Sound Control: Supporting Custom Musical Interface Design for Children with Disabilities

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ABSTRACT

We have built a new software toolkit that enables music therapists and teachers to create custom digital musical interfaces for children with diverse disabilities. It was designed in collaboration with music therapists, teachers, and children. It uses interactive machine learning to create new sensor- and vision-based musical interfaces using demonstrations of actions and sound, making interface building fast and accessible to people without programming or engineering expertise. Interviews with two music therapy and education professionals who have used the software extensively illustrate how richly customised, sensor-based interfaces can be used in music therapy contexts; they also reveal how properties of input devices, music-making approaches, and mapping techniques can support a variety of interaction styles and therapy goals.

Author Keywords

Instrument design, accessibility, interactive machine learning

CCS Concepts

•Human-centered computing → Accessibility systems and tools; •Applied computing → Sound and music computing; •Computing methodologies → *Machine learning;*

1. INTRODUCTION

We have created a new software toolkit, Sound Control, that uses interactive machine learning to enable music teachers and therapists to build custom digital musical interfaces for and with children with a wide range of disabilities. This work was motivated by teachers' and therapists' desire to more flexibly customise digital instruments for children they worked with. The software design was informed by eight workshops with music therapists and teachers, seven sessions observing and supporting two practitioners working with children, and interviews with these two practitioners after more than six months of using the software. These activities helped ensure the new software would be appropriate and usable for teachers and therapists, including those without extensive technology experience. Further, they helped inform a better understanding of how more richly customised interfaces can be used in music therapy contexts, and of how properties of input devices, music-making approaches, and mapping techniques can support a variety of musical interaction styles and therapy goals.

2. RELATED WORK

The British Association for Music Therapy defines music therapy as "an established psychological clinical intervention, [delivered by] registered music therapists to help people whose lives have been affected by injury, illness or disability through supporting their psychological, emotional, cognitive, physical, communicative and social needs" [1]. When offered to people with disabilities, music therapy can "provide a means of self-expression," "empower people by offering choices," "encourage and stimulate physical movement and co-ordination," "help child[ren] to listen," "nurture social interaction and communication skills," and "excite imagination and creativity." Therapists tailor the activities and goals of a session to each client, and improvisation is a common practice in therapy sessions.

Several technologies have been developed to support music performance and therapy for people with disabilities. Some function as simple instrument-building toolkits that combine specific sensing hardware (e.g., Soundbeam[1] uses ultrasonic distance sensors and switches, Skoog[2] uses pressure-sensitive pads, AUMI [7] a webcam) with sound playback and/or MIDI functionality. Their GUIs enable users to choose the sound samples and/or MIDI notes triggered, as well as the sensing sensitivity and range. These tools often offer quite conventional music-making approaches, for instance making tonal melodies. With a few exceptions (e.g., Skoog's aftertouch control), they offer little ability for users to continuously control sound qualities such as pitch or timbre. While some more general-purpose ac-

[1] www.soundbeam.co.uk
[2] http://skoogmusic.com

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cessible input devices can also be used to make music (e.g., switch buttons[3] or eye trackers[4]), usage is typically to trigger samples or notes, with limited configuration ability (e.g., changing the choice of sample).

Instruments with more diverse sensing capabilities and musical control approaches have occasionally been engineered for specific individuals with disabilities. Such work is supported by organisations such as the British Paraorchestra[5], Drake Music[6], and the One-Handed Musical Instrument Trust[7]. However, the expertise and expense required to build such instruments puts this option out of reach for most people with disabilities and their collaborators or families.

Frid [4] reviews 30 recent papers on accessible instruments published at NIME, Sound and Music Computing, and the International Computer Music Conference. Most of these papers concern instruments with a limited degree of end-user configurability (e.g., the ability to change samples or re-position sensors) rather than describing toolkits that disabled people, teachers, or therapists can use to assemble unique DMIs. Further, Frid notes that most of these were developed for performance, not therapy.

