

Bespoke Design for Inclusive Music: The Challenges of Evaluation

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ABSTRACT

In this paper, the authors describe the evaluation of a collection of bespoke knob cap designs intended to improve the ease in which a specific musician with dyskinetic cerebral palsy can operate rotary controls in a musical context. The authors highlight the importance of the performer's perspective when using design as a means for overcoming access barriers to music. Also, while the authors were not able to find an ideal solution for the musician within the confines of this study, several useful observations on the process of evaluating bespoke assistive music technology are described; observations which may prove useful to digital musical instrument designers working within the field of inclusive music.

Author Keywords

NIME, accessibility, HCI, inclusive music, assistive music technology, 3D printing

CCS Concepts

- Applied computing → Sound and music computing;
- Human-centered computing → Empirical studies in accessibility;

1. INTRODUCTION

Over recent years, there has been an increase in the design and fabrication of bespoke assistive music technologies (AMTs), designed as a means for overcoming access barriers to music performance and composition and, in part, facilitating inclusion in music. Access barriers can remain hidden from designers if they do not directly experience them, which makes the validation of AMT designs through a robust evaluation process particularly important. In this paper, the authors describe the evaluation of a *seemingly* simple solution to an access barrier faced by an individual with cerebral palsy when operating rotary controls on commercially available digital musical instruments (DMIs). The authors discuss the ethical, social and practical considerations which arose while working with the participant and conclude by reflecting on how this study will inform their future practice.

2. DESIGNING FOR A SINGLE MUSICIAN

Commercial product designers, often encapsulate the goals, behaviours and abilities of a broad target *user-group* into a fictional archetype known as a *persona*. The use of personas is widespread in the design of digital products and services [6], including the design of DMIs. Personas feature a name, demographic and a constructed narrative. In some cases, stock imagery is used to bring life to these fabricated characters. Personas are a useful tool, used by designers, for keeping the requirements of the target user-group at the forefront of their mind when making design decisions. Unfortunately, often the persona approach does not suitably factor in any variance from 'atypical' abilities in a user-group. There are some efforts to avoid the exclusion of individual users in the design process, for example through the use of *diverse personas* [1] in inclusive design practices which aim to describe individuals living with certain conditions. However, within the disabled community, even under the same medical diagnosis, the lived experience of individuals can vary considerably from person to person.

There is value in evaluating new DMI designs regardless of whether they are intended to be used by a broad user-group or by an individual. It is important to note however that the goals of a DMI evaluation, the evaluation criteria and the intended outcomes of the evaluation can vary considerably depending on the nature of the design. For example, one designer may be particularly interested in how a DMI performs with a broad user-group in regard to Donald Norman's criteria for good design [11], that of *visibility*, *good conceptual model*, *good mappings* and *feedback*. A qualitative study with many participants may be applicable here. Whereas a second DMI designer may be more interested in the speed and accuracy in which it is possible to accomplish a specific musical action, therefore a series of quantitative tests may be a more appropriate means of evaluation. An essential question to ask is from whose perspective is the evaluation based, that of the performer, the designer or the audience? The adage 'Nothing About Us Without Us', encapsulates the idea that people with disabilities know what is best for themselves and their communities [2], a philosophy that also extends to the design of AMTs. Musical performance is an action that aims to be a conduit of individual expression, therefore it is understandable that more often than not the performer's insight is sought in DMI evaluation [9]. The apparent value of the performer's perspective serves to increase further the importance of involving users of bespoke AMT in the evaluation process.

3. AN EVOLUTION OF THE KNOB CAP

In order to operate a rotary potentiometer, such as those featured on Novation's Launchkey range of MIDI controller



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keyboards¹, the user will typically pinch the knob cap between their thumb and index finger of one hand and roll the knob cap a short distance across the finger and thumb respectively. Also, there will often be some degree of wrist movement, either *ulnar flexion* or *radial flexion* [3], depending on the direction of rotation. For the remainder of this paper, the term *pinch-roll* is used to describe the typical actions involved in operating a rotary potentiometer.

