Super Size Me: Interface Size, Identity and Embodiment in Digital Musical Instrument Design

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Figure 1: A performer with arms outstretched in front of a large digital instrument. Photo used with permission by the participant. ©Lia Mice

ABSTRACT

Digital interfaces are shrinking, driven by pressures of mass production and consumer culture, and often accompanied by a discourse of control, precision or convenience. Meanwhile, human bodies remain the same size, and the changing size of interfaces has implications for the formation of user identities. Drawing on embodied cognition, effort and entanglement theories of HCI, we explored the impact of interface size on the co-constitution of humans and technology. We designed an oversized digital musical instrument and invited musicians to use the instrument to create original performances. We found that both the performances and the musicians' self-perception were influenced by the large size of the instrument, shining new light on the ways in which designing technology is designing humans and in turn culture.

*Both authors contributed equally to this research.

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CCS CONCEPTS

• **Human-centered computing → Sound-based input / output**; **HCI theory, concepts and models**.

KEYWORDS

size, interface design, digital musical instrument, embodiment, entanglement, effort, interaction

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1 INTRODUCTION

"When we design for/with bodies, we actually design bodies themselves." — Sarah Homewood et al. [21]
"The extent to which digital technology shapes who we are means that whoever shapes technology, puts the chisel on humanity." — Christopher Frauenberger [13]

Advancements in digital technology allow for the design of ever smaller interfaces, while human bodies remain stubbornly the same size. This paper considers the missed opportunities of small interfaces and explores an alternate scenario where digital interfaces are larger in size.

The trend of shrinking interfaces is especially evident in digital musical instrument (DMI) design. For example, 2019 saw the introduction of jewelry-shaped miniature MIDI controllers designed to be worn on fingers as rings, including Enhancia Neova (now distributed by Roland) and Genki Instruments Wave [1]. Such scaled-down DMIs are the culmination of decades of synthesizer companies offering instruments of smaller sizes, whether to cater for the desktop music producer (as seen with Korg's immensely popular Volca series of compact synthesizers and drum machines); for portability (as seen when the same product is available at multiple sizes, such as the Arturia Keylab which comes in sizes of 88, 61, 49 or 25 keys); or for performance via sequencing rather than physical gestures (such as Arturia Minibrute 2S).

While large digital musical instruments have been designed for public interactive installations [14, 42], the lack of widespread availability of large DMIs makes them a fertile ground for exploring the role of size in technology design and its ensuing impact on human perception and creative output.

In this paper we investigate the role of interface size on both the actions of musicians and the creation of user identities. We present a study in which 10 musicians performed on a very large DMI (2 metres wide and tall). Based on the actions and comments of the musicians, we reflect on the diversity of embodiment relationships and explore how designing a musical instrument might shape the personal identity of the musician who plays it.

2 BACKGROUND

2.1 Bodies, Interfaces and Size

The history of human-computer interaction (HCI) research can be traced not only through successive generations of technology, but through an evolving understanding of humans. As part of HCI's 'somatic turn' [31], focus has gradually shifted from the 'user' in traditional user-centred design [41] to the body [12, 22]. Human perception and action have always been interdependent [51], and interfaces can serve a mediating role such that they become effectively extensions of the body. This feeling is especially common amongst instrumental performers, where the instrument becomes a part of the body [29, 30, 40, 49] and integral to the performer's identity [3]. More recently, the notion of a singular 'body' in embodied interaction has been problematised [50], identifying harmful gender and cultural norms on how bodies should exist and behave. Taking support from feminist theories of HCI [2, 45], a shift is now underway from a 'body' to the plural 'bodies', reflecting a diversity of experience and perspectives [21, 50].

The role of interface size in HCI has been examined periodically throughout this shift. Through a traditional user-centred design lens, size-related inquiries include comparisons of size of interactive tabletops for around-the-table collaboration [59]; impact of screen scale on moving target selection [5]; how display size affects spatial memory [58] and the effect of table and mobile phone screen sizes on communication modality [26]. From an embodiment perspective, the size of our body plays an important role in how we visually experience the world: the world appears larger to a small observer and smaller to a large observer [53]. Changing the size of an interface changes its dimensions relative to any individual's body, affecting the way in which it mediates perception and action. However, despite the obvious importance of size, relatively few studies explicitly consider large-scale interfaces from the perspective of subjective experience.

2.2 Size, Effort and Context in Musical Interfaces

In the domain of musical interaction [19], large-scale instruments are often studied through the lens of effort [48]. Effort is an important aspect of musical creation for both performer and audience [55]. Waisvisz credits physical effort as a cause of musical tension perceived by audiences[1] [27]. Similarly, Waters [56] explored the role of resistance and difficulties in music performance through his VPFI (Virtual/Physical Feedback Instrument), finding that difficulties and resistance of the instrument give its repertoire character and meaning [57].

Instrument designers aiming to penetrate the industrial mainstream of instrument design know that what's on the mass market must be accessible. New DMIs featured on crowdfunded websites (such as Kickstarter) have been steadily aiming for effortlessness, often advertising instruments for their ostensible expressive power or ease of use [35]. Reducing the size and weight of interfaces has been part of that trend, which also provides the companies with other economic benefits for manufacturing and distribution. Not all new DMIs are designed for ease of use. Some, such as Eigenharp[2], the Karlax[3] and the Sylphyo[4], deliberately target a small market of players willing to put in the time to develop the expertise, but these instruments tend to emerge from and exist within a niche

[1] "The creation of an electronic music instrument shouldn't just be the quest for ergonomic efficiency. You can go on making things technically easier, faster, and more logical, but over the years I have come to the conclusion that this doesn't improve the musical quality of the instrument. I'm afraid it's true one has to suffer a bit while playing; the physical effort you make is what is perceived by listeners as the cause and manifestation of the musical tension of the work." — Michel Waisvisz [27].
[2] http://www.eigenlabs.com/
[3] http://www.dafact.com/
[4] https://www.aodyo.com/

counter-commercial music community. DMIs are designed both as part of quantitative research methods and artistic performance practices [6, 25], and the work presented in this paper essentially draws on both of those reasons. We are doing this study to investigate impacts of interface size while also being motivated by the creative practices of the first author.

On the other hand, performers of large acoustic instruments often cite the effort of playing them as a positive factor, forming a bond with these large instruments and the music they create with them such that they prefer the large instruments to their smaller counterparts [36]. Another factor related to size is the feel of the instrument. A large instrument may typically feel sturdy whereas a small instrument may feel fragile. Gallagher finds that the feel of an instrument is intimately tied to how the performer interacts with it [15].

Ryan [48] observes that over time, instruments have 'improved' in many ways but not regarding effort, while Ihde [23] notes that each evolution of music technology has brought changes in embodiment relations. Ryan suggests that it might be more interesting to make a digital controller as difficult as possible, noting that beyond its impact on expression, effort plays an important role in the formal construction of music: "Effort maps complex territories onto the simple grid of pitch and harmony. And it is upon such territories that much of modern musical invention is founded" [48].

