From the Speculative to the Tangible: Incorporating Generative AI Tools into an Accessible Instrument Design Workflow

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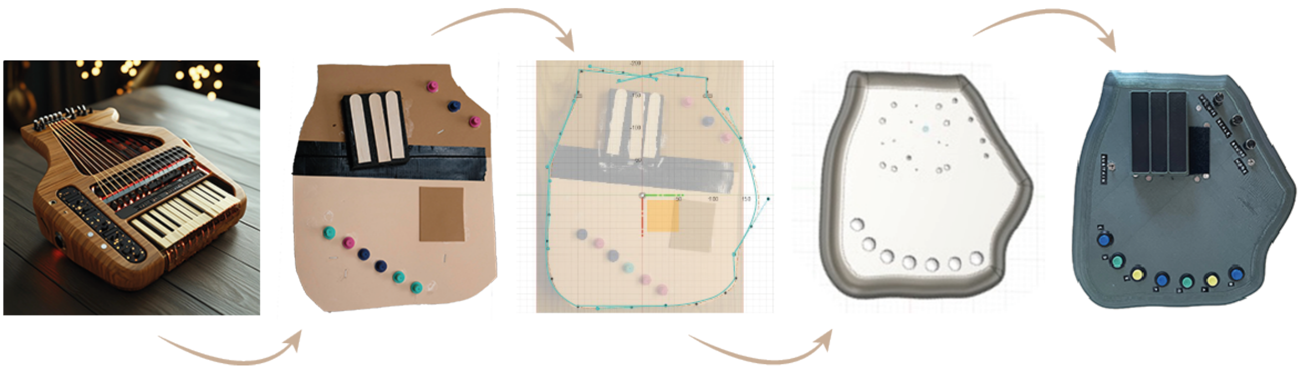

Figure 1: A five step procedural accessible instrument design workflow that progresses generative AI images into 3D printed prototypes

Abstract

Accessible Digital Musical Instruments (ADMIs) offer vital opportunities for Disabled musicians, yet the design and development of bespoke ADMIs remains lengthy, expensive and inaccessible to much of the community. Whilst there are promising indications that generative AI tools have the potential to enhance inclusion, participation, and independence for Disabled people, their use within ADMI design remains under-explored.

This paper investigates how AI tools, specifically text-to-image generators, can facilitate the co-design process of hyper-bespoke ADMIs between Disabled musicians and instrument designers. We explore how emerging AI technologies can be incorporated into a participatory action research methodological approach to progress participants' ideas from AI-generated images into viable 3D-printed prototypes.

We propose a procedural design workflow that incorporates conceptual 2D designs, low-fidelity craft mock-ups and iterative design into a co-design process for Disabled musicians and instrument designers with the intention of opening new pathways for personalised, participant-led design approaches to ADMI development.

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Keywords

Accessible Digital Musical Instruments, Applied Artificial Intelligence, Participatory Workshops, Collaborative Design.

1 Introduction

Participation in music-making has been shown to have a range of personal and societal benefits [36], including enhanced self-esteem and self-confidence among individuals [35], as well as improvements in community and societal well-being [14, 58]. However, access to the opportunities, services and instruments that enable music-making for the wider population, especially for Disabled people, remains limited [1, 22, 37].

The endeavour to increase participation in music-making has resulted in a range of novel adaptive and accessible digital musical instruments [21, 39, 56]. Whilst there are promising signs that digital sensors, electronic components and rapid prototyping technologies can support the design of new accessible musical instruments [23, 28], the use of artificial intelligence in this field remains under-explored. In June 2019, the Conference of State Parties to the UN Convention on the Rights of Persons with Disabilities (CRPD) recognised that AI has the potential to enhance inclusion, participation, and independence for Disabled people [2]. This research is concerned with how novel AI technologies can be incorporated into the design and fabrication process of ADMIs, with the intention of offering new opportunities to music-making for Disabled people.

This paper introduces a six-month collaboration with a Disabled musician, Miggy Barker (they/them) that explored the use of AI tools to support the ideation, modelling, and fabrication stages of a new bespoke ADMI. The collaboration seeks to question how AI tools can be used in different stages of instrument design development, from ideation to a more embodied and tangible response. The five workshops that form this paper are set out in detail and the workshop activities and outcomes are presented alongside four stages of iterative fabrication, culminating in the fabrication of a new ADMI, 'Tacta'. 'Tacta' is a bespoke musical instrument specifically designed for Miggy and is centred around their design decisions and contributions from different workshop activities. Section 4 proposes an instrument design framework based on the findings from the collaboration. A six-cycle process is outlined where we offer strategies to workshop facilitators, practitioners, instrument designers, and Disabled musicians looking to incorporate AI tools into the design process of a new ADMI.

2 Background

A discussion into the design and fabrication of accessible musical instruments span a wide range of multi-disciplinary perspectives and approaches and this section situates the research within a broader context informed by critical disability studies, design methodologies and artificial intelligence. Specifically, we introduce the motivation behind designing bespoke ADMIs, discuss the ethical considerations and creative potential of artificial intelligence within instrument design practices and the field of NIME, and look to participatory design methodologies as a method to invite Disabled people into research projects as co-creators.

2.1 Accessible Digital Musical Instruments

Accessible Digital Musical Instruments (ADMIs) is a term which is gaining popularity, especially within the NIME community as enabling technological tools, used for musical purposes [40] which act as an interface to active participation in the arts. Although there are several commercially available ADMIs and organisations working focused on the development of these instruments, there are still many social and technical barriers which are facing Disabled musicians in accessing suitable interfaces [28]. The reasons that ADMIs have had restricted uptake include a) the financial cost of music technology [56], b) the musical output can be seen as lacking expression [44] or c) impersonal and lacking sophistication [49]. Although since 2007, with the advancements of new, affordable, and DIY-focused music technology there is a potential for the field to become more diverse and for ADMIs to benefit larger groups of users [21].