Interactive machine learning (IML) methods can make it faster and easier to build complex interactions with sensors, even for people without programming expertise, and even with noisy and high-dimensional sensors. For instance, Wekinator [2] and GRT [5] enable users to create new mappings from actions (sensed with arbitrary sensors) to sound synthesis or playback parameters, by providing examples of actions and sounds the user would like in response to those actions. A supervised learning algorithm learns the desired relationship between sensor data and sound parameters from these examples and produces a model capable of controlling sound as a user interacts with sensors in realtime. Users can modify an instrument by iteratively adding or removing examples.

IML has been used by professional DMI creators (e.g., [9]) and for configuring commercial DMIs[8]. Katan et al. [6] experimented with IML to support bespoke instrument creation for adults with disabilities in public event contexts, but found it cumbersome to train new personalised instruments on-the-fly; instead, they used IML to create static instruments that could be played by people with diverse ranges and patterns of motion. Scurto and Fiebrink [8] conducted a workshop with disabled youth in which they trialled a faster but less precise approach to building mappings from demonstrations, called "grab and play" mapping. They found this approach promising for quickly building instruments matched to the unique range of motion of each person. Yet to our knowledge, no other work has used IML to offer greater musical customisation possibilities to people with disabilities, nor explored how therapists or teachers might want to exploit greater customisability.

[3] `www.inclusive.co.uk/ablenet-bigmack-p2039`
[4] `www.inclusive.co.uk/ii-music`
[5] `http://paraorchestra.com/`
[6] `www.drakemusic.org/`
[7] `www.ohmi.org.uk`
[8] e.g., `https://mimugloves.com/`

3. DESIGN PROCESS, REQUIREMENTS

The Sound Control project was initiated by music educators and music therapists associated with a community music centre's "Musical Inclusion" programme. Programme members worked with a wide variety of youth—including but not limited to children with physical and learning disabilities—in one-on-one and group settings. Some had previously used technologies such as SoundBeam and Skoog. All had experience supporting youths' acoustic music-making (e.g., singing, using simple percussion instruments) and using simple switch-based controllers to trigger pre-recorded samples. They were aware of bespoke instrument design projects such as those led by Drake Music, and they were interested in how they might use bespoke sensor-based instruments with youth in their programmes.

Our team led eight workshops (approximately 1–3 hours each) with Musical Inclusion programme personnel and other music therapists and educators from the local community. Early workshops showed participants demonstrations and videos of existing approaches to creating bespoke musical instruments (e.g., the British Paraorchestra, Wekinator), then engaged participants in brainstorming activities. In later workshops, we taught participants to use prototype technologies developed for the project, then elicited feedback about them. In parallel, our team attended seven classroom and workshop sessions in which two practitioners from the programme worked with children with disabilities in a school (five sessions) or community centre (two sessions). In the first three sessions, we used prototypes based on existing technology to support the creation of new instruments. These used input devices such as webcams, game controllers, and eye gaze trackers; sound synthesis playback patches written in Max/MSP and Chuck; and Wekinator and its "Grab-and-play" extension [8] for quickly building mappings. The last four sessions employed increasingly mature prototypes of the software developed for this project, called Sound Control. A typical session involved one teacher or therapist working one-on-one with 3–6 children for 10–30 minutes each, with members of our team helping with technology as needed. Additionally, the two practitioners began using Sound Control independently after the fourth of these sessions, and they sent us bug reports, feature requests, and updates on their usage by email.

