as key part of a complex ecology. In this thesis, this has been referred to as the "guitar ecology."

Different embodied practices with the guitar, as well as embodied interactions with other associated artefacts, such as guitar gear, gadgets, technologies, accessories, reading and learning resources, stores, and services drive the creation of new artefacts and vice versa (the creation of new artefacts can also generate new kinds of embodied interactions with the instrument). In some cases, embodied interactions with these new artefacts also permeate the existing artistic and performative practices with the instrument, when the instrument is successfully integrated in the guitar ecology.

There is a plethora of technological and non-technological artefacts that have (and are) been developed to support embodied interactions with guitar in both the commercial and academic spheres, which serve different purposes for different activities and different contexts of use. In this sense, guitar-related artefacts may potentially be classified as auxiliary, technique oriented, instrument-modifying and electronically augmenting artefacts (Figure 86):

- **Auxiliary artefacts.** These are artefacts that support embodied interactions with guitar but not the production of sound with the instrument per se. For example, the guitar strap is meant to hold the guitar in place, whilst allowing the guitarist to perform while standing up. Similar artefacts are the guitar foot stool, the music stand, and the practice chair as well as other mechanical, electronic, or digital auxiliary tools such as the tuner, the metronome, and the Fret Zealot.
- **Technique-oriented artefacts.** Latching on the concept of technique in instrumental performance in music, traditional techniques on the guitar are generally performed with the hands. Thus, these artefacts would be those that are usually in the guitarist's hands, such as the plectrum or the guitar slide. Other more unconventional technique-oriented artefacts are the guitar "Triller" (a hand-held mallet-like artefact for percussive string striking), and the "Pickaso" guitar bow (for bowing guitar strings as with other bowed instruments, like the violin). There are also electronically driven hand-held devices that enable extended techniques, such as the E-bow, and the Magpick (Morreale et al., 2019).
- **Acoustically-modifying artefacts.** These artefacts can either be mechanical contraptions or physical interventions that are temporarily affixed to the instrument. Thus, these artefacts temporarily modify the physical and material composition of the

instrument to alter its sound in non-digital ways. A common example of this type of artefacts is the capo, a device which is clamped onto the neck of the guitar to change the length of the strings, thus raising the pitch of the instrument—depending on the fret to which it is clamped onto. There are also other variants of the capo, like the "Spider capo" which can clamp individual strings, or the "Chordinero," which can additionally clamp individual strings across different frets using rods of different lengths.

Other modifications dramatically change the character of the guitar, making it sound like another instrument. For example, the "Passerelle" is an attachable bridge that when positioned over a fret on the guitar it can make the instrument sound similar to a Japanese Koto. Other attachments are the "Harpad," which adds six additional strings to an acoustic guitar to make it sound like a 12-string guitar, and the "GUITAR-JO" which slightly muffles the strings to make it sound similar to a banjo.

There are also mechanical (and electro-mechanical) contraptions, like the "Hammer Jammer," which is a device that hammers the individual strings of the guitar when individual keys are pressed (as with a piano), and the "Gizmotron," which triggers spinning wheels on each string to make bowing-like sounds, by also using keys.

- **Electronically-augmenting artefacts.** These artefacts are temporary additions to the instrument that may extend is sonic capabilities or digitally expand its qualities. A simple example of this kind of artefacts would be placing a contact microphone on an acoustic guitar allowing it to be electrically amplified. The same principle applies for temporary electromagnetic pick-ups for acoustic guitars, or *hexaphonic* pick-ups for electric guitars (i.e., pick-ups that can isolate each individual guitar string into a separate output), or the "Submarine" pick-up, which is a small attachable pickup that can output the signal of a group of strings. Furthermore, once the instrument is plugged into a signal chain, its sonic output can be processed by using guitar effects pedals and other signal processing devices.

  There are also attachable artefacts that can allow the instrument to interface with digital devices, such as the Fishman MIDI pickup, the Guitar Wing, the ACPAD, or the "Virtual Jeff Pro," an attachable device which harnesses the lever affordance of the whammy bar to wirelessly control the expression of a pedal. Coincidentally, the Fret Zealot would also be an instance of this kind of artefacts.

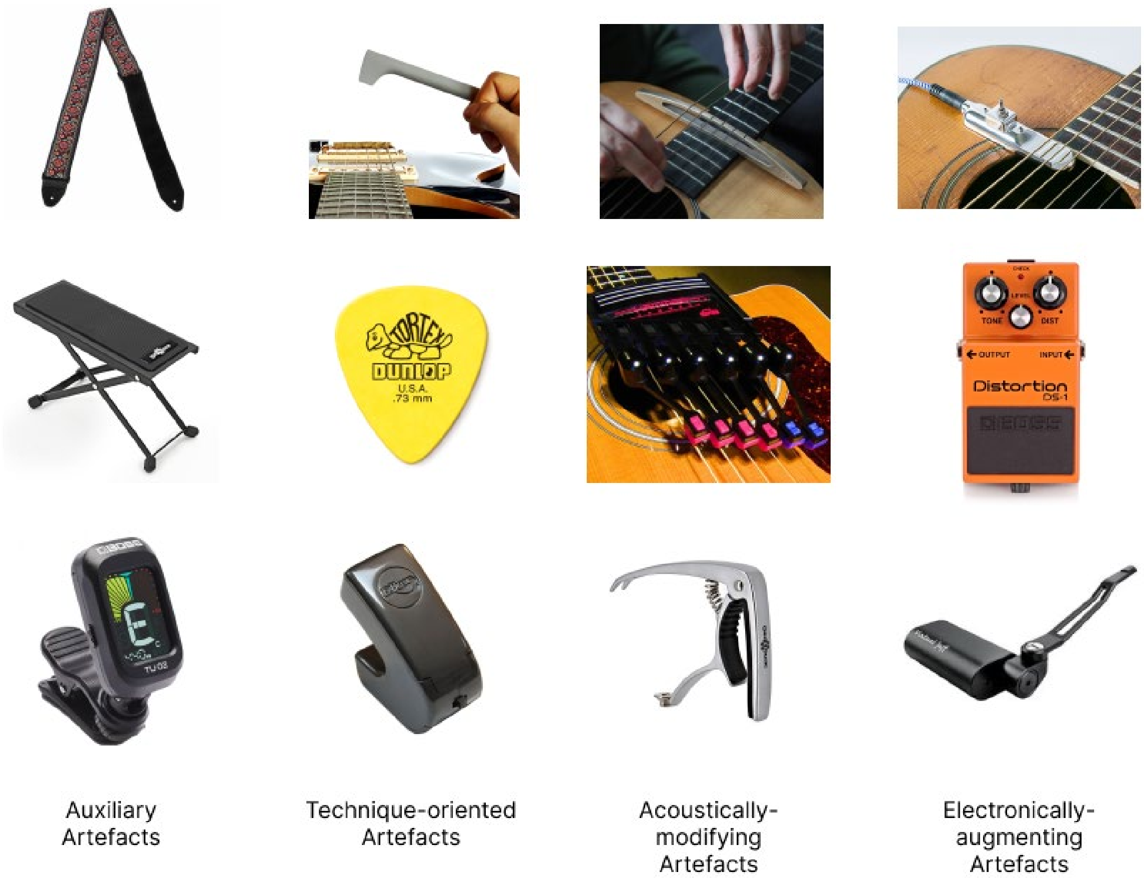


Figure 86. Artefacts that support embodied interactions with guitars.

However, using this classification, some of the prototypes developed in the co-design study would not fall into any of the categories. For example, the foot controller prototype was used to navigate sections on a music track but did not interface with the guitar as an electronically-augmenting artefact would. The same can be said about the VUI prototype, which used a voice activated commands on a laptop computer to navigate the track but did not interact with the guitar in any way. In contrast, the touch controller prototype would indeed fall into this latter category, as it was a temporary attachment in the instrument's body that allowed it to interface with a computer. Likewise, the Muzicodes (Greenhalgh et al., 2016), harnessed the signal input of the guitar—by playing musical notes on the instrument—to achieve the same interaction. Alternatively, the Stretchy Strap would be classified as both auxiliary and electronically-augmenting, as it doubles as a regular strap but also as a media and expression controller. Nonetheless, something that all these artefacts have in common is that they were meant to support embodied interaction with the guitar. However, it must also be considered that the guitar ecology encompasses other intangible and non-artefactual elements, such as online communities, services, rehearsal spaces and even other guitarists.

7.3 How Can We Design Embodied Interactions for Guitarists Preparing to Perform?

Findings from across the four studies lead to the unpacking three design considerations for embodied interactions for guitar during the performance preparation process, namely, (1) considering the instrument, (2) considering embodied practices, and (3) considering the practice ecology. The ethnographic study revealed aspects of the embodied practice with the instrument when interacting with other elements of the guitar ecology, such as learning resources, other guitarists, and different practices spaces. It also allowed for charting the guitar ecology per se, throughout the observation of multiple instances of performance preparation, the tools, and resources the supported it, and how it occurred across different spaces.

The co-design study uncovered the values and attitudes of guitarists towards the intervention (and disruption) of their instruments, their embodied practices, and their practice ecology. In contrast, the soma design study and the embodied ideation techniques that were employed during this process were helpful in defamiliarizing existing preconceptions of embodied interactions with guitars and associated artefacts from the ecology, leading to the creation of the Stretchy Strap. Lastly, the study with strap tested how a new artefact to support embodied interactions during performance preparation was evaluated by guitarists.

7.3.1 Considering the Instrument

When thinking of designing for the guitar, the instrument must naturally be taken into consideration. The guitar comes in many varied materials, shapes and sizes, and its design elements can vary dramatically across different guitar models and variations. For example, a Flamenco guitar is different from a solid-body Stratocaster, in this sense that the former is thicker, lighter, considerably frailer, and that its material composition and acoustics allow for particular idiomatic performance techniques and a sound that is characteristic of Flamenco music, whereas the latter is thinner, heavier, sturdier, and it also features characteristic design elements of electric guitars, such as strap buttons, pick-ups, tone and volume knobs, and a pick-up selector. Likewise, its distinct sound is often associated with Rock and other popular music styles.

Arguably, specific types of guitars are predominantly used to play particular styles of music (Figure 87), albeit with rare exceptions. For example, the Selmer guitar is associated with Gypsy Jazz, Flamenco guitarists will often use Flamenco guitars, Djent is almost exclusively performed with 8-string guitars, and similarly Jazz guitarists often use hollow body archtop guitars.

Figure 87. Flamenco, Selmer, Archtop, and 8-string guitars.

Taking these material and cultural aspects into account, the guitar presents interesting challenges for augmentation. Although it is common for experimental and prepared guitar performers to deconstruct and alter the guitar in unusual ways, other kinds of guitarists would often be more conservative about intervening their instrument, as observed in Chapter 5. There are several reasons for these contrasting attitudes, which are related to the financial, aesthetic, sentimental, and material values of each individual guitarist towards their guitar.

For instance, experimental guitarists perform with the guitar in unconventional ways. For example, during his free improvisation performances with prepared guitar, Fred Frith is sometimes seen placing different objects on top of his guitar as it sits on his knees. He also places objects like drumsticks in between the strings of the guitar and uses a special kind of capo which doubles as a pick-up (Figure 88). This does not imply that Frith does not place any sentimental value on his guitars, but rather that his musical practice involves heavily and transiently altering the instrument during performances.

Figure 88. Fred Frith performing with a prepared guitar.

However, for other guitarists, doing these interventions to their guitars would be unthinkable, especially for those who want to conserve the material integrity of their instrument due to their highly financial, aesthetic, or sentimental values (e.g., a four or five-figure cost vintage guitar). Interestingly, in some cases, the objective of some guitarists is to preserve the damage their guitars have sustained over the years (e.g., Willie Nelson's "Trigger" guitar) or to acquire guitars that have been pre-battered to look old, or like replicas of a famous guitarist's used guitar, including its blemishes (i.e., relic guitars)—for visual and aesthetic purposes (Figure 89).

Other cultural aspect to consider is that guitarists in the co-design study mentioned that some kinds of guitars' visual appearance would make them look like more professional performers, and vice versa. For example, they mentioned not wanting to perform with a guitar that would look like a "practice guitar," but rather use the same guitar across different settings, i.e., both individual practice, group rehearsal and live performance.

Figure 89. Willie Nelson's Trigger guitar and a relic replica of SRV's guitar.

Lastly, if one were to pragmatically think of temporarily attaching a device to a guitar, further things to consider are the shape and material of the instrument. For example, during the co-design workshops various participants mentioned not wanting to attach anything to their acoustic guitars as it would change the acoustics of the instruments. Others were reticent to do this due to concerns of adhesives leaving residue on the paintwork of the instrument. However, if these concerns were circumvented, one should still consider the “real estate” available on the guitar per se. For example, a Gibson SG has arguably more space available for attaching a device than a Steinberger Spirit GT-Pro, whereas a Yamaha SLG200S has barely any space available to attach a device on its body (Figure 90).

Figure 90. Different guitars have different "real estate" available.

7.3.2 Considering Embodied Practices

As evidenced in the ethnographic and co-design studies, the performance practice, the space where the action happens, and the tools to support it, impact the embodied practice with the guitar. Let us consider the case of a guitarist whose performance practice involves using multiple pedals—e.g., Nick Reinhart from Tera Melos (Figure 91). Arguably, this guitarist would have developed an embodied practice that extends from only focusing on the guitar, to focusing on the feet to integrate the different pedals into the composition and performance processes.

Another common example of this would be guitarists who use looper pedals as the basis of their performance. In this case, stomping on the pedal is tightly interwoven and precisely timed with the rhythmic flow of the music. Similarly, some guitarists develop proficiency with simultaneously playing the guitar and rocking the foot lever on a Wah pedal, enabling certain sounds and techniques idiomatic to this device.

In contrast, more complex digital multi-effects guitar processor pedals that have multiple inputs and set up options (e.g., Line 6’s Helix) sometimes require guitarists to engage more attentively with the pedal in order to operate it and program it, thus transiently detaching them from an embodied performance state, to place them into a more hermeneutic relation (Ihde, 1990) with the device, as it requires complex navigation and information input from the guitarist. In other words, the interaction with the pedal transitions from being part of the performance to a focused interaction with a separate system.

Figure 91. One of Nick Reinhart's pedalboards.

Something similar happens during performance preparation when supported by physical and/or digital media resources. As mentioned at several points in this thesis, with UGC platforms such as YouTube and Ultimate Guitar, guitarists have access to a milliard of video, audio, and written resources. To navigate these resources, they often employ digital devices with different interaction modalities, such as touch screens in mobile devices or peripherals, like mouse and keyboard on personal computers. As guitarists spend more time developing proficiency with their guitars, not only do their skills and expertise with the instrument improve, but also the organisation and efficiency of their preparation activities, as well as the choice of tools they use to support the process. Thus, they also develop embodied expert practices in the performance preparation setting after extended periods of practice with the same tools.

Strikingly, encumbered interactions are still observed with both the instrument and the devices, experienced as physical and cognitive overload, even in professional musicians, as evidenced and examined in this thesis. This suggests that most encumbrances and interruptions in the context of performance preparation supported by digital resource may emerge when the guitarist is required to repeatedly switch from embodied instrumental performance towards engaging with a digital system's operation. Nonetheless, it should also be noted that some activities will invariably break the flow of performance during preparation, especially when the mode of interaction with a device demands more attention, such as when browsing for media resources on the Internet or when configuring equipment prior to rehearsal.

Yet another aspect of embodied practices with guitar to be considered is the body—and the soma—of the guitarist per se. In other words, this aspect not only involves the physical body but also the somatic connoisseurship (Schiphorst, 2011) that is developed with expert instrumental embodied practices and the tacit knowledge about the instrument and its ecology. For instance, a guitarist with a physical impediment may have difficulties playing a traditional guitar but may be able to develop an instrumental practice with a bespoke adapted guitar to their physical abilities (Harrison & McPherson, 2017). Likewise, proficient guitarists who mainly play electric guitar display the ability to inadvertently manipulate whammy bars, volume knobs, pickup switches and other controls whilst performing, suggesting that they have developed an eyes-free embodied practice with their instrument after years of practice.

Overall, in the case of performance preparation, one should thus consider that embodied instrumental practices with the guitar require extensive manual engagement and are sometimes accompanied by singing and feet stomping, and we should avoid overloading these interaction modalities. Thus, when designing embodied interactions for the guitar, it is important to critically inspect the specific embodied practices of the performer, but also the physical challenges and constraints that may emerge from their particular practice ecology.

7.3.3 Considering the Practice Ecology

As evidenced in this thesis, the guitar is seldom used alone but in conjunction with a multifaceted ecology of physical and digital tools (i.e., artefacts such as the ones described in Subsection 7.2.2, as well as software like Guitar Pro), resources (in this case, resources of information, such paper lead sheets and books, or online audio-visual materials), and services (e.g., online courses, music tutors, virtual pedal simulators[20]). Thus, over time, guitarists assemble ecologies of such tools, resources, and services as they develop an embodied practice with their instrument. In this thesis, tools to support embodied interactions for guitar during performance preparation have been designed by taking into consideration the embodied practices of musicians, their instruments, and their existing ecologies. As previously mentioned, the tools that have been designed here are physical tools that incur in the areas of auxiliary and electronically augmenting artefacts. Auxiliary artefacts, such as the strap or the foot stool are designed to support the existing embodied practices of guitarists, and they only become practical when they are used in conjunction with a guitar. These artefacts are often used temporarily, meaning they do not modify the guitar in an invasive way. The same can be said about technique-oriented artefacts, such as the plectrum or the E-bow.

