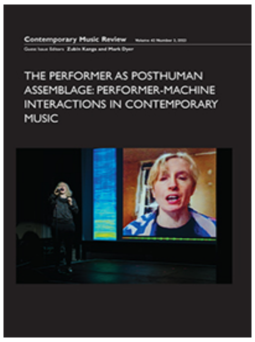


Routledge
Taylor & Francis Group

Contemporary Music Review

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/gcmr20

# Chaos Bells: Instrument Size and Entangled Music Performance

**Lia Mice & Andrew P. McPherson**

**To cite this article:** Lia Mice & Andrew P. McPherson (2023) Chaos Bells: Instrument Size and Entangled Music Performance, Contemporary Music Review, 42:3, 363-375, DOI: 10.1080/07494467.2023.2277556

**To link to this article:** https://doi.org/10.1080/07494467.2023.2277556



Published online: 04 Dec 2023.

CONTEMPORARY MUSIC REVIEW
2023, VOL. 42, NO. 3, 363–375
https://doi.org/10.1080/07494467.2023.2277556



# Chaos Bells: Instrument Size and Entangled Music Performance

Lia Mice[a] and Andrew P. McPherson[b]

[a]Centre for Digital Music, Queen Mary University of London, London, UK; [b]Dyson School of Design Engineering, Imperial College London, London, UK

**ABSTRACT**

There is a current trend in the instrument design industry of scaling down physical dimensions, resulting in smaller and smaller 'desktop' instruments, but research conducted with large interfaces reveals the role of instrument size on music performance. Chaos Bells is a very large digital musical instrument designed with both artistic and analytical goals in mind: it is a probe into the effect of instrument size on performance, while also being a vehicle for the first author's performance practice. Drawing on entanglement theories of HCI we supplement the findings of lab-based studies with Chaos Bells with new discoveries made by the first author when touring with Chaos Bells. This research elucidates the indirect influences of stakeholders on instrument design culture, and ways that taking a large instrument design approach can benefit designers of instruments of all sizes.

**KEYWORDS**

Performance practice; human computer interaction; digital musical instruments; large instruments; entanglement

## Introduction

This article presents findings of research that explore the role of instrument size on music performance. In line with the *Entanglement Theories of HCI* (Frauenberger 2019) that consider humans and technologies as ontologically inseparable, musical entanglement (Rodger et al. 2020; Waters 2021) recognises music as created within systems of actors that include humans, objects, and also political and sociocultural systems. Reflecting on our lab-based research and performing with a large instrument outside the lab, we propose that the practice of designing large instruments may foster the development of new designs for instruments of all sizes.

The overall goal of this article is not to prescribe guidelines for designing large DMIs, but to highlight the constellation of entanglements that contribute to music making as revealed through the lens of large instruments. In doing so we argue that investigation of niche musical practices that are under-explored in academic research and commercial industries can result in knowledge that benefits the broader instrument design field.

**CONTACT** Lia Mice l.mice@qmul.ac.uk

## *Large Dmis: The State of the Art*

The design of acoustic instruments is coupled with size as a matter of physics-based necessity. Typically acoustic instruments are designed to a scale required for the sonic output, and the dimensions of large instruments such as organ, contrabass flute and octobass, are directly related to the sound chambers or string lengths required to result in their sound. DMIs however can be designed at any size and shape irrespective of their sonic output. There is currently a trend in commercial DMI design of scaling down instruments and interface dimensions, resulting in smaller and smaller 'desktop' instruments (Mice and McPherson 2020). These desktop instruments are often encased in a rectangular black box and feature keyboard keys, touch pads, display screens, potentiometers and/or sliders that are performed with fingertip control.

Outside the commercial instrument design industry, desktop and regular-size are also the trending dimensions within the academic instrument design counter-culture of the New Interfaces for Musical Expression (NIME) community. However, within this sphere, designs are commonly moving away from button-controlled instruments. The analysis of over 1200 papers published during the first fifteen years of the NIME conference indicates a preference for designs that require 'fluid full-bodied interaction' (Jensenius and Lyons 2016).