2.1.1 Bespoke Accessible Digital Musical Instruments. Whilst ADMIs provide vital opportunities for Disabled musicians to participate in music-making, "there is not one universal solution that every disabled person wants." [34] and bespoke musical instruments therefore have the potential to provide Disabled people with more suitable access to music-making [27]. Bespoke ADMIs are personalised musical instruments designed specifically for one individual, in line with their access requirements and musical objectives. As suggested by Lucus, ADMIs which are bespoke or customisable have greater chance of longevity as well as the potential for a more expressive output [40]. Whilst there is a strong argument for bespoke instruments, the process of fabrication can limit the availability of these instruments to certain individuals and can exclude much of the community. Additionally, as Kinsella et al state in their AHRC report 'Accessible Instrument Design Beyond Techno-Solutionism', "Bespoke instruments are expensive and their longevity may depend on the continuing availability of the maker" [34]. Due to the bespoke nature of the instruments, designers may go through several revisions before reaching a playable and suitable interface for the end user [33]. In addition, financial and funding considerations are another barrier to access and as a result, "the cost of bespoke technologies will render them out of reach for many disabled people" [34].

2.2 Artificial Intelligence

Artificial intelligence (AI) is becoming increasingly present in everyday life with the continuing introduction of new products, services and systems [48] as we quickly progress into the next stage of the 'Age of AI' [53]. Generative AI (GenAI) is a subfield of AI that is commonly used to create new content such as images, text, and music based on input data or textual prompts [59]. Recent advances in GenAI have enabled highly detailed and realistic images to be generated from text prompts given in natural language [6] and text-to-image (TTI) generators can replicate a wide range of artistic styles.

Since the mid-2010s, machine learning and neural network-based AI systems have slowly encroached on creative fields [13]. For example, there has been a large expansion in research that explores the use of generative AI to compose music [45], draw free hand sketches [25] and produce digital art [46]. Similarly within the domain of musical instrument design, an interest in exploring the creative potential of AI within instrument design and musical composition has been a growing topic in the NIME community in the past few years [50] [20]. Furthermore, recent research highlights the growing role that generative machine learning and large language models (LLMs) can play in creative design processes, from ideation to early prototyping [51].

There are early signs that AI tools are beneficial during the early stages of ideation due to their ability to provide a common ground between collaborators to further discuss a design. Lin et al state that as TTI generators "are increasingly used in the design process for ideation, communication, and production - often to flesh out ideas with details that would otherwise be time-consuming to produce" [38]. There are pervious examples of NIME workshops that explore the use of AI tools as the basis for the workshop activities, with a focus on fictional designs within a speculative design mindset [4] [3]. Whilst there are indications that AI tools are beneficial for conceptual and fictional design, the use of "these models in creative tasks that bridge the 2D digital world and the creation of physical artefacts has been understudied" [47].

2.2.1 Ethical Considerations of Artificial Intelligence Technologies. Whilst considering the critical implications of new technologies for creative practice, the ethical use of AI TTI and LLM generators are currently a highly debated topic. Several articles question whether such systems are taking artists' jobs [29] or replacing programmers [26], while others highlight the racial and sexist biases present within their generated outputs [52]. In addition, the ethical implications of the training data of AI models is a much discussed topic due to the potential for the infringement of copyright [32] and intellectual property [31]. In addition to bias, there is also criticism that GenAI tools leave a significant carbon footprint due to the energy intensive nature of training and using these systems [16, 24]. Furthermore, GenAI models are often seen as neutral, but they have been criticised for producing biased outcomes, which can inherently perpetuate stereotypes, discrimination and can unfairly disadvantage certain groups [61].

In relation to music, there are other ongoing ethical concerns around cultural biases in relation to musical practices, musicians and musical styles [12].

2.2.2 Accessibility and Artificial Intelligence. Whilst acknowledging the wide range of ethical concerns associated with large AI data sets and GenAI image creation, this research seeks to focus on the use of these technologies to benefit the under-represented communities within technological innovation and the arts [27]. Strikingly, only 10% of those who need Assistive Technology (AT) currently have access to it [30] and therefore it is vital to consider how novel technologies can can enable greater access to services, activities and devices with Disabled people.

There are emerging signs that AI technologies can support bespoke, personalised devices, where each user's requirements differ according to their behaviour and context [30]. There are existing AI technologies developed and used by Disabled people, such as an application created by a blind developer using AI2 to identify objects and faces [55]. Yet as Wald notes, that among all characteristic groups defined by the Equality Act 2010 [19] including age, disability, gender reassignment, race, religion/ belief, sex; disability is the most heterogeneous, and therefore requires unique and flexible solutions [55]. This presents a challenge for AI systems because, as Wald argues, "classification using big data struggles to cope with the individual uniqueness of disabled people" [55].

3 Methodology

Despite growing interest into accessible digital musical instruments, there remains a limited understanding of how such instruments are developed through long-term, collaborative processes with Disabled musicians [60]. Whilst participatory and co-design methods are increasingly advocated in HCI [5], few studies apply participatory action research to the context of musical instrument building, where both the craft of instrument making and the relational dynamics of collaboration shape the resulting design. Additionally, whilst it is widely promoted that Disabled musicians should be at the centre of new design approaches [57], it is still undefined how best to incorporate and situate their design choices and access requirements into a participatory design process. This motivated us to trial the use of participatory action research (PAR) as the primary methodology for designing and developing a new ADMI.

The methodological approach to PAR consists of two main principles: the co-construction of knowledge and the promotion of self and critical awareness that can lead to individual, collective and social change [41]. This research project adopts a PAR methodology by positioning participants not simply as sources of data but as active collaborators whose knowledge and lived experience are central to the research process and its outcomes.