Other factors affect embodiment in musical performance. Dalsgaard and Hansen [10] point out that it is not only the interaction between the performer and the system (instrument) that changes the performer's perception, but also the performer's knowledge of being observed by an audience. Dalsgaard and Hansen call the perception created by this three-way engagement between user, system and spectator "performing perception", and they acknowledge that during all performances the user is simultaneously engaged in all three actions: interacting with the system (understanding the performance possibilities and how to operate the system); perceiving the relation between the user, the system and the surroundings; and performing for others to observe. The richness of musical performance is also never static. Waters defines a musical instrument not as an object but "a process: a dynamic system in a constant state of change" [57], suggesting that rather than designing instruments, designers create "contexts for musicking". Along this line, Rodger et al. consider the instrument as not a device, but a constellation of processes. In this way, "instruments may mean different things to different musicians" [46].

2.3 More-Than-Human Bodies and Entanglement

The most recent, and most radical, reconception of bodies in HCI has been to challenge the independent existence of a body and an interface. Arguably, the body is always more-than-human: "Not only can bodies not be separated from all that surrounds them, whether these are animals, technological objects or societal or cultural constructions, but their combination produces something new" [21]. The idea that humans and technologies are ontologically inseparable forms the basis of so-called *entanglement theories* of HCI [13], including actor-network theory [28] and postphenomenology [54], which explicitly decentre the human, recognising the agency of objects and also of political and sociocultural systems. Barad's agential realism goes further by redefining agency as an enactment, and therefore not something that belongs to an entity but rather emerges via an entanglement between entities [17]. Therefore, the potential of entities and in turn what they are is *intra-actively* produced. In this way, entities (both human and non-human) co-constitute themselves through intra-actions [13]. This view carries important implications, in that changes to technology also change human-technology entanglements: "designing technology is designing human beings" [54].

Considering entanglement HCI in a musical context, the instrument does not become an instrument until it is played by a performer [16], and conversely, a performer only acquires that identity in relation to their instrument. But how does this act of co-constitution impact human experience and identity? And what does it mean for the music being created? Costello [8] poses these questions as being central to the perspective of Entanglement HCI: "this perspective asks design researchers to focus on how designs become different things, to focus on processes of emergence and re-configuration, and to focus on what humans and designs become as they are entangled together" [8]. What role, then, does size play in this entanglement? Prosaically, it ought to have an effect on the body: larger instruments will engage different muscular groups (requiring arm span rather than finger span), will require different amounts of force and have differing requirements in spatial precision. But changing the instrument size will also affect the performer's experience of their own body and their own musicianship. In turn, this entanglement also encompasses the diversity of individual bodies, considering physical health, gender, race and (dis)ability [50], prior experience on other instruments, and cultural contexts and priorities [57].

Time is also a factor in musical entanglements: instruments require time for musicians to develop the skills for performing them [34, 46]. Therefore, to understand the role that size plays on the entanglement of players learning instruments, we designed a study that tracks 10 musicians as they learn to perform a large digital musical instrument over a period of 3 weeks. We embarked on a study that is longitudinal, exploratory, pluralistic (admitting a diversity of individual perspectives rather than seeking universality) and experience-oriented rather than music-theoretical. In contrast to traditional HCI in the workplace, musical performance is essentially a taskless interaction [46]. On that basis, if performance is embodied and features an entanglement between performer and instrument, we should see a few features:

- The patterns of performance should reflect the physical or gestural affordances of the instrument in relation to the particular body of the player. In other words, the musical patterns will not be explainable by music theoretical notions alone such as harmony, melody, rhythm.
- We may see bodily interactions that are ancillary to the ostensible goal of producing sound, which have a personal or communicative purpose rather than simply enabling sound production.
- Each performer will approach the instrument differently in relation to their stylistic background but also in relation to

other instruments they might play, as those other instruments have shaped their bodily experience.

The above effects should not be entirely arbitrary but should be traceable to particular relationships between bodies and technologies. If indeed the performer and the instrument are inherently entangled, then we may also see an influence of the instrument on the player's self-perception of their own body: not just what they do, but how they experience themselves.

3 METHOD

3.1 Study Design Overview

We designed an exploratory study that uses size as a probe, deliberately inverting the prevailing trend toward smaller, more portable, more general-purpose interfaces. The study invited musicians to create new performances with a large-scale digital musical instrument over the course of 3 sessions. Participants were instructed to create compositions that are repeatable and that represent themselves musically, and were informed that a video-recording of their final composition would be broadcast on a public online concert[5].

For consistency, one investigator (the first author) administered all sessions.

3.2 Instrument Design

A large-scale DMI was designed for this study in accordance to guidelines developed by Mice and McPherson [36] in response to research about performers of large acoustic instruments. For instance, the sound design is inspired by findings that performers of large acoustic instruments are drawn to the ability for micro gestures to influence the overall sound of the instrument ('the microscale within the macroscale') and the way large instruments feature timbral variations across registers [36]. Lower register tones feature a clear fundamental frequency and sound like a synthesised electric guitar, meanwhile the higher register tones contain more inharmonic partials for a bell-like quality.

3.2.1 Hardware. The instrument, shown in Figure 2, is constructed from PVC pipe that has been painted silver to give the impression of metal. The instrument features 20 pendulums that can swing up to 90 degrees forwards or backwards. Each pendulum features a textural pattern of raised rings inspired by the Latin-American *güiro*. Embedded in each pendulum is an analog accelerometer which is sampled at 22.05kHz, with several kilohertz of usable analog bandwidth. The 20 accelerometers are connected to 4 Bela Minis [37] (5 per Bela Mini) for sound synthesis. The 4 audio outputs are combined via an analog mixing board and amplified by a guitar amplifier.

3.2.2 Software and Sound Design. The audio code is developed in Pure Data [43]. The audio-rate accelerometer signals drive a modified Karplus-Strong [24] algorithm based on Chair Audio's Tickle instrument [39].

[5]The purpose of this methodology was to ensure that participants authentically engaged with the study. Creating repeatable compositions ensured that the performers were indeed composing rather than improvising. Broadcasting the performance gave the participants incentive to invest genuine artistic effort in the process and attempt to create a composition that authentically reflected their musical priorities.

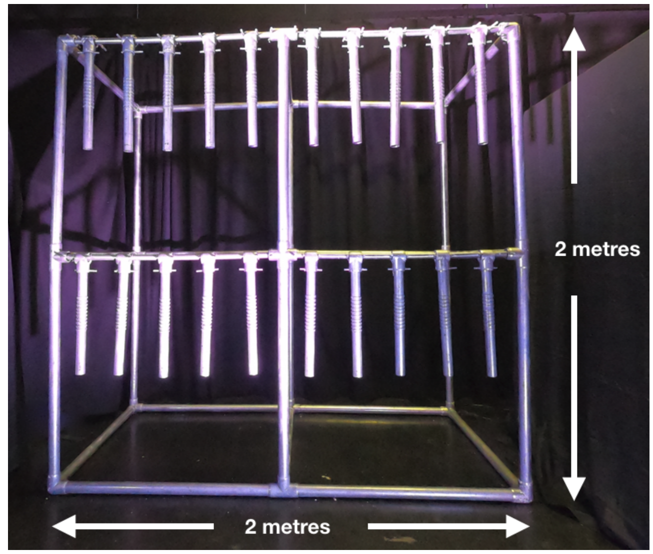

Figure 2: Photo of the study instrument with dimensions shown. ©Lia Mice

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 pendulum angle changes the feedback coefficient of the Karplus-Strong algorithm, thereby changing the decay and the timbral quality of the drone. Somewhere between 45 and 90 degrees on each pendulum, the feedback coefficient becomes greater than 1, producing an unstable system where the drone grows over time and eventually becomes chaotic and distorted as it is clipped by the digital system, finally disintegrating into broadband noise with no clear fundamental tone.