While far from catching on as a trend, in recent years interest in designing large DMIs has increased among independent artists and builders. These larger-than-the-performer instruments tend to take the form of multiplayer designs (Fels and Vogt 2002; Jordà et al. 2007; Tanaka 2000); automated designs (Sayej 2013); virtual, or hybrid hardware-internet large-scale instruments (Tanaka and Bongers 2002); interactive architectural spaces in which the room or building itself is the instrument (Bongers 1999) and pre-programmed musical installations, performed robotically or mechanically via smaller control interfaces (Hinde 2014; Marantz 2017). As for large single-player tangible DMIs that are performed via *instrumental interaction* with the large-scale instrument itself, there is a trend for their designs to feature MIDI controlled sample players with only an on–off level of expressivity (Johnston, Bailey, and McKinnon 2014; Zwerenz 2017).

These trends reveal a gap in the construction and exploration of gesturally performed large DMIs. Examples of large DMIs that are gesturally and expressively controlled through *instrumental interaction* (Bleau 2017; Cargnel 2021; Langevin-Tétrault 2016; Riccardo 2021) are few and far between.

## *Chaos Bells: A New Large DMI*

Chaos Bells (Figure 1) is a 2 × 2 m instrument featuring 20 gesturally performed pendulums that we designed with both artistic and analytic goals in mind (Mice and McPherson 2020; 2022a; 2022b). Chaos Bells' unique sound design features bell sounds can drone and become chaotic. A staccato (short) tone is produced by striking or tapping the instrument either on the pendulums (to create a clear tone) or the instrument frame (to create a cacophony of tones). Tilting a pendulum produces a drone (sustained tone).

The sound is created when 20 embedded accelerometers (one per pendulum) excite a modified Karplus-Strong (Jaffe and Smith 1983) synthesis algorithm adapted from

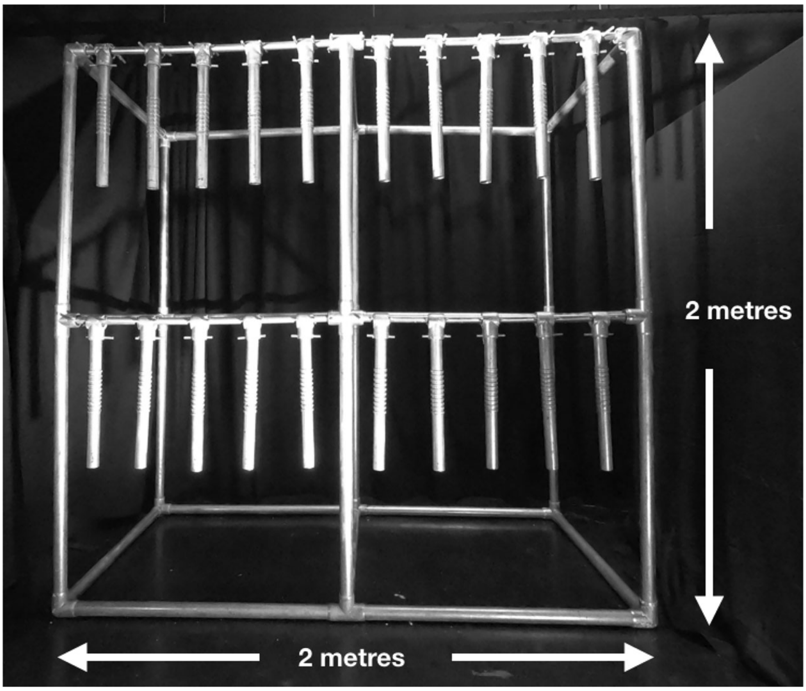


**Figure 1.** Chaos Bells is a large digital musical instrument 2 × 2 m with 20 performable pendulums. Photo taken by the first author.

Chair Audio's Tickle instrument (Neupert and Wegener 2019). The pendulum tilt angle changes the Karplus-Strong algorithm feedback coefficient, thereby changing the drone decay and timbre. When tilted close to 90 degrees, the feedback coefficient becomes greater than one producing an unstable system: the drone grows over time, eventually becoming chaotic and distorted as it is clipped by the digital system, finally disintegrating into broadband noise.

Chaos Bells features tones tuned to a C sharp melodic minor scale. Chaos Bells can produce many timbres per tone, whether striking or tilting. Even a millimetre change in pendulum tilt angle affects the drone timbre. When striking Chaos Bells, the timbre changes depending how forcefully the instrument is struck and the firmness of the performance tool (such as hands, soft mallets, drum sticks etc.).