The actions of moving one's hand to the position of a small control, extending specific fingers, pinching with appropriate force, moving fingers in a controlled manner and flexing the wrist can be challenging for individuals with impaired motor control. Placing these actions in a musical context adds complexity. The user may be executing other actions in tandem, for example, playing keys or may face the added pressure of completing time-based actions such as that of changing a parameter to a target value before the end of a musical section. There are of course ways to work around the access barriers some individuals face when controlling musical parameters with rotary potentiometers. One solution is the application of an alternative control modality. Faders (i.e. sliding potentiometers) that feature a *DJ-style* raised cap, while also typically pinched between the thumb and index finger when being operated, support pushing and pulling actions which, in comparison to the pinch-roll action can be more efficiently executed by other parts of the hand or indeed other body parts. Rotary potentiometers are ubiquitous in commercial music technology devices, often used as the primary control modality for parameters which are not MIDI assignable, for example, menu navigation and configuration, or sound-sculpting parameters on analogue synthesisers, therefore remaining inaccessible to some. There is value in exploring adaptive techniques for improving rotary control accessibility.

The authors' original intentions for this study were, through the application of an action research methodology, to provide a particular individual with a disability with improved access to rotary potentiometers in a musical context. Bespoke design is a viable option for tackling access barriers faced on an individual level due to the complex and unique manner in which disabilities can present themselves. As part of the ethical considerations of this study, any accessibility improvements needed to apply to equipment available to the participant. Furthermore, it was deemed that at the end of the study, the participant must be provided with any solutions deemed to improve access.

3.1 Participant Background Information

The participant is male, thirty-six years of years of age and has been composing and performing music with the inclusive music organisation, the *Drake Music Project Northern Ireland* (DMNI) for approximately twenty-five years. The primary author of this paper has been supporting the participant at weekly DMNI music workshops, in the capacity of an *Access Music Tutor* for approximately twelve months. Out of all of the mainstream and assistive music technology devices available for use through DMNI, the participant's preference is mainstream MIDI keyboard controllers. The participant has access to a Novation Launchkey 61 MkII MIDI controller keyboard at DMNI music workshops; the study, therefore, focused on this device. The participant has *dyskinetic cerebral palsy*, a condition which affects aspects of motor control skills and expressive language capabilities [10]. The participant often experiences involuntary movements when attempting to move in a controlled manner which makes it challenging for the participant to target

physical objects with his upper limbs. Due to low/weak muscle tone, the participant experiences stiffness and resistance to movement in his hands and fingers, resulting in considerable difficulty executing the pinch-roll action. Rotary potentiometers are not currently a viable control modality for the participant. Therefore, when presented with the task of manipulating a continuous musical parameter during a workshop, a MIDI-assignable DJ-style fader is typically used. While research suggests that there is no performative difference between sliding and rotary potentiometers [4], personal preferences do exist. For example, it may seem alien to some to control a parameter such as audio signal panning on a sliding potentiometer. Both the participant and the authors had a desire to expand the number of control modalities available to the participant to include rotary potentiometers.

3.2 Design Goals

There were two primary design goals: 1) To improve the ease in which the participant can rotate the rotary potentiometers of the Launchkey, 2) To improve the ease in which the participant can target these controls.

By way of physical attributes, the Launchkey features a row of eight rotary potentiometers spaced 23mm apart (centre to centre). These controls feature a 6mm *D-shaped* shaft. End stops constrain rotation at approximately five and seven o'clock.