3.2.3 Tuning. The instruments are tuned to an ascending C# melodic minor scale (C#, D#, E, F#, G#, A#, B#). The lower register consists of 10 tones spanning from C#1 to E2 and the upper register consists of 10 tones from G#3 to B#4. The characteristics of the synthesis algorithm mean that each pendulum has a distinctive timbre from slightly different combinations of harmonics and inharmonicity.

There were two different layouts of tones (Figure 3). Half the participants received layout A and half the participants received layout B for the duration of the study. Layout A features lower register tones that ascend left-to-right across the lower tier, and higher register tones that ascend left-to-right across the upper tier. Layout B features lower register tones that ascend in a zigzag pattern (inspired by the chromatic layout of piano keys) on the left and higher register tones that ascend in a zigzag on the right[6].

[6]The tuning of the instrument was designed to encourage composition of melodic, tonal music so that the compositions could be compared. By creating a gap of over an octave between the lower and higher registers, the instrument features distinct lower and higher registers. Meanwhile, having two layouts allowed comparisons which reveal tonal versus ergonomic effects on the choice of musical material. These design choices created fertile ground for comparing compositions and performances created during the study.

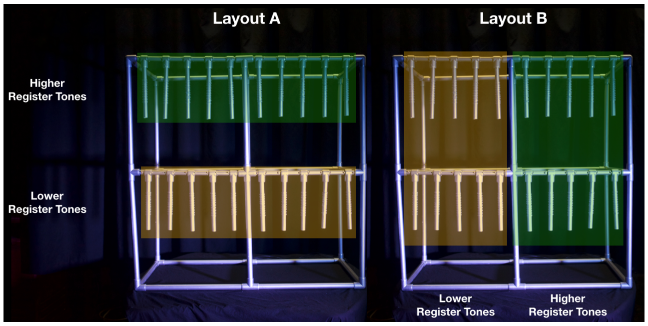

Figure 3: Photo of instrument Layouts A and B. ©Lia Mice

3.3 Selection of Participants

An open call was circulated on social media for musicians to perform a new musical instrument in an upcoming online concert as part of an instrument design study. All participants that were available for the study sessions were accepted for the study, regardless of their musical backgrounds, genres and primary instruments[7].

3.4 Study Sessions

Each participant completed 3 weekly 1-hour sessions during which time they had private access to the instrument. They were instructed to complete several compositions in response to various creative prompts. Each session concluded with a semi-structured interview. The study was reviewed and approved by the Queen Mary University of London ethics board (ethics approval reference #2393) prior to research commencing[8].

3.4.1 Session 1. Initially, the investigator introduced the participant to the study instrument and explained to them that the instrument is safe to perform as long as the participant does not attempt to climb the instrument. Having seen the instrument, the participant confirmed that they would participate in the study and completed a consent form.

The investigator then explained the instrument's tuning and pattern of tones, and demonstrated how the instrument may be performed. The following gestures were demonstrated: striking the pendulum with the soft and hard ends of a mallet so as to create clear tones; scraping the pendulum rings with the hard end of the mallet so as to create repeated tones and textures; striking the instrument frame with the mallet so as to create a cacophony of tones; raising the pendulum to create a drone; raising the pendulum above the chaos threshold to create white noise; dropping the pendulum to demonstrate the slow release of the drone/white noise. The participant was given 5 minutes to explore performing the instrument, after which time they were given 40 minutes to compose a short 1-minute sketch of a composition that responds to the creative prompt of being "dynamic in its registers" in that it makes use of the range of tones afforded with the instrument. Upon completion, the participant performed the 1-minute dynamic registers sketch twice and answered questions about their musical background and experience with the instrument during this session.

3.4.2 Session 2. The second session began with the participant performing their 1-minute dynamic registers sketch (that they composed in their previous session) twice. They were then given 40 minutes to compose a different 1-minute sketch of a composition which responded to the creative prompt of being an exploration of rhythm. The participant performed the 1-minute rhythm sketch twice and answered questions about their experience with the instrument during this session.

3.4.3 Session 3. The third session began with the participant performing their 1-minute rhythm sketch (that they composed in their previous session) twice. They were then given 10 minutes to compose a different 1-minute sketch of a composition that responded to the creative prompt of being an exploration of texture. The participant performed the 1-minute texture sketch twice. They were then given 30 minutes to compose a 3-minute composition that responds to the creative prompt of showing their favourite aspects of music created with the instrument. They were told that this final composition would be recorded for broadcast on an online streaming concert. The participant performed the 3-minute concert composition twice and answered questions about their experience with the instrument during this session.

3.5 Data Collection and Analysis

Each time a participant performed a composition the performance was captured on video. The interviews were also captured on video. The interviews were transcribed using `otter.ai`, an online automated transcription tool, and manually corrected. The interview data was analysed following a thematic analysis methodology [11]. Codes emerged through a theory-driven iterative process [47], in that the raw interview data was examined for trends and correlations that relate to conceptions of the body [21], size [53], effort [48], performing perception [10] and entanglement theories of HCI [13]. The 949 coded segments were clustered into the codes: *effort*; *entanglement*; *characteristics of the compositions*; *reflections on the instrument*; *gestures and techniques*; *performing perception*; *performer's body*; *movement*; *learning the instrument over time*; and *'edge-like interactions'*[9] [38].

3.6 Participants

10 participants (3 women, 4 men and 3 gender-fluid people) who have been trained on a variety of instruments and have varying musical backgrounds and genres participated in the study. Table 1 shows information pertaining to the participants' bodies including heights (ranging from 157 centimetres to 186 centimetres), arm spans (ranging from 153 centimetres to 191 centimetres), ages (within the age ranges of 25 to 54) and self-identified conditions that may impact musical performance. Table 2 shows the participants' musical backgrounds and the layout they were assigned. Figure 1 shows a participant (P9) with her arms outstretched in front of the study instrument.

[7]While some musicians in the study have lived experience of conditions that may impact music performance, the call for participants did not target such musicians.
[8]While the instrument is large in size it is lightweight and therefore does not put participants at risk of injury, hence the ethics facilitator deemed the study extremely low risk.

[9]'Edge-like interactions' is the term used by Mudd et al. to describe exploratory performance interactions at the boundary between stability and instability.