However, we must also consider that whilst some of these artefacts allow the guitarist to access an extended range of sounds, they also impose physical limitations to other instrumental techniques. For example, when an E-bow is used, the guitarist can infinitely sustain a note but cannot pick the strings. Strikingly, while some of these artefacts become adopted others are rejected. For example, guitar plectra are ubiquitous to certain guitar traditions (and across several stringed instruments) and have existed for thousands of years. In contrast, other artefacts like the "Jellifish" guitar pick, have briefly entered the market and then have been discontinued, possibly due to their minimum utility in expanding the sound of the guitar or supporting the performer.

This technique-oriented artefact design space has previously been explored in the digital augmentation of musical instruments. For example, the Magpick (Morreale et al., 2019) collocates the locus of intervention within a familiar artefact for guitarists (the plectrum**)** and harnesses the existing physical gestures that have potentially already been internalised when performing with the instrument—i.e., picking the strings or strumming—to control nuanced sound effects with their picking hand. From this perspective, the guitar strap can also be digitally augmented to harness existing bodily interactions with the instrument. Guitar straps are typically mundane and unexceptional accessories, but ubiquitous for guitar players. They can be readily attached to a guitar without having to make physical interventions to the

[20] https://www.thomann.de/gb/stompenberg_devices.html

instrument (unless it does not have built-in strap buttons), facilitating its transference from one guitar to another, and it does not affect the way the instrument is played when attached. With hindsight this seems like an ideal point at which to innovate without deeply modifying the instrument or the usual embodied practices with it.

Considering other kinds of products, some would seem to be very accessory and/or gadget-friendly, for example home computers and cars. So, researchers and designers should consider the whole ecology of devices and resources at play, and be open to intervening through accessories and gadgets, especially in domains where the core technology or device may be more resistant to direct change or replacement (such as the case of guitars).

7.4 Contributions of this Thesis

Findings from this thesis confirm and expand on previous ethnographic observations of guitar playing, informal music learning practices and the use of tools, resources, as well as on phenomenological accounts of instrumental performance and the material and cultural aspects of the guitar (through the elicitation of values and attitudes of guitarists towards guitar augmentation). The findings also contribute a series of interaction design implications for augmenting guitars by considering the existing embodied practices of guitarists and the tools and resources they already use to support them. More specifically, these findings contribute a series of considerations and provocations for designing embodied interactions guitar—and musical instrument—augmentation insights, and the use of different human-centred design exploration, ideation, and prototyping methods (i.e., design ethnography, participatory design, and soma design) to tackle a singular design rationale (i.e., supporting encumbered interaction during instrumental performance preparation with guitar), as well as illuminating contrasts between these methods.

Furthermore, in terms of methodological contributions, the ethnographic study here provides a first of its kind ethnographic exploration to gather design implications for guitar augmentation from observations of guitarists' performance preparation practices. Likewise, the use of embodied ideation methods (such as estrangement with material explorations and the use of Soma Bits, as well as bodystorming and embodied sketching with guitar-shaped props) within a broader soma design process to generate design concepts for DMIs, as well as elicit reflection on existing technological interventions was also the first study in the area of digital musical instrument design and analysis to explore the soma design method.

Somatic explorations with the guitar also provoked further research questions for soma design, such as harnessing the naivety of non-experts in a domain to facilitate the estrangement process of an experience, such as by disrupting preconceptions of a particular interaction with an artefact, as was the case in the soma design workshops presented here. In addition, the Stretchy Strap—and the other guitar-related prototypes that emerged from the soma design process—present contribution to the areas of deformable interfaces and DMIs, as well as the use of e-textiles for media control and musical expression.

7.5 Methodological Reflections

As previously described, the concept of the Stretchy Strap emerged through a relatively complex and extended design process that engaged guitarists throughout distinctive design methods and techniques. Another potential influential factor in the design process was my role as researcher, designer, and guitarist with expertise in the embodied practices involved with guitar performance and preparation, as well as my acquaintance with the guitar ecology. In summary, the overall design process was: (1) to identify the focal problem and initial requirements based on previous ethnographic studies; (2) to explore a range of potential solutions using early but functional prototypes in co-design workshops with users; (3) to perturb the process and introduce a fresh perspective that then led us in a new direction through the soma-design workshop; and (4) to create a higher fidelity prototype—the Stretchy Strap—and test this with users.

Essentially, design work began with an exploration of a particular human activity—i.e., performance preparation with guitars using multimedia—by conducting an ethnographic study. Thus, ecologically-valid data of this activity was gathered by observing guitarists in their "natural environments"—i.e., the actual places where they engage in their preparation activities, such as rehearsal rooms and home practice spaces—as well as interviewing them about the details of their activities and how they personally accomplish their preparation goals. This study also facilitated the charting of the rich interplay of actors, activities and artefacts involved in performance preparation practices with guitar, and also to elicit design opportunities to support these activities (Crabtree et al., 2012; Dourish, 2006).

These observations then led to identifying the design challenge of supporting encumbered interaction during performance preparation with guitar (Chapter 4). Having staged the ground for design interventions with this challenge in mind, a series of technological interventions that sought to accommodate the observed embodied practices were prototyped and then probed with guitarists though a series of co-design workshops, in which they were utilised as materials for discussion, reflection, and critique on the subject of augmenting guitars.

Ultimately, these workshops were useful for evaluating guitarists' attitudes and concerns regarding the augmentation of guitars and their practice spaces—in a participatory fashion—through a variety of co-design techniques (Lucero et al., 2012) and the rough evaluation of the prototypes from guitarists. Thus, this stage of the process led to gathering more insights about potential design interventions with a focus on supporting encumbered interaction during performance preparation.

At the workshops it was confirmed that participating guitarists experienced difficulties with interruptions and multitasking during performance preparation. Moreover, it became apparent that these guitarists were reticent to introduce unfamiliar technologies that could potentially disrupt their established preparation practices or alter the aesthetics of their instrument (both material and acoustic). Although this value-sensitive information was certainly helpful for subsequent design activities it did not offer any immediate practical implications for designing an artefact that would enable guitarists to operate media resources whilst preserving the embodied flow of instrumental practice with guitar.

In search for alternative design methods that focused on embodied interactions, soma design serendipitously emerged in my way as a design activity to be explored when Kristina Höök—the precursor of soma design (Höök, 2018)—and her lab members ran a two-day workshop at the Mixed Reality Lab. During this workshop (and a subsequent one in which we solely focused on guitars), we once again tinkered with the idea of augmenting the guitar to support performance preparation, but this time we utilised embodied ideation methods, such as defamiliarization and embodied material explorations though bodystorming and the use of Soma Bits. These soma design explorations with guitars revealed interesting tensions between guitar players and non-players, to balance the different somatic appreciations of guitar playing among guitar experts and non-experts, guitarists in the group harnessed their connoisseurship of the instrument, the embodied practices with it, and its ecology as the starting point of the design process, thus orienting the soma design experts—who coincidentally did not play guitar—around the scope of intervention.

Moreover, guitarists led a series of somatic facilitation and other somatic awareness techniques (Loke & Schiphorst, 2018) (As described in Subsection 6.3.2) to allow non-guitarists to feel the experience of guitar playing to some extent. Conversely, soma designers facilitated the defamiliarization of the guitar to guitarists in the group (including myself) by guiding the bodily exploration of different points of contact between the body and the guitar, and by intervening its materiality through *material* and *technological encounters* (Schiphorst, 2011).

In particular, the kinaesthetic properties and affordances of elastic and soft materials were explored in conjunction with performative bodily movements with guitar, as well as other artefacts associated with guitar's embodied practices such as straps and pedals, to defamiliarize guitarist's habitual movements and experiences within their familiar artefact ecologies. Combining soma design and guitar expertise—and non-expertise from both parties in their respective domains—was helpful for untapping unique and unfamiliar bodily interactions with the guitar by thriving off defamiliarization techniques and encounters with unusual materials that perturbed the embodied relationship with the guitar. Not only did these bodily and material explorations expanded the space of design possibilities under consideration, but it also revealed unnoticed possibilities in one specific element of the guitar ecology: the strap.

Rooted in the physicality of playing and manipulating the instrument and the strap, and in the self-conscious exploration of alternative actions and ways of moving in that context, proved to be a very embodied or bodily form of control, but without overloading hands and feet that are already in use, leading to the conceptualization of the Stretchy Strap (Avila et al., 2020). In retrospect, although engaging in co-design methods was useful in uncovering values, sensibilities, and attitudes from guitarists towards the intervention of their practice ecologies, these were only able to provide feedback on how the technologies that we presented sat within their existing practices and ecologies. Moreover, although the guitarists in these workshops are experts in the craft of playing their instrument, none of them were trained designers at the time of the workshops (to the best of my knowledge).

Hence, employing soma design techniques in this thesis's design process, allowed me to zoom out from my own pre-conceptions of the instrument as a guitarist, by defamiliarizing my own practices. However, as a designer, this methodological supplement oriented me to reframe the design process to focus on supporting fluid interactions with the guitar during performance preparation, rather than problematizing the interruptions that emerge during the transition between the instrument and supporting media during the process.

The design process then transitioned back to a more task-driven phase of prototype development that brought together the distinctive possibilities and experiential qualities of the stretchy strap from the soma design activity with the practical insights and values from the co-design workshops. This process involved fine-grained interaction design and implementation choices to yield a fully functioning prototype that could then be tried by musicians during a more realistic performance preparation task and setting.

7.6 Limitations and Future Work

The design work presented in this thesis provides a case for combining a series of human-centred design methods to explore the intervention of existing embodied practices with guitars. Naturally, however, there were limitations and constraints to each study. For example, many of the interviews that were conducted for the ethnographic study were not factored into the ethnographic corpus that was subsequently analysed for design implications. Nonetheless, data from the 23 interviews was rich in details about personal instrumental practices and use of tools and resources, and this methodological approach could be explored in future studies of musicians preparing to perform

In the co-design study, the prototypes were only used by a handful of participants, for a brief period of time during the workshops, due to time constraints, since there was only one instance of each interaction modality available and only one of each could be used at a time. Thus, an improved version of this study could perhaps employ toolkits with several prototypes, which could then be used by guitarists at home for a longer period of time at home. The soma design study generated many augmented guitar concepts that are yet to be explored as functional prototypes, such as the soft pedal, the breathing guitar, and the breathing strap. The final Stretchy Strap prototype was not robust enough to be deployed as a research product (Odom et al., 2016) in the wild (Chamberlain & Crabtree, 2020). Likewise, the study could not be conducted in the wild, due to the UK government's lockdown restrictions during the COVID-19 pandemic.

Future work with the Stretchy Strap could explore a more robust version of this device in the wild at guitarists homes, who could spend longer periods of time exploring and reporting on their embodied experiences with the strap. Likewise, using the Stretchy Strap as a controller for musical expression is currently being explored in both academic and commercial settings.

7.7 Concluding Remarks

The main outcome of this thesis are the considerations for designing embodied interactions with guitars I offer, namely, (1) considering the instrument, (2) considering embodied practices, and (3) considering the practice ecology. These considerations are informed by findings from the studies I conducted throughout my research, which employ a distinct combination of human-centred design methodologies, each offering insights on different aspects of what I refer to as the "guitar performance preparation ecology", which encompasses the interplay between guitarists, the artefacts with which they undertake their embodied instrumental preparation practices (i.e., their guitar, and other associated artefacts), and the rehearsal and personal practice spaces where these practices happen. This ecology coexists with other ecologies of guitar-related embodied activities, ranging from performance ecologies to free-improvisation ecologies, and so on, all encompassed within a wider guitar ecology.

In other words, a guitar ecology may be understood as the set of interrelationships between emergent embodied expert practices with the guitar (which in turn emerge from long-term sustained interaction between guitarist and guitar), the emergent assemblages of existing artefacts with which the practices are supported and the configuration of the available spaces where such artefacts are laid out and the embodied practices happen. As these interrelationships progress over time, new artefacts will emerge to support, augment, enhance or explore particular nuances of embodied practices, and so will new space configurations (or new spaces overall), that is, the development of expert practices in a particular place implies the configuration of the space and the assemblage of the necessary equipment (i.e., tools and resources) to carry out the activities involved in the practice. For example, one may think of the specialist technique-oriented artefacts that have emerged to explore new sounds with the guitar, like the Pickaso guitar bow; or how studio spaces are soundproofed and furnished to accommodate the workspace for professional audio production and recording.

In this thesis, the focus lies on the intervention of the guitar performance preparation ecology, as an underexplored design space (in contrast to that of performance). Thus, to observe the embodied practices involved in preparation I conducted an ethnographic study which consisted in going to people's homes or their rental rehearsal rooms to observe them practice individually or rehearse with their bands and interviewing them about their personal approaches to these activities. This initial study was particularly important to delimit the scope of design intervention in this thesis, as performance preparation with guitar can drastically vary depending on musical tradition, playing style, resources available, or preparation format (i.e., individual practice or collaborative rehearsal).

Thus, the performance preparation practices observed here were fairly similar in the sense that most of the guitarists participating in the study were interested in learning and practicing Popular music songs from English-speaking countries in the style of Rock, Pop, Funk, Blues and Folk. Moreover, most of these guitarists learned music through informal learning practices, such as learning by ear, reading tablature, and learning from other musicians during rehearsals. In addition, most of them learned by ear and read tablature by using online resources such as YouTube and Ultimate Guitar. In this sense, focusing on this specific group of people allowed me to chart a more specific guitar performance preparation ecology.

Hence, when analysing the observational data gathered from this group of participants, many similarities were observed in terms of socio-technical practices, space configurations, embodied practices, and use of artefacts, tools, and resources during their preparation activities. Another phenomenon that was observed across these cases was the emergence of encumbered interactions during instrumental practice with guitar whilst using a computer to access and navigate multimedia learning resources. In this regard, it was apparent that encumbered interactions emerge when different practices clash, such as operating a computing device and playing a guitar.

However, although most of the artefact assemblages and space configurations that were observed were to some extent similar to each other (i.e., most of them featured a tabletop on which guitarists would place their computing devices, and a chair to sit in whilst practicing), their embodied practices still varied depending on the specific activity being enacted, e.g., playing whilst singing or transcribing music with the instrument (aka learning by ear). Therefore, it is important to consider the specificities of the embodied practice that we are designing for. Thus, while multiple embodied practices were characterised in the initial ethnographic study that I conducted, subsequent design endeavours where solely focused on supporting fine-grained instrumental transcription with the guitar when using multimedia resources. Hence, in the subsequent co-design study I conducted, the focus of the prototypes that were deployed for participant evaluation mainly lay on the latter specific embodied practice. During this study, participants also pondered on the idea of augmenting their guitars with media controllers either as temporary attachment or as permanent design features, along with discussing other potential interaction modalities with the other prototype devices such as pedal-based controllers, and gesture-based controllers, among others.

While my initial ethnographic study set the basis for characterising the concept of the guitar ecology employed here, the co-design study highlighted the value that guitarists put into their artefact assemblages and space configurations, but also on their guitars. As previously mentioned, their attitudes towards augmenting their guitars (and other artefacts from their practice space) were also addressed. For example, when discussing the design features and interaction modalities of the different prototype devices that were introduced, guitarists considered specific aspects related with the instrument, as well as bodily interaction, and resulting ecological intervention with and from each prototype, such as how these would potentially remediate (or disturb) their existing embodied instrumental transcription practices with computing devices, and how they could be integrated within their existing personal practice spaces, tools, and resources, as well as how instrument-mounted interventions would modify or alter their guitars, or if they would be usable across different guitar shapes, sizes, or materials.

The subsequent soma design study was useful for approaching the design of artefacts to mediate between instrument playing and media navigation from an alternative angle. In this case, rather than addressing the design process from a third-person perspective—i.e., observing guitarists' embodied practices from an outsider's point of view, or asking them to evaluate prototype devices—I instead approached the design process from my first-person perspective as a guitar player, harnessing my somaesthetic appreciation of guitar playing aided by embodied ideation methods and various somatic methods which were facilitated by soma designers (e.g., Feldenkrais, contact improvisation, among others). The focus in this case, lay on designing for the bodily and the subjective felt experience of playing guitar, rather than on exploring a range of interaction modalities for mediating computer navigation and guitar playing. Thus, the embodied ideation and somatic methods employed here, such as the material and bodily explorations with soma bits and other materials were centred around specific points of contact between body and guitar, but also on the whole-body experience when playing the instrument. Moreover, during this soma design process, we latched on existing artefacts of the broader guitar ecology, such as pedals, straps, and guitars, and perturbed their habitual affordances through defamiliarization techniques and material explorations in order to introduce novel interaction modalities to these familiar artefacts. The outcomes of this study were a series of design concepts for guitar that use deformable materials which facilitate the enaction of bodily gestures in proximity to specific points of contact with the guitar during playing, namely, the Stretchy Strap, as well as a series of breathing guitars and guitar straps, and soft guitar pedals.