By the fifth design workshop, we had agreed on the target users and design requirements for the project. The target users were children with diverse disabilities (including profound and multiple learning disabilities, as well as significant motor disabilities), ages 6–11. A long-term goal was to support collaborative music-making (including supporting participation of disabled children in mainstream music classrooms), but the near-term focus was to support children in individual music sessions guided by a therapist or teacher who would manage the instrument creation in software. The new technology should enable adults to configure instruments for a child very quickly (diverting the adult's attention for under a minute at a time, ideally much less), and it should support music-making using a wide variety of physical actions and ranges of motion. It should run on a standard laptop and require a minimum amount of custom hardware. Further, it should support a variety of sound-making activities—not only playing melodies and triggering samples, but also other activities appropriate to diverse child preferences and educational or therapy goals (see Section 5).

Functionality offered by Wekinator and its Grab-and-Play extension [8] supported the creation of such instruments to an extent, but workshops showed these were too complicated to support efficient use by music therapists and teachers. Further, those tools merely offer functionality for mapping creation; they rely on external modules to acquire sensor data and produce sound. Implementing such modules is outside most teachers' and therapists' expertise, and in any case, it was unclear what functionality such modules should entail for this context of use. Designing appropriate sensing and sound-making capabilities for this new software therefore involved substantial research and prototyping effort in the subsequent project activities.

4. THE SOUND CONTROL SOFTWARE

The Sound Control software (see Fig. 1 and accompanying video) is implemented in Max/MSP and distributed as a standalone application.[9] The current version supports ten types of inputs (Fig. 1, top). These include three webcam-based modes: two track one or more user-defined colours (e.g., to track a toy or piece of clothing in front of the camera), and one uses low-level video features to capture changes in lighting or position. Mouse position and microphone volume (e.g., sensing breath on a headset mic) can also be used without any specialist hardware. Sound Control also supports input from Leap Motion (to track palm position or hand width), BBC micro:bit (a device many schools already use; senses 3 axes of tilt or touch), and GameTrak (a game controller sensing 3D position of two strings pulled from a base [3]). The software supports six modes of music-making (Table 1), which use digital sound synthesis, MIDI, and samples. The software comes pre-loaded with sample banks and users can also add their own.

To create a new instrument, a user first chooses one input and one music mode using the top interface in Fig. 1. Clicking the "Generate" button then launches a new window (e.g., Fig. 1, bottom) containing, from left to right: (i) a monitor of the input, with ability to customise the input if applicable; (ii) a GUI for controlling the sound mode (e.g., adjusting volume, choosing or importing samples); and (iii) a "training" GUI for specifying how the input should be mapped to control over the sound.

Sound Control offers two methods for creating mappings. The first ("precise") employs IML in a manner similar to Wekinator. When a user clicks the "Precise" button, a series of training examples are created, each using the current input sensor values as its feature vector and the current value(s) of its sound parameter(s) as its target(s). A learning algorithm immediately trains on these examples to build a model of the desired mapping. Clicking "Run" will run this model in realtime, so that new sound parameters are continually predicted from the current sensor values. To modify a mapping, a user can click "Precise" again to add more examples and immediately train a new model on all previously recorded examples. Clicking "Clear" erases all examples; "Undo" erases only the last batch. Sound Control employs the k-nearest-neighbour ("kNN") algorithm for classification and a multilayer perceptron neural network ("NN") with one hidden layer for regression, using a Max external built on the RapidMix C++ machine learning library[10]. These algorithms were chosen because they are capable of learning complex mapping functions from small numbers of examples. (They are also the default algorithms in Wekinator.)

All music modes but Sample Player and MIDI Mapper also offer a second approach, "quick" mapping creation, which functions similarly to "grab-and-play" mapping [8]. In this mode, a user holds the "Quick" button while demonstrating a range of input values (e.g., demonstrating the full range of motion one intends to use for the instrument). Upon releasing the button, a new mapping is built that randomly associates different input values in this range with different sounds. This is implemented by generating a small supervised learning training set in which several of the observed input values are used as feature vectors, and each of these is randomly associated with a set of sound parameter values (within an allowable range). A supervised learning algorithm is then trained on this set. Users can therefore refine these mappings simply by adding additional examples using the "precise" mode to modify the trained model.