Table 1: Table of Participants' Bodies

Participant	Gender, Pronouns	Age range (Years)	Height, Arm Span (CM)	Conditions that may impact music performance
P1	Man, He/Him	25-34	180, 180	Occult ganglion (right wrist and shoulder)
P2	Man, He/Him	35-44	186, 181	Neurodiverse
P3	Woman, She/Her	35-44	163, 167	N/A
P4	Gender-fluid, They/Them	35-44	175, 170	Neurodiverse, Chronic anxiety, Memory issues
P5	Gender-fluid, She/Her	25-34	157, 153	Hyperventilation syndrome (HVS)
P6	Woman, She/Her	25-34	168, 166	Dyspraxia
P7	Man, He/Him	25-34	184, 191	N/A
P8	Gender-fluid, She/They	35-44	167, 168	Performance anxiety
P9	Woman, She/Her	25-34	173, 172	N/A
P10	Man, He/Him	45-54	175, 172	Pulled arm muscle

Table 2: Participants' Musical Background and Study Instrument Layout

Participant	Primary instrument	Other instruments performed	Performing instruments (total years)	Primary genre	Secondary genre	Study instrument layout (A/B)
P1	Piano	Guitar, Synthesizer, Drums, Bass	23	Electronic, New Psychedelic, Ambient	Noise, Drone, IDM, Shoegaze	A
P2	Cello	Synthesizer, Handmade electronic instruments	25	Improvisation	Avant garde, Classical	A
P3	Piano	Synthesizer, Gong	20	Electronic	Experimental pop	B
P4	Piano	Viola, Guitar, Bass, Recorder, Harmonica	19	Noise	Industrial, Punk, Metal, Avant garde	A
P5	Guitar	Photophonics, Recorder, Electromagnetic frequencies, Voice	18	Experimental electronics	Irish folk	A
P6	Piano	Computers, Guitar	21	Experimental electronic	Dance, Pop, Classical	B
P7	Saxophone	Bass guitar, Synthesizer	29	Rock	Electronic	A
P8	Piano	Bass, Violin, Synthesizer, Organ, Guitar, Recorder, Congas, Triangle	40	Electronic, Avant garde	Baroque, Singer-songwriter, Krautrock, Contemporary classical, Latin, Rock, Pop, Disco bass	B
P9	Piano	Synthesizer	20	Electronic	N/A	B
P10	Drum kit	Snare drum, Tympani, Piano	36	Rock	Jazz, Electronic, Ambient, Classical	B

4 RESULTS

4.1 Longitudinal Performance Data

4.1.1 Completion of Compositions. All 10 participants completed the 3 sessions. During each session all participants confirmed that they succeeded in completing each composition according to the creative prompts, and, despite only the final composition being featured in an online concert, participants acknowledged that all compositions created during the study represent themselves musically in that they would be happy for them to appear in an online concert. In response to each creative prompt, all participants created fixed compositions that were repeatable twice with only minor performance-related differences. The participants all successfully created the compositions during the allotted times and were not drawing on previous compositions or ideas, with the exception that for the final 3-minute concert composition all participants included segments from at least one of their 1-minute compositions.

Only one participant, P8, mentioned that the request for compositions to be repeatable may have resulted in minimising the compositions and range of performance techniques. "I think I put a bit more restraint on things so that they could be repeated", P8 commented. When comparing the goal of creating repeatable compositions to their regular improvisation-based practice they said "when I go do some crazy stuff, it departs quite radically. But then can I remember that? Sometimes I don't actually often want to remember it. I just go with it like you do in improvisation or something."

4.1.2 Evolution of Performance Techniques. As the participants became familiarized with the instruments over the course of the 3 sessions, the participants added new gestures and performance techniques. The gestures used to perform the instrument included those that the investigator demonstrated to the participants, such as striking the instrument with fingers, the soft or hard ends of the mallet, and tilting the pendulums to create a drone, as well as original gestures and techniques created by the participants.

In the second session, 7 participants (P1, P2, P4, P5, P6, P8, P9) performed new sound-producing gestures or techniques. Some new techniques were creative gestures developed to perform the instrument with fine control. P1 used the soft end of a mallet to plug the opening of the pendulum and used the mallet to raise the pendulum. He commented that using this technique he had more control changing the angle of pendulum while making a drone.

During the third session, in which the participants composed both a short texture composition and their final concert composition, all 10 participants added new sound-producing gestures or techniques at some point during the session. 1 participant (P3) performed new gestures only in their texture composition, 3 participants (P2, P4, P9) performed new gestures only in their concert composition, and 6 participants (P1, P5, P6, P7, P8, P10) added new gestures during both the short sketch and the concert composition, indicating that the process of creating a new composition encourages the development of new performance methods. P10 commented "there are lots of other sounds that I haven't really gotten out of this (instrument) yet. You know, maybe if I kept on doing this (study), I would explore more".

Some of the techniques developed in the third session resulted in radical shifts in instrument performance. For instance P5 changed from performing the instrument with mallets to solely using her hands.

P3 explained how the session 3 creative prompt to create a sketch of a composition that explores texture led her to try out new gestures during this session which ultimately led to new gestures and performance techniques in her compositions such as striking the pendulum support beam and scraping the pendulum rings. Elaborating on the process of developing these performance techniques, P3 said "because it was texture, I wanted to experiment with playing in a different spot that I hadn't touched yet before. So that's why I picked in between (playing on the support beam between the couplers that attach each pendulum)".

Tables 3 and 4 show the progression of gestures and techniques performed by the participants during each session. Table 3 shows the sessions in which participants first performed techniques demonstrated by the investigator, and Table 4 shows the sessions in which participants first performed techniques that they developed themselves.

Some of the more inventive performance gestures created by the participants involved using their legs. Figure 4 shows P7 performing his concert composition during session 3 balanced on one leg so as to use the other knee to raise a lower-tier pendulum to create a drone, a technique that freed up his hands for performing other gestures. Similarly, during the first session P9 used an extended leg to push a pendulum and sustain a drone. During the third session P10 used his hands to raise a lower-tier pendulum to create a drone and sustained the drone by resting the pendulum against his leg. P3 reported attempting to perform the pendulums with her leg but moving on from the idea without including it in her composition.

Other creative performance methods included inserting a finger (P5) or the hard end of the mallet (P5, P7, P8) into the pendulum and rattling it like a bell, a technique that P5 further extended by additionally using the hard end of the mallet to raise the pendulum to create a drone.

Some participants spoke of not performing certain techniques because they did not have enough time with the instrument to practice those techniques to get good enough at them. P10 said he avoided performing the *güiro*-esque pendulum rings because "it's a bit hard to get yourself in exactly the right position and use them. As a drummer, my inclination is always to sort of try and get a controlled movement on them, and I'd have to practice very hard". Meanwhile P5 opted for performing the instrument with her hands during the third session because she was dissatisfied with her abilities with the mallets. She said "I feel like there's a skill to be learned in how one holds them. Like, do you hold them at the fulcrum? How tight, how loose, whereabouts on the stick? And then also, you've got a hand eye coordination situation with this extra long bit. Whereas when it's your own hands, you can stop looking and not need to be quite so accurate and still get what you want to achieve".

P8 (the third-shortest participant) opted to perform the instrument with mallets rather than her hands because at 41.5 centimetres in length each, the mallets substantially add to her 168 centimetre arm span.