Figure 2 shows the nature of the longer-term collaboration incorporating a PAR approach where there are several stages to the process, each with varying degrees of questioning, developing, implementing, and refining, based on the current activities within the cycle. A shift in narration is an important aspect in PAR as Wadsworth argues that PAR "involves an imaginative leap from a world of 'as it is' to a glimpse of a world 'as it could be'" [54]. To take this leap, it is important to understand the realities of "what is" for participating designers in the PAR project as well as to take seriously what "could be" in the resulting design artefact. Each of the five PAR cycles within this study iteratively

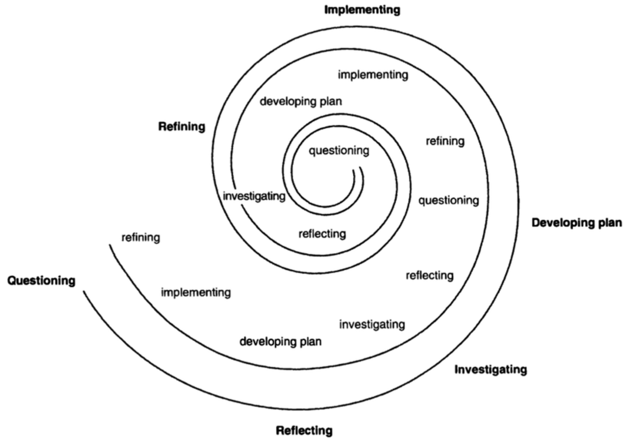

Figure 2: PAR process braided within one another in a spiral reflection, investigation, and action-recursive process (adapted from McIntyre, 2008).

refine a prototype from an initial speculative concept into a fully realised bespoke musical instrument.

3.1 Summary

The related work presented above demonstrates how design methodologies and novel technologies can be incorporated to ideate, participate, and reflect, furthering our understanding of what 'participation' means for Disabled people. Specifically, prior research in inclusive design showed how people can be enabled or disabled through design [7]; work in speculative design highlighted how such approaches can help envision potential futures [17]; and workshops were identified as providing vital space and opportunity to create novel designs [18]. Whilst the importance of participation in co-design projects was discussed, how different stakeholders are involved in an ADMI design process, how much agency participants have, and which stages of the design process they take part in, remains limited in scope [60]. In response to this research gap, participatory action research (PAR) was incorporated as the central methodology for this research to trial the use of AI tools and rapid prototyping technologies within the design of new ADMIs.

4 ADMI Design Workflow

This section provides a high level overview of the ADMI instrument design workflow using rapid fabrication technologies, 3D modelling and AI tools. Figure 3 shows the different fabrication activities in each cycle of the workflow. A detailed version of the workflow can be found in Appendix C.

The overview of the workflow shows the fabrication activities for each cycle, starting by developing a speculative AI-generated image which is then used as the basis for the design in the following steps. Below is an outline of each of the PAR cycles, demonstrating the workshops activities developed alongside the evolving fabrication process of 'Tacta'.

5 Workshop Plan and Development

This section presents a long-term study with a Disabled musician, Miggy, who was recruited to co-design and actively participate in the development of a new instrument tailored to their own musical practice. Miggy took part in a series of five co-design workshops over a six-month period, and each workshop was

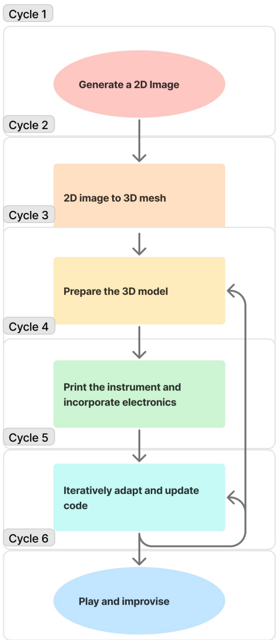

Figure 3: Overview of the ADMI design workflow using AI tools and rapid prototyping technologies

arranged to explore the role of AI tools at various stages of a bespoke musical instrument co-design process. The cycles consist of one four-hour workshop and one period of fabrication lasting between five-ten weeks before then starting the next cycle.

5.0.1 Access Profile of the Participating Musician. The participating musician has quadriplegia which significantly shapes their interaction and playing style with musical instruments. Four considerations were central to the design process: (1) limited arm function constrained reach, so the instrument needed to be positioned close to the body; (2) reduced grip strength and fine motor control excluded intricate interactions, although gross motor abilities allowed for broader forms of input; (3) fatigue was a consistent challenge, particularly when sustaining repetitive patterns over time; and (4) as neither hand was stronger than the other, the instrument would need to support multiple orientations, enabling the instrument to be played at a variety of angles as a way of managing fatigue during performance.

5.0.2 Public Participation and Project Funding. Compensation for the participant's time and contributions is a key aspect of this research, reflecting our view of the collaboration as a co-dependent, collaborative relationship, where both parties contribute to and shape the research process and resulting outcomes. To support this, the project received funding from the Arts and Humanities Research Council (AHRC) Impact Acceleration Account (IAA) 2022–24, which enabled us to pay the participants for their time and contributions in line with the Musician's union (MU) recommended pay rate.

Cycle 1: Starting the process Focus: What is? and What Could Be?

The first cycle served as an understanding and empathising around the question of 'What is'? by discussing the realities of learning and playing musical instruments from Miggy's perspective. The process started with a semi-structured interview and gave an opportunity for the researcher and participating musician to meet and understand the common goals of the project.

The second part of the workshop looked to question 'What could be?' by facilitating a speculative design workshop to design an 'ideal musical instrument' using GenAI tools. This idea was developed through discussions around several GenAI images that helped to frame the project, acting as jumping off points into further reflection and dialogue (see Figure 4). The designers chose one GenAI image to be a central reference point for the duration of the project and served as an essential boundary object in the resulting workshops. Cycle 1 provided a rich understanding of Miggy's musical practice, their goals for the project, and several design considerations to be incorporated in the following design cycles.

