

Transmitting Digital Lutherie Knowledge: The Rashomon Effect for DMI Designers

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ABSTRACT

As the field around computer-mediated musical interaction drives attention to its sociotechnical, political and epistemological exigencies, it becomes important to be guided by disability studies, and for researchers and designers of accessible digital musical instruments (ADMIs) to foreground the lived experience of disabled musicians. This resonates with the movement to promote disability justice in HCI. In this paper, we introduce a case study of the design of a stringless guitar, which was developed in collaboration with a guitarist who lost his ability to play due to impairment. We present this work as an exploration of the Rashomon effect, a term that refers to the phenomenon of multiple witnesses describing the same event from their own perspective. We argue that the Rashomon effect is a useful way to explore how digital musical instrument (DMI) designers respond to NIME's interdisciplinarity, and to reflect on how we produce and transmit knowledge within our field.

Author Keywords

accessibility, disability, epistemology, DMI, guitar, Rashomon

CCS Concepts

•Applied computing → Sound and music computing; •Human-centered computing → Accessibility; Human computer interaction (HCI);

1. INTRODUCTION

Creating new musical artefacts is a practice which involves design, as well as composition, engineering, and art. This is true whether the aim is to further the possibilities of musical work or to expand knowledge through research [9]. This article situates epistemological questions within and beyond NIME [21, 44, 14, 26, 13], and explores how designers of digital musical instruments (DMIs) clarify their processes and build narratives to justify design decisions. Understanding the diverse contributions [46] of NIME activity not

only clarifies epistemological questions, but also informs the development of NIME pedagogy and didactics. Epistemological questions then become questions about knowledge transmission.

Pressures to publish research, driven by market demands of the neoliberal university, can lead to post-hoc narratives about motivations and processes [21]. These narratives can leave out the messiness of the work and may not reflect what actually happened [21, 33, 15, 16]. Of course, we cannot find out what really happens without the accounts of witnesses to design and in NIME, individual designers are often the only witnesses. We might read into designers' narratives about their processes and decisions. We can analyse discourse, infer what is not said, what their intended audience is [5, ch. 8]. As designers ourselves, we can reflect on our own practices and provide examples of engaging with aesthetic and political dimensions of our work. Thus, it is a shared goal to develop new means of producing discourse in NIME which are reflexive, critical and inclusive of the plurality of perspectives in the field [33, 20, 21, 3, 49, 7, 29, 32].

To explore diverse perspectives we turn to the *Rashomon* effect [22, 10, 37, 40]. This term, derived from the 1950 film *Rashomon* by Akira Kurosawa, describes a storytelling method whereby different individuals give contradictory accounts of an event they experienced. We adapt this method to our design accounting, as it resonates with our view on knowledge production and transmission. Reporting what we do in design from different perspectives can provide a diffractive reading of our work, producing more reliable accounts. In NIME, drawing from *Rashomon* could involve different individuals involved in a project providing accounts of their involvement from their particular outlook.

However, in NIME, a single individual can occupy multiple roles [45], and could provide multiple accounts depending on their disciplinary viewpoint and reporting venue. This has led us to adopt a *Rashomonian* perspective that highlights the messiness and frictions of shifting roles. We can explore how the roles of composer, performer, designer, engineer, etc. overlap by engaging with the multiple points of view within and beyond our field. Instead of back-rationalisation [15], fitting success stories into a dominant narrative that best serves a particular outlet, we can embrace the plurality of perspectives in our work.

Our understanding of the *Rashomon* effect is that there is a shared reality with differing truths which can be said about it, as Heider [22] describes, and that this pluralism of perspectives can also be unpacked from within the individual, who may disagree with themselves depending on the voice they adopt. While *Rashomon* have different interpretations, we focus on its potential as a method for contrasting multiple perspectives on a common reality.



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Figure 1: The capacitive touch guitar.

Digital lutherie requires we see our instruments as more than technical objects. As Waters [47] identifies, instruments belong in larger assemblages, entangled with social contexts which characterise musicking [43]. As Born [5, ch. 8] remarks, NIME is packed with tech demos and scientific papers, skewing the focus on technical descriptions rather than musical, aesthetic or political dimensions of the work presented. This is one of the exigencies identified by Hayes and Marquez-Borbon [20, 21], an “epistemological crisis” NIME faces, requiring reflection and intervention. They point out pluralisms of the community are to be proud of and provide a rich mosaic of possibility when engaged with. Bin [3] expands on this by proposing we meaningfully address this issue—understanding NIME’s historical record and the multiple perspectives shaping our discourse.