Although all participants understood that the instrument is digital, various participants said they had uncanny, disorienting experiences with the instrument because the instrument creates the convincing effect of being acoustic. During the second session, P2 (who regularly performs bass guitar) said that due to the "physical", "acoustic" presence of the instrument, without thinking he grabbed a pendulum to try to mute it, as one would a vibrating string or drum skin. Also during the second session, P3 (who is trained on piano and gong) said she felt disoriented because the instrument sounds like a string but is performed like a drum. "It kind of took me out of my head for a while, which was really nice. And then I came back and I was like 'Wow, that was a really interesting experience'. You know, that's what happens when you play music, you get lost in it. But this was quite a different experience, because I was standing up with sticks. But it sounded like a piano. Like it was quite disorienting in a really nice way".

Figure 4: Photos of the large instrument with participants P7 and P2 performing gestures they created themselves: P7 sustaining a drone with his knee, P2 waving arms towards the pendulums in an ancillary gesture. Photos used with permission by the participants. ©Lia Mice

Aside from sound-producing gestures, participants also incorporated into their performances exaggerated ancillary (non-sound-producing) gestures [9]. Table 5 shows the number and description of ancillary gestures performed by participants with the study instrument. These gestures ranged from freezing in place at the end of the composition (P10) to exaggerated, performative gestures such as waving arms in the air while a drone sustains as though conducting the sound (P3, P4, P5), skipping or dancing when moving between locations of the instrument (P5), and moving between performing from the inside to the outside of the instrument (P3, P6).

P8 developed various gestures that created sounds in an exaggerated performative way that could have otherwise been performed with less effort: for instance, they performed a drone with 2 pendulums at the same time by simultaneously pushing forward one pendulum and pulling another, and they performed the frame of the instrument in various locations even though they recognised it sounds approximately the same regardless of where it is struck. P8 explained that they incorporated these exaggerated gestures into their composition because of the way an audience would view the performance: "you can drone in each direction, so it looks nice when you do like this. I mean, you can work with the aesthetics of the droning as much as with the sounds". 2 participants (P5, P9) said they enjoy the feeling of moving around the large instrument as part of the performance.

Once familiarised with the instrument (during the second and third sessions), 9 participants (P2, P3, P4, P5, P6, P7, P8, P9, P10) stated that the fact that the pendulums all look the same does not affect their ability to remember the location of the tones. P8 and P9 commented that they consider the large gestures in relation to their own body to help with their memory of the location of tones. P8 commented that remembering the location of tones is "actually not as difficult as I thought. I think it's partly because you start associating them with a sound. And also you have this body gesture and maybe because the gestures are quite large as well… If you are struggling to memorize you could also use your body to measure, I guess. But I didn't find it that difficult". P9 said "Because the gestures are so big for each note and it's so physically in front of you, you quickly get to realize what's what".

4.1.3 Effort and Performance. Participants commented that performing the study instrument requires the effort of reaching or stretching (P1, P4, P6, P10) and strength (P4, P8). P8 and P10 consider that the instrument also requires effortful concentration.

P2 spoke of creating different gestures for performing drones with the pendulums on each tier, opting for gestures that required him to move his arm the least and therefore did not require effortful reaching. For the lower tier pendulums he tilted the pendulums by holding the pendulum coupler (the part of the instrument that connects the pendulum to the support pole), whereas for the upper tier pendulums he tilted the pendulums by holding on to the pendulum tube.

Although the instrument requires effort related to its size, P5 (the shortest participant) suggested adding a 3rd tier that could be performed by climbing, and P2 (the tallest participant) suggested adding more mass to the pendulums to create more inertia when swinging. We find these suggestions interesting because they would both result in the instrument requiring more effort to perform.

4.1.4 Gestural Explorations of Millimetre Control. A trend emerged showing that participants found that the most difficult technique of performing the study instrument was controlling the drones because the drone feature of the instrument is very sensitive and a small change in gesture can result in a large sonic change. Participants commented on the challenge of maintaining a drone without accidentally creating white noise (P1, P2) or keeping the drones in the "sweet spot" (P1, P3, P4, P9, P10). P2 likened the millimetre control required to perform the drone to "walking on a tightrope", saying "sometimes I can't stop it from feeding back. It's like getting that balance right. Sometimes I don't get it right".

Other aspects that make the drones difficult included starting them on time as they may not start when expected (P1) or accidentally stopping a drone before intended "because that would be quite anticlimactic" (P1). P3 pointed out that maintaining more than one drone at a time is particularly difficult because of the size and the spacing of the pendulums.

Even though participants identified performing the drone as a difficult performance technique to achieve with the study instrument, various participants (P1, P2, P5, P9) commented that they enjoyed playing with the changing timbres of the drone, such as

Table 3: Performance of Sound-Producing Gestures and Techniques Initially Demonstrated By The Investigator

Sound-producing gesture or technique that was originally demonstrated by the investigator	Participant that first performed this gesture in Session 1	Participant that first performed this gesture in Session 2	Participant that first performed this gesture in Session 3
Raise pendulum tube to create a drone	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10	None	None
Strike pendulum tube with soft end of mallet	P3, P4, P5, P6, P7, P8	P1, P9	P10
Strike pendulum coupler with soft end of mallet	P3, P5, P6, P7, P10	P1, P4	None
Raise pendulum tube to create a drone including chaos	P2, P4, P5, P7, P9	P1	P10
Strike pendulum support beam with soft end of mallet	P4, P6, P9	None	P3, P5, P6, P7, P8
Scrape pendulum rings with hard end of mallet	None	P1, P9	P3, P5, P6
Strike pendulum tube with hard end of mallet	None	P9	P6
Strike instrument frame with soft end of mallet	None	None	P6, P8

exploring how micro-movements of the angle of the pendulum can result in large changes in the sonic characteristics. P1 said "just finding that sweet spot, and then being able to subtly move your hand and drastically change the phasing of the done. That sounds awesome".

4.2 Characteristics of the Compositions

Each participant had been instructed to create compositions that represent themselves musically. During the interviews, 3 participants (P1, P2, P9) commented that the compositions they created were reminiscent of the kind of compositions they create on their primary instrument. When discussing her concert composition, P9, whose primary instrument is synthesizer, said "I think I've made synthscapes that have that same kind of expansive, rolling, slow feel". P2, a cello player, said that his method of composing with the study instrument was inspired by "not necessarily cello, but the way I play cello".

For the concert composition, 3 participants (P1, P6, P10) created compositions that were intended to be performed metronomically in their entirety, 3 participants (P2, P5, P8) created compositions with no fixed pulse, and 4 participants (P3, P4, P7, P9) created compositions that move between a fixed pulse and more flexible time keeping. The resulting concert compositions spanned various tempos from compositions without a discernible tempo (P2, P5, P8) to tempos spanning 80 BPM (P1) to 174 BPM (P10).