5. HOW AND WHY PRACTITIONERS USED SOUND CONTROL

The two practitioners ('JH' and 'RP') observed in the seven observation sessions have now each used Sound Control on their own for nearly one year. JH is a music therapist and music teacher with 25 years' experience working in special needs schools. She was previously familiar with some music technologies (SoundBeam, Skoog) but did not use them regularly in her work. RP is a professional musician and music teacher with 5 years' experience working as a teaching assistant in a special needs school. She had not used any technology beyond switches before this project. After they had used Sound Control independently for more than six months, we conducted one-on-one semi-structured interviews with JH and RP to learn about how and why they integrated it into their work. Interviews lasted 32 (JH) and 56 (RP) minutes. They were audio recorded and transcribed.

5.1 Context of Use

Nearly all their usage of Sound Control has been in one-on-one music therapy sessions in special needs schools, with children aged 6–11. The children have a very wide range of physical and learning disabilities.

[9] Sound Control is open source and can be downloaded from `http://www.soundcontrolsoftware.com`.

[10] `www.rapidmixapi.com`

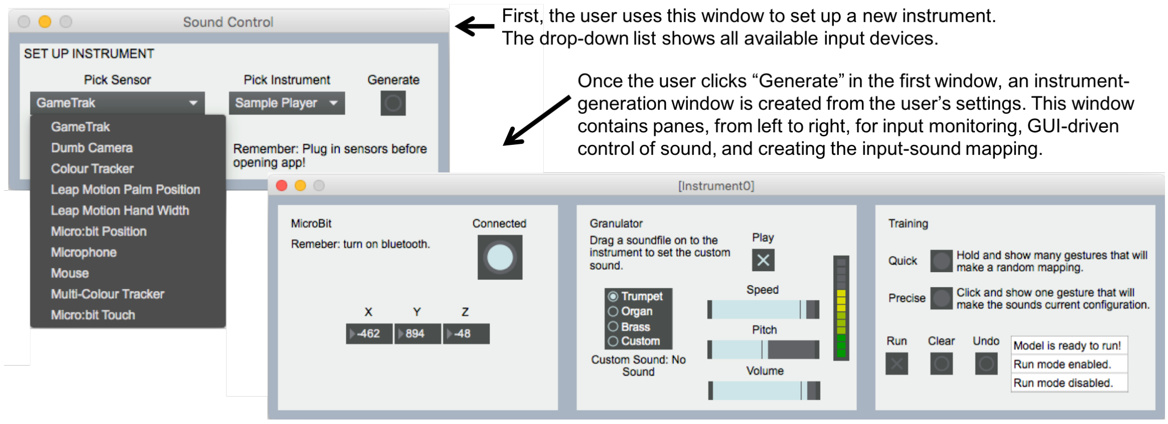

Figure 1: The Sound Control software

Table 1: Sound Control's music/sound modes, chosen using the "Pick Instrument" list in Fig. 1.

Name	**Description**
Sample Player	Triggers sample playback (one sample at a time). Uses kNN to choose which sample.
Granulator	Smoothly controls a sample's speed, pitch, and volume using 3 NNs. kNN turns sound on/off.
Looper	Uses kNN to choose a combination of up to 6 simultaneous samples to play as repeated loops.
Mixer	Smoothly control the volume of three samples, using 1 NN per sample.
FMSynth	Smoothly controls carrier frequency, harmonicity, and modulation index of FM synthesis using 3 NNs. A kNN turns sound on/off.
MIDI Mapper	Triggers MIDI notes and/or chords; MIDI can be played from the app or in another application such as GarageBand. Uses kNN to choose current note(s).

Many use wheelchairs, and many have significant limitations in their motion range, accuracy, and strength. Many do not communicate verbally. Some are good at following complex instructions; others often do not respond in obvious ways to spoken interaction. Some are autistic. Some experience changes in their range of motion, energy level, and other factors over time.