## Materials and Methods

In two studies (Mice and McPherson 2020; 2022a) 10 participants performed Chaos Bells in response to various creative prompts. While all participants are performer-composers within the London experimental electronic music scene and are trained in Western music, their primary instruments varied. The following sections summarise the study methods and results. Recounting detailed methods and individual outcomes of each study is beyond the scope of this article. Instead, this article focuses on the pivot from instruments in studies to instruments in practice.

## Method of Study 1

In Study 1 the participants improvised with Chaos Bells twice while the instrument was not turned on: once before and once after hearing the types of sounds the instrument creates. Subsequently the participants improvised with Chaos Bells with the sound turned on and amplified through a PA.

## Findings of Study 1

Study 1 revealed ways that the instrument sound design, and production of sound at all, influenced performer's gestural interactions with the instrument. During each phase of the study (before and after hearing the sound, playing with sound on), performers reshaped their performance gestures: eliminating gestural interactions that do not result in changing the sonic output of the instrument, reinforcing similar findings by Jack, Stockman, and McPherson (2016).

Identical patterns of successive tones were performed by different participants regardless of tonal output.[1] These findings indicate that what is idiomatic to Chaos Bells has less to do with tonal layout and more to do with the instrument's physical layout and its relationship to the body. Participants reflected that the size of the instrument can influence their movements in ways that influence their compositions. For example, one participant said the instrument's size encouraged her to move around it to make use of more of the tones on offer.

## Method of Study 2

Study 2 featured four private one-hour sessions with Chaos Bells per participant. Musicians were instructed to create various one-minute fixed (non-improvised) performances with the instrument. In the third session they created a three-minute performance with Chaos Bells for broadcast in an online concert.

During the fourth and final session, the participants were introduced to a smaller version of Chaos Bells (Figure 2) and were invited to perform their composition with

**Figure 2.** A study participant standing with arms outstretched in front of the original Chaos Bells (left) and the smaller version (right). Photos taken by the first author.

it. In this way, the smaller version probed the participants to consider ways the size of the larger Chaos Bells had influenced their compositional choices.

### Findings of Study 2

The Study 2 results were analysed to reveal the complex role of instrument size in musical entanglements. In the lexicon of musical entanglement (Waters 2021), changes to the Study 2 actors, (the performer, the performer's musical history, the lab environment and the larger/smaller Chaos Bells), resulted in changes to the musical performance. We found examples of the large size of the instrument influencing the tonal choices of composing performers as they preferred performing tones located comfortably in front of the body. Some even considered their spatial relationship with the instrument as a new compositional approach that they would not use when creating performances with a smaller instrument. We noticed examples of participants enjoying the extra effort and larger gestures required of performing the oversized instrument, and as a result incorporating large and effortful gestures and musical patterns into their compositions. When performing the larger version of Chaos Bells, some performers changed perceptions of their own bodies, including feeling powerful and desiring longer or more limbs. We also discovered that musicians bring musical entanglements that they have developed through years of training with other instruments to their approaches to performing new unfamiliar instruments such as Chaos Bells.

## Discussion

Instrument designers and researchers recognise that more discoveries can be made about instruments when lab-based findings are supplemented with explorations within music communities (Harrison 2020; Martelloni, McPherson, and Barthet 2021). After completing the research studies in London, the first author embarked on a short tour of the UK performing electro-pop tracks from her solo album.[2] The first author's live performances with Chaos Bells offer additional insight into the role of instrument size in music performance. Although not part of the research studies, taking Chaos Bells out of the lab environment reminded us of the pragmatic considerations of touring artists that differ to those of non-touring music producers, instrument design companies and installation artists. In this section we give an account of her experiences and insights gained through touring with Chaos Bells.

### The Performance Set-Up

As an electronic two-piece. Odd Lust[3] performed Chaos Bells, and the first author played an eight-track sampler (for live-sampling her voice and triggering stems of drum machine beats and synthesisers) and a mixing board for controlling the volume of the sampler tracks and Chaos Bells.