Figure 4: Cycle 1: Starting the Process

Cycle 2: HCI Bricolage

Focus: Using multiple workshop modalities to further understand the design

Building on the initial speculative designs developed in Cycle 1, the second cycle used the AI-generated image as the basis of tangible mock-ups using low-fidelity craft materials (see Figure 5. The use of craft mock-ups provided the designers with opportunities to name and frame the complex design situation through boundary objects and continue to question what is and what could be? This cycle explored several design tasks such as arranging foam pieces to replicate sensors, exploring comfortable playing positions, talking about the mapping strategies between the instrument's sensing capabilities and the resulting sound output to better understand the 2D design through embodied activities.

The first period of fabrication developed the 2D GenAI image into a 3D mesh using the AI modelling tool 'Meshy' [43] and the image of the craft mock-up was imported into the 3D modelling software. The dimensions and placement of the sensors from the craft mock-up were then scaled and aligned with the AI generated 3D model to create a new prototype based firmly upon both of the participant's contributions in the workshops.

Figure 5: Cycle 2: HCI Bricolage

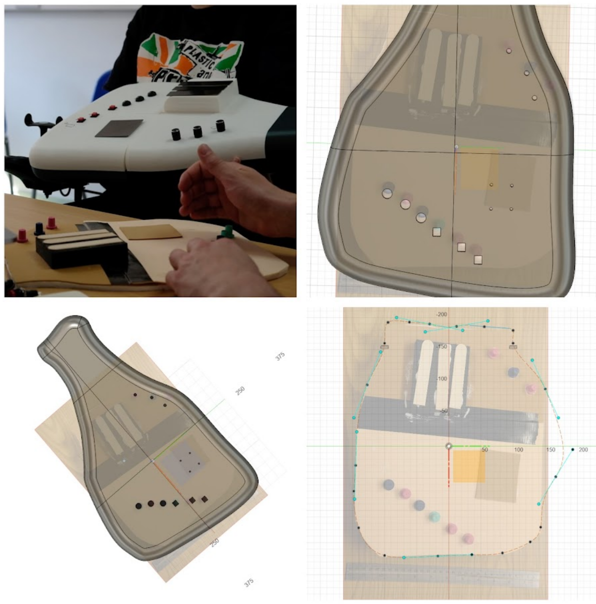

Figure 6: Cycle 3: Interaction Design Prototyping

Cycle 3: Interaction Design Prototyping

Focus: How might the technology feel? Cycle 3 involved developing the image-based and craft-based prototypes into a 3D mesh to be printed using a 3D printer. The first prototype can be seen in Figure 5. The third cycle built on the prototype designs generated in first two cycles into more embodied activities. The workshop included iterative design conversations on the how the 3D printed instrument body feels to play and to trial the placement of the embedded sensors. The third cycle followed the more traditional cylindrical nature of interaction design, where designers and users interact with the object which in turn informs the design choices.

During the workshop, the sensors and components were trialled through speculative design activities. This was to test the viability and accessibility of the components before embedding them permanently into the instrument.

Cycle 4: Iterative and Collaborative Design

Focus: Refining and Questioning through iterative design

The fourth cycle continued to move further from a speculative mindset and to more specific design decisions around the playability of the instrument. The significance of this cycle was that it worked with the second 3D printed prototype which served as the final instrument for the project. The fourth cycle began with printing the instrument body parts and mounting the sensors onto the instrument body. The subsequent stages focused on attaching the sensing components to an embedded computer, in this case, a Bela board [42], and routing signals from the components into the software environment. There were a few changes to the physical body of the instrument but the focus at this stage was editing the code to reflect the communal decisions on how the instrument should respond to the input data. Final adaptions for the last stage of fabrication were discussed within the workshop and the fourth fabrication stage served as the last opportunity to change any aspects to the instrument body.

Cycle 5: Testing and Evaluating

Focus: Reflect, Analyse, Document, Present

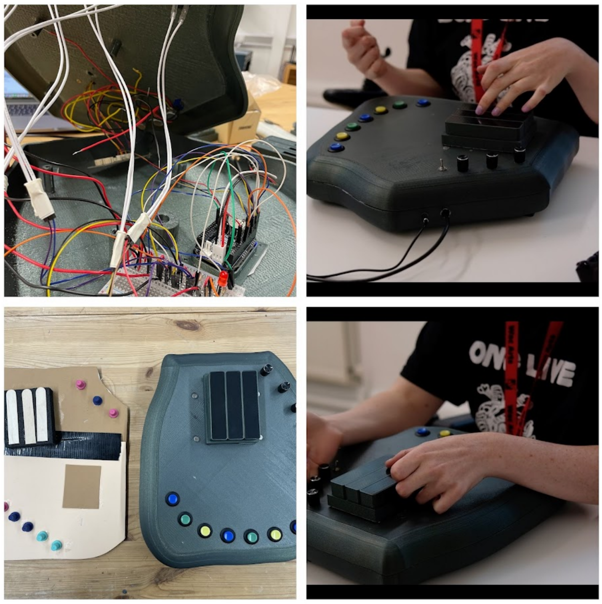

Figure 7: Cycle 4: Iterative Collaborative Design

The fifth cycle developed the initial code from Cycle 4 into a more complex patch that reflects the design team's conversations in the fourth workshop. The design team was able to iteratively change the code in the workshop using LLMs, which allowed for quick changes in the code based upon conversations and explorations with the instrument.

The final cycle served as an opportunity to document the final prototype by improvising with the resulting musical instrument and by collectively evaluating the five-cycle process. The primary objective at this stage was to reflect on the role of AI tools within a longer-term collaboration with Miggy and an additional semi-structured interview was arranged to understand how perceptions of the tools changed over the duration of the project.

Figure 8: Cycle 5: Testing and Evaluating

Cycle 6: Play Cycle six was focused around improvising with the instrument, developing playing techniques and understanding the affordances of the instrument and give time to learn how to play 'Tacta'.

Figure 9: Cycle 6: Play

5.1 Technical Overview of Tacta

A table can be found in Appendix A where we provide a detailed overview of the mapping strategies between the instrument's sensors/components and the sound engine. An additional image is provided in Appendix B that shows a image of Tacta with the labelled sensors and components.