The Stretchy Strap concept was then prototyped and refined to be used as the main interaction modality to remediate encumbered interaction during performance preparation with guitar when navigating secondary multimedia resources. The design was further developed to navigate multimedia in SoundSlice (i.e., videos synchronised with interactive scores) by triggering media control actions with three stretch inputs which could be actuated with bodily gestures involving subtle bodily movements with and near the guitar—e.g., (1) pulling the guitar neck down to play and pause, (2) pushing the lower bout of the guitar down to rewind, and (3) pulling the “rip cord” on the side of the frontal input of the strap to set a loop. To evaluate this design the strap was trialled by 10 guitarists at a home practicing space.

Findings from the evaluation study provided insights on the nuances of the Stretchy Strap as an embodied media navigation controller, as well as more specific aspects of the embodied practice of musical transcription with the guitar, such as how some particular media actions, like play and pause—which were used more frequently—were facilitated by the strap, whereas other media actions like “scrubbing back” the playback (aka rewinding) by pushing the lower bout of the guitar or pulling the rip cord on the strap to set a loop, were respectively less helpful than selecting a point in the playback directly with the mouse, or stopping rehearsal to manually set in and out points for a loop, as these latter activities do not need to happen in the "flow" of the embodied practice of musical transcription as much as playing and pausing the playback do. Nonetheless, the Stretchy Strap is an exemplary case of considering the guitar (i.e., having the aim of preserving its material integrity through non-invasive augmentations), the embodied practices of guitarists (in this case, performance preparation, and more specifically, musical transcription with guitar supported by multimedia on computing devices), and the ecology (in this case, the ecology performance preparation, involving common assemblages of tools and resources, and common specific configurations to support this practice).

Besides the design considerations proposed above, designers can also take into consideration the role they assume during the design process. For example, the inventor of a new musical instrument, (or an innovative design feature of an existing musical instrument, e.g., an augmentation or an alteration) might be an expert musician who advises a designer on the requirements they need to develop it, as it is the case when instrument companies make signature instruments in collaboration with artists. Notable cases are Mike Portnoy's snare "throw-off" which he conceptualised but was developed by TAMA, Christian Scott's design of the "Sirenette" which was developed by Adams, as well as many guitarists' signature guitars, developed by guitar companies. The inventor may also be an engineer, designer or luthier who produces a design by tinkering with the instrument.

For example, Gene Parsons is a mechanical engineer, multi-instrumentalist, performing musician, and luthier who invented the "string bender" as a commission from Clarence White form The Byrds. This invention then became instrumental for White's style, and it also became part of the idiomatic expressions of the Country music tradition and continuing to be used by other guitarists to date, such as Marty Stuart. Within the NIME community, many instrument makers and inventors have similar multifaceted backgrounds and skills which are useful for designing new instruments and music technologies in this space. Thus, the inventor can also be a researcher-designer and musician, who acts as an observer of a particular practice and then looks for ways of intervening it as it has been my case.

Hence, a designer looking to design interactive systems, accessory devices, or augmentations for the guitar could use this thesis as a guide, by following the design considerations that have been proposed, in order to consider the material, cultural and aesthetic specificities of the guitar and the aesthetic values that the musicians who perform with them hold towards the instrument, as well as the embodied practices and ecologies of their specific musical traditions, but also the guitar-related activity to be designed for (e.g., performance, improvisation, preparation, etc.).

The design considerations provided here could potentially also be explored to inform the intervention of other musical instruments, and even other embodied practices (albeit with further consideration of their bodily and ecological nuances). As a thought experiment one could think of augmenting the piano employing these considerations. Starting with considering the instrument, one could think of the various kinds of piano form factors there are, ranging from grand, upright, Rhodes, Wurlitzer, and digital pianos (e.g., Nord), among others.

Now let us imagine that we would like to augment a piano with magnetic resonators, as in the case of the Magnetic Resonator Piano. This augmentation is generally observed in grand pianos, in which a bar of magnetic resonators are placed on top of the braces inside of the tail of the piano directly above of the strings, which are then magnetically resonated with the magnet allowing the instrument to have infinite sustain. However, if the same augmentation were to be explored in a Rhodes piano or in a Wurlitzer piano, then the magnetic resonators would perhaps need to have a different placement inside these pianos, as well as a different form factor to accommodate their specific tine (Figure 92) and reed-based mechanisms, respectively.

When considering the embodied practices of piano players, one could for example think of a few nuanced bodily activities with the instrument, like page-turning or pedal-stomping (thinking of the three pedals of the grand piano, i.e., the *una corda*, the *sostenuto*, and the damper pedal). Continuing with the magnetic resonators in a Rhodes piano example, to consider the ecology of this piano as well as the aforementioned bodily movements involved in pedal-stomping, one could then think of how to harness the sustain pedal mechanism used for the Rhodes to modulate the resonance of the magnets as a design speculation.

Figure 92. Fender Rhodes electric piano tine-based sound generating mechanism.

However, we should consider that this is a quick and dirty thought experiment on the use of the design considerations provided in this thesis. In practice, the specificities of the instrument, the nuances of the embodied practice to be designed for, and the elements of the ecology should be carefully addressed from first-, second- and third-person design perspectives, utilising methods which can analytically elicit these aspects during the design process as illuminated in this thesis.

Chapter 8
Appendix

8.1 Interview Schedule for Ethnographic Study

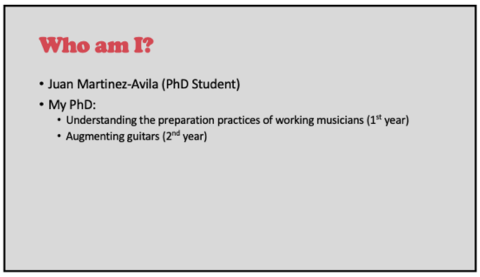
MUSICIAN INTERVIEW
SECTION 1 – ON PLAYING THE INSTRUMENT
0. Could you tell me a little about the primary instrument you play?
1. What has been your learning experience with the instrument? *(Non-institutional vs institutional level of training)*
2. For how long have you played your primary instrument? *(Months / years?)*
3. In what context does most of your play happen? *(Alone at home / with others)*
4. What musical styles / genres do you play?
5. Do you play other instruments?
6. Is music your main source of income / What is your role as a musician? *(Hobbyist / Freelance / Instructor / Performer)*
SECTION 2 – ON INDIVIDUAL PRACTICE
7. How often and for how long do you practice for? *(Frequency and amount)*
8. In what context does most of your practice happen? *(Alone at home / with others)*
9. What are you trying to achieve when you play? Is your play planned? *(What sort of things have you been practicing with the instrument? Why?)* *(Have you developed or set any personal goals?)*
10. Do you think your own personal motivations define what things you search to learn? *(What do you think would make you more motivated to practice and play?)*

11. How would you summarise your personal practice process? *(What tools / sources support this process?)*
12. Do you learn songs by ear? *(What tools / sources support this process?) [Records; YouTube; etc.]* *(Distracted / Attentive / Purposive listening)*
13. Do you manipulate audio materials to support this process? (e.g., transpose a track to another key, slow it down, trim it, loop it, etc.)
14. Do you read / write musical notation? [Tab; ABC; Lead sheet; Chord chart; Fake books] *(What tools / sources support this process?)*
15. How do you manage to build and maintain your repertoire? *(What tools / sources support this process?)*
16. Do you use any sort of practice logbook?
SECTION 3 - ON COLLABORATIVE PRACTICES
17. Do you play with a band? *(Or planning to make one?)* *(Covers or original?) (Style of music?)* *(Size of aggrupation?)* *(Do you play in other bands? How many?)*
18. How often do you rehearse? *(What do you usually do during rehearsals?)* *(Summarise the rehearsal process)*
19. Does playing with others improve your playing? (Group learning / Peer teaching)
20. Do you do "jamming" sessions? [In what contexts?] *(What do you consider jamming?)* *(Tools that support this process)*
21. Do you compose original music (individually)? *(Do you compose collaboratively?)* *(Describe the process between Songwriters and the Band)* [Sharing process]

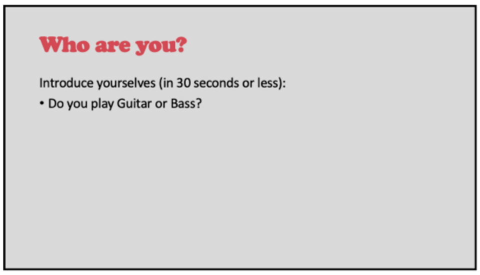
(Tools that support this process) (Does composing feed off jamming?) [Embellishing / arranging]?
SECTION 4 – WRAP UP
22. What is your main role within your band? *(Composer / arranger / performer)*
23. Do you have any experience of live performance? [Solo / band project]
24. Where do you mostly perform (Common venue)? [Open Mic / Social events / Concerts]
25. What satisfying experiences have you had in your musician career? [Recorded an album / Tour / Concert / Support band / Winning a contest / Other]
26. Is there anything else you want to mention that was not covered here about your personal experience as a musician?

8.2 Co-design Study Workshop Slides

1

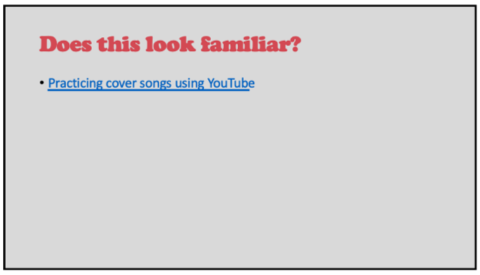


2



3

4



5

6

Learning cover songs

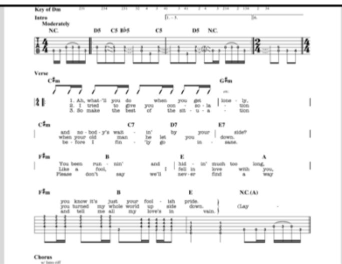
General approach I've observed:

- Understanding the structure of the song (The form)
- Segment the song into sections
- Learn each section individually
- Do a play through

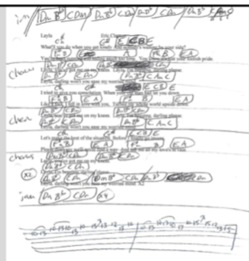
7

Song Structures

8

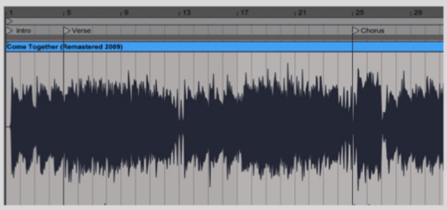


9



10

11



12

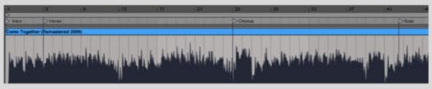
Prototypes

13

What we will be controlling:

Navigating a song with:

- Transport controls
- Section markers



14

Round 1

15

Do these look familiar?

16

Controls on the instrument

17

Controls on the instrument

18

Thoughts?

- Would you use something like this? Yes? / No?
- What would be some pros and cons?
- Could this be useful for something else?

19

Controls on a pedalboard

20

21

Thoughts?

- Would you use something like this? Yes? / No?
- What would be some pros and cons?
- Could this be useful for something else?

22

Let's refine them!

- Which one do you prefer?
- Could you improve it?
- Use the whiteboard guitars / post-its / sheets of paper as you wish
- 5 mins

23

Show and tell

- Show your design
- Comment on other people's design
- Would you add stuff to your design from other people's ideas?
- 10 mins

24

Round 2

25

Voice Commands

26

Voice Commands

Voice commands → Computer Listens → Matches commands → Does stuff

27

Voice Commands

Voice commands for sections:

"Intro"	"Verse"	"Chorus"	"Solo"	"Solo 2"

Voice commands for transport controls:

"Last"	"Left"	"Play/Stop"	"Mark"	"Right"	"Next"
|<	<	▶II	⊥	>	>|

28

Thoughts?

- Would you use something like this? Yes? / No?
- What would be some pros and cons?
- Could this be useful for something else?

29

Make your own

- What if you could make your own voice commands?
- Write down your ideas for commands and what actions would they trigger.
- 5 mins

30

Muzicodes

Musical notes in → Computer Listens → Matches Muzicodes → Does stuff

31

Muzicodes

32

Thoughts?

- Muzicodes = Using musical notes as triggers for media actions, controls, etc.
- Would you use something like this? Yes? / No?
- What would be some pros and cons?
- Could this be useful for something else?

33

Make your own

- What if you could make your own voice Muzicodes?
- Write down your ideas for Muzicodes and what actions would they trigger.
- 5 mins

34

Round 3

35

Gesturing with the guitar (or body)

- Could we do the same thing by moving the guitar or body?
- What if we wore something? (a glove, a ring, a special shoe?)
- Let's use the cardboard guitars and think.
- Would you use something like this? Yes? / No?
- What would be some of the pros and cons?
- Could this be useful for something else?

36

Show and tell

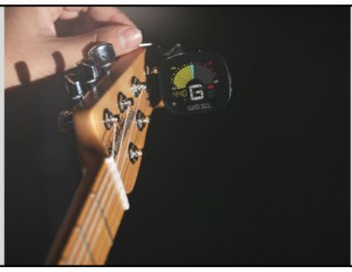
- Show your moves
- Comment on other people's ideas
- Would you add stuff to your design from other people's ideas?
- 10 mins

37

Augmenting Guitars

- Ways we could add these designs to guitars:
  - Temporarily (something you can put on and off)

38



39

Augmented Guitars

- Ways we could add these designs to guitars:
  - Temporarily (something you can put on and off)
  - Permanently (modifying your guitar forever)

40

41

Augmented Guitars

- Ways we could add these designs to guitars:
  - Temporarily (something you can put on and off)
  - Permanently (modifying your guitar forever)
  - Embedded (a new kind of guitar)

42

43

Wrap up discussion

- Do you think any of these designs support what you are already doing?
  - If not, why?
  - What would you prefer?
  - Would you invest time to learn to use such a tool?
- Would you add more functionality?
  - If not, why?
  - What would you prefer?
- Would you prefer a solution that could be temporarily attached or something that is embedded within the instrument?
  - If not, why?
  - What would you prefer?
- If embedded, would you replace your guitar/bass for that?
  - If not, why?
  - What would you prefer?
- Would you combine designs? (Have the abilities of all of them?)

44

Thank you!

45

8.3 Strap Evaluation Interview Schedules

If previously interviewed, skip to the next section:

BRIEF INTERVIEW ON PRACTICES
0. For how long have you played your [primary instrument]? How did you learn to play? *(Months / years?)*
1. In what context does most of your playing practice happen? *(Alone at home / with others)*
2. How often and for how long do you practice for? *(e.g., How many days a week?)*

Next section before the strap evaluation:

ON TRANSCRIPTION & NAVIGATION
1. Do you often learn melodic passages on the guitar? i.e., Solos? Riffs? Licks?
2. What resources would you say support this process? *(Classical notation, tabs, chord charts, audio, tutorial videos, multimedia)*
3. Could you describe your process?
4. Are you more inclined towards learning by ear or using visual aids in videos, or just reading?
(Do you think learning a song is a step-by-step process, like a recipe where ingredients are stacked up one by one or how would you describe it?)
5. What tools do you use for this process? *(Computer, phone – GP5, DAW, YT, UG (or others); Looper, drum machine?)*
6. How would you describe your navigation experience with these tools when having a guitar at hand?
(Do you use loops, slowing down, transposition?) to facilitate the process.
7. Do you often find yourself using multiple resources, or tools whilst also using the guitar?
How would you describe this experience (look for cognitive and physical encumbrances – i.e., interruptions and switching, and device' juggling').

Exit interview:

EVALUATION
1. What are some cons and pros of the strap?
2. Do you think the strap was responsive enough in detecting your actions?
Where there any unwanted triggers?
3. Would you like to have some sort of feedback when triggering an input? Haptics, sounds, lights?
4. What are your thoughts on the number of inputs? *-Are three enough? (Play, Pause, Loop, Cancel Loop, Rewind)*
-If not, what would you consider the primary inputs that you would like to have? (Inner loop)
5. Is there anything you would change about the way the controls were mapped to the different actions? *(Would you change the layout of the mappings?)*
6. Would you add more inputs or functions to the current strap? *(Let them think)*
7. Could you describe your experience with the textile-based controller? (The strap) *Would you think other materials might be also interesting?*
8. What do you think about having buttons on a strap to control media? *(Show the footfalls prototype)*
To what extent will it be comparable to a regular computer keyboard in a practice situation?
9. Were the bodily movements used for control comfortable for you?
Or were they physically challenging? (Pulling, pushing, pressing) *(Could you think of other bodily alternatives that could better support this?)*
10. Do you think using bodily movements allowed you to focus more on playing the instrument? Or were they distracting?

11. Were there times during the practice where you would have preferred to use the conventional computer inputs instead of the strap?
(*Would you rather have a separate device to do the same thing, e.g., a pedal or special keyboard*?) *(Would you have preferred other technologies?)*
12. Does the strap support what you are already doing, or does it make it more difficult?
13. Do you think this technology could be used across different guitars?
14. Would you like to see this technology transfer to other platforms beyond Soundslice?
15. Do you think using Soundslice (something perhaps different from what your used to) may have affected you practice?
16. Anything else that I may have missed that you would like to add?