### Concert Performances

Adding Chaos Bells, a new actor, to the first author's musical system for performing live music resulted in some interesting observations. The first author noticed that audience was intrigued by the large instrument on stage. Aware that audiences of live electronic music already find it difficult to identify the source of sounds within the music, she turned Chaos Bells up in the mix to a volume that was louder than she would ordinarily mix a synthesiser part to make obvious which tones were being created live with Chaos Bells.

## Insights from Touring with Chaos Bells

This section outlines additional implications of performing with large DMIs that we discovered while touring nationally and internationally with Chaos Bells. While some of these considerations, such as fatigue, transport costs and storage, will be familiar to performers of large acoustic instruments, others such as those pertaining to show day logistics and breakages, are specific to touring with large DMIs.

### Fatigue

The first author reflects that the physical demands of touring with Chaos Bells were much more than touring with her previous live set-up (a sampler, microphone and vocal effect unit) and therefore resulted in fatigue during and after the event. This fatigue was caused by carrying Chaos Bells into the venue, constructing and deconstructing it in addition to the regular demands of a live show (soundcheck and the performance itself). The result of this fatigue was less enjoyment of the performance, undermining the main reason the first author performs live.

### Transport costs

The first author noted that touring with Chaos Bells made touring substantially more expensive. Before incorporating Chaos Bells into her live show, the first author toured alone via train (her preferred mode of transport for environmental reasons) or plane, with all luggage and equipment in one small carry-on-sized suitcase. Adding Chaos Bells to her setup however required touring by van or large cab. For international events, Chaos Bells was posted in both directions.

These additional expenses were not offset by higher performance fees. The higher transport costs of performing such a large instrument were not recognised by promoters as the performance being of higher value than other performances. This renders it impossible for the first author to make a profit touring with Chaos Bells, making touring unsustainable as part of her artistic practice without subsidising it via other forms of income.

### Show day logistics

To accommodate the extra time required to load in and construct Chaos Bells, plus some buffer time in case of unexpected troubleshooting, the first author confirmed each event under the condition that she could access the venue at least 2 h prior to soundcheck. All venues agreed, but days before the one show the promoter requested to shorten the load-in and soundcheck time to 1 h. They also requested Chaos Bells to be set-up for the day event, then moved to another room for the night event, doubling the physical labour required to install and break down the instrument. The promoter's last-minute requests were not feasible. The result of arguing with the promoter so close to the performance was that the first author felt devalued by the promoter and as a result enjoyed the concert less than they otherwise would have. This experience reminds us that so few artists tour with large DMIs that it is unlikely that promoters and venues may agree to making special accommodations during the booking process but may forget why they agreed to them by the show date.

### Breakages

While being posted to New Orleans, one of the microcomputers was damaged resulting in only three quarters of the instrument working upon its arrival. The only other time that a part of Chaos Bells broke while on tour was during an event in which children damaged the interface hardware by playing the instrument too roughly, resulting in five pendulums stopping working. As a result the instrument only partially worked for a concert that evening. This experience makes us wonder whether due to the instrument's size the children played rougher with it than they would a smaller instrument. Chaos Bell's aesthetic similarity to playground equipment may further explain the lack of caution exhibited by children performing the instrument.

### Storage

Space is a valuable commodity in London. Queen Mary University of London only permitted the first author to store Chaos Bells on campus in its constructed form while conducting research studies. To prepare for touring, the first author installed Chaos Bells in her personal music studio for several months however it occupied so much space that the studio became unusable for its initial intention: music production. As a result the first author did not produce any music in those months.

## Indirect Influence of Stakeholders on Large Instrument Culture

The influence of music industry stakeholders, such as session musicians, roadies, promoters and venue staff, on instrument design practices is often overlooked (McPherson and Kim 2012; O'Modhrain 2011). The first author's account of touring with Chaos Bells reveals frictions with stakeholders, such as promoters and venue staff, over fair payment for the increased work and expenses required when touring with large instruments, and the reluctance of venue staff to accommodate of the extra time required for setting up and breaking down Chaos Bells. Even though the laboratory studies found that the music performed with large instruments is different to the music performed with smaller instruments, affirming that the world is currently missing the unique music of large instruments, these touring experiences deter the first author from wanting to tour with large instruments. These examples illuminate ways that stakeholders in the music industry may be contributing to the cultural erasure of large instruments in favour of desktop instruments.