5.2 Research Tools and Procedures

The workshops were documented through video and/or audio recordings of key activities, supplemented by short semi-structured interviews designed to prompt reflection on the workshop experience. The outcomes of the data include images of generated workshop data (AI-generated images), post-workshop conversations and several co-designed artefacts. The outcomes are presented in a manner that protects the anonymity of participants where requested and respects their contributions to the research.

5.2.1 Data collection methods and Procedures. All data collection procedures were conducted with respect for participants' autonomy and privacy and all recordings and transcripts were anonymised.

5.3 Reflexive Thematic Analysis Process

The reflexive thematic analysis (RTA) presented below was guided by Braun and Clarke's guidelines for undertaking reflexive thematic analysis [11] [9]. This method of analysis was chosen due to its accessibility and theoretical flexibility in analysing qualitative data [10]. The RTA process is described below to demonstrate how its methods and approach are suited to understanding participants' viewpoints and perspectives on the use of AI tools within the workshops. The RTA process followed five phases, as outlined by Braun and Clarke:

- **Phase 1 and 2:** Familiarisation with the data and initial coding
- **Phase 3:** Generating initial themes
- **Phase 4:** Developing and reviewing themes
- **Phase 5:** Refining, defining, and naming themes

The analysis process was conducted by the lead researcher using the qualitative data analysis software 'NVivo' [15], and the findings were discussed with the participating musician to ensure they were accurate and representative of their experience prior to publication.

6 Insights from the Process

During the first and final workshops with Miggy, two semi-structured interviews were conducted to close the collaboration with a deeper understanding into the musician's experience of designing a new musical instrument with AI tools. The interviews allowed time to reflect on the co-design process of 'Tacta' and to talk about Miggy's experience of participating as a co-designer over the 6-month period. A RTA was carried out on both of the interviews and eight themes that appeared consistently throughout the interviews were generated.

During the first interview, comments that repeatedly arose from the interview around Miggy's *musical identity*; their prior experience with playing musical instruments; their *barriers to access* and several *design considerations* for a new, bespoke musical instrument alongside their *perceptions of AI tools*.

In the final interview, the generated themes were more specific in relation to Miggy's experience of the project. The first theme focuses on *Feedback on the design process with an emphasis on physicality*. The second theme covers the *Challenges of a speculative design approach* when working towards a situated accessible design. The third theme looks into the *Perceptions of AI tools Used in the Design Process* that brings to light some vital perspectives on the use of GenAI tools for designing physical prototypes of ADMIs from a Disabled musician's standpoint. Finally, the *Impact of the Co-design Approach* highlights Miggy's motivations to learn the 'Tacta' as a result of the process alongside reflections on the challenges and joys of designing the instrument.

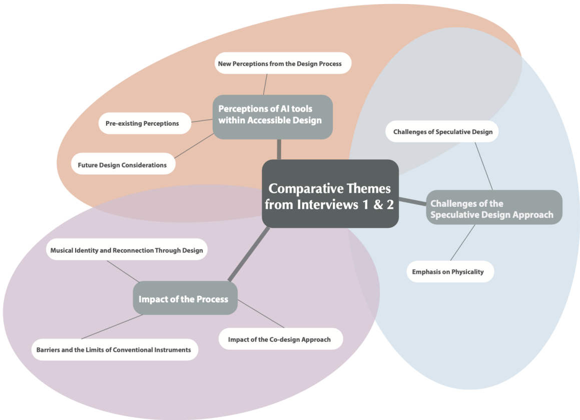

Figure 10: Comparative Themes Identified Across Two Interviews

Below we provide a comparative discussion into the two interviews to understand how AI tools and the methodological approach affected Miggy's experience of designing a new ADMI. The overarching themes are demonstrated in Figure 10 alongside the generated themes from the individual interviews.

6.1 Perceptions of AI tools within Accessible Design

Miggy's perceptions of AI tools began with a range of concerns from the ethical considerations of AI technologies to the usefulness of the tools themselves. Miggy showed a balanced approach to the new technologies yet started with some scepticism about intellectual property and the environmental impact of the tools as mentioned here,

> *"I only really know the like negative side of stuff, of the like stealing from artists and how much energy they'd have to use to work, and just the sustainability side of stuff not being great."*

This reflection touches on some of key ethical considerations of the AI tools and it is important to question when choosing to work and thereby promoting the technologies. Despite initial reservations about GenAI tools, Miggy was open to engaging with the TTI generators in the workshop, provided that they served a functional role within the process when there's *"actual use coming out of it"*. Miggy was asked about how they felt about using AI tools in the process, they shared:

> *"I'm aware that like for projects like this, where it's incorporated into like finding, like generating thoughts to then find something that will work and you can focus on and like develop out of, feels like what AI tools should be used for"*

During the final interview, Miggy's perceptions of AI tools for designing musical instruments had shifted towards a more critical view that the tools themselves were uncontrollable and difficult to access. The theme brought to light important responses from a situated Disabled musician using AI tools within a longer design process and they highlight the learning process and questioned their necessity within the process. Additionally, whilst Miggy could see the potential use of AI tools to generate initial ideas, they expressed that it was an additional skill to learn in order to use them effectively:

> *" it is a language that you have to learn in order to get what you want out of it. And that felt like another step between me and what I want to work out"*

The difference between using the AI tools to generate purely fictional designs to incorporating them into a longer bespoke process was highlighted. Miggy goes on to to say that once they had a clearer idea of what the design should look like, the tools started to produce better outcomes.