8.4 Coded Transcript Excerpts

The following transcript excerpts were collated with NVivo and curated for demonstration in this appendix. These were coded under the "Avoid overloading interaction modalities" code when analysing the data from the Stretchy Strap Evaluation study. The transcripts were generated with speech recognition tools provided by the University of Nottingham's transcription services; thus, some grammatical errors can be observed. Key verbalisations from anonymised participants are highlighted here for demonstrative purposes. Note that pseudonyms are the same as in the study report.

Files\\Charles - § 1 reference coded [1.98% Coverage] Reference 1 - 1.98% Coverage

00:22:50.90 When you would like to add more inputs like
00:22:54.64 more physical ones and more most also more actions yeah
00:22:58.91 no I think that it would be best to
00:23:01.73 keep it under five I think just to make it
00:23:05.01 more user friendly rather than having lots of inputs I
00:23:09.21 think that yeah in terms of the functions like you
00:23:13.02 said I think it's a matter of personal preferences so
00:23:17.27 maybe obviously stop and play that has to be there
00:23:21.27 Maybe the others could be user programmable or you could
00:23:25.67 choose

Files\\Krist - § 2 references coded [2.08% Coverage] Reference 1 - 1.51% Coverage

00:31:11.23 Would you like to have more
00:31:14.61 Oh For me it felt like enough I think
00:31:22.99 Because like I say what was nice about it was
00:31:26.40 this kind of simplicity of it was the tactile nature
00:31:30.34 of it so
00:31:30.94 I don't know if you added another two things another
00:31:35.05 like with that kind of
00:31:36.76 Spoil the simplicity of it and
00:31:42.37 I don't know you maybe maybe like
00:31:47.35 If you had Another one that was the total rewind
00:31:50.79 or something like that that's the only kind of thing
00:31:54.51 I could think of
00:31:55.64 But In terms yeah for me it was kind of
00:32:00.56 felt like it got enough going on
00:32:04.50 Especially for and you know for me like so I'm
00:32:07.93 not particularly technical so just to have those yeah, I
00:32:12.11 know that what this is doing I know what this
00:32:15.47 is going to do since it works really well

Reference 2 - 0.58% Coverage

00:38:06.56 Like I say maybe maybe the scope for having like
00:38:11.45 Your three basic the three things you got on
00:38:15.06 the moment and then maybe a couple of other things
00:38:18.89 But yeah but not going much further than that otherwise
00:38:23.03 you starting to get Too complicated yeah too many things
00:38:28.97 in one place

Files\\Gene - § 1 reference coded [0.84% Coverage] Reference 1 - 0.84% Coverage

00:36:53.88 Then you've got obviously got your feet before you are
00:36:58.14 now you got pedals the potential for pedals with you
00:37:02.25 know you could assign
00:37:03.88 Plug E strap into your pedal into you looking into
00:37:07.72 your computer There's this potential there isn't there to have
00:37:12.47 some more controls on there but it depends how many
00:37:16.32 controls you want there really isn't it yeah for me
00:37:20.64 I just I just want it
00:37:22.39 Learn the song and keep it simple as possible

Files\\Mike - § 2 references coded [9.18% Coverage] Reference 1 - 2.79% Coverage

00:16:10.47 This one rewinds yeah, I think three are enough or
00:16:15.59 maybe you wanted more things I think possibly a move
00:16:21.03 move forward
00:16:22.26 But again personally I think more than four would be
00:16:27.01 too much to think about yeah yeah whilst you're also
00:16:31.76 like well she's also concentrating on playing and learning
00:16:36.97 And also the sort of functions that are mapped to
00:16:41.07 the different inputs do you think those are the ones
00:16:45.41 you use more regularly or maybe you would would like
00:16:49.68 to have the things I think that the most useful

00:16:54.29 most
00:16:54.68 Commonly used Actions yeah yeah

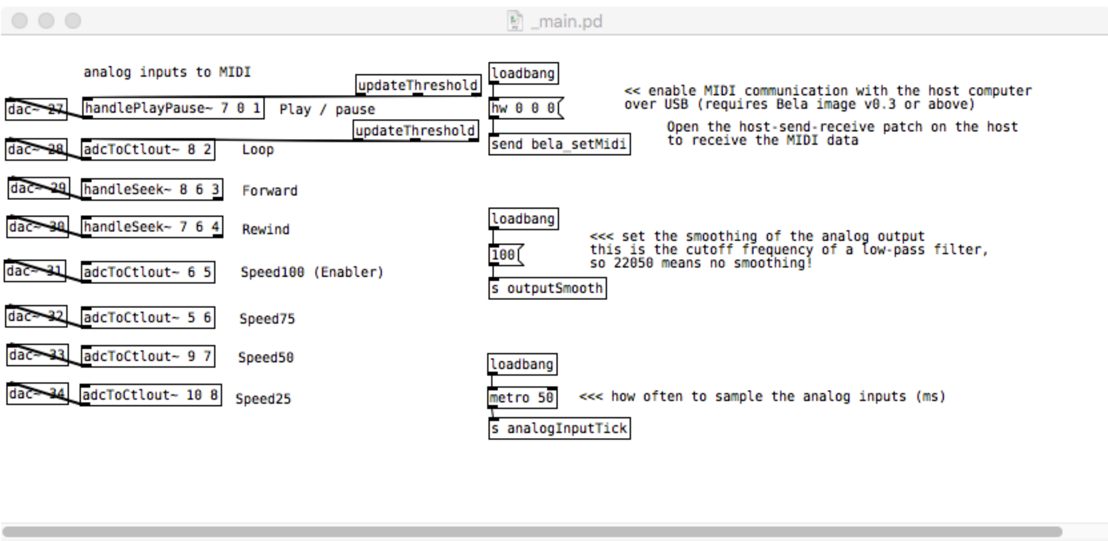
Files\\Tom - § 1 reference coded [2.16% Coverage] Reference 1 - 2.16% Coverage

00:22:26.58 like have Maybe Adding more stuff to this would be
00:22:30.54 way too much stuff to think about yeah possibly you
00:22:34.57 don't want to overcomplicate it to be honest because you're
00:22:39.15 relying on physical movement as well right that's that's something
00:22:43.73 that you've got to balance with this is very high
00:22:47.15 tech stuff yeah and bodily movement is very basic stuff
00:22:50.92 so you've got it like balance the two and find
00:22:54.14 a little middle ground somewhere and think well OK that
00:22:57.98 that works but if I make it too complicated It's
00:23:01.27 not going to work 'cause people are going to get
00:23:03.93 fazed with it and they're going to just
00:23:06.06 Phase out on Yeah, I mean the applications are probably
00:23:10.71 unlimited but you know it's uncertain for for comp you
00:23:15.37 know I'm saying more competent musicians than me it's going
00:23:20.36 to be an amazing music

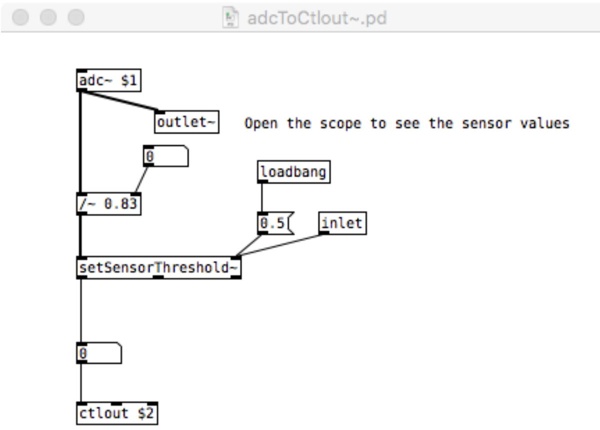
8.5 Stretchy Strap Scripts

8.5.1 Pure Data Patches

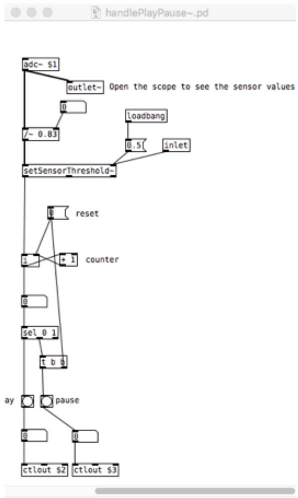
_main.pd



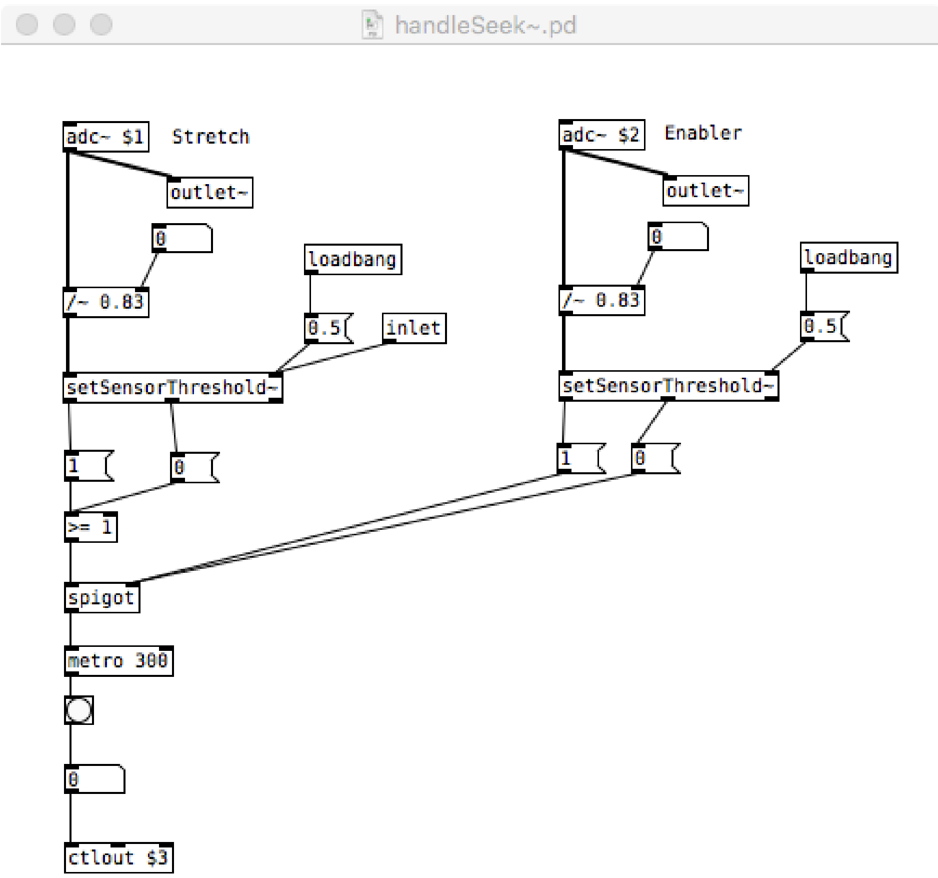
adcToCtlout~.pd



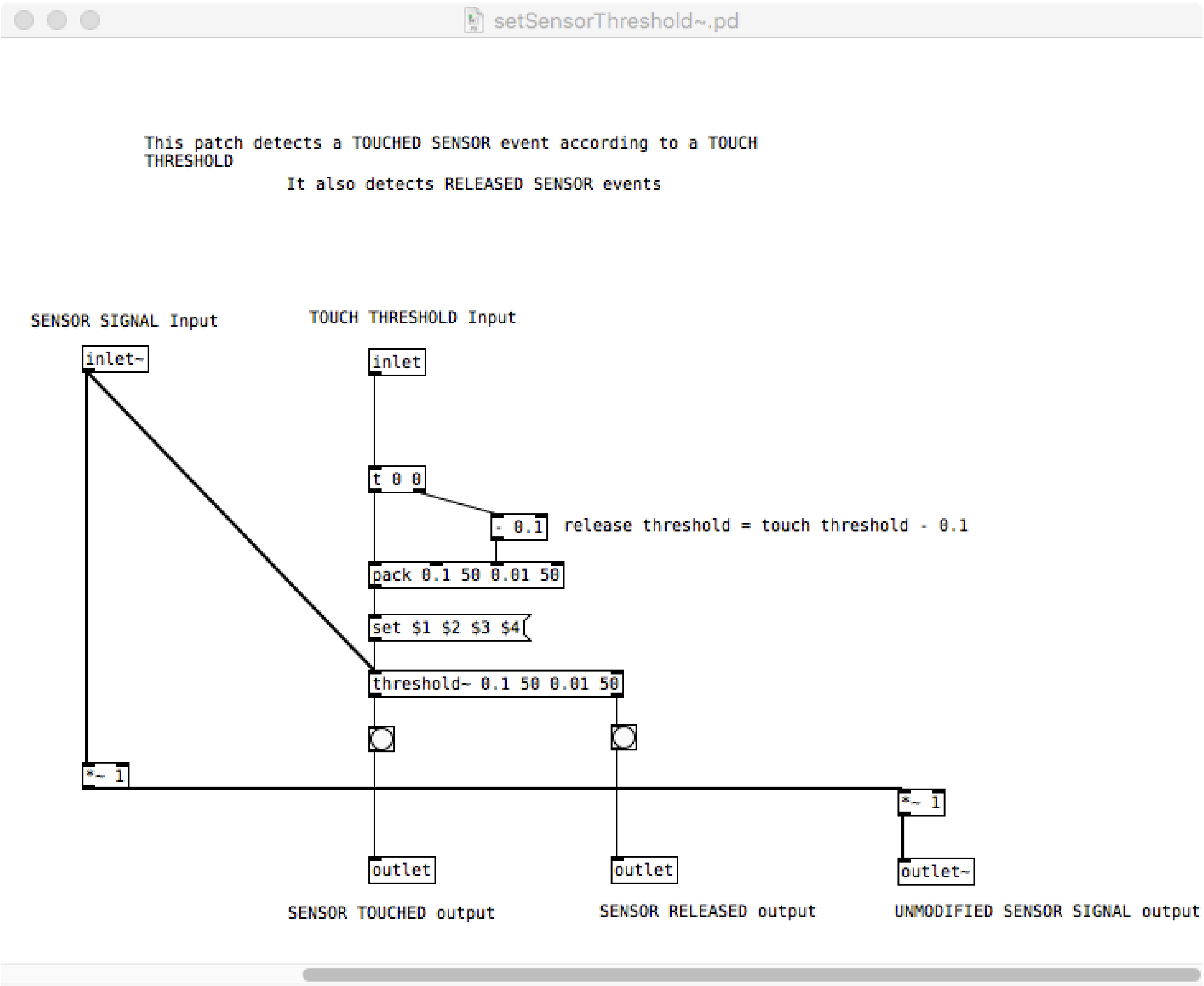
handlePlayPause~.pd



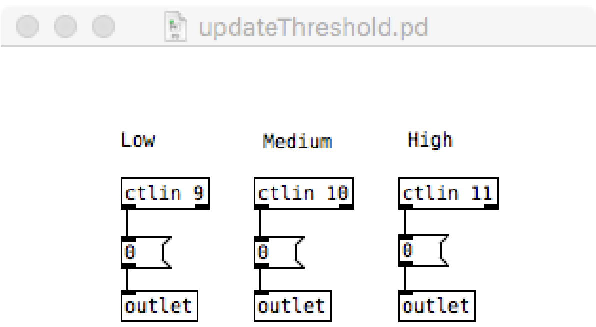
handleSeek~.pd



setSensorThreshold~.pd



updateThreshold.pd



8.5.2 SoundSlice-powered Website

index.html

```
<!-- Juan Martinez Avila and Chris Greenhalgh, The University of Nottingham 2020. -->
<!DOCTYPE html>
<html lang="en">
  <head>
    <meta charset="utf-8" />
    <meta name="viewport" content="width=device-width, initial-scale=1" />
    <title>Strap</title>
  </head>

  <noscript>You need to enable JavaScript to run this app.</noscript>
  <script src="loglevel.min.js"></script>
  <script src="loglevel-plugin-remote.min.js"></script>
  <link rel="stylesheet" href="styles.css">
  <link rel="stylesheet" href="https://www.w3schools.com/w3css/4/w3.css">

  <header class="w3-container w3-blue">
      <div class = "w3-row">
        <div class = "w3-col m3">
          <div>
            <select id="midiin">
              <option value="">(no MIDI IN)</option>
            </select>
            <input type="button" value="Start" onclick="handleMIDIIN()">
          </div>
          <div>
            <select id="midiout">
              <option value="">(no MIDI OUT)</option>
            </select>
            <input type="button" value="Start" onclick="handleMIDIOUT()">
         </div>
        </div>
      <div class = "w3-col m6 w3-center">
        <div>
          <input type="text" id="participant" placeholder="Your name">
          <button onclick="participantID()">Submit</button>
        </div>
        <div>
          <input type="text" id="roundType" placeholder="Practice or Evaluation?">
          <button onclick="roundType()">Submit</button>




        </div>
      </div>

      <div class = "w3-col m3">
        <div>
          <b>Front threshold </b>
          <button onclick="handleMedium()"> Reset </button>
          <button onclick="handleLow()"> - </button>
          <button onclick="handleHigh()"> + </button>
          <input type="text" id="fThreshold" value="0.23" readonly/>
        </div>

        <div>
          <b>Back threshold </b>
          <button onclick="handleMediumB()"> Reset </button>
          <button onclick="handleLowB()"> - </button>
          <button onclick="handleHighB()"> + </button>
          <input type="text" id="bThreshold" value="0.26" readonly/>
        </div>
      </div>
    </div>
  </header>

  <body>
    <div class="iframe-container">
      <iframe id="ssembed" src="https://www.soundslice.com/slices/lmDfc/embed/?
scroll_type=1&force_side_video=1&side_video_width=100&api=1"
      width="100%" height="100%" frameBorder="0" allow=autoplay; allowfullscreen></iframe>
    </div>

    <script src="strap.js"></script>
  </body>

  <footer class="w3-container w3-blue">
      <p>Juan Martinez Avila and Chris Greenhalgh, The University of Nottingham 2020.</p>
  </footer>
</html>
```