## An Account of Building a Desktop Version of Chaos Bells

After the completion of the Chaos Bells studies, an opportunity arose in which a smaller, desktop version was needed. It was therefore decided that the first author would reconfigure the smaller ($1 \times 1 \times 0.5$ m) Chaos Bells materials into an even smaller yet desktop version of the instrument.

## *Chaos Bells Desktop*

The cuboid ($0.5 \times 0.5 \times 0.5$ m) design of Chaos Bells Desktop (Figure 3) reduces the instrument to half the desk space as the original smaller Chaos Bells. While Chaos Bells Desktop is small enough to fit on a desktop, it retains some design aspects of the large version of Chaos Bells. For instance, the selective aspect to performing pendulums that is imposed with the large version due to its sheer size is evident in the desktop version due to the physical design of pendulums being located on all four lateral sides of the cube. In this way, with Chaos Bells Desktop, it is not possible to reach all pendulums at once.

Chaos Bells Desktop is constructed of smaller PVC pipes than the large version and retains the same hardware design of embedded analogue accelerometers that control the same sound synthesis. Therefore, just like the large version, the desktop version has incorporated the concept of the 'micro-scale within the macro-scale', in which very small gestures such as a millimetre change in the angle of tilt of a pendulum can result in a large change in the overall sonic output of the instrument. The desktop version sound design also features timbral variation across registers: the lower register tones feature a clear fundamental frequency meanwhile the higher register tones contain more inharmonic partials.

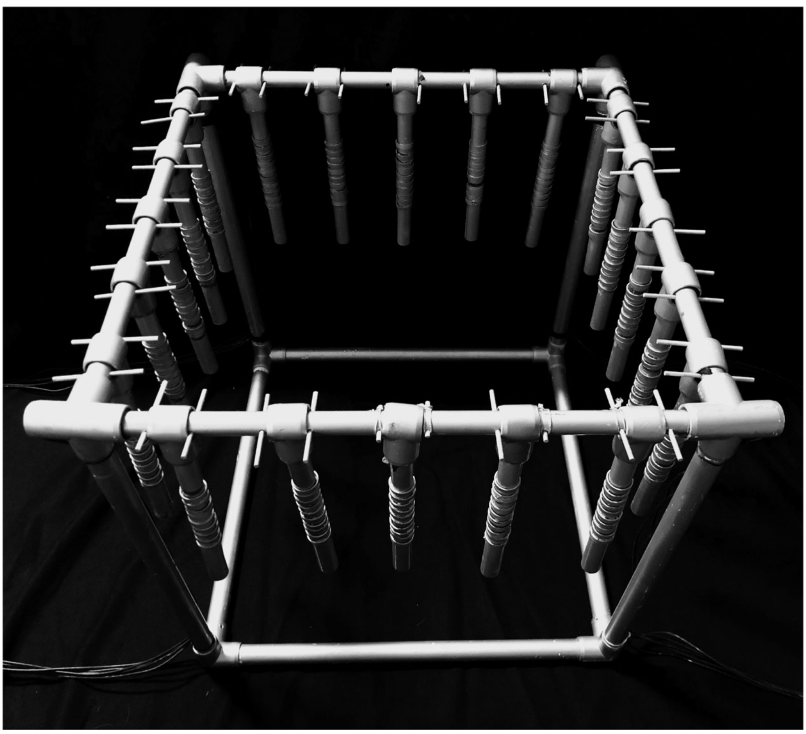

**Figure 3.** Chaos Bells Desktop is a $0.5 \times 0.5 \times 0.5$ m version of Chaos Bells. Photo taken by the first author.

## *Thinking Big, Building Small*

Chaos Bells Desktop interface design of 20 silver pendulums that are performed with mallets or whole hand movements stands apart from both the commercial industry trend of fingertip controlled black box desktop instruments, and other instruments designed within the NIME community. The controlled tilting of pendulums is a unique gestural interaction not commonly seen in desktop instruments. This interaction allows for micro-gestural exploration of Chaos Bells Desktop's sound design, which, like the other versions of Chaos Bells, has the potential to create sustained 'drones' with tones that range on a spectrum from clear and stable to broadband noise. These distinctive visual and sonic design characteristics came about because the original Chaos Bells was designed as an instrument that is larger than the bodies of the performers, with the intention to be performable with both large and small gestures.