5.2 Reasons to Use Customisation

JH and RP both made extensive use of the ability to create customised instruments, changing the input device, sound mode, and mapping often. As originally anticipated, they made entirely different interfaces for different children, tailoring their choice of input method and sound (see Sections 5.3, 5.4) to each child's motor skills and preferences. However, the goal of customisation was almost never to build personalised instruments that enabled children to play specific musical material in a performance. Rather, JH and RP used their ability to create custom interfaces to achieve a number of other goals.

5.2.1 Recognising and exercising agency

Foremost among these goals was to build interfaces that enabled children to exercise control over their environment, and to recognise that they were doing so. RP described "step one of using Sound Control" as getting children to discover that "that they are making a difference." She often began sessions by building a new instrument that mapped a child's frequent movements (whether intentionally executed or not) to very obvious changes in sound, to encourage children to notice that their actions were changing the sound.

JH saw instruments as vehicles for offering a child more choice. For her, building instruments that offer a richer space of possible sound qualities than existing interfaces (e.g., for sample triggering) was essential: "if [a child] really wants to do something really loud one day, then they can only do that [with other instruments/tools] if I give them that option, whereas they'd be able to do that themselves [in Sound Control]." Exercising choice is especially important for children who often cannot communicate their preferences or control their environments in other contexts: "Because really what they need is to be able to tell people what they want and what they don't want... even if they don't do anything else, that's huge, because everything's done to them, so this is a chance for them to do something for themselves." Over time, JH often changed instrument configurations as she learned more about what sounds a child enjoyed—offering them choices increasingly tailored to them.

5.2.2 Encouraging moving and listening

Encouraging particular physical movements was another common goal. For instance, JH described creating an instrument for a child whom she knew needed practice "bringing his hands to mid-line." This was usually frustrating for him, but linking sound changes to his motions was enough to motivate him.

JH and RP both described building instruments with an aim to encourage children to listen or to explore new sounds and movements. RP described modifying a Gametrak/Looper instrument in real-time as a child moved: "I can see that they're extending their movement and looking for another sound, and... if I've loaded the Looper with [all six samples], I can add another [training example with a new sound] 'just like that' within the session, and it's seamless. So if they're reaching for another sound then it's there." RP also sometimes designed a sort of musical game using the Sample Player to encourage movement and listening: she "hid" a special sound (e.g., a dog bark) somewhere in the gesture space accessible to a child, then challenged the child to explore the space until they found the sound (e.g., "Now see if you can find the doggy!"). JH described the value of giving children unfamiliar sounds and mappings: "[It was] lovely to watch the way they explore where the sounds were—to see children really listening—because it's something different, they're trying to work out 'why is that happening with their [movement]?"'

5.2.3 Supporting social aims

RP created a bespoke instrument for one physically disabled child to use in a school performance. She describes this child as "quite bright" and capable of "picking up [Sound Control] in a matter of minutes." She worked with him to design the training set for a Gametrak/Looper instrument to trigger different seaside sounds to accompany a seaside-themed musical performance by other children. Her goal was not to make an instrument for him to play in an "accurate" way; rather, it was most important to build an instrument that enabled him to participate meaningfully in the larger social and musical context of group performance. "For him to be able to take part in a performance [with] an active part and a solo part... that's so special for [him]... His parents said he didn't eat breakfast that day... he was so excited with the anticipation of knowing that he had this starring role in one of the pieces... Sound Control enabled that. Without that, he might've had a switch, but still that's only a little bit of input from him, and [with this] he was improvising on the spot with the sounds he wanted."

RP has also experimented with using Sound Control to adapt acoustic instruments for use by disabled children. For instance, she affixed a micro:bit inside a euphonium and trained Sound Control to trigger brass samples as the instrument was tilted. RP and JH were enthusiastic about the potential of such technology to enable students with physical disabilities to participate in acoustic band and orchestra ensembles.