When reflecting on how they chose the tempos of all compositions created during the study, participants reported various methods including what felt 'natural' or 'intuitive' (P2, P4, P8, P10); the speed that they can move their fingers or hands (P1, P7); the physicality of the instrument such as the speed at which the pendulums can swing (P2, P6); choosing a tempo at random (P10); and fitting their musical ideas within the length of the composition requested by the investigator (P1, P3, P5, P10). When describing how the study requested a 1-minute composition influenced the composition tempo, P5 said "I set a timer a couple of times to get a feel for how long a minute was. And I would play with different sections within it. And if I've got to a point where the timer was going off and I hadn't quite got everything done then I knew I needed to speed that bit up, and vice versa". During the first session, P10 figured out a tempo that would fit his composition idea within the requested time-limit of one minute. "It was about 71 BPM or something so that enabled me to get pretty much the exact number of bars at that speed in the space of a minute. It happened to work out. Four beats in a bar, I think it worked out, you know. I had sort of four complete cycles, each taking 15 seconds".

4.2.1 Effort and Compositional Features. A trend emerged in which most compositions featured extended periods in which the participant stood still, punctuated by moments of moving to other parts of the instrument, rather than continuous motion back and forth around the instrument.

Regardless of which tonal layout version participants performed, 73% of all compositions created during the study featured only tones within the width of 5 pendulums (100 centimetres), compared to the full width of the instrument: 10 pendulums (200 centimetres). This was a width in which all pendulums are located in front of the performer's body and are therefore reachable without much effort. This is interesting because the tones located within the width of 5 pendulums on layout A are different from those located within the width of 5 pendulums on layout B, indicating that the performer's compositional choices of which tones to include were influenced more by physical location than pitch.

Regardless of the instrument version performed, 88% of all compositions featured tones located in both the upper tier and lower tier, and only 27% of tones chosen to be included in the compositions were located on the upper tier. This is interesting because on layout A the upper and lower tiers are different registers, whereas on layout B they are adjacent tones. That this trend emerged in all performers regardless of instrument layout indicates that the extra

Table 4: Progression of Sound-Producing Gestures and Techniques That Were Developed By the Participants

Sound-producing gesture or technique that was developed by the participant	Participant that first performed this gesture in Session 1	Participant that first performed this gesture in Session 2	Participant that first performed this gesture in Session 3
Finger tapping on pendulum coupler or instrument frame	P4, P10	None	P1
Rattle hard end of mallet between 2 neighbouring pendulums to repeatedly strike pendulums	P5	None	P3, P9
Strike pendulum tube or coupler with soft end of mallet while holding 2 mallets in 1 hand	P6	None	P1, P4
Rotate pendulum coupler to create a drone including chaos	P2	None	P5
Strike pendulum tube, coupler or support beam with hand	P4	None	P5
Scrape pendulum rings with fingers or jewelry	P8	None	P5
Push pendulum with foot or knee to create drone	P9	None	P7
Rattle finger or hard end of mallet inside pendulum tube opening	None	P5	P5, P7, P8
Hold already sustaining pendulum with other hand or rest on knee	None	P6	P5, P10
Scrape pendulum rings with soft end of mallet	None	P8	P6
Forcefully release pendulum to make it swing	None	P2	None
Rattle hard end of mallet inside pendulum tube opening, use same mallet to raise pendulum to create drone and chaos	None	P5	None
Raise pendulum to make a drone while striking the same pendulum with soft end of mallet	None	None	P1, P3, P10
Raise pendulum to create a drone and scrape rings of the same pendulum with hard end of mallet or finger	None	None	P3, P5
Raise pendulum to create drone using hard end of mallet or finger	None	None	P5, P8
Raise pendulum to create drone while using same hand to strike the same pendulum or another pendulum with soft end of mallet	None	None	P6, P9
Use soft end of mallet to plug the end of pendulum to control changing the angle of pendulum while making a drone	None	None	P1
Use forearm to raise multiple neighbouring pendulums to create drones	None	None	P2
Foot tapping on instrument frame	None	None	P5

physical effort required to raise the arms to perform the pendulums located on the upper tier resulted in participants performing fewer tones located on the upper tier in their compositions.

P8 commented that when choosing which pendulums to include in a composition she favoured pendulums within her reach. She performed instrument layout B, and said "I was going to try and use (the bass) side a bit more and other low notes than the ones I was playing, and I didn't end up, I just kept it to (the right) side. It always depends on what pattern I start with. I find something and then I have to find stuff that sonically goes with it and that I can reach in time as well". Additionally, a comment from P9 (who at 173 centimetres tall is the 5th shortest participant and performed layout B) indicated that between the instrument size and it only featuring tones within a scale, she may have not prioritised choosing the best tones for the melody of her composition and instead opted for the easiest to perform. P9 said "all the notes sound good together. So I was kind of just reaching for notes that were convenient, as opposed to thinking more about the melody. So I'm not sure that I found exactly the right combination".

P4 (who performed layout A, in which the higher register tones are all located on the upper tier) was reminded of a famous anecdote by the Velvet Underground drummer Moe Tucker. "She had this thing of saying that the ride cymbal should be used very, very rarely. So she would sort of hide it slightly above where she could reach so if she wanted to use it, she had to really feel like it was necessary." In a similar way, P4 considered the effort required to perform the upper tier tones was beneficial to their composition as this way they would not play the tones more than necessary. "(The upper register tones are) too high pitched. Too high pitched to have all the time. Like occasionally it makes a nice protrusion into the piece. It sharpens it up just a bit".

Table 5: Ancillary Gestures Performed by Participants During Each Session

Ancillary gesture	Participant that performed this gesture in Session 1	Participant that performed this gesture in Session 2	Participant that performed this gesture in Session 3
Performing from inside the instrument	P3, P6		
Exaggerated side bend with body while finger tapping on instrument frame	P4	None	None
Looking up to the ceiling in an exaggerated way while raising a pendulum to create a drone	P5	None	None
Standing on 1 leg in a performative way for no sound-related reason	P5	None	None
Holding mallets frozen in mid-air at the end of the composition	None	P10	None
Exaggerated hand movements while a drone fades out as though conducting the drone	None	None	P4, P5
Moving from performing inside the instrument to outside the instrument	None	None	P3
Exaggerated arm gesture to indicate letting go of pendulum	None	None	P3
Looking up at the ceiling in an exaggerated gesture as final drone fades out	None	None	P4
Exaggerated arm and head movements while raising pendulums located on upper tier	None	None	P4
Pushing a pendulum and pulling another at the same time to create drones in an overly performative way	None	None	P8
Striking the frame of the instrument in different locations	None	None	P8

P4 composed a section of their concert composition based around an effortful motion of using their arms to raise alternating pendulums on the upper tier. They referred to this section of the composition as the "gym equipment move". They commented that they created it based on the way their body felt, rather than because of the sound it produces, and said it is their favorite part of the composition.

Some participants were aware that, as a by-product of the effort it takes to perform pendulums that are located far away from each other, their compositions were made up of smaller parts, each located within easy-to-reach sections of the instrument. P8 mentioned that their compositions included moments of pause (which would appear in music notation as a fermata) during which time they could move to another part of the instrument. P8 explained "You need a gap. It's like when, on piano, you go to a different register... You just work with the instrument, and even if it's not mega sophisticated, that's how it came out. I'm kind of applying a bit of classical training to it". P4 also spoke of the pause of sound while relocating their body to another location of the instrument, pointing out that this influences not only the music composed but also the audience experience of the performance. P4 said "you can't necessarily smoothly go from doing one thing to the next. It does put this more performative aspect in it of you having to switch around like that. And I enjoyed it".