> *"I feel like that has been an interesting process. I feel once we got a bit more into that session of what it was that we were asking for, we were getting better results."*

As the project progressed and AI tools were incorporated into several stages of development, Miggy's perception of these tools evolved reflecting on the process as a whole and the role that AI tools played:

> *"Through the sessions in general, like I can see AI coming into play and being useful in some points, but as a rule, like, I've found it quite difficult to access, which is interesting when the point is around access."*

6.2 Challenges of the Speculative Design Approach

The second theme highlights the friction of a speculative design approach when working towards a bespoke accessible device. As mentioned in the first interview, Miggy touched on the difficulty of getting into the speculative mindset and they reflected on this challenge again at the end of the project:

> *"So I think it's definitely shown me some like interesting images that I thought looked really impressive, but I think in actuality, the impressiveness of them made me very sceptical about using them, because from an access perspective, that was then a limit, that was then going to be a problem, as opposed to, like something that would work."*

It was interesting to hear that Miggy saw the 'impressiveness' of the AI tools as a sign that they wouldn't be accessible to them. Miggy's reflection is an interesting response to the process and demonstrates how an image doesn't overcome access barriers and that the use of speculative design in procedural processes needs to be validated with reason or explored further through embodied activities. Miggy highlighted the importance using physical materials within the process, firstly for helping to articulate their ideas beyond the 2D images and secondly for demonstrating access considerations to be incorporated into the design:

> *"the session where we had all foam pieces and paper and stuff that was helpful, not just having visual images, but having physical things to hold and see, like where they would fit and how, where they would need to be within an object for me to be able to reach them"*

Whilst this workshop helped Miggy to understand the instrument design from a tangible perspective, Miggy also highlighted that they would have preferred to incorporate digital components earlier on in the process as the difference between seeing a button and understanding the strength needed to push it are vitally different.

> *" And so, yeah, I think if the components are available, to have them as early as possible in the process of, here is a way of making sound. Is this going to be*

> *something that you can use? Yeah? Yes, amazing. This can be a component of what comes later."*

Miggy highlights the importance of having digital components and sensors early in the process so that co-designers can make a judgment on the viability of the technologies in relation to their access requirements rather than anticipating how they might feel or behave.

6.3 Impact of the Process

Throughout the first interview, Miggy was clear in describing their experiences of playing musical instruments, before and after their injury. Miggy's account of feeling *"I used to be a musician. I am still a musician."* shows the complexities of identity that acquiring an impairment can have on musicians and the positive approach of being part of this research project is highlighted in this quote *"I'm trying to get back into doing stuff more, hence wanting a musical instrument I can use".* The conversation highlighted several frustrations that Miggy had in accessing and playing musical instruments as well as new instruments that they have tried playing since their injury. This was highlighted in this quote where Miggy was discussing their experience with the learning musical instruments available to them *"I think every time I've tried, I kind of get frustrated and have to put it down, or I give up, or it gets boring".*

Miggy described the process of designing a new ADMI as a positive experience. This is reflected in this quote that highlights the importance of design methodologies that centre the co-designer in a participatory role in the process:

> "*I can play it like, it's been really nice to be able to like, focus on what I would want to do, whether we get there exactly or not, is great, as opposed to like, well, how can I work around the problems I have with something that already exists.*"

They go onto say,

> "*Yeah it's been cool – I've been very grateful to be part of something that's making something for me – that's fun! And now I get to like use it. It's nice that it is an actual thing in of itself now.*"

It was a positive ending to the experience which highlights the importance of bespoke ADMI design. Crucially, Miggy showed that by participating as a co-designer in the process, their motivation to learn a musical instrument has increased:

> "*So yeah, I think being excited about playing music is something that has come back which I didn't really have in my head for a long time because there wasn't, like I'm sure there's not nothing I could play, I'm sure there's things but like I didn't try very hard because it was sad, right?*"

This reflection touches on the reality of many Disabled musician's experience of learning pre-existing instruments and how the motivation of learning inaccessible instruments is a difficult one to sustain. As mentioned in the first interview in workshop one with Miggy, they had tried to learn several existing musical instruments but found frustrations with the dexterity needed to play and learn the instrument to a level that they would like to.

> "*I'm really excited to learn how to play this thing. Like I know mentally how to play this thing but to go away and like actually, I don't know, create stuff on it, see how that sounds and like get to grips with it*"

By centring Miggy into the design process of an bespoke ADMI, their motivation to learn a new instrument has increased and highlights an overall positive reaction to the PAR process and the resulting instrument outcome.

7 Findings

The later workshops revealed how central physicality and embodied access were to Miggy's design experience. While the AI tools offered visually interesting possibilities, Miggy found that the speculative images rarely aligned with what was practically reachable or usable for them. The gap between visually impressive images and embodied reality created a disconnect, particularly when accessibility considerations that were clear in conversation and physical demonstration, were not reflected in the generated designs.

Introducing tangible materials and real components later in the process proved far more valuable, as these allowed Miggy to assess what they could actually hold, press and interact with. The final interview highlighted the limits of speculative, image-based design when working toward a bespoke accessible instrument from Miggy's perspective. The design process repeatedly returned to preferences of touch, accessibility of hardware components and available technology over aesthetic exploration. Despite the challenges of engaging with AI tools and speculative prompts, the co-design process overall had a positive impact by centring Miggy's access requirements, preferences and musical goals led to an instrument they felt motivated to play, underscoring how deeply bespoke ADMI design is grounded in opportunity, involvement and participatory design.

8 Discussion

The importance of different workshop modalities and physical responses are highlighted as a key finding due to their vital role of progressing image-based ideas to an understandable and relational object. Physicality and embodied responses became a key factor to respond to these perspectives as it highlighted divergences between fictional ideas and embodied responses.

Additionally, the workshop findings show a friction between speculative design and realistic, buildable musical instruments. Although speculative design practices encourage a anti-solutionist perspective [8], and proposes speculation as a method to resisting the impulse to produce solutions to defined outcomes; Miggy repeatedly articulated a desire to ground speculative designs for real world, accessible designs.