strap.js

```
var ssiframe = document.getElementById('ssembed').contentWindow;
var midiin = document.getElementById("midiin");
var midiout = document.getElementById("midiout");
var midiinputs = {};
var midioutputs = {};

function uuidv4() {
  return ([1e7]+-1e3+-4e3+-8e3+-1e11).replace(/[018]/g, c =>
    (c ^ crypto.getRandomValues(new Uint8Array(1))[0] & 15 >> c / 4).toString(16)
  );
}
// unique logging ID for this session/window
var uuid = uuidv4();
console.log('my uuid: '+uuid);

function format(log) {
  log.level = log.level.label;
  log.windowid = uuid;
  return log;
}
// enable remote logging
remote.apply(log, {
  format: format,
  url: "/3/loglevel/strap",
  // TODO fix me ?? what does this do?? how does it relate with the uuid
  token: "1EpP1BXoLQmscEvA41M01M7pwxBF-jbX"
});

// log info and above
log.setLevel("info");

function load() {
  // console.log("load event detected!");
  navigator.requestMIDIAccess()
  .then(function(access) {
     // Get lists of available MIDI controllers
     const inputs = access.inputs.values();
     for (let input of inputs) {
       log.info('MIDI input:', input);
       var option = document.createElement("option");
       option.text = input.name;
       option.setAttribute('value', input.id);
       midiin.add(option);
       midiinputs[input.id] = input;
     }

    const outputs = access.outputs.values();
      for (let output of outputs) {
       log.info('MIDI output:', output);
       var option = document.createElement("option");
       option.text = output.name;
       option.setAttribute('value', output.id);
       midiout.add(option);
       midioutputs[output.id] = output;
     }
  });
}

window.onload = load;
//Handle inbound messages
var callbacks = [];
window.addEventListener('message', function(event){
  var message = JSON.parse(event.data);
  for (var i=0; i<callbacks.length; i++) {
    var callback = callbacks[i];
    if (callback.method == message.method) {
      callback.callback(message.arg);
      callbacks.splice(i, 1);
      i--;
```

```
    }
  }

document.onkeydown = keyDown;
  function keyDown(e) {
    var event = window.event ? window.event : e;
      if (event.keyCode == '32' && message.method =='ssPlay') {
        log.info('Space bar has been pressed to play');
      }

      if (event.keyCode == '32' && message.method =='ssPause') {
        log.info('Space bar has been pressed to pause');
      }

      if (event.keyCode == '37' && message.method =='ssSeek') {
        log.info('Left arrow has been pressed to rewind to ' + message.arg + ' seconds.');
      }
      if (event.keyCode == '39' && message.method =='ssSeek') {
        log.info('Right arrow has been pressed to fast forward to ' + message.arg + '
seconds.');
      }
  }

      if (message.method == 'ssLoopChange') {
        log.info('Loop has changed to ' + message.arg);
      }

      if (message.method == 'ssSpeed') {
        log.info('Speed is ' + (message.arg * 100) + ' percent.');
      }
  });

function withCurrentTime(callback) {
    callbacks.push({method:"ssCurrentTime", callback: callback});
    ssiframe.postMessage('{"method": "getCurrentTime"}', 'https://www.soundslice.com');
  }

function handleMIDIIN() {
  var midiid = midiin.options[midiin.selectedIndex].value;
  if ( ! midiid ) {
    alert('Please select MIDI input');
    return;
    }
  // console.log('use MIDI input '+midiid);
  midiinputs[midiid].onmidimessage = handleMidiMessage;
  }

function handleMIDIOUT() {
  var midiid = midiout.options[midiout.selectedIndex].value;
  if ( ! midiid ) {
    alert('Please select MIDI output');
    return;
  }
  // console.log('use MIDI input '+midiid);
  midioutputs[midiid].onmidimessage = handleMidiMessage;
}

//Front threshold
function handleLow() {
  var midiid = midiout.options[midiout.selectedIndex].value;
  if ( ! midiid ) {
    alert('Please select MIDI output');
    return;
  }
  lowMIDI( midiid );
  log.info('Front threshold decremented');
  var value = parseFloat(document.getElementById('fThreshold').value, 10);
  value = isNaN(value) ? 0 : value;
  value -= 0.01;
```

```
  document.getElementById('fThreshold').value = value.toPrecision(2);
}
function lowMIDI( portID ) {
  var noteOnMessage = [0xB0, 09, 0x00];
  var output = midioutputs[portID];
  output.send( noteOnMessage );
}

function handleMedium() {
  var midiid = midiout.options[midiout.selectedIndex].value;
  if ( ! midiid ) {
    alert('Please select MIDI output');
    return;
  }
  mediumMIDI( midiid );
  log.info('Front threshold reset');
  document.getElementById("fThreshold").value = "0.23";
}

function mediumMIDI( portID ) {
  var noteOnMessage = [0xB0, 10, 0x00];
  var output = midioutputs[portID];
  output.send( noteOnMessage );
}

function handleHigh() {
  var midiid = midiout.options[midiout.selectedIndex].value;
  if ( ! midiid ) {
    alert('Please select MIDI output');
    return;
  }
  highMIDI( midiid );
  log.info('Front threshold incremented');
  var value = parseFloat(document.getElementById('fThreshold').value, 10);
  value = isNaN(value) ? 0 : value;
  value += 0.01;
  document.getElementById('fThreshold').value = value.toPrecision(2);
}

function highMIDI( portID ) {
  var noteOnMessage = [0xB0, 11, 0x00];
  var output = midioutputs[portID];
  output.send( noteOnMessage );
}


//Back threshold
function handleLowB() {
  var midiid = midiout.options[midiout.selectedIndex].value;
  if ( ! midiid ) {
    alert('Please select MIDI output');
    return;
  }
  lowMIDIB( midiid );
    log.info('Back threshold decremented');
    var value = parseFloat(document.getElementById('bThreshold').value, 10);
    value = isNaN(value) ? 0 : value;
    value -= 0.01;
    document.getElementById('bThreshold').value = value.toPrecision(2);
}
function lowMIDIB( portID ) {
  var noteOnMessage = [0xB0, 12, 0x00];
  var output = midioutputs[portID];
  output.send( noteOnMessage );
}

function handleMediumB() {
  var midiid = midiout.options[midiout.selectedIndex].value;
  if ( ! midiid ) {
```

```
    alert('Please select MIDI output');
    return;
  }
  mediumMIDIB( midiid );
  log.info('Back threshold reset');
  document.getElementById("bThreshold").value = "0.26";
}

function mediumMIDIB( portID ) {
  var noteOnMessage = [0xB0, 13, 0x00];
  var output = midioutputs[portID];
  output.send( noteOnMessage );
}

function handleHighB() {
  var midiid = midiout.options[midiout.selectedIndex].value;
  if ( ! midiid ) {
    alert('Please select MIDI output');
    return;
  }
  highMIDIB( midiid );
  log.info('Back threshold incremented');
  var value = parseFloat(document.getElementById('bThreshold').value, 10);
  value = isNaN(value) ? 0 : value;
  value += 0.01;
  document.getElementById('bThreshold').value = value.toPrecision(2);
}

function highMIDIB( portID ) {
  var noteOnMessage = [0xB0, 14, 0x00];
  var output = midioutputs[portID];
  output.send( noteOnMessage );
}

function participantID() {
  var participantID = document.getElementById("participant").value;
  if ( ! participantID ) {
    alert('Please enter your name');
    return;
  }
  log.info('Participant: '+participantID);
}

function roundType() {
  var roundType = document.getElementById("roundType").value;
  if ( ! roundType ) {
    alert('Practice or Evaluation?');
    return;
  }
  log.info('Participant has begun '+roundType);
}


//Parse basic information out of a MIDI message.
function parseMidiMessage(message) {
  return {
    command: message.data[0] >> 4,
    channel: message.data[0] & 0xf,
    note: message.data[1],
    velocity: message.data[2] / 127
  }
}

function handleMidiMessage(message) {
  // Parse the MIDIMessageEvent.
  const {command, channel, note, velocity} = parseMidiMessage(message)
  // console.log('midi message', message);
  if (command === 11) {
```

```
    if (note === 0){
      handlePlay();
    }

    if (note === 1) {
      handlePause();
    }

    if (note === 2) {
      handleLoop();
    }

    if (note === 3) {
      // handleForward();
      // handleRewind();
    }

    if (note === 4) {
      // handleRewind();
      handleForward();
    }

    if (note === 5) {
      // handleSpeed100();
      // handleRestart();
      handleRewind();

    }

    if (note === 6) {
      clearLoop();
    }

    if (note === 7) {
      // handleSpeed50();
    }

    if (note === 8) {
      // handleSpeed25();
    }
  }
}

function handlePlay() {
  log.info('Play event triggered by strap');
  ssiframe.postMessage('{"method": "play"}', 'https://www.soundslice.com');
}

function handlePause() {
  log.info('Pause event triggered by strap');
  ssiframe.postMessage('{"method": "pause"}', 'https://www.soundslice.com');
}

function handleLoop() {
    withCurrentTime(function(currentTime) {
        log.info('Loop event triggered by strap');
        ssiframe.postMessage(JSON.stringify({"method": "setLoop", "arg": [currentTime,
247.481]}), 'https://www.soundslice.com');
      })
}

function clearLoop(){
  ssiframe.postMessage('{"method": "clearLoop"}', 'https://www.soundslice.com');
  log.info('Loop cancel by strap');
}

function handleForward() {
    withCurrentTime(function(currentTime) {
      log.info('Seek to fast forward event triggered by strap');
```

```
      ssiframe.postMessage(JSON.stringify({"method": "seek", "arg":
currentTime + 1}), 'https://www.soundslice.com');
    })
}

function handleRewind() {
    withCurrentTime(function(currentTime) {
      log.info('Seek to rewind event triggered by strap');
      ssiframe.postMessage(JSON.stringify({"method": "seek", "arg":
currentTime - 1}), 'https://www.soundslice.com');
    })
}

function handleRestart() {
  ssiframe.postMessage(JSON.stringify({"method": "seek", "arg":
0.0}), 'https://www.soundslice.com');
}

function handleSpeed100() {
  log.info('Speed set to 100 by strap');
  ssiframe.postMessage('{"method": "setSpeed", "arg": 1}', 'https://www.soundslice.com');
}

function handleSpeed75() {
  log.info('Speed set to 75 by strap');
  ssiframe.postMessage('{"method": "setSpeed", "arg": 0.75}',
'https://www.soundslice.com');
}

function handleSpeed50() {
  log.info('Speed set to 50 by strap');
  ssiframe.postMessage('{"method": "setSpeed", "arg": 0.5}',
'https://www.soundslice.com');
}

function handleSpeed25() {
  log.info('Speed set to 25 by strap');
  ssiframe.postMessage('{"method": "setSpeed", "arg": 0.25}',
'https://www.soundslice.com');
}
```

styles.css

```css
/* styles.css */

.iframe-container {
  overflow: hidden;
  padding-top: 56.25%; /* 16:9*/
  position: relative;
}

.iframe-container iframe {
   border: 0;
   height: 100%;
   left: 0;
   position: absolute;
   top: 0;
   width: 100%;
}
```

loglevel.min.js

```javascript
/*! loglevel - v1.6.8 - https://github.com/pimterry/loglevel - (c) 2020 Tim Perry -
licensed MIT */
!function(a,b){"use strict";"function"==typeof define&&define.amd?
define(b):"object"==typeof module&&module.exports?module.exports=b():a.log=b()}
(this,function(){"use strict";function a(a,b){var c=a[b];if("function"==typeof
c.bind)return c.bind(a);try{return Function.prototype.bind.call(c,a)}catch(b){return
function(){return Function.prototype.apply.apply(c,[a,arguments])}}}function b()
{console.log&&(console.log.apply?
console.log.apply(console,arguments):Function.prototype.apply.apply(console.log,
[console,arguments])),console.trace&&console.trace()}function c(c){return"debug"===c&&
(c="log"),typeof console!==i&&("trace"===c&&j?b:void 0!==console[c]?a(console,c):void
0!==console.log?a(console,"log"):h)}function d(a,b){for(var c=0;c<k.length;c++){var
d=k[c];this[d]=c<a?h:this.methodFactory(d,a,b)}this.log=this.debug}function e(a,b,c)
{return function(){typeof console!==i&&
(d.call(this,b,c),this[a].apply(this,arguments))}}function f(a,b,d){return
c(a)||e.apply(this,arguments)}function g(a,b,c){function e(a){var b=
(k[a]||"silent").toUpperCase();if(typeof window!==i){try{return
void(window.localStorage[l]=b)}catch(a)
{}try{window.document.cookie=encodeURIComponent(l)+"="+b+";"}catch(a){}}}function g(){var
a;if(typeof window!==i){try{a=window.localStorage[l]}catch(a){}if(typeof a===i)try{var
b=window.document.cookie,c=b.indexOf(encodeURIComponent(l)+"=");-1!==c&&
(a=/^([^;]+)/.exec(b.slice(c))[1])}catch(a){}return void 0===j.levels[a]&&(a=void
0),a}}var h,j=this,l="loglevel";a&&(l+=":"+a),j.name=a,j.levels=
{TRACE:0,DEBUG:1,INFO:2,WARN:3,ERROR:4,SILENT:5},j.methodFactory=c||f,j.getLevel=function(
){return h},j.setLevel=function(b,c){if("string"==typeof b&&void
0!==j.levels[b.toUpperCase()]&&(b=j.levels[b.toUpperCase()]),!("number"==typeof
b&&b>=0&&b<=j.levels.SILENT))throw"log.setLevel() called with invalid level:
"+b;if(h=b,!1!==c&&e(b),d.call(j,b,a),typeof console===i&&b<j.levels.SILENT)return"No
console available for logging"},j.setDefaultLevel=function(a)
{g()||j.setLevel(a,!1)},j.enableAll=function(a)
{j.setLevel(j.levels.TRACE,a)},j.disableAll=function(a){j.setLevel(j.levels.SILENT,a)};var
m=g();null==m&&(m=null==b?"WARN":b),j.setLevel(m,!1)}var h=function()
{},i="undefined",j=typeof window!==i&&typeof window.navigator!==i&&/Trident\/|MSIE
/.test(window.navigator.userAgent),k=["trace","debug","info","warn","error"],l=new g,m=
{};l.getLogger=function(a){if("string"!=typeof a||""===a)throw new TypeError("You must
supply a name when creating a logger.");var b=m[a];return b||(b=m[a]=new
g(a,l.getLevel(),l.methodFactory)),b};var n=typeof window!==i?window.log:void 0;return
l.noConflict=function(){return typeof window!==i&&window.log===l&&
(window.log=n),l},l.getLoggers=function(){return m},l});
```