3.3 Alternative Designs

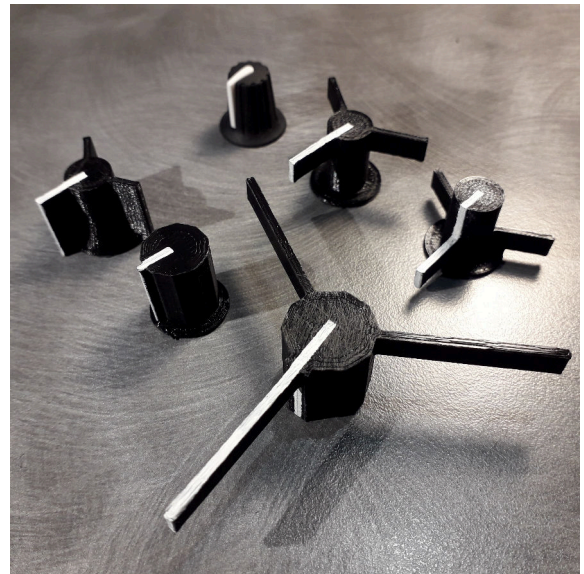


Figure 1: Alternative designs fabricated from PLA plastic filament alongside the original knob cap.

Through the successful use of faders, the participant has previously demonstrated that both *push* and *pull* actions are achievable. Modifications to the design of the original knob cap can provide affordances that support these alternative actions. *Fitts's Law* is an empirical model which describes the trade-offs between speed and accuracy in human muscle movements [5]. According to the *Index of Difficulty* described in Fitts's Law, in addition to the distance the participant's hand is required to travel, the size of the knob cap is likely to be a factor in how easy it is for the participant to target.

The study proceeded based on the hypothesis that push and pull actions are a viable way to operate a rotary potentiometer and that larger knob caps, will be easier to target.

¹<https://novationmusic.com/keys/launchkey>

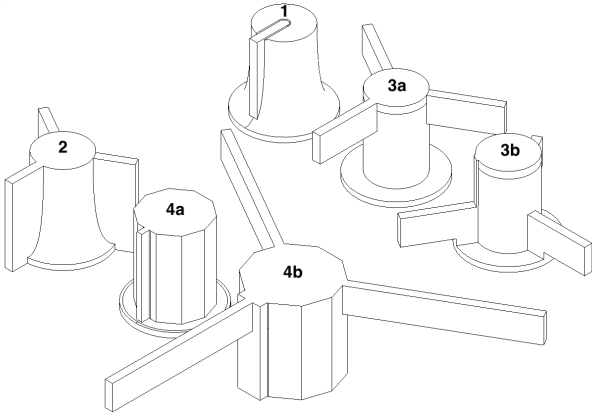


Figure 2: Original Knob Cap Alongside Alternative Designs.

In preparation for the evaluation phase of this study, the following three alternative designs were fabricated from polylactic acid (PLA) plastic filament using a 3D printer, shown alongside the original knob cap (Design 1) in Figure 1.

3.3.1 Design 1: The Original Knob Cap

The original knob cap features a flange at the base of 16mm in diameter. At the top of the knob cap, the diameter is much smaller at just 9mm. A white, positional pointer protrudes from the side of the knob cap. A rubber material covers the knob cap providing the user with additional grip.

3.3.2 Design 2: Constrained Tri-Blade

The introduction of three blades in this design aims to provide the user with contact points which can be pushed or pulled by a single finger. Design 2 is 'constrained' in size to allow use on adjacent controls of the Launchkey without the blades touching each other.

3.3.3 Design 3: Overlapped Tri-Blade

Design 3 consists of two knob caps (3a and 3b), each with three blades extended in length in comparison to Design 2. The blades of these two knob caps are designed to overlap one-another upon rotation.

3.3.4 Design 4: Keyed Tri-Blade

Design 4 consists of two parts: a modified knob cap (4a) and a key (4b). The intention of this design was for the user to fit the key to the control they would like to operate. As the key is not a permanent fixture, it is viable for the blades to extend over adjacent controls. The knob cap and key each feature an embedded magnet which assists in their connection.