9 Conclusion

The intertwined nature of opportunity, funding, technical affordances, musical preferences, instrument designer's abilities, and available tools highlights the complex and entangled ecosystem that ADMIs inhabit. The long term collaboration with Miggy explored a wide range of novel techniques and methodologies to incorporate AI tools in several stages of ADMI design, development and fabrication. This paper demonstrates the nature of working with the novel technologies and their affordances whilst balancing with the wide range of design considerations present in a bespoke ADMI process. The ethical considerations and inaccurate behavioural affordances of the tools brings us to conclude that bespoke ADMI design remains a human-focused design process where interpretation, awareness and skills of instrument designers and collaborating musicians, remain central to the inception and fabrication of new suitable bespoke ADMIs.

10 Ethical Standards

Full ethical approval was received from the University of the West of England for the duration of this project. Participants gave informed consent to be part of this research and had the right to withdraw at any time throughout the study.

11 Acknowledgements

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Appendix A AI Tools Used Throughout the Process

A1. Generative AI Tools Used at Each Stage

The following GenAI tools were used across different stages of the design and development process:

- Midjourney was used for 2D image generation.
- Meshy API was used to convert 2D images into 3D mesh models.
- Claude LLM was used for C++ code generation.

A2. Representative Prompts

The following prompts were developed during the first workshop. Prompt 3 represents the version used to generate the final prototype for this design cycle.

(1) “a lap based digital stringed musical instrument made from digital touch sensors which has a mic input that controls the pitch of the instrument, 4K, photorealistic”
(2) “a reversible digital stringed musical instrument that you hold made with MPC pads and buttons which the pitch of the instrument, 4K, photorealistic”
(3) “a reversible digital stringed musical instrument in the shape of a body of a guitar that you hold made with MPC pads and buttons which the pitch of the instrument, 4K, photorealistic”

A3. Who Operated the AI Generators?

The AI tools were operated by the lead researcher. However, the prompt craft was a collaborative effort that foregrounded the musician’s desires within the activities, including using their own language as prompts as the basis for new designs.

A4. How Were Outputs Selected or Rejected?

Outputs were selected or rejected through speculative design activities based around the AI generated outcome, conversations around feasibility of fabricating the instrument, as well as questions around how the instrument could be accessible to Miggy’s playing style.

A5. Examples of Discarded Outputs

One example of an unhelpful output was an image generated in response to Prompt 2, which incorporated sewing buttons into the musical instrument design, deviating from the intended use of digital button switches. Additionally, during the 3D generation phase (Cycle 4), multiple iterations of the 3D mesh were also discarded due to visual and structural glitches in the outputs, as different parameter configurations were trialled.

Appendix B Mappings Between Physical Controls and Sound Engine Functions

Sensor / Component	Role / Function	Mapping Strategy	Sound Engine Function
Trill Bar 1	Melody 1	Single touch = quiet strum; multiple touches = loud strum	Triggers multiple samples within scale (mapped by velocity and density of touches)
Trill Bar 2	Melody 2	Same mapping as Melody 1, transposed a harmonic 5th above	Triggers interval-shifted notes within scale
Trill Bar 3	Drone / Strum Source	Default: drone pitch control; alternate mode: strum control	Controls pitch of sustained drone or triggers strummed layer depending on mode
Potentiometer 1	Master Volume	Continuous volume control	Global gain control
Potentiometer 2	Scale / Voicing Selector	Selects chord voicings and harmonic sets	Indexes chord voicing table based on potentiometer value and Mode Switch 1
Potentiometer 3	Sound Selector	Selects instrument from the sound bank	Switches sample set or instrument preset
Switch 1	Mode Switch	Toggles Trill Bar 3 function: drone or strum mode	Routes Trill Bar 3 output between drone and strum samples
Switch 2	Sustain	Toggles sustain behaviour	Engages note hold with short reverb
7× Arcade Buttons	Note Set Input	Single button = major; two buttons combined = minor (e.g., C + D = Cm)	Defines base MIDI pitch and chord quality for synthesis