loglevel-plugin-remote.min.js

```
!function(e,t){if("function"==typeof
define&&define.amd)define(["module","exports"],t);else if("undefined"!=typeof
exports)t(module,exports);else{var r={exports:{}};t(r,r.exports),e.remote=r.exports}}
(this,function(e,t){"use strict";Object.defineProperty(t,"__esModule",{value:!0});var
i="function"==typeof Symbol&&"symbol"==typeof Symbol.iterator?function(e){return typeof
e}:function(e){return e&&"function"==typeof
Symbol&&e.constructor===Symbol&&e!==Symbol.prototype?"symbol":typeof
e},f=window;if(!f)throw new Error("Plugin for browser usage only");var r=void 0;function
s(e){try{return JSON.stringify(e)}catch(e){if(!r)try{var t=
{};t.a=t,JSON.stringify(t)}catch(e){r=e.message}if(e.message===r)return"[Circular]";throw
e}}function w(c){var e="",l=0;return 1<c.length&&"string"==typeof c[0]&&(e=
(e=c[0].replace(/(%?)(%([sdjo]))/g,function(e,t,r,n){if(t)return e;var
o=c[l+=1],i="";switch(n)
{case"s":i+=o;break;case"d":i+=+o;break;case"j":i=s(o);break;case"o":var a=s(o);"
{"!==a[0]&&"["!==a[0]&&(a="<"+a+">"),i=function(e)
{if(!Object.getOwnPropertyDescriptor||!Object.getPrototypeOf)return
Object.prototype.toString.call(e).slice(8,-1);for(;e;){var
t=Object.getOwnPropertyDescriptor(e,"constructor");if(void 0!==t&&"function"==typeof
t.value&&""!==t.value.name)return t.value.name;e=Object.getPrototypeOf(e)}return""}
(o)+a}return i})).replace(/%{2,2}/g,"%"),l+=1),c.length>l&&(e&&(e+="
"),e+=c.slice(l).join(" ")),e}var p=Object.prototype.hasOwnProperty;function k(){try{throw
new Error}catch(e){return e.stack}}function n(t){var r=this,n=[],o=
[];this.length=function(){return n.length},this.sent=function(){return
o.length},this.push=function(e){n.push(e),n.length>t&&n.shift()},this.send=function()
{return o.length||(o=n,n=[]),o},this.confirm=function(){o=
[],r.content=""},this.fail=function(){var e=1+n.length+o.length-t;0<e&&
(o.splice(0,e),n=o.concat(n),r.confirm())}}var o=!!k(),j=void 0,a=void 0,v=void 0;function
c(e){return"["+e.timestamp+"] "+e.level.label.toUpperCase()+(e.logger?"
("+e.logger+")":"")+": "+e.message+(e.stacktrace?"\n"+e.stacktrace:"")}function l(){throw
new Error("You can't set token for a not appled plugin")}var u=f.remote,g=
{url:"/logger",method:"POST",headers:{},token:"",onUnauthorized:function()
{},timeout:0,interval:1e3,level:"trace",backoff:
{multiplier:2,jitter:.1,limit:3e4},capacity:0,stacktrace:{levels:
["trace","warn","error"],depth:3,excess:0},timestamp:function(){return(new
Date).toISOString()},format:c},remote={noConflict:function(){return f.remote===remote&&
(f.remote=u),remote},plain:c,json:function(e){return
e.level=e.level.label,e},apply:function(e,t){if(!e||!e.getLogger)throw new
TypeError("Argument is not a root loglevel object");if(j)throw new Error("You can assign a
plugin only one time");if(!f.XMLHttpRequest)return e;j=e;var d=function e(){for(var t=
{},r=0;r<arguments.length;r+=1){var n=Object(arguments[r]);for(var o in n)p.call(n,o)&&
(t[o]="object"!==i(n[o])||Array.isArray(n[o])?n[o]:e(t[o],n[o]))}return t}
(g,t);d.capacity=d.capacity||500;var r=d.backoff,c="object"===(void
0===r?"undefined":i(r))?function(e){var t=e*r.multiplier;return t>r.limit&&
(t=r.limit),t+=t*r.jitter*Math.random()}:r,l=d.interval,h=void 0,m=void 0,s=!1,u=!1,y=new
n(d.capacity);function b(){if(!u&&!s&&void 0!==d.token){if(!y.sent())
{if(!y.length())return;var e=y.send();y.content=m?'{"logs":
['+e.join(",")+"]}":e.join("\n")}s=!0;var t=new
f.XMLHttpRequest;t.open(d.method,d.url,!0),t.setRequestHeader("Content-
Type",h),d.token&&t.setRequestHeader("Authorization","Bearer "+d.token);var
r=d.headers;for(var n in r)if(p.call(r,n)){var o=r[n];o&&t.setRequestHeader(n,o)}var
i=void 0;d.timeout&&(i=f.setTimeout(function()
{s=!1,t.abort(),a()},d.timeout)),t.onreadystatechange=function()
{if(4===t.readyState)if(s=!1,f.clearTimeout(i),200===t.status)l=d.interval,y.confirm(),a(!
0);else{if(401===t.status){var e=d.token;d.token=void
0,d.onUnauthorized(e)}a()}},t.send(y.content)}function a(e){e||
(l=c(l||1),y.fail()),u=!0,f.setTimeout(function(){u=!1,b()},l)}}return
a=e.methodFactory,v=function(s,e,u){var
f=a(s,e,u),p=o&&d.stacktrace.levels.some(function(e){return
e===s}),v=j.levels[s.toUpperCase()],g=v>=j.levels[d.level.toUpperCase()];return function()
{for(var e=arguments.length,t=Array(e),r=0;r<e;r++)t[r]=arguments[r];if(g){var
n=d.timestamp(),o=p?k():"";if(o){var i=o.split("\n");i.splice(0,d.stacktrace.excess+3);var
a=d.stacktrace.depth;if(a&&i.length!==a+1)o=i.splice(0,a).join("\n"),i.length&&(o+="\n
and "+i.length+" more");else o=i.join("\n")}var c=d.format({message:w(t),level:
{label:s,value:v},logger:u||"",timestamp:n,stacktrace:o});void 0===m&&(h=
(m="string"!=typeof c)?"application/json":"text/plain");var
l="";if(m)try{l+=JSON.stringify(c)}catch(e){return f.apply(void 0,t),void
j.getLogger("logger").error(e)}else l+=c;y.push(l),b()}f.apply(void
0,t)}},e.methodFactory=v,e.setLevel(e.getLevel()),remote.setToken=function(e)
{d.token=e,b()},e},disable:function(){if(!j)throw new Error("You can't disable a not
appled plugin");if(v!==j.methodFactory)throw new Error("You can't disable a plugin after
appling another plugin");j.methodFactory=a,j.setLevel(j.getLevel()),j=void
0,remote.setToken=l},setToken:l};t.default=remote,e.exports=t.default});
```

8.6 Guitars, Guitar Accessories, Guitar Interventions and Musical Instrument Glossary

Figure 93. A Bahian guitar (Guitarra Baiana) held by Armando da Costa Macêdo (Armandinho).

Figure 94. The Chordinero Capo. A capo that can clamp individual strings across different frets using rods of different lengths.

Figure 95. The Fishman Triple Play MIDI pickup

Figure 96. The Gizmotron. An attachment for electric guitars that electronically triggers spinning wheels on each guitar string to make bowing-like sounds when its keys are pressed.

Figure 97. The Guitar-Jo. A device that muffles the strings of the guitar to make it sound like a banjo.

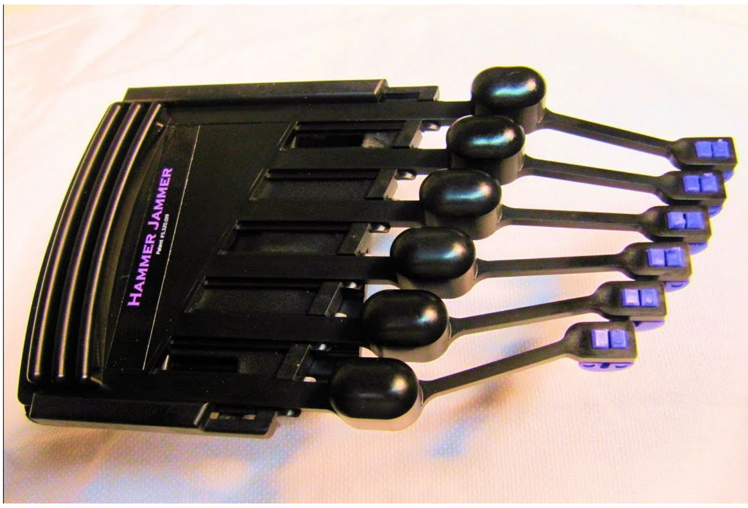


Figure 98. The Hammer Jammer. A device that hammers the individual strings of the guitar when individual keys are pressed (as with a piano).

Figure 99. The Harpad. An attachment that adds six additional strings to acoustic guitar to make it sound like a 12-string guitar

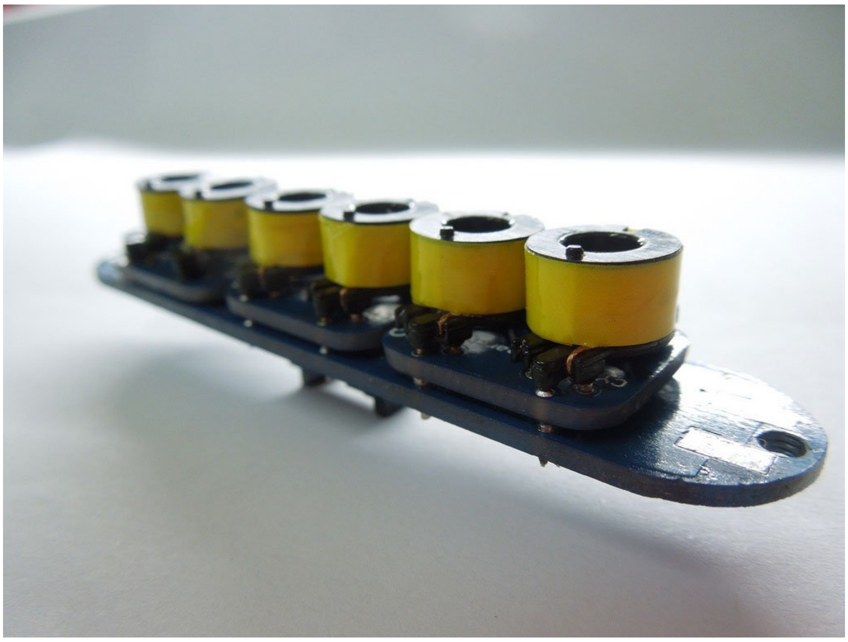


Figure 100. A hexaphonic pickup made by Cycfi.

Figure 101. The Jammy portable guitar. First iteration above and current model below.

Figure 102. The JamStik Guitar Trainer above and the JamStik Studio MIDI guitar below.

Figure 103. The Jellifish guitar pick (now discontinued).

Figure 104. The Kill Switch.

Figure 105. Kaki King's Passerelle Bridge

Figure 106. The Pickaso Guitar Bow.

Figure 107. Luthier Linda Manzer and her Pikasso guitar.

Figure 108. Vidushi Dr. Kamala Shankar and her Shankar Guitar.

Figure 109. Christian Scott's Sirenette by Adams.

Figure 110. The Spider Capo.

Figure 111. Mike Portnoy's TAMA Melody Master signature snare featuring his "throw-off" mechanism idea.

Figure 112. The String Bender mechanism (originally conceived by Gene Parsons).

Figure 113. The Submarine pick-up.

Figure 114. The Guitar Triller.

Figure 115. The Virtual Jeff Pro and accompanying pedal by FOMOfx.

Bibliography

Achard, K. (1996). *The History and Development of the American Guitar*. Bold Strummer.

Ahmed, A., Benford, S., & Crabtree, A. (2012). Digging in the crates: An ethnographic study of DJS'work. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1805–1814. https://doi.org/10.1145/2207676.2208314

Andersen, K., & Gibson, D. (2017). The Instrument as the Source of New in New Music. *Design Issues*, *33*(3), 37–55. https://doi.org/10.1162/DESI_a_00450

Andersen, K., & Wakkary, R. (2019). The magic machine workshops: Making personal design knowledge. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–13. https://doi.org/10.1145/3290605.3300342

Appadurai, A. (1990). Disjuncture and difference in the global cultural economy. *Theory, Culture & Society*, *7*(2–3), 295–310.

Atkinson, P. (2020). *Amplified: A Design History of the Electric Guitar*. Reaktion Books.

Avila, J. M., Tsaknaki, V., Karpashevich, P., Windlin, C., Valenti, N., Höök, K., McPherson, A., & Benford, S. (2020). Soma Design for NIME. *Proceedings of the 2020 International Conference on New Interfaces for Musical Expression (NIME'20)*.

Avila, J. P. M., Greenhalgh, C., Hazzard, A., Benford, S., & Chamberlain, A. (2019). Encumbered Interaction: A Study of Musicians Preparing to Perform. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–13. https://doi.org/10.1145/3290605.3300706

Avila, J. P. M., Hazzard, A., Greenhalgh, C., & Benford, S. (2019). Augmenting Guitars for Performance Preparation. *Proceedings of the 14th International Audio Mostly Conference: A Journey in Sound*, 69–75. https://doi.org/10.1145/3356590.3356602

Avila, J. P. M., Hazzard, A., Greenhalgh, C., Benford, S., & McPherson, A. (2022). The Stretchy Strap: Supporting Encumbered Interaction with Guitars. *Journal of New Music Research*.

Bell, G., Blythe, M., & Sengers, P. (2005). Making by making strange: Defamiliarization and the design of domestic technologies. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *12*(2), 149–173.

Benford, S., Hazzard, A., Chamberlain, A., Glover, K., Greenhalgh, C., Xu, L., Hoare, M., & Darzentas, D. (2016). Accountable artefacts: The case of the Carolan guitar. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 1163–1175. https://doi.org/10.1145/2858036.2858306

Benford, S., Hazzard, A., Chamberlain, A., & Xu, L. (2015). Augmenting a Guitar with Its Digital Footprint. *Proceedings of the International Conference on New Interfaces for Musical Expression*, 303–306.

Benford, S., Tolmie, P., Ahmed, A. Y., Crabtree, A., & Rodden, T. (2012). Supporting traditional music-making: Designing for situated discretion. *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work*, 127–136. https://doi.org/10.1145/2145204.2145227

Bennett, A., & Dawe, K. (2020). *Guitar cultures*. Routledge.

Bergvall-Kareborn, B., Hoist, M., & Stahlbrost, A. (2009). Concept Design with a Living Lab Approach. *2009 42nd Hawaii International Conference on System Sciences*, 1–10. https://doi.org/10.1109/HICSS.2009.123

Bjerknes, G., Ehn, P., & Kyng, M. (1987). Computers and democracy. *Aldershot, England Avebury*.

Blythe, M., Andersen, K., Clarke, R., & Wright, P. (2016). Anti-Solutionist Strategies: Seriously Silly Design Fiction. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 4968–4978. https://doi.org/10.1145/2858036.2858482

Bødker, S., & Grønbæk, K. (1991). Cooperative prototyping: Users and designers in mutual activity. *International Journal of Man-Machine Studies*, *34*(3), 453–478. https://doi.org/10.1016/0020-7373(91)90030-B

Boer, L., & Donovan, J. (2012). Provotypes for participatory innovation. *Proceedings of the Designing Interactive Systems Conference*, 388–397. https://doi.org/10.1145/2317956.2318014

Bomba, M. S., & Dahlstedt, P. (2019). Somacoustics: Interactive Body-as-Instrument. *NIME*. International Conference on New Interfaces for Musical Expressions.

Booth, G., & Gurevich, M. (2012). Proceeding from Performance: An Ethnography of the Birmingham Laptop Ensemble. *ICMC*. ICMC.

Borgo, D. (2012). Embodied, situated and distributed musicianship. *Sound Musicianship: Understanding the Crafts of Music*, 202–212.

Born, G. (1995). *Rationalizing culture: IRCAM, Boulez, and the institutionalization of the musical avant-garde*. Univ of California Press.

Borning, A., & Muller, M. (2012). Next steps for value sensitive design. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1125–1134.

Borst, J. P., Taatgen, N. A., & van Rijn, H. (2015). What Makes Interruptions Disruptive?: A Process-Model Account of the Effects of the Problem State Bottleneck on Task Interruption and Resumption. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*, 2971–2980. https://doi.org/10.1145/2702123.2702156

Brandt, E., & Grunnet, C. (2000). Evoking the future: Drama and props in user centered design. *Proceedings of Participatory Design Conference (PDC 2000)*, 11–20.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.

Brown, D., Nash, C., & Mitchell, T. (2018). Simple mappings, expressive movement: A qualitative investigation into the end-user mapping design of experienced mid-air musicians. *Digital Creativity*, *29*(2–3), 129–148. https://doi.org/10.1080/14626268.2018.1510841

Brudy, F., Holz, C., Rädle, R., Wu, C.-J., Houben, S., Klokmose, C. N., & Marquardt, N. (2019). Cross-Device Taxonomy: Survey, Opportunities and Challenges of Interactions Spanning Across Multiple Devices. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*, 1–28. https://doi.org/10.1145/3290605.3300792

Buchenau, M., & Suri, J. F. (2000). Experience prototyping. *Proceedings of the Conference on Designing Interactive Systems Processes, Practices, Methods, and Techniques - DIS '00*, 424–433. https://doi.org/10.1145/347642.347802

Burns, A.-M., Bel, S., & Traube, C. (2017). *Learning to play the guitar at the age of interactive and collaborative Web technologies*.

Burns, C., Dishman, E., Verplank, W., & Lassiter, B. (1994). Actors, hairdos & videotape—Informance design. *Conference Companion on Human Factors in Computing Systems*, 119–120. https://doi.org/10.1145/259963.260102

Chamberlain, A., & Crabtree, A. (2016). Searching for music: Understanding the discovery, acquisition, processing and organization of music in a domestic setting for design. *Personal and Ubiquitous Computing*, 1–13. https://doi.org/10.1007/s00779-016-0911-2

Chamberlain, A., & Crabtree, A. (Eds.). (2020). *Into the Wild: Beyond the Design Research Lab* (Vol. 48). Springer International Publishing. https://doi.org/10.1007/978-3-030-18020-1

Chamberlain, A., McGrath, S., & Benford, S. (2015). *Understanding social media and sound: Music, meaning and membership, the case of SoundCloud*.

Chang, M., Truong, A., Wang, O., Agrawala, M., & Kim, J. (2019). How to Design Voice Based Navigation for How-To Videos. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1–11). Association for Computing Machinery. https://doi.org/10.1145/3290605.3300931

Charmaz, K. (2006). *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis*. SAGE.

Clark, A. (1998). *Being There: Putting Brain, Body, and World Together Again*. MIT Press.

Coyne, R., & Snodgrass, A. (1991). Is designing mysterious? Challenging the dual knowledge thesis. *Design Studies*, *12*(3), 124–131. https://doi.org/10.1016/0142-694X(91)90020-W

Crabtree, A., Chamberlain, A., Davies, M., Glover, K., Reeves, S., Rodden, T., Tolmie, P., & Jones, M. (2013). Doing innovation in the wild. *Proceedings of the Biannual Conference of the Italian Chapter of SIGCHI on - CHItaly '13*, 1–9. https://doi.org/10.1145/2499149.2499150

Crabtree, A., Rouncefield, M., & Tolmie, P. (2012). *Doing design ethnography*. Springer.