3.4 Evaluation

It was in planning the evaluation of the knob cap designs that the authors began to gain an insight into the challenges of evaluation in the context of bespoke AMT. Often one of the first questions asked in any study is whether to test the hypothesis by qualitative or quantitative means. As discussed earlier, the performer's perspective was perhaps, above all else, the most important perspective to understand, regarding the effectiveness of each design, this observation suggested to the authors that a qualitative study would be appropriate. A common approach for gathering

insight into an individual's perspective is through the use of semi-structured interviews; historically, researchers have excluded participants with expressive language impairments from such studies [8]. The authors were keen not to rule out such an approach but as the participant does not use any communication aids, the authors needed to be vigilant in ensuring they did not misunderstand and therefore misrepresent the views of the participant. A quantitative approach to evaluation also presents challenges in this context. When designing for a broad user-group, one can obtain useful quantitative data from task-based evaluations with multiple participants. The alternative knob cap designs are intended to overcome unique access barriers faced by an individual. For this study it would not have been overly useful to test the designs with other participants. Also, the authors were mindful of participant fatigue and therefore factored this into the evaluation of the knob caps by limiting the overall number of tasks. Due to time constraints and the availability of the participant, it was not possible to run multiple tests; therefore the quantity of quantitative data collected for this study was limited.

In order to adequately evaluate the alternative knob cap designs, it was vital to test them in context. A peculiarity of musical tasks is that not only do they need to be executed with accuracy, often tasks are temporal due to the consideration of musical timing and rhythm [12]. Commonly used in HCI quantitative evaluation, Fitts's Law also has relevance in the assessment of DMIs, particularly in a temporal context. Limited research exists regarding the applicability of Fitts's Law in movement studies with individuals with cerebral palsy. However, a 2002 study conducted with a group of eight individuals with cerebral palsy suggested that the movement times of the individuals in this group did not conform to Fitts's Law [7]. A secondary consideration is the relevance of strict musical timing in this context. Often in music workshops at DMNI the participant is provided with support to allow him to play musical passages *in-time*. The use of MIDI quantisation and arpeggiators were factors considered when devising the context in which to test the knob cap designs. Bearing in mind the considerations listed above, the authors decided to follow a holistic approach in the evaluation of the knob cap designs as described below.

3.4.1 Scenario

A fabricated musical scenario, based on activities the participant might typically be engaged in during a music workshop, provided a context for the evaluation. The participant was asked to perform a series of tasks, based mainly upon control rotation. The knob caps under test were placed on the two rotary potentiometers to the far left of the bank of eight on the Launchkey, in *Position 1* and *Position 2*. This placement allowed, each knob cap design to be tested with adjacent controls either side and with just one control to the right of the control under test. Video footage of the test session was recorded for later analysis along with MIDI CC data from the two controls for each task performed. The Launchkey was configured to control a monophonic virtual software-based instrument. The virtual instrument played a latched arpeggiated pattern based on input from the keyboard of the Launchkey removing the requirement for the participant to press and hold keys while operating the controls. The two controls under test were assigned to the *Filter 1 Frequency* and *Filter 2 Frequency* parameters of the virtual instrument.

3.4.2 Tasks

The participant was asked to perform the following tasks with each knob cap design, placed on controls in Position 1

and Position 2 of the Launchkey, amounting to forty tasks:

1. Rotate the control from fully anti-clockwise to fully clockwise.
2. Rotate the control from fully clockwise to fully anti-clockwise.
3. Rotate the control from fully anti-clockwise to its central position.
4. Rotate the control from fully clockwise to its central position.

A series of additional tasks were planned to ascertain the ease in which the participant could move the the key of design 4 (4b) between the two controls.

1. Move the key from Position 1 to Position 2. Each control is set to its fully anti-clockwise position.
2. Move the key from Position 2 to Position 1. Each control is set to its fully anti-clockwise position.