P6 reflected less positively on the realisation that relocating her body to different parts of the instrument to more comfortably perform a musical phrase creates pauses in the repertoire. P6 performed instrument layout B in which the lower register tones are all located on the left hand side of the instrument, and the higher register tones are located on the right hand side. P6 said "say I was playing a melody down here (in the lower register) and I went to repeat it in the higher octave, you kind of have that gap between, like 'I've finished here, and I have to go over there and play it'. You get a bit of incongruity then". Likewise, P7 (who performed layout A) expressed frustration that due to the size of the instrument, reaching to play certain pendulums can result in playing tones out of time.

4.3 Edge-like Interactions and Composition

4 participants (P1, P2, P5, P9) enjoyed exploring the point where the tone degrades into white noise, which led to developing moments in their compositions based around these 'edge-like interactions' [38]. P9 said "I really like how you can play with the distortion. So like pulling (the pendulum) up and down, just kind of playing with where the breaking point is". P2 said "the edge of feedback sort of thing, I find that's where it's got all the really nice interactions... It's kind of a subtle bouncing thing". P5 said "playing with that moment when it's just about to go mad, but not letting it, if you can, is fun".

P2 commented that the fine control required to perform the drone resulted in him accidentally performing white noise, which then resulted in him improvising around the mistake and creating a performance he preferred to his intended approach. P2 said "It just sort of ended up kind of going a little bit more into feedback when I didn't mean it to. But I still played with that and liked it". Similarly, during another performance, P2 had a compositional idea after unintentionally ending a drone. "Something cut short, and then I kind of went 'Oh, actually, let's put a bit of space in it!'"

4.4 Participants' Reflections on Their Own Bodies

During the course of the study, we noticed examples of participants feeling differently about their bodies while performing the instrument. Some comments were overwhelmingly positive, for example P5 said the instrument makes her body feel powerful, while other comments implied that participants would like to change their bodies to be more suitable for performing such an oversized instrument. P5 said performing the instrument "makes me want more arms", and P8 commented "I need bigger arms". P9 said "I wish I had 3 hands".

We found 4 examples of musical composition that the participants created despite causing discomfort or pain to themselves. P10 and P7 incorporated a gesture in their concert compositions in which they used their leg to sustain a drone by using a knee to push a pendulum forward (P7) or by resting a pendulum on the upper leg (P10). They both reported that maintaining these postures during performance were effortful to the point of extreme discomfort.

For almost the entirety of his concert composition, P1 performed a finger drumming gesture which he said was tiring but liked the sound it created so much that he was willing to perform it. ("Finger drumming is great because you can get more interesting rhythms than I probably could playing it with drumsticks".) Additionally, P1 has a wrist and shoulder injury that makes performing the pendulums on the upper tier more painful. Despite this, he still opted to perform the high-pitched pendulum on the upper register in his sketch in session 1[10]. He said pain is "something I live with" and he chose to play the high pendulum for the sake of improving the composition, saying "I wanted the polyphony of the low and high notes".

During the first session, P7 (the participant with the longest arm span) repeatedly performed a pendulum on the upper tier using a striking gesture which he said "kills" his hand due to the height of the pendulum. ("It was really high and it was really hurting my shoulder".) He later reported that his arm was sore for several days afterwards. The pain P7 encountered due to performing the upper-tier pendulums led him to suggest that the tones of the instrument be rearranged so that he could perform the upper-tier tones on the lower tier instead, or that the upper tier be lowered. ("It can be at least 20 centimetres lower. But it's also nice, the *big* thing. It's a big instrument, like, it has the presence of something large. So trying to keep the same sound or something and make it smaller would make it a different thing".)

4.4.1 Body Movement as a Tool for Memory and Composition. 4 participants (P4, P5, P8, P9) commented that using their bodies while performing the instrument helped them remember the compositions, describing this as "body memory" (P8) or "muscle memory" (P4, P5, P9). P8 said "I think a lot of music is body memory... I think once you've played it a few times then the body remembers as much as the mind. That's how I tend to remember things".

Beyond considering his body as a tool for remembering the composition, P10 additionally recognises that when performing this oversized instrument, as opposed to smaller instruments, his body movements in themselves become the process of creating the compositions in the first place, as he engages with the instrument on a spatial, topological level. "If you say make a piece of music, I'm just going to try and come up with some melodic pattern where it's not really about trying to remember which order to put my fingers anywhere, it's more a spatial problem about where am I going next? Everything is sort of enlarged. This is a very enlarged instrument compared to something very fiddly, or that you've got to blow in or whatever. I mean, those are all very tiny areas of working compared to this. You just think 'Okay, the next one's over there'. And in a way, it's possibly easier to remember 'okay, I'm going there next' because then it becomes sort of a topological thing".

5 DISCUSSION

Here we explore the findings of our study in relation to the three conceptions of the body in HCI identified by Homewood et al. [21]: *body* (embodied interaction), *bodies* (plurality) and *more-than-human bodies* (entangled assemblages). We draw a path from specific interactions between performers and instruments to a wider reflection on the way that the design of interfaces is also implicitly the design of bodies.

The shift from user to body (also referred to as the somatic turn [31]) was motivated by the recognition that everyone is embodied [21]. Through embodied interaction the instrument becomes an extension of the performer [40], shaping their choices through its affordances and constraints [33] and transforming the instrument to 'ready-to-hand' [18] as the performer shifts focus from the instrument to the act of musicking [32]. We found examples of how embodied interaction created the codependency between the instrument and the composition: the instrument size and effort required to perform it resulted in specific performative and compositional choices. Performers largely narrowed their performances to tones that are located in front of the performers' bodies, prioritising tones that were comfortable to reach over melodic or harmonic considerations. The compositions are mostly performed by a musician standing still, with musical pauses to accommodate the musician relocating their body to another location of the instrument.

5.1 Bodies: Significance of Plurality of Performers in the Context of Interface Size

Homewood et al. [21] and Spiel [50] adopt tenets of feminist HCI [2] of epistemological plurality, arguing for the singular 'body' in embodiment to be replaced with a recognition of the diversity of bodies. In our study, although all 10 participants identified as able-bodied, their bodies varied in physical proportions (height and arm span), gender identity and impacts of health and cognition-related conditions. The participants were also diverse in musical training,

[10]At the start of session 1 all participants were shown various performance methods for performing the instrument, and were told all techniques are optional, as is all participation in any aspect of the study. Subsequently, P1 performed the upper pendulum in this way. It was only later in the session that he disclosed his long-term condition (occult ganglion of the right wrist and shoulder) to the investigator.

tastes and practices, and approached the creative prompts with different priorities. The product of these pluralities – bodies, interfaces and musical tastes – result in the diverse musical performances that we observed.

Our methodology is deliberately explorative and qualitative: in embracing the diversity and pluralism of bodies as physical, musical and cultural entities, we are more interested in the breadth of outcomes and notable particulars as opposed to 'average' behaviour across all participants or predictive statistical models.