Dawe, K. (2013). Guitar Ethnographies: Performance, Technology and Material Culture. *Ethnomusicology Forum*, *22*(1), 1–25. https://doi.org/10.1080/17411912.2013.774158

Dawe, K. (2017). *The New Guitarscape in Critical Theory, Cultural Practice and Musical Performance*. Taylor & Francis.

Denis, G., & Jouvelot, P. (2005). Motivation-driven educational game design: Applying best practices to music education. *Proceedings of the 2005 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology*, 462–465. https://doi.org/10.1145/1178477.1178581

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining 'gamification'. *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, 9–15. https://doi.org/10.1145/2181037.2181040

Dey, A. K., Abowd, G. D., & Salber, D. (2001). A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications. *Human–Computer Interaction*, *16*(2–4), 97–166. https://doi.org/10.1207/S15327051HCI16234_02

Dindler, C., & Iversen, O. S. (2007). Fictional Inquiry—Design collaboration in a shared narrative space. *CoDesign*, *3*(4), 213–234. https://doi.org/10.1080/15710880701500187

Donovan, L., & McPherson, A. (2014). The Talking Guitar: Headstock Tracking and Mapping Strategies. *NIME*, 351–354.

Dopyera, J. (1980). Stringed musical instrument. *The Journal of the Acoustical Society of America*, *67*(6), 2130–2130. https://doi.org/10.1121/1.384407

Dorrestijn, S., van der Voort, M., & Verbeek, P.-P. (2014). Future user-product arrangements: Combining product impact and scenarios in design for multi age success. *Technological Forecasting and Social Change*, *89*, 284–292. https://doi.org/10.1016/j.techfore.2014.08.005

Dourish, P. (2004a). What we talk about when we talk about context. *Personal and Ubiquitous Computing*, *8*(1), 19–30.

Dourish, P. (2004b). *Where the action is: The foundations of embodied interaction*. MIT press.

Dourish, P. (2006). Implications for design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 541–550). Association for Computing Machinery. https://doi.org/10.1145/1124772.1124855

Ehn, P., & Kyng, M. (1991). Cardboard Computers: Mocking-it-up or Hands-on the Future. In *Design at Work*. CRC Press.

Fallman, D. (2003). Design-oriented human-computer interaction. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 225–232. https://doi.org/10.1145/642611.642652

Fasciani, S., & Goode, J. (2021). *20 NIMEs: Twenty Years of New Interfaces for Musical Expression*. Proceedings of the International Conference on New Interfaces for Musical Expression.

Faulkner, R. R., & Becker, H. S. (2009). *'Do you know...?': The jazz repertoire in action*. University of Chicago Press.

Feldenkrais, M. (1972). *Awareness through movement* (Vol. 1977). New York: Harper & Row.

Flick, U. (2018). *An Introduction to Qualitative Research*. SAGE.

Fogtmann, M. H., Fritsch, J., & Kortbek, K. J. (2008). *Kinesthetic interaction: Revealing the bodily potential in interaction design*. 89–96.

Françoise, J., Candau, Y., Fdili Alaoui, S., & Schiphorst, T. (2017). Designing for Kinesthetic Awareness: Revealing User Experiences through Second-Person Inquiry. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (pp. 5171–5183). Association for Computing Machinery. https://doi.org/10.1145/3025453.3025714

Frengel, M. (2017). *The Unorthodox Guitar: A Guide to Alternative Performance Practice*. Oxford University Press.

Friedman, B. (1996). Value-sensitive design. *Interactions*, *3*(6), 16–23.

Furniss, P., & Dudas, R. (2014). *Transcription, Adaptation and Maintenance in Live Electronic Performance with Acoustic Instruments*. Computer Music Association.

Gallagher, S. (2006). *How the Body Shapes the Mind*. Clarendon Press.

Garfinkel, H. (2016). Studies in ethnomethodology. In *Social Theory Re-Wired* (pp. 85–95). Routledge.

Gaver, B., Dunne, T., & Pacenti, E. (1999). Design: Cultural probes. *Interactions*, *6*(1), 21–29. https://doi.org/10.1145/291224.291235

Gaver, W. W., Beaver, J., & Benford, S. (2003). Ambiguity as a resource for design. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 233–240. https://doi.org/10.1145/642611.642653

Geertz, C. (2008). Thick description: Toward an interpretive theory of culture. In *The cultural geography reader* (pp. 41–51). Routledge.

Gong, N.-W., Zhao, N., & Paradiso, J. A. (2012). A Customizable Sensate Surface for Music Control. *NIME*, *12*, 417–420.

Green, L. (2017). *How popular musicians learn: A way ahead for music education*. Routledge.

Greenbaum, J., & Kyng, M. (2020). *Design at Work: Cooperative Design of Computer Systems*. CRC Press.

Greenhalgh, C., Benford, S., & Hazzard, A. (2016). ^muzicode$: Composing and Performing Musical Codes. *Proceedings of the Audio Mostly 2016 on - AM '16*, 47–54. https://doi.org/10.1145/2986416.2986444

Grudin, J. (1990). The computer reaches out: The historical continuity of interface design. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 261–268. https://doi.org/10.1145/97243.97284

Haken, L., & Eagan, E. (2010). Playing the Continuum Fingerboard: New performance techniques for a continuous instrument. *The Journal of the Acoustical Society of America*, *128*(4), 2345–2345. https://doi.org/10.1121/1.3508304

Han, J., & Gold, N. E. (2014). *Lessons learned in exploring the Leap Motion™ sensor for gesture-based instrument design*.

Harrison, J., & McPherson, A. P. (2017). Adapting the Bass Guitar for One-Handed Playing. *Journal of New Music Research*, *46*(3), 270–285. https://doi.org/10.1080/09298215.2017.1340485

Harrison, S., Tatar, D., & Sengers, P. (2007). The three paradigms of HCI. *CHI'07*, 1–18.

Hattwick, I., Malloch, J., & Wanderley, M. M. (2014). Forming Shapes to Bodies: Design for Manufacturing in the Prosthetic Instruments. *NIME*, 443–448.

Heinz, S., & O'Modhrain, S. (2010). Designing a shareable musical TUI. *The International Conference on New Interfaces for Musical Expression*. NIME.

Hoare, M., Benford, S., Jones, R., & Milic-Frayling, N. (2014). Coming in from the margins: Amateur musicians in the online age. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1295–1304. https://doi.org/10.1145/2556288.2557298

Holland, S., Mudd, T., Wilkie-McKenna, K., McPherson, A., & Wanderley, M. M. (2019). *New Directions in Music and Human-Computer Interaction*. Springer.

Holland, S., Wilkie, K., Mulholland, P., & Seago, A. (2013). Music interaction: Understanding music and human-computer interaction. In *Music and human-computer interaction* (pp. 1–28). Springer.

Holtzblatt, K., Wendell, J. B., & Wood, S. (2004). *Rapid contextual design: A how-to guide to key techniques for user-centered design*. Elsevier.

Höök, K. (2018). *Designing with the body: Somaesthetic interaction design*. MIT Press.

Höök, K., Benford, S., Tennent, P., Tsaknaki, V., Alfaras, M., Avila, J. M., Li, C., Marshall, J., Roquet, C. D., Sanches, P., Ståhl, A., Umair, M., Windlin, C., & Zhou, F. (2021). Unpacking Non-Dualistic Design: The Soma Design Case. *ACM Transactions on Computer-Human Interaction*, *28*(6), 40:1-40:36. https://doi.org/10.1145/3462448

Höök, K., Caramiaux, B., Erkut, C., Forlizzi, J., Hajinejad, N., Haller, M., Hummels, C., Isbister, K., Jonsson, M., & Khut, G. (2018). Embracing first-person perspectives in soma-based design. *Informatics*, *5*(1), 8.

Hopkin, B., & Landman, Y. (2012). *Nice Noise: Modifications and Preparations for Guitar*. San Anselmo (USA): Experimental Musical Instruments.

Hracs, B. J. (2012). A Creative Industry in Transition: The Rise of Digitally Driven Independent Music Production. *Growth and Change*, *43*(3), 442–461. https://doi.org/10.1111/j.1468-2257.2012.00593.x

Iacucci, G., & Kuutti, K. (2002). Everyday Life as a Stage in Creating and Performing Scenarios for Wireless Devices. *Personal and Ubiquitous Computing*, *6*(4), 299–306. https://doi.org/10.1007/s007790200031

Ihde, D. (1990). *Technology and the lifeworld: From garden to earth*. Indiana University Press.

Ingold, T. (2019). Thinking through the cello. *Thinking in the World: A Reader*, 202.

Janssen, C. P., Gould, S. J. J., Li, S. Y. W., Brumby, D. P., & Cox, A. L. (2015). Integrating knowledge of multitasking and interruptions across different perspectives and research methods. *International Journal of Human-Computer Studies*, *79*, 1–5. https://doi.org/10.1016/j.ijhcs.2015.03.002

Jenkins, H. (2009). *Confronting the challenges of participatory culture: Media education for the 21st century*. The MIT Press.

Jensenius, A. R., Gonzalez Sanchez, V. E., Zelechowska, A., & Bjerkestrand, K. A. V. (2017). Exploring the Myo controller for sonic microinteraction. *Proceedings of the International Conference on New Interfaces for Musical Expression*, 442–445.

Jensenius, A. R., & Lyons, M. J. (Eds.). (2017). *A NIME Reader* (Vol. 3). Springer International Publishing. https://doi.org/10.1007/978-3-319-47214-0

Jensenius, A. R., & Wanderley, M. M. (2010). Musical gestures: Concepts and methods in research. In *Musical Gestures* (pp. 24–47). Routledge.

Johansson, M. (2005). *Participatory inquiry: Collaborative Design*. Blekinge Institute of Technology.

Jordà, S. (2004). Instruments and Players: Some Thoughts on Digital Lutherie. *Journal of New Music Research*, *33*(3), 321–341. https://doi.org/10.1080/0929821042000317886

Jordà, S., Kaltenbrunner, M., Geiger, G., & Bencina, R. (2005). The reacTable. *In Proceedings of the International Computer Music Conference (ICMC 2005*, 579–582.

Jung, H., Stolterman, E., Ryan, W., Thompson, T., & Siegel, M. (2008). Toward a framework for ecologies of artifacts: How are digital artifacts interconnected within a personal life? *Proceedings of the 5th Nordic Conference on Human-Computer Interaction: Building Bridges*, 201–210. https://doi.org/10.1145/1463160.1463182

Kane, S. K., Wobbrock, J. O., & Smith, I. E. (2008). Getting off the treadmill: Evaluating walking user interfaces for mobile devices in public spaces. *Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services*, 109–118.

Kensing, F., & Madsen, K. H. (1992). Generating visions: Future workshops and metaphorical design. In *Design at work: Cooperative design of computer systems* (pp. 155–168).

Kiverstein, J., & Clark, A. (2009). Introduction: Mind Embodied, Embedded, Enacted: One Church or Many? *Topoi*, *28*(1), 1–7. https://doi.org/10.1007/s11245-008-9041-4

Knotts, S. (2020). Live coding and failure. *The Aesthetics of Imperfection in Music and the Arts: Spontaneity, Flaws and the Unfinished*, 189.

Koefoed Hansen, L., & Kozel, S. (2007). Embodied imagination: A hybrid method of designing for intimacy. *Digital Creativity*, *18*(4), 207–220.

Kollock, P. (1998). The economies of online cooperation: Gifts and public goods in computer communities. *Communities in Cyberspace*.

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*. Sage publications.

Lähdeoja, O. (2008). An Approach to Instrument Augmentation: The Electric Guitar. *NIME*, 53–56.

Lähdeoja, O., Wanderley, M. M., & Malloch, J. (2009). Instrument augmentation using ancillary gestures for subtle sonic effects. *Proc. SMC*, 327–330.

Larsen, J., Overholt, D., & Moeslund, T. B. (2014). The Actuated guitar: Implementation and user test on children with Hemiplegia. *NIME*, *14*, 60–65.

Lepri, G., & McPherson, A. (2019). Making Up Instruments: Design Fiction for Value Discovery in Communities of Musical Practice. *Proceedings of the 2019 on Designing Interactive Systems Conference*, 113–126. https://doi.org/10.1145/3322276.3322353

Lepri, G., McPherson, A., & Bowers, J. (2020). Useless, not Worthless: Absurd Making as Critical Practice. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (pp. 1887–1899). Association for Computing Machinery. https://doi.org/10.1145/3357236.3395547

Lesaffre, M., Maes, P.-J., & Leman, M. (2017). *The Routledge companion to embodied music interaction*. Routledge New York, NY.

Levitin, D. J., McAdams, S., & Adams, R. L. (2002). Control parameters for musical instruments: A foundation for new mappings of gesture to sound. *Organised Sound*, *7*(2), 171–189. https://doi.org/10.1017/S135577180200208X

Lim, Y., Stolterman, E., Jung, H., & Donaldson, J. (2007). Interaction gestalt and the design of aesthetic interactions. *Proceedings of the 2007 Conference on Designing Pleasurable Products and Interfaces - DPPI '07*, 239. https://doi.org/10.1145/1314161.1314183

Loke, L., & Robertson, T. (2013). Moving and making strange: An embodied approach to movement-based interaction design. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *20*(1), 1–25.

Loke, L., & Schiphorst, T. (2018). The somatic turn in human-computer interaction. *Interactions*, *25*(5), 54–5863.

Lucas, A., Schroeder, F., & Ortiz, M. (2020). Enabling Communities of Practice Surrounding the Design and Use of Custom Accessible Music Technology. *Computer Music Journal*, *44*(2–3), 9–23. https://doi.org/10.1162/comj_a_00567

Lucero, A., Vaajakallio, K., & Dalsgaard, P. (2012). The dialogue-labs method: Process, space and materials as structuring elements to spark dialogue in co-design events. *CoDesign*, *8*(1), 1–23. https://doi.org/10.1080/15710882.2011.609888

MacConnell, D., Trail, S., Tzanetakis, G., Driessen, P., Page, W., & Wellington, N. (2013). Reconfigurable autonomous novel guitar effects (range). *Proc. Int. Conf. Sound and Music Computing (SMC)*.

Magnusson, T. (2009). Of Epistemic Tools: Musical instruments as cognitive extensions. *Organised Sound*, *14*(2), 168–176. https://doi.org/10.1017/S1355771809000272

Magnusson, T. (2014). Herding Cats: Observing Live Coding in the Wild. *Computer Music Journal*, *38*(1), 8–16. https://doi.org/10.1162/COMJ_a_00216

Magnusson, T., & Mendieta, E. H. (2007). The acoustic, the digital and the body: A survey on musical instruments. *Proceedings of the 7th International Conference on New Interfaces for Musical Expression*, 94–99. https://doi.org/10.1145/1279740.1279757

Márquez Segura, E., Turmo Vidal, L., Rostami, A., & Waern, A. (2016). Embodied Sketching. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 6014–6027. https://doi.org/10.1145/2858036.2858486

Marquez-Borbon, A., & Martinez Avila, J. P. (2018). The problem of DMI adoption and longevity: Envisioning a NIME performance pedagogy. *NIME*. NIME.

Marshall, M. T., & Wanderley, M. M. (2011). Examining the Effects of Embedded Vibrotactile Feedback on the Feel of a Digital Musical Instrument. *NIME*, 399–404.

Masu, R. (2021, April 29). NIME Scores: A Systematic Review of How Scores Have Shaped Performance Ecologies in NIME. *International Conference on New Interfaces for Musical Expression*. NIME 2021. https://doi.org/10.21428/92fbeb44.3ffad95a

Masu, R., Bettega, M., Correia, N. N., Romão, T., & Morreale, F. (2019, October 23). *ARCAA: A framework to analyse the artefact ecology in computer music performance* [Conference Proceedings]. University of Greenwich; ACM. https://doi.org/10.1145/3359852.3359870

Mayo, E. (2003). *The Human Problems of an Industrial Civilization*. Routledge. https://doi.org/10.4324/9780203487273

McGarry, G., Tolmie, P., Benford, S., Greenhalgh, C., & Chamberlain, A. (2017). *'They're all going out to something weird': Workflow, legacy and metadata in the music production process*. https://doi.org/10.1145/2998181.2998325

McGrath, S., Chamberlain, A., & Benford, S. (2016). The Grime scene: Social media, music, creation and consumption. *Proceedings of the Audio Mostly 2016*, 245–250.

McGrath, S., & Love, S. (2017). The user experience of mobile music making: An ethnographic exploration of music production and performance in practice. *Computers in Human Behavior*, *72*, 233–245. https://doi.org/10.1016/j.chb.2017.02.046

McPherson, A., & Kim, Y. (2012). The Problem of the Second Performer: Building a Community Around an Augmented Piano. *Computer Music Journal*, *36*(4), 10–27. https://doi.org/10.1162/COMJ_a_00149

McPherson, A., Morreale, F., & Harrison, J. (2019). Musical Instruments for Novices: Comparing NIME, HCI and Crowdfunding Approaches. In S. Holland, T. Mudd, K. Wilkie-McKenna, A. McPherson, & M. M. Wanderley (Eds.), *New Directions in Music and Human-Computer Interaction* (pp. 179–212). Springer International Publishing. https://doi.org/10.1007/978-3-319-92069-6_12

McPherson, A. P., & Kim, Y. (2010). Augmenting the Acoustic Piano with Electromagnetic String Actuation and Continuous Key Position Sensing. *NIME*, 217–222.