Finally, RP and JH saw instrument building as a way to better support two-way musical interaction between them and a child. JH often plays recorder and sings during therapy sessions, and she was interested in creating Sound Control instruments that offered children the chance to be "more equal" musical partners with her: "I can change how I play depending on what I pick up from them, how I'm feeling... But [Sound Control] means they can do some of that themselves rather than [just] me supporting and matching [them]." RP stated she sometimes built instruments in which "I can give them a little musical arrangement, a collection of notes that might fit in with what I'm doing on the piano, and see if there's any focus towards trying to play sympathetically with me."

5.3 Input Methods

RP and JH developed a set of favourite inputs that they used often: the Gametrak (RP and JH), micro:bit (RP and JH), colour tracker (RP and JH), and microphone (JH). Versatility was key: RP and JH used GameTrak in many ways (held in the hand, attached to a bracelet, tied to a shoe). They affixed the micro:bit to bracelets, shoes, and headbands. They used the colour tracker to track toys and parts of the body (e.g., a coloured sticker on a chin). This variety of use was key not only to support children with different movement abilities, but to support children's unique preferences (e.g., an aversion to having something affixed to their body, or a desire to interact with a favourite toy). The Leap Motion was considerably less versatile, as it required a hand placement and posture that was unnatural or impossible for many children. Visual feedback on the Sound Control GUI and passive haptic feedback from the Gametrak were also cited as important, helping both children and practitioners understand what was being tracked.

5.4 Music/Sound Modes

RP and JH found uses for all music modes. RP found Granulator often "a good place to start": its "different" and "raw" sound was helpful in grabbing children's attention. Both Granulator and FM Synthesis modes had wide timbral ranges that made it easy to map children's natural movements to very noticeable sound changes, supporting the goal of helping children become aware that they were affecting the sound.

RP and JH also used sample-based sound modes in many activities. These included creating natural soundscapes and mimicking acoustic instruments (see above), triggering phrases from familiar pieces, and designing listening activities (e.g., "find the doggy"). They sometimes recorded and used their own samples, but emphasised the usefulness of having access to a variety of sample libraries. This led us to provide them with libraries of instrument samples, classical music snippets, animal sounds, and "fart" sounds.

RP and JH both emphasised the importance of finding sounds that children enjoyed and responded to, even if they didn't match adults' ideas about what sounded "nice." RP said, "I let them explore rather than me saying 'this is what we're doing today' so it's difficult to [generalise about a favourite sound]." Exploration of new sounds seemed to strongly motivate some children, as well; RP described one child who seemed "really engaged" with Granulator instruments, "exploring and finding something new in there, something that surprises him, he seems to go for... it's kind of play for him, rather than a deliberate 'I want this sound'—he maybe doesn't know what sound he wants till he finds it, and then he's interested."

5.5 Mapping Methods

At the time of the interview, JH had not yet learned how to use the "quick" mapping, but RP had become comfortable with it. She mainly used "quick" mappings when beginning to work with a new child, as it offered her a fast way to "sort of set the tone and get going straight away." Mostly, however, she used "precise" mappings created with some care: "I love having the space bar function [a keyboard shortcut to record new examples] because it means I don't have to be watching the screen, I just hover over and I can watch the child and I can wait for the moment when they make the movement that I know they can make."

6. DISCUSSION

This work suggests that, presented with the ability to create highly customised musical interfaces using a variety of input devices and music-making modes, music therapists and educators may employ customisation to support a range of goals. Unlike much of the work by organisations like the British Paraorchestra or Drake Music—and unlike many accessible instruments created in academic work cited by Frid [4]—our users' goals were not usually to create polished, bespoke instruments that supported performance of particular musical material by individuals (or groups of individuals with similar abilities). Rather, they used customisation to dynamically support diverse goals such as developing a sense of agency, encouraging movement and listening, and supporting social interactions.