These tasks were stopped early due to the obvious challenging access barrier presented to the participant. Therefore the authors have decided to only document the first four tasks.

3.4.3 Difficulty of Use Criteria

Before beginning the evaluation, the authors devised a list containing criteria that, if met would indicate the participant is having difficulty operating the control.

1. The participant inadvertently operates a different control.
2. The participant cannot rotate the control.
3. The participant cannot set the control to the target position.
4. There are pauses in the operation of the control (i.e. none smooth operation).
5. The participant moves the control in a direction opposite to that intended.
6. The knob cap becomes detached from the control.

In addition to the criteria above, the primary author had a conversation with the participant where he was asked to provide his subjective opinion on which knob cap design he found most comfortable to operate.

3.5 Observations

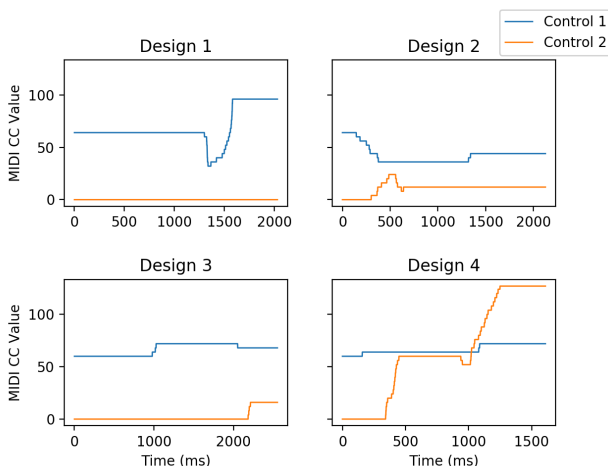


Figure 3: A depiction of the MIDI data recorded during Task 2.

3.5.1 Quantitative Results

Task 2 involved the participant rotating the control in Position 2 from a fully anti-clockwise position to a fully clockwise position with each knob cap design. It is clear, from examining the captured MIDI data displayed in Figure 3, that a number of the *Difficulty of Use Criteria* are present for all four designs, indicating that participant was experiencing difficulty in operating the controls with ease. For example, it is apparent that for each design the participant had difficulty not inadvertently changing the value of the control in Position 1. During Task 2, the control in Position 2 reached the target destination on only one occasion, when Design 4 was under test. Figure 4, provides an overview of how often each design met the Difficulty of Use Criteria. Although a somewhat limited amount of data, some provisional observations can be made through examination of Figure 4, as listed below.

1. Use of blades on a knob cap increase the likelihood that the participant will be able to rotate the control.
2. Knob cap blades increase the likelihood of there being pauses in control data when being operated by the participant.
3. The larger the knob cap blade, the greater the likelihood of the participant operating the control in the opposite direction to that intended.

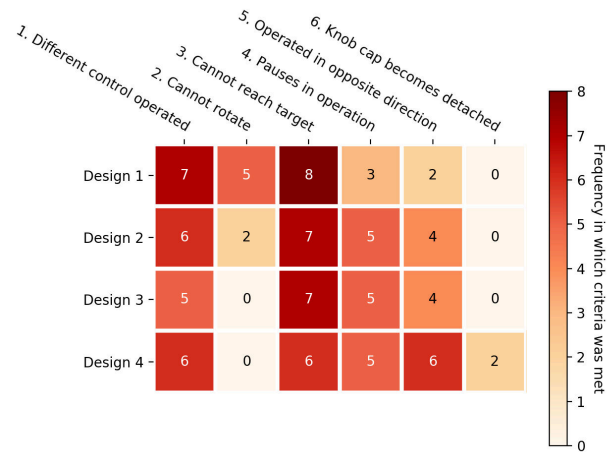


Figure 4: The frequency in which the Difficulty of Use Criteria were present for each design.