McPherson, A., & Zappi, V. (2015). An environment for submillisecond-latency audio and sensor processing on BeagleBone Black. *Audio Engineering Society Convention 138*.

Meneses, E. A., Freire, S., & Wanderley, M. M. (2018). GuitarAMI and GuiaRT: two independent yet complementary Augmented Nylon Guitar projects. *NIME*. NIME.

Merleau-Ponty, M. (1979). *Phenomenology of Perception*. Routledge.

Miranda, E. R., & Wanderley, M. M. (2006). *New Digital Musical Instruments: Control and Interaction Beyond the Keyboard*. A-R Editions, Inc.

Moran, T. P., & Carroll, J. M. (2020). *Design Rationale: Concepts, Techniques, and Use*. CRC Press.

Morreale, F., & Angeli, A. D. (2014). Musical Interface Design: An Experience-oriented Framework. *New Interfaces for Musical Expression*. NIME.

Morreale, F., Guidi, A., & McPherson, A. (2019). *Magpick: An Augmented Guitar Pick for Nuanced Control*. New Interfaces for Musical Expression.

Newman, M. W., Izadi, S., Edwards, W. K., Sedivy, J. Z., & Smith, T. F. (2002). User interfaces when and where they are needed: An infrastructure for recombinant computing.

Proceedings of the 15th Annual ACM Symposium on User Interface Software and Technology, 171–180. https://doi.org/10.1145/571985.572009

Newton, D., & Marshall, M. T. (2011). Examining How Musicians Create Augmented Musical Instruments. *NIME*, 155–160.

Ng, A., Brewster, S. A., & Williamson, J. (2013). The Impact of Encumbrance on Mobile Interactions. In P. Kotzé, G. Marsden, G. Lindgaard, J. Wesson, & M. Winckler (Eds.), *Human-Computer Interaction – INTERACT 2013* (pp. 92–109). Springer. https://doi.org/10.1007/978-3-642-40477-1_6

Ng, A., Brewster, S. A., & Williamson, J. H. (2014). Investigating the effects of encumbrance on one- and two- handed interactions with mobile devices. *Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems - CHI '14*, 1981–1990. https://doi.org/10.1145/2556288.2557312

Ng, K., & Nesi, P. (2008). i-Maestro: Technology-Enhanced Learning and Teaching for Music. *NIME*, 225–228.

Nijs, L. (2017). The merging of musician and musical instrument: Incorporation, presence, and levels of embodiment. In *The Routledge companion to embodied music interaction* (pp. 49–57). Routledge.

Odom, W., Wakkary, R., Lim, Y., Desjardins, A., Hengeveld, B., & Banks, R. (2016). From research prototype to research product. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 2549–2561.

O'Hara, K., & Brown, B. (2006). Consuming Music Together: Introduction and Overview. In K. O'Hara & B. Brown (Eds.), *Consuming Music Together: Social and Collaborative Aspects* *of Music Consumption Technologies* (pp. 3–17). Springer Netherlands. https://doi.org/10.1007/1-4020-4097-0_1

Olwal, A., Starner, T., & Mainini, G. (2020). E-Textile Microinteractions: Augmenting Twist with Flick, Slide and Grasp Gestures for Soft Electronics. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–13. https://doi.org/10.1145/3313831.3376236

Otto, J. A. (1833). *Treatise on the construction, preservation ... Of the violin and all bow instruments, tr. With notes and additions by T. Fardely*.

Oulasvirta, A., & Bergstrom-Lehtovirta, J. (2011). Ease of juggling: Studying the effects of manual multitasking. *Proceedings of the 2011 Annual Conference on Human Factors in Computing Systems - CHI '11*, 3103. https://doi.org/10.1145/1978942.1979402

Pardue, L. S., Buys, K., Overholt, D., McPherson, A. P., & Edinger, M. (2019). Separating Sound from Source: Sonic Transformation of the Violin through Electrodynamic Pickups and Acoustic Actuation. *Proceedings of the International Conference on New Interfaces for Musical Expression*.

Percival, G., Wang, Y., & Tzanetakis, G. (2007). Effective use of multimedia for computer-assisted musical instrument tutoring. *Proceedings of the International Workshop on Educational Multimedia and Multimedia Education - Emme '07*, 67. https://doi.org/10.1145/1290144.1290156

Pestova, X. (2008). *Models of interaction in works for piano and live electronics*. McGill University.

Petitmengin, C. (2006). Describing one's subjective experience in the second person: An interview method for the science of consciousness. *Phenomenology and the Cognitive Sciences*, *5*(3), 229–269. https://doi.org/10.1007/s11097-006-9022-2

Poyatos Andújar, M. del M. (2014). *Antonio de Torres Jurado (La Cañada, Almería, 1817 - Almería, 1892): Trabajo de documentación para el estudio del guitarrero almeriense*. Universidad Internacional de Andalucía. https://dspace.unia.es/handle/10334/3728

Righi, V., Sayago, S., & Blat, J. (2017). When we talk about older people in HCI, who are we talking about? Towards a 'turn to community' in the design of technologies for a growing ageing population. *International Journal of Human-Computer Studies*, *108*, 15–31. https://doi.org/10.1016/j.ijhcs.2017.06.005

Rodger, M., Stapleton, P., Van Walstijn, M., Ortiz, M., & Pardue, L. (2020). What Makes a Good Musical Instrument? A Matter of Processes, Ecologies and Specificities. *Proceedings of the International Conference on New Interfaces for Musical Expression, Birmingham City University*, 484–490.

Rogers, Y. (2004). New theoretical approaches for human-computer interaction. *Annual Review of Information Science and Technology*, *38*(1), 87–143.

Rogers, Y., Yuill, N., & Marshall, P. (2013). Contrasting lab-based and in-the-wild studies for evaluating multi-user technologies. *The SAGE Handbook of Digital Technology Research, SAGE, London*, 359–373.

Sacks, H. (1992). Lectures on conversation: Volume I. *Malden, Massachusetts: Blackwell*.

Saldaña, J. (2021). *The coding manual for qualitative researchers*. SAGE.

San Juan, C. A. M. (2020). The Guitar as a Laboratory for Experimentation. *Revista Vórtex*, *8*(3).

Sanders, E. B. (2001). Virtuosos of the experience domain. *Proceedings of the 2001 IDSA Education Conference*. Proceedings of the 2001 IDSA education conference.

Sanders, E. B.-N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *CoDesign*, *4*(1), 5–18. https://doi.org/10.1080/15710880701875068

Sanders, E.-N. (2000). Generative tools for co-designing. In *Collaborative design* (pp. 3–12). Springer.

Schiavio, A., van der Schyff, D., Gande, A., & Kruse-Weber, S. (2019). Negotiating individuality and collectivity in community music. A qualitative case study. *Psychology of Music*, *47*(5), 706–721. https://doi.org/10.1177/0305735618775806

Schiphorst, T. (2011). Self-evidence: Applying somatic connoisseurship to experience design. *CHI'11 Extended Abstracts on Human Factors in Computing Systems*, 145–160.

Schiphorst, T., & Andersen, K. (2004). *Between bodies: Using experience modeling to create gestural protocols for physiological data transfer*.

Schleicher, D., Jones, P., & Kachur, O. (2010). Bodystorming as embodied designing. *Interactions*, *17*(6), 47–51. https://doi.org/10.1145/1865245.1865256

Sharp, H., Preece, J., & Rogers, Y. (2019). *Interaction Design: Beyond Human-Computer Interaction*. John Wiley & Sons.

Shear, J., & Varela, F. J. (1999). *The View from Within: First-person Approaches to the Study of Consciousness*. Imprint Academic.

Shusterman, R. (2008). *Body consciousness: A philosophy of mindfulness and somaesthetics*. Cambridge University Press.

Shusterman, R. (2012). *Thinking through the body: Essays in somaesthetics.* Cambridge University Press.

Simonsen, J. (2013). *Routledge international handbook of participatory design* (Vol. 711). Routledge New York, NY.

Spiel, K., Makhaeva, J., & Frauenberger, C. (2016). Embodied Companion Technologies for Autistic Children. *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction*, 245–252. https://doi.org/10.1145/2839462.2839495

Suchman, L. (1988). Designing with the user: Book review of Computers and democracy: A Scandinavian challenge, G. Bjerknes, P. Ehn, and M. Kyng, Eds. Gower Press, Brookfield, VT, 1987. *ACM Transactions on Information Systems (TOIS)*, *6*(2), 173–183.

Suchman, L. A. (1987). *Plans and situated actions: The problem of human-machine communication*. Cambridge university press.

Sudnow, D. (2001). *Ways of the Hand: A Rewritten Account*. MIT Press.

Svanæs, D., & Barkhuus, L. (2020). The Designer's Body as Resource in Design: Exploring Combinations of Point-of-view and Tense. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1–13). Association for Computing Machinery. https://doi.org/10.1145/3313831.3376430

Svanæs, D., & Solheim, M. (2016). Wag Your Tail and Flap Your Ears: The Kinesthetic User Experience of Extending Your Body. *Proceedings of the 2016 CHI Conference Extended*

Abstracts on Human Factors in Computing Systems, 3778–3779. https://doi.org/10.1145/2851581.2890268

Tanaka, A. (2019). Embodied Musical Interaction: Body Physiology, Cross Modality, and Sonic Experience. In S. Holland, T. Mudd, K. Wilkie-McKenna, A. McPherson, & M. M. Wanderley (Eds.), *New Directions in Music and Human-Computer Interaction* (pp. 135–154). Springer International Publishing. https://doi.org/10.1007/978-3-319-92069-6_9

Tanaka, A., & Donnarumma, M. (2019). The body as musical instrument. *The Oxford Handbook of Music and the Body*, 79–96.

Tennent, P., Höök, K., Benford, S., Tsaknaki, V., Ståhl, A., Dauden Roquet, C., Windlin, C., Sanches, P., Marshall, J., Li, C., Martinez Avila, J. P., Alfaras, M., Umair, M., & Zhou, F. (2021). Articulating Soma Experiences Using Trajectories. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. https://doi.org/10.1145/3411764.3445482

Tolmie, P., Benford, S., & Rouncefield, M. (2013). Playing in Irish Music Sessions. In *Ethnomethodology at Play*. Routledge.

Trail, S., Dean, M., Odowichuk, G., Tavares, T. F., Driessen, P. F., Schloss, W. A., & Tzanetakis, G. (2012). Non-invasive sensing and gesture control for pitched percussion hyper-instruments using the Kinect. *NIME*.

Tsaknaki, V. (2021). The Breathing Wings: An Autobiographical Soma Design Exploration of Touch Qualities through Shape-Change Materials. *Designing Interactive Systems Conference 2021*, 1266–1279. https://doi.org/10.1145/3461778.3462054

Tuncer, S., Lindwall, O., & Brown, B. (2021). Making Time: Pausing to Coordinate Video Instructions and Practical Tasks. *Symbolic Interaction*, *44*(3), 603–631. https://doi.org/10.1002/symb.516

Turchet, L. (2019). Smart Musical Instruments: Vision, Design Principles, and Future Directions. *IEEE Access*, *7*, 8944–8963. https://doi.org/10.1109/ACCESS.2018.2876891

Turchet, L., & Barthet, M. (2019). An ubiquitous smart guitar system for collaborative musical practice. *Journal of New Music Research*, *48*(4), 352–365. https://doi.org/10.1080/09298215.2019.1637439

Turchet, L., Fischione, C., & Barthet, M. (2017). Towards the Internet of Musical Things. *Proceedings of the Sound and Music Computing Conference*, 13–20.

Turchet, L., Fischione, C., Essl, G., Keller, D., & Barthet, M. (2018). Internet of Musical Things: Vision and Challenges. *IEEE Access*. https://doi.org/10.1109/ACCESS.2018.2872625

Turchet, L., Pauwels, J., Fischione, C., & Fazekas, G. (2020). Cloud-smart Musical Instrument Interactions: Querying a Large Music Collection with a Smart Guitar. *ACM Transactions on Internet of Things*, *1*(3), 15:1-15:29. https://doi.org/10.1145/3377881

Vamvakousis, Z., & Ramirez, R. (2016). The EyeHarp: A Gaze-Controlled Digital Musical Instrument. *Frontiers in Psychology*, *7*, 906.

Varela, F. J., Thompson, E., & Rosch, E. (2017). *The Embodied Mind, revised edition: Cognitive Science and Human Experience*. MIT Press.

Vargas, A. (2014). A guitarra baiana: Tradição e desuso. In Valente, Heloísa de A. Duarte et al.(eds.) (Ed.), *Actas del XI Congreso de la IASPM-AL.* Letra e Voz.

Vavoula, G. N., & Sharples, M. (2007). Future technology workshop: A collaborative method for the design of new learning technologies and activities. *International Journal of Computer-Supported Collaborative Learning*, *2*(4), 393–419.

Verbeek, P.-P. (2015). Beyond Interaction: A Short Introduction to Mediation Theory. *Interactions*, *22*(3), 26–31.

Vets, T., Degrave, J., Nijs, L., Bressan, F., & Leman, M. (2017). PLXTRM: Prediction-Led eXtended-guitar Tool for Real-time Music applications and live performance. *Journal of New Music Research*, *46*(2), 187–200. https://doi.org/10.1080/09298215.2017.1288747

Vogl, A., Parzer, P., Babic, T., Leong, J., Olwal, A., & Haller, M. (2017). StretchEBand: Enabling Fabric-based Interactions through Rapid Fabrication of Textile Stretch Sensors. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 2617–2627. https://doi.org/10.1145/3025453.3025938

Vyas, D., & Dix, A. (2007). *Artefact Ecologies: Supporting Embodied Meeting Practices with Distance Access*. Proceedings of UbiComp (Ubiquitous Computing) 2007 Workshops.

Waldron, J. (2007). Once the beat gets going it really grooves: Informal music learning as experienced by two Irish traditional musicians. *International Journal of Community Music*, *1*, 89–103. https://doi.org/10.1386/ijcm.1.1.89_0

Waldron, J. (2009). Exploring a virtual music community of practice: Informal music learning on the Internet. *Journal of Music, Technology & Education*, *2*(2–3), 97–112.

Waldron, J. (2013a). YouTube, fanvids, forums, vlogs and blogs: Informal music learning in a convergent on- and offline music community. *International Journal of Music Education*, *31*, 91–105. https://doi.org/10.1177/0255761411434861

Waldron, J. (2013b). User-generated content, YouTube and participatory culture on the Web: Music learning and teaching in two contrasting online communities. *Music Education Research*, *15*(3), 257–274. https://doi.org/10.1080/14613808.2013.772131

Waters, S. (2007). Performance Ecosystems: Ecological approaches to musical interaction. *EMS: Electroacoustic Music Studies Network*, 1-20.

Weiser, M. (1991). The Computer for the 21st Century. *Scientific American*, 94–104.

Weiser, M., & Brown, J. S. (1997). The coming age of calm technology. In *Beyond calculation* (pp. 75–85). Springer.

Wenger, E. (1999). *Communities of practice: Learning, meaning, and identity*. Cambridge university press.

Wilde, D. (2015). Embodying material ideation. In R. Valkenburg, C. Dekkers, & J. Sluijs (Eds.), *Proceedings of the 4th Participatory Innovation Conference 2015* (pp. 386–393). The Hague University of Applied Sciences.

Wilde, D., Vallgårda, A., & Tomico, O. (2017). Embodied Design Ideation Methods: Analysing the Power of Estrangement. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 5158–5170. https://doi.org/10.1145/3025453.3025873

Windlin, C., Ståhl, A., Sanches, P., Tsaknaki, V., Karpashevich, P., Balaam, M., & Höök, K. (2019). Soma Bits-Mediating Technology to Orchestrate Bodily Experiences. *RTD*

2019-Research through Design Conference 2019, the Science Centre, Delft, on 19th to 22nd March 2019.

Wolf, K., Naumann, A., Rohs, M., & Müller, J. (2011). A Taxonomy of Microinteractions: Defining Microgestures Based on Ergonomic and Scenario-Dependent Requirements. In P. Campos, N. Graham, J. Jorge, N. Nunes, P. Palanque, & M. Winckler (Eds.), *Human-Computer Interaction – INTERACT 2011* (Vol. 6946, pp. 559–575). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-23774-4_45

Xia, G., & Dannenberg, R. B. (2018). ShIFT: A Semi-haptic Interface for Flute Tutoring. In T. M. Luke Dahl Douglas Bowman (Ed.), *Proceedings of the International Conference on New Interfaces for Musical Expression* (pp. 162–167).

Zappi, V., & Mcpherson, A. (2014). Design and use of a hackable digital instrument. *International Conference on Live Interfaces*. International Conference on Live Interfaces.

Zayadine, F., & Al-Asad, M. (2000). *The Umayyads: The Rise of Islamic Art*. Museum With No Frontiers, MWNF (Museum Ohne Grenzen).