Subsequently, when reducing the size of Chaos Bells to the desktop version, the goal was to capture the essence of the large Chaos Bells, therefore we retained the instrument's sound design and the choice of using pendulums as the tonal control interface.

We find it interesting to consider the unique design of Chaos Bells in the context of musical entanglement (Waters 2021). By considering instrument size as an actor in an entangled musical system, we can recognise the influence of the goal of designing a large (rather than desktop) instrument on the design choices. If we had started by designing Chaos Bells Desktop first, we would not have conceived of using hanging pendulums to control the drone timbre because other mechanisms such as knobs or sliders would suffice. By designing Chaos Bells Desktop by way of the original large-scale Chaos Bells, we discovered that designing at a large-scale then exploring how to pragmatically reduce the size gets the designer to a different aesthetic space than designing small to begin with. In this case, the result was a more unique instrument than would have otherwise been designed, resulting in different musical performance capabilities. However in other design situations, the result could be different and potentially better for any many other reasons. We recognise that due to the additional time, money and physical exertion required, performing with large instruments may be unfeasible for many artists, but we argue that building a smaller instrument by way of a large instrument is an approach that can result in designs that would not have otherwise been conceived of, resulting in different assemblages, and can therefore benefit designers of instruments of all sizers.

Having now spent four years designing large instruments including Chaos Bells, the first author recognises that there is a different type of thinking required when designing large instruments as opposed to small ones. Large instruments are not just small instruments scaled up, but instead offer different sonic and performative features to their smaller counterparts and can require precise gestural control that is certainly not scaled up (Mice and McPherson 2022a). Additionally, for obvious reasons, musical gestures for performing interfaces that are smaller-than-the-performers'-bodies do not scale up to adequately control interfaces that are larger-than-the-performers' bodies, as comically demonstrated in the famous oversized piano scene in the film Big. Therefore designing large gesturally performed instruments calls for different design approaches and solutions than those required for designing small instruments.

In addition to developing the first author's approach to designing desktop instruments by way of larger instruments, this longitudinal large instrument design practice has changed the first author's perspectives within her music performance and composition practice. She now recognises that there is a homogenisation that comes with musicians using the same tools (instruments) that is not conducive to creating work that stands apart from the work of others. Aside from curbing the horizons of creative expression in live music performance, this homogenisation sets the foundation for a music industry that is content with the normalisation of inaccessible interfaces and the marginalisation of musicians whose practice exists outside the status quo, due to reasons including countercultural aesthetic taste, access requirements, and unique artistic perspectives and visions.

### Future Directions in Large DMI Research and Design

There are many more aspects of large instrument design to be explored in the future. The second Chaos Bells study revealed findings related to the responsibility of instrument designers to the bodies of performers, and performers' perceptions of their own bodies. Future large instrument design research could further explore this domain in the context of Accessible Digital Musical Instrument design and collaborative design with disabled musicians and musicians with access needs.

### Concluding Remarks

Lab-based studies conducted with Chaos Bells have resulted in findings surrounding the role of instrument size in music performance and musical entanglements however due to economic factors it is unlikely that the commercial instrument design companies and the wider music industry would move towards a culture of large DMI design and performance.

By taking Chaos Bells outside the lab for live performances and interactive demoes, we gained a broader understanding of the instrument's influence on live music performance and culture. We uncovered ways that stakeholders in the music industry, such as venue staff and promoters, may be contributing to the instrument design industry's fascination with desktop instruments by not recognising the extra work required to perform live concerts with large instruments.

By creating a desktop version of Chaos Bells we inadvertently designed a unique instrument that does not feature the design tropes found in commercial or NIME instruments. This led us to understand that regardless of whether the final goal is a large or small instrument, starting by designing large can be of value to all instrument designers.

Before this research, most of the first author's artistic output was focused on releasing albums and touring music that she had performed with desktop commercially available instruments such as drum machines and samplers. However, through this research she has come to understand the role that instruments play in musical entanglements, and no longer aims to play the instruments designed by the commercial instrument industry. She instead hopes to continue exploring the instruments they *do not* offer, including large instruments, despite their inconveniences.