Despite the strong focus of existing technologies on triggering MIDI notes and enabling the production of conventional-sounding musical material, our users also saw clear benefits to interfaces that allowed children to explore rich timbral spaces offered by digital synthesis methods. And despite the limitation of most existing technologies to just one or two fixed input modalities, our users exploited the ability to switch between multiple input devices—not merely choosing different devices for different children, but also changing devices for different activities with the same child.

IML was essential to supporting fast and on-the-fly customisation. It would be tedious if not impossible to use GUIs or programming to design many of the mappings our users found valuable. Despite prior work [6] finding on-the-fly re-training cumbersome, RP frequently re-trained to refine interfaces while working with children. (A streamlined user interface, keyboard shortcuts, and automatic re-training following recording of new examples helped facilitate this.) Despite having little prior experience with technology or machine learning, our users were able to gain excellent proficiency in Sound Control. This works suggests that other music accessibility tools such as SoundBeam and AUMI could likewise be extended using IML-based approaches.

We encourage other researchers who want to support people with disabilities to consider developing or contributing to instrument-building toolkits, rather than merely making one-off instruments designed for individuals or small populations. Our experience shows that music teachers and therapists—even those with little technology experience—are capable of ingenious instrument designs when given the right tools. Putting creation in the hands of teachers and therapists—or people with disabilities and their families and friends—is not only more scalable than relying on experts, it also leverages their expert personal and domain knowledge. Likewise, we underscore the importance of working closely with users in any such work; our workshops and observations were essential in pushing us beyond our initial assumptions about our collaborators' goals and how technology could support them.

7. CONCLUSIONS

We have produced an open-source tool, Sound Control, that others can use to create new musical interfaces. We have shown that, given appropriate design tools, music therapists and educators can successfully create a wide variety of interfaces that help them to achieve goals beyond just the development of personalised instruments. We have presented some preliminary evidence about how input devices, music modes, and mapping strategies can support the creation of custom interfaces for children with disabilities.

Further work is still needed to realise this project's long-term goal of supporting integration of children with disabilities into musical ensembles. Achieving this will require creating new music-making modes and exploring cheaper platforms (e.g., Raspberry Pi). Additionally, now that the software has been released, studying the use of Sound Control by more people—including getting feedback directly from children with sufficient verbal communication skills—will help to validate our findings, improve usability of the software for new users, and further broaden our understanding of how and why richly customisable interfaces can be useful in music therapy.

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9. REFERENCES

[1] British Association of Music Therapy. `https://www.bamt.org/music-therapy/what-is-music-therapy.html`, 2019.

[2] R. Fiebrink, D. Trueman, and P. R. Cook. A meta-instrument for interactive, on-the-fly machine learning. In *Proc. NIME*, 2009.

[3] A. Freed, D. McCutchen, and A. Schmeder et al. Musical applications and design techniques for the Gametrak tethered spatial position controller. In *Proc. SMC*, pages 23–25, 2009.

[4] E. Frid. Accessible digital musical instruments: A survey of inclusive instruments presented at the NIME, SMC and ICMC conferences. In *Proc. ICMC*, pages 53–59, 2018.

[5] N. Gillian and J. A. Paradiso. The gesture recognition toolkit. *The Journal of Machine Learning Research*, 15(1):3483–3487, 2014.

[6] S. Katan, M. Grierson, and R. Fiebrink. Using interactive machine learning to support interface development through workshops with disabled people. In *Proc. ACM CHI*, pages 251–254, 2015.

[7] P. Oliveros, L. Miller, J. Heyen, G. Siddall, and S. Hazard. A musical improvisation interface for people with severe physical disabilities. *Music and Medicine*, 3(3):172–181, 2011.

[8] H. Scurto and R. Fiebrink. Grab-and-play mapping: Creative machine learning approaches for musical inclusion and exploration. In *Proc. ICMC*, pages 12–16, 2016.

[9] D. Trueman. Clapping machine music variations. In *Proc. ICMC*, 2010.