Interface designers have a responsibility to people's bodies. We found it interesting that only 1 participant (P7) suggested rearranging the tones of the instrument or lowering the height of the instrument to better suit his body, whereas 3 participants (P5, P8, P9) made comments about changing their bodies to better suit the instrument size. We found examples of participants that chose to perform tones and musical phrases that incurred pain, with the potential for injury, such as P1 who has an occult ganglion of the wrist yet performed an upper-tier pendulum, suffering through the discomfort because he wanted that particular tone in his performance. On the other hand, some participants recognized ways in which the large size of the instrument governs their movement and commented that they enjoy the way these movements made their bodies feel. These participants enjoy taking large steps (P5), moving around the instrument, exploring space and creating large gestures. P9 said "it feels really nice to be using physicality to play an instrument", finding enjoyment in the change of perspective created by interacting with a large instrument compared to her usual desktop music practice. ("When you're like doing tiny movements on Ableton or a synthesizer it's very much in a tiny world".) We acknowledge that performing with large instruments may be enjoyable to some users (such as those in our study who found the instrument performative, unique, and enjoyed creating large, forceful gestures), and exclude others. If the diversity of bodies means there cannot be a "universal user", then perhaps there should not be a universal interface size. In fact, two participants suggested that the instrument could be modified to require *more* effort to perform by adding extra weight (P2) or height (P5). We can only speculate on whether an even larger version of the instrument would result in even more characterful repertoire.

5.2 More-Than-Human Bodies: Size, Entanglement and Assemblages

Homewood embraces entanglement theories of HCI [13, 21] to argue that the body is always more-than-human. We suggest that in musical performance, the instrument co-determines the very identity of the performer: an instrumentalist only acquires that identity in relation to an instrument, and conversely the status of an object as a musical instrument heavily depends on its relationship to a musician [16]. Thus, when designing instruments we are also designing performers.

This is a significant responsibility. Redström argues that user-centred design often devolves into *user design* [44]: "we risk trapping people in a situation where the use of our designs has been over-determined and where there is not enough space left to act and improvise". An over-determined design might also privilege certain bodies or musical cultures over others.

P10's description of his process of composing with the instrument (quoted in section 4.4.1) provides insight into how a large instrument can shape a performer's identity. He said unlike his compositional approach when composing with smaller, 'fiddly' instruments, due to the 'enlarged' size of the study instrument he approached the composition of melodic patterns from the perspective of a 'spatial problem', in which he engaged in a 'topological' partnership with the instrument. From the perspective of the entanglement theories of HCI, P10's comments reveal that the composer that P10 becomes when composing with this large instrument is one who prioritises physical location of the body as a solution to the creation of melodic patterns.

P2's description (quoted in section 4.3) of creating a preferred version of a composition after improvising around a drone that mistakenly turned to white noise elucidates the positive impacts that errors and 'happy accidents' can have on performance and composition [4, 7]. In this moment, composing with the study instrument shaped P2's identity as a composer from one that does not include white noise to one that does.

To understand how our instrument might form part of a more-than-human entanglement, it is perhaps more productive to consider the instruments that each participant *usually* plays. P10, a drummer, described how his years of performing the drum kit informed his approach to composition with the study instrument, with which he performed a maximum of 8 pendulums per composition. "A more adventurous composition would go all over. And maybe a player of tonal instruments would do that. I've never really done that as a player. I'm used to sort of sitting in one spot and then things all being there and making their individual sounds".

P9 said her concert composition has an "expansive, rolling, slow feel" similar to compositions she has created with the instrument she most frequently performs and composes on, the synthesizer. Meanwhile, P2 described his compositions as something he would typically create on his primary instrument, the cello. Just as Sudnow's "piano-knowing hand" finds keyboards everywhere [52], our participant P2, who has played cello for 25 years, found a cello in the large instrument. P2 commented that the music he composed for the study instrument was inspired by the way he plays the cello.

We might say that P2 and the study instrument are entangled into a more-than-human assemblage. On the other hand, we might instead focus on what has been *removed* from such an entanglement: the cello. Removal of technology has previously been studied as an HCI research method [20]. In this case, after many years of intimate familiarity with a particular instrument, removing it leaves a peculiarly-shaped hole in a performer's (more-than-human) body. Our study instrument partially fills that hole, as seen by repertoire that bore the resemblance of the participants' primary instruments and musical styles. In recognition of the implications of the formation of performer identities through musical entanglement, we acknowledge that no instrument can be ideal for multiple users. As Homewood et al. put it, "once bodies are understood as more-than-human assemblages, then designing a technological device for more than one person becomes difficult" [21]. Is the instrument a cello-like instrument? And in which case would it be improved if it were bowable (as was suggested by P8)? Or is the instrument a piano-like instrument, and in which case would it be improved with the addition of a sustain pedal (as was suggested by P9)? Or is the instrument an organ-like instrument in which case would it be improved with the addition of foot-operated bass pedals (as was suggested by P7)?

5.3 The Value of Continued Explorations of Interface Size

We have shown how large-scale interfaces produce distinctive relationships to the body which depend strongly on the individual, and can sometimes result in conflicting feelings. P8 said "I think it would be cool to have more bigger instruments, and also electronic instruments because most of the bigger instruments tend to be acoustic... But if I had it as my own instrument, then it would be a problem with the storage". Meanwhile, P5, the shortest participant, reported that performing such a large-scale instrument makes her body feel powerful, that she would like to climb on the instrument, and that it also makes her want more arms.

In commercial practice, the economic reasons for favouring small interfaces are obvious, but HCI research does not need to adopt a fixation with miniaturised technologies. There is a whole constellation of entanglements to explore, yet the musical instrument industry at large is preoccupied with creating smaller instruments that serve an entanglement centred on using the fingers, which is tied in with precision and fine control [35]. We ask who is being favoured by the preference for this specific type of interaction.

6 CONCLUSION

This longitudinal explorative study invited musicians to perform with a large DMI. We found examples in which the large size of the instrument influenced the music created with it as performers exhibited a penchant for tones located comfortably in front of the body, and even approached the act of composition from the perspective of their spatial relationship with the instrument. We also found that playing this instrument highlighted the *absence* of the familiar instruments the musicians already played, with musicians attempting to adapt their familiar playing techniques to an unfamiliar context. We found examples of participants changing perceptions of their own bodies including feeling powerful and feeling that they could benefit from longer or more limbs. Collectively, our results highlight the complex entanglement of bodies, instruments, social and cultural contexts which are present in musical performance, and we show how exploring music performance with an oversized instrument can perturb this entanglement in sometimes idiosyncratic ways. This work is intended to open up avenues of exploration rather than focus on one. We acknowledge that the performances created during this study were diverse, and that repeating the study with different performers may result in different findings.

In an era when companies miniaturize synthesizers and drum machines to cater for the bedroom electronic music producer, there are no digital musical instruments on the market that are as large as the instrument used as a probe in this study. By highlighting the distinctive patterns of interaction at large dimensions, we provide a critical perspective on existing music technologies and a resource for understanding the design trade-offs in other areas of experience-oriented HCI.

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