While the research conducted with Chaos Bells both in and outside the lab indicates that there are missed opportunities of musical entanglements due to the commercial industry's fascination with small instruments, as instrument designers and performers, we choose to 'go large'. Furthermore, we recommend to others working in instrument design, regardless of the final dimensional goal, to explore the potentials of including large DMIs in your performance and design practice.

## Notes

1. Half the participants were assigned a tonal layout in which the tones ascend left to right on the lower tier and left to right on the upper tier, and half the participants were assigned a tonal layout in which the tones ascend from left to right in a zig-zag formation across both tiers.
2. https://liamice.bandcamp.com/album/sweat-like-caramel.
3. https://soundcloud.com/oddlust.

## Disclosure Statement

No potential conflict of interest was reported by the author(s).

## Funding

This research is supported by EPSRC under Grants [EP/L01632X/1] and [EP/N005112/1] and by the Royal Academy of Engineering under the Research Chairs and Senior Research Fellowship programme.

## Notes on Contributors

*Lia Mice* is a multidisciplinary artist whose works include digital musical instrument design, live audio-visual performance and interactive sculpture. She is the Programme Leader of the MA Creative Music Production at the Institute of Contemporary Music Performance, London. Recipient of the 2021 Oram Award for Innovation in Sound, Music and Associated Technologies, Mice holds a Master's of Music in Creative Practice from Goldsmiths University of London and a PhD in Electronic Engineering and Computer Science from Queen Mary University of London.

*Andrew P. McPherson* is a computing researcher, composer, electronic engineer, and musical instrument designer and a Senior Research Fellow of the Royal Academy of Engineering. He is Professor of Design Engineering and Music at Imperial College London, where he leads the Augmented Instruments Laboratory. Andrew holds undergraduate degrees in both engineering and music from MIT, an MEng in electrical engineering from MIT, and a PhD in music composition from the University of Pennsylvania.

## References

Bleau, Myriam. 2017. "Soft Revolvers et les Interfaces Créées sur Mesure: La Performance de Musique Numérique Dans une Perspective D'œuvre Totale." PhD diss., University of Montreal.

Bongers, Bert. 1999. "Exploring Novel Ways of Interaction in Musical Performance." In *Proceedings of Creativity and Cognition Conference*, 76–81. Loughborough, UK.

Cargnel, Tabita. 2021. "Venus Smiles in Nature." *Tabita Cargnel*. Accessed 23 October 2022. https://tabitacargnel.com/venus-smiles

Fels, Sidney, and Florian Vogt. 2002. "Tooka: Exploration of Two Person Instruments." In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 116–121. Dublin, Ireland.