1.1 Capacitive Touch Guitar

This paper builds on a case study of the *capacitive touch guitar* to explore the issues introduced above. This guitar resulted from a dialogic design process with the first author and disabled musician Victor Chiruta between 2020 and 2021 [50]. The instrument is a modified electro-classical guitar with sixty touch sensors on the fretboard and six touch sensors on the body. It sounds similar to a guitar, with two actuators mounted on the guitar body. It is designed for playing both melodically and rhythmically in a way which requires reduced strength and dexterity compared to a traditional guitar.

1.2 Contributions

This article explores how we describe our design processes and decisions and how we can account for the plurality of perspectives in the field. This leads to an exercise where the first author adopts three different voices for describing the work from multiple perspectives. We discuss how these accounts complement each other and how the method helped us learn more about our case study. We conclude by proposing this as a way for the NIME community to reflect on its practice and engage with its aesthetic and political dimensions.

2. BACKGROUND

Here we contextualise knowledge production and transmission within NIME; give an overview of qualitative methodologies growingly employed to query, articulate and understand experience; and look back to recent examples of the NIME record to discuss how interdisciplinarity is conveyed through instrument descriptions. We begin by discussing the epistemological questions arising in the field and how

they are addressed. Then, we outline methods which we are inspired by when producing and transmitting knowledge in our work. Ultimately, we suggest NIME practitioners should seek not to adopt an objective voice but to diffract and reconcile complementary perspectives already emerging within one’s practice.

2.1 Producing and Transmitting Knowledge

“Facts are not truth” —Hilary Mantel [31]

“This is the culture within which contingent facts—the real case about the world—can be established with all the authority, but none of the considerable problems, of transcendental truth. This self-invisibility is the specifically modern, European, masculine, scientific form of the virtue of modesty. This is the form of modesty that pays off its practitioners in the coin of epistemological and social power. This kind of modesty is one of the founding virtues of what we call modernity. This is the virtue that guarantees that the modest witness is the legitimate and authorized ventriloquist for the object world, adding nothing from his mere opinions, from his biasing embodiment. And so he is endowed with the remarkable power to establish the facts. He bears witness: he is objective; he guarantees the clarity and purity of objects. His subjectivity is his objectivity. His narratives have a magical power—they lose all trace of their history as stories, as products of partisan projects, as contestable representations, or as constructed documents in their potent capacity to define the facts.” —Donna Haraway [18]

As Haraway [18] observes, production of knowledge needs to be rethought from *modest witnessing* to an epistemology based on critical reflection, attention to differences and the importance of context. As Barad [1] notes, knowledge is produced by engaging with and being part of the world. Nonetheless, as put forth in this article, knowledge we transmit in research papers is only as good as our own accounts. Thus, more thought should be given to how we write, from what perspective, what constitutes the centre of our narratives, and to what disciplines and paradigms we respond. Therefore, NIME needs not lose itself in a search for objectivity but can focus on contributing to more robust discourse [17, 21, 3] which acknowledges its idiosyncratic and pluralistic contributions [46].

Understanding and communicating epistemological commitments within NIME has some of the same challenges as wider HCI. As Hook and Löwgren [27] put forth, interaction-design research “mainly produces knowledge on the levels of *instances* and *theories*”, yet identify a middle territory they call *intermediate-level knowledge*. Instances can also be understood as what Stolterman [44] describes as *ultimate particulars*. While many concepts have been proposed in HCI literature to better understand how we produce knowledge; designerly modes of knowing, aesthetics, and other intangible aspects of designing, remain poorly understood and theorised by the field [14, 26, 28]. Furthermore, Frauenberger’s work [13], urges we think about producing knowledge using entanglement theories, and critiques the view that instances and theories can be seen as a continuum. Within NIME, we observe many disciplines and paradigms with various epistemological commitments and methodological assumptions, which only add complexity to how we produce knowledge [17, 21].

2.2 Methodologies for Querying Experience

The witness accounts that will follow in this paper are derived from different research approaches, which we will review here. These are not a comprehensive view of 1st/2nd-person methods [23] but the ones most relevant to this paper.

2.2.1 Micro-phenomenology

Micro-phenomenology [35, 36] is a qualitative method being used in HCI/design for articulating the nuances, complexity and diversity of users' experiences beyond surface descriptions. Prpa et al. argue that HCI's 3rd wave move towards more experiential and affective focus regarding interaction has brought up "the need for an in-depth understanding and articulation of users' experiences, as lived and felt, multi-dimensional, ever-present and ever-changing phenomena" [36]. Furthermore, adoption of this method could