Table 1: Mapping between physical controls and sound engine functions of Tacta

Appendix C Technical Overview of Tacta

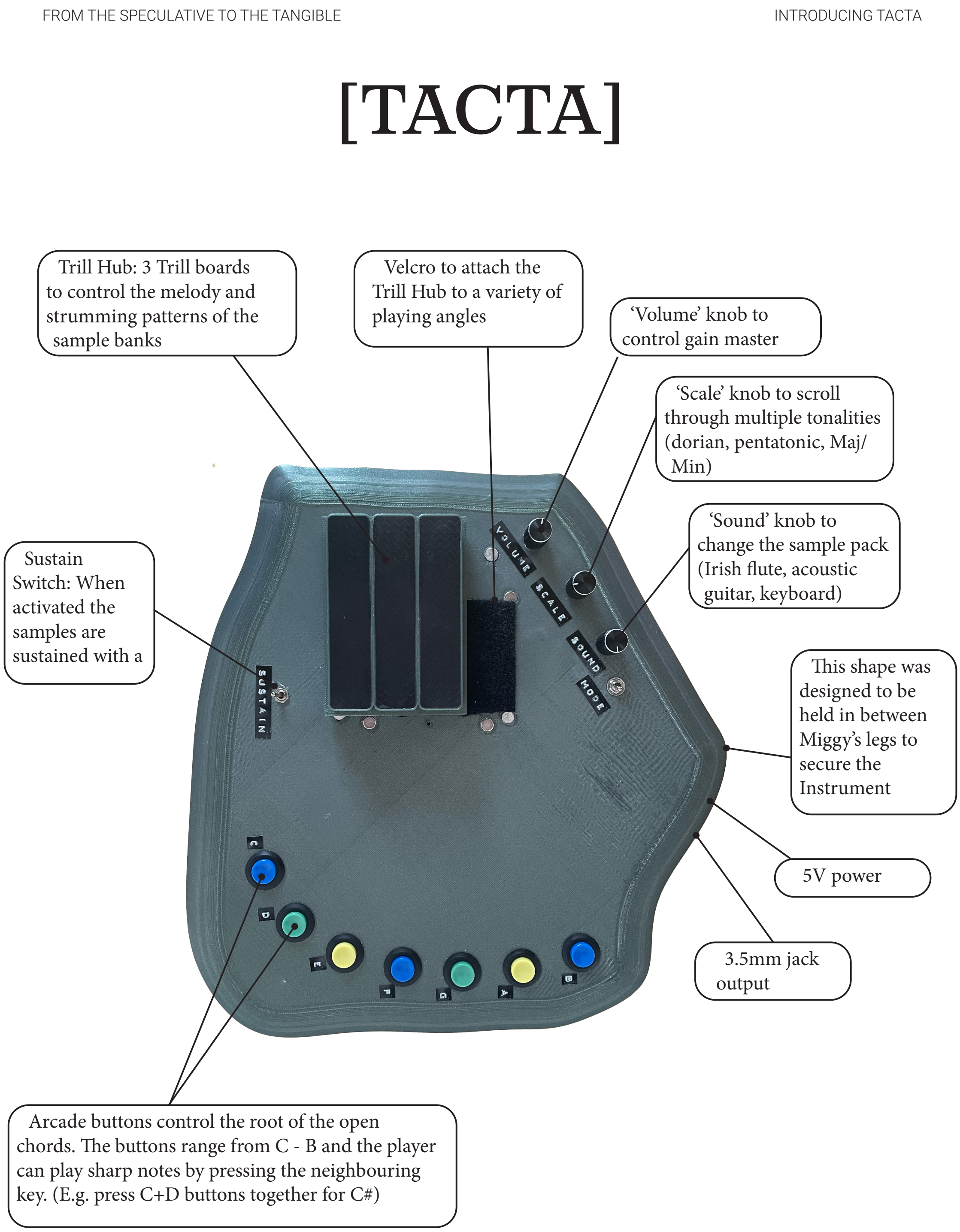

Figure 11: An overview of Tacta with corresponding component descriptions

Appendix D ADMI Design Workflow using AI tools and Rapid Prototyping Technologies

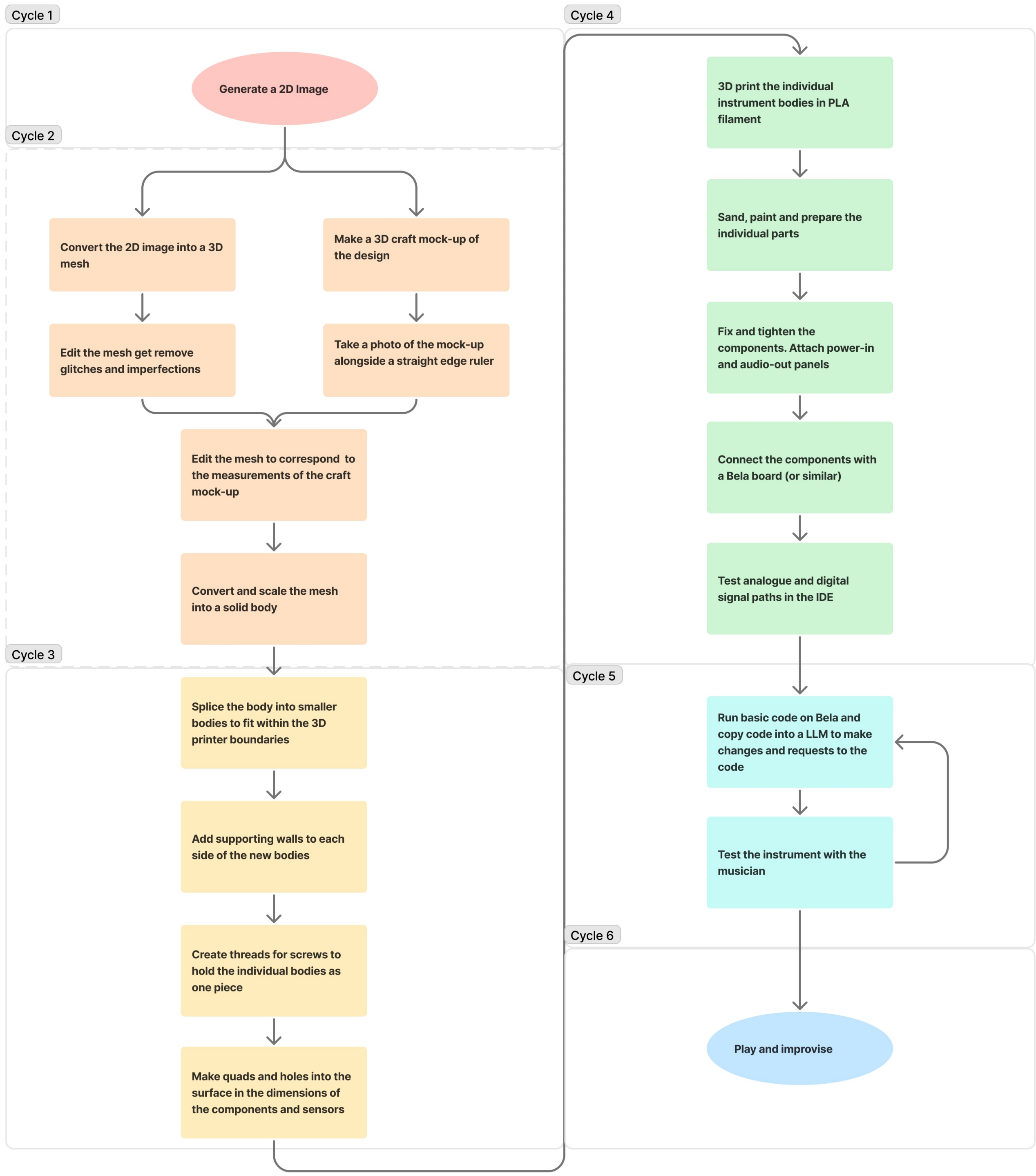

Figure 12: ADMI design workflow using AI tools and rapid prototyping technologies