3.5.2 Qualitative Results

The primary author was able to make the following observations, from a designers perspective, after observing the participant during the evaluation session. First, the primary author gained a clear understanding how the participant operates rotary potentiometers with regular knob caps. In the evaluation session, the participant would typically position the index finger of his left-hand perpendicular to the top surface of the Launchkey and then proceed to roll the side of his finger around the side of the knob cap, starting at the side furthest from him, pulling his finger back towards himself. The participant essentially performs the *roll* of the pinch-roll action in isolation. At times, the participant extended the other fingers of his left hand which resulted in the inadvertent operation of adjacent controls. The rubber coating of the original knob cap (Design 1) provides additional grip, a physical attribute which the participant benefited from when operating the controls in the manner

described above. Rotations were often performed in stages as the participant would need to reposition his finger several times to rotate a control across its entire travel.

The participant demonstrated that the blades present in the alternative designs did indeed provide affordances which supported push and pull actions. However, the height of the blades and the position of the control under test appeared to add significant factors in how easy it was for the participant to operate the control. Design 3b with its low blades, embedded between two controls was challenging for the participant to operate due to there being little room between adjacent knob caps for the participant to navigate his index finger between, particularly when the blades of Design 3a were obstructing the path of the participant's finger.

When using the alternative designs, it was clear that the participant still needed to operate the control in stages to perform a full rotation across its entire range. On occasion, the blades appeared to impede the participant's ability to reposition his finger during a control operation; the participant was required to lift his finger over at least one blade to reach a comfortable position to start the next stage of rotation.

The primary author observed conformity to the Index of Difficulty described in Fitts's Law as the largest of the knob caps (Design 4) appeared to be more comfortable for the participant to target. However, a significant issue occurred with this design; the key became detached from the control on two occasions during the test.

With regards to the performer's perspective, the primary author asked the participant for his subjective opinion on which design he found most comfortable to use. At the end of the evaluation session, using multiple choice response methods, the participant indicated that he found Design 4 most comfortable to use. The tests progressed in numerical order of design, from 1-4. During the evaluation session, the participant indicated that each design was progressively easier than the last to operate, suggesting that an increased size in knob cap improved ease of use.

On an aside, a secondary access barrier presented itself when using the Launchkey in this context. In order to reach the rotary controls of the Launchkey, the participant is required to extend his arm forward. The participant's forearm has a somewhat fixed position. The keys of the Launchkey were inadvertently pressed by the participant's forearm when operating the rotary controls. The Launchkey was placed on a wheelchair accessible table and therefore positioned quite high from the floor during the evaluation. Use of a height adjustable keyboard stand, suited to the dimensions of the participant's wheelchair might help to overcome this secondary access barrier in future evaluations.

4. CONCLUSIONS

In this paper, the authors described the challenges of evaluating bespoke assistive music technology designed for a musician with dyskinetic cerebral palsy. The authors experimented with a holistic approach to the evaluation of a series of knob caps designed as a means of overcoming the unique access barriers faced by this musician. Quantitative data and qualitative observations, coupled with the views of the participant, helped to paint a picture as to the effectiveness of each knob cap design regarding improving the ease of operation of rotary controls. At this initial stage of the design, the authors have shown that larger knob caps improved the ease at which the participant could target controls. However, through analysing the knob cap designs against the Difficulty of Use Criteria devised by the authors, they cannot conclusively say that one design was

easier for the participant to operate than another. This work will inform the next stage of designing and testing, to be carried out in February - March 2019. At the beginning of this paper, observations made by Barbosa et al. [9] coupled with philosophical views of inclusion held by the disabled community represented by the adage of Nothing About Us Without Us [2], the authors noted the importance of the performer's perspective in a study of this kind. The participant provided such a perspective in this study. The authors would benefit from discussing further with the performer his preference for Design 4 as this would help to inform future iterations of the design. The authors made some progress toward their original design goals but have not yet completed this journey.

5. ACKNOWLEDGMENTS

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