Frauenberger, Christopher. 2019. "Entanglement HCI The Next Wave?" *ACM Transactions on Computer-Human Interaction* 27 (1): 1–27. https://doi.org/10.1145/3364998.
Harrison, Jacob. 2020. "Instruments and Access: The Role of Instruments in Music and Disability." PhD diss., Queen Mary University of London.
Hinde, Kathy. 2014. "Tipping Point." *Kathy Hinde*. Accessed 7 December 2018. http://kathyhinde.co.uk/tipping-point/
Jack, Robert, Tony Stockman, and Andrew P. McPherson. 2016. "Effect of Latency on Performer Interaction and Subjective Quality Assessment of a Digital Musical Instrument." In *Proceedings of the 11th International Audio Mostly Conference*, 116–123. Norrköping: ACM.
Jaffe, David, and Julius Smith. 1983. "Extensions of the Karplus-Strong Plucked-String Algorithm." *Computer Music Journal* 7 (2): 56–69. https://doi.org/10.2307/3680063.
Jensenius, Alexander Refsum, and Michael J. Lyons. 2016. "Trends at NIME: Reflections on Editing 'A NIME Reader'." In *Proceedings of the Conference on New Interfaces for Musical Expression*. Brisbane, Australia.
Johnston, Blake, Josh Bailey, and Dugal McKinnon. 2014. "NICO: An Open-Source Interface, Bridging the Gap Between Musician and Tesla Coil." In *Proceedings of the 2014 International Computer Music Conference*. Athens, Greece.
Jordà, Sergi, Günter Geiger, Marcos Alonso, and Martin Kaltenbrunner. 2007. "The ReacTable: Exploring the Synergy Between Live Music Performance and Tabletop Tangible Interfaces." In *Proceedings of the International Conference on Tangible and Embedded Interaction*, 139–146. Baton Rouge, USA.
Langevin-Tétrault, Alexis. 2016. "Interferences (String Network)." *Alexis Langevin-Tétrault*. Accessed 31 October 2022. https://alexislt.com/interferences-string-network
Marantz, Andrew. 2017. "Inventing Björk's Gravity Harp." *The New Yorker*, March 6. Accessed 31 October 2022. http://www.newyorker.com/culture/culture-desk/inventing-bjrks-gravity-harp
Martelloni, Andrea, Andrew McPherson, and Matthieu Barthet. 2021. "Percussive Fingerstyle Guitar Through the Lens of NIME: An Interview Study." In *Proceedings of the International Conference on New Interfaces for Musical Expression*. Royal Birmingham Conservatoire, Birmingham, UK.
McPherson, Andrew P., and Youngmoo E. Kim. 2012. "The Problem of the Second Performer: Building a Community Around an Augmented Piano." *Computer Music Journal* 36 (4): 10–27. https://doi.org/10.1162/COMJ_a_00149.
Mice, Lia, and Andrew P. McPherson. 2020. "From Miming to NIMEing: The Development of Idiomatic Gestural Language on Large Scale DMIs." In *Proceedings of the International Conference on New Interfaces for Musical Expression*. Royal Birmingham Conservatoire, Birmingham, UK.
Mice, Lia, and Andrew P. McPherson. 2022a. "Super Size Me: Interface Size, Identity and Embodiment in Digital Musical Instrument Design." In *Proceedings of the Conference on Human Factors in Computing Systems*. New Orleans, USA.
Mice, Lia, and Andrew P. McPherson. 2022b. "The M in NIME: Motivic Analysis and the Case for a Musicology of NIME Performances." In *Proceedings of the International Conference on New Interfaces for Musical Expression*. Auckland, New Zealand.
Neupert, Max, and Clemens Wegener. 2019. "Interacting with Digital Resonators by Acoustic Excitation." In *Proceedings of the 16th Sound & Music Computing Conference*, 80–81. Malaga, Spain.
O'Modhrain, Sile. 2011. "A Framework for the Evaluation of Digital Musical Instruments." *Computer Music Journal* 35 (1): 28–42. https://doi.org/10.1162/COMJ_a_00038.
Riccardo, Marsella. 2021. "The Musical Playground as a Vehicle for Community-Building." PhD diss., University of Toronto.
Rodger, Matthew, Paul Stapleton, Maarten Van Walstijin, Miguel Ortiz, and Laurel Pardue. 2020. "What Makes a Good Musical Instrument? A Matter of Processes, Ecologies and Specificities." In *Proceedings of the Conference on New Interfaces for Musical Expression*. Birmingham, UK.
Sayej, Nadja. 2013. "What The Hell is a Sharpsichord?" *Vice*. Accessed 31 October 2022. https://www.vice.com/en/article/rqwwxr/what-the-hell-is-a-sharpsichord

Tanaka, Atau. 2000. “Musical Performance Practice on Sensor-Based Instruments.” In *Trends in Gestural Control of Music*, edited by Marcelo Wanderley, and Marc Battier, 389–406. Paris: IRCAM-Centre Pompidou.

Tanaka, Atau, and Bert Bongers. 2002. “Global String: A Musical Instrument for Hybrid Space.” In *International Computer Music Conference*. Gothenburg, Sweden.

Waters, Simon. 2021. “The Entanglements Which Make Instruments Musical: Rediscovering Sociality.” *Journal of New Music Research* 50 (2): 133–146. https://doi.org/10.1080/09298215.2021.1899247.

Zwerenz, Milena. 2017. “Meet Björgvin Tomasson, Iceland’s First and Only Pipe Organ Builder.” *Friends of Friends*. Accessed 7 December 2018. https://www.freundevonfreunden.com/interviews/meet-bjorgvin-tomasson-icelands-first-and-only-pipe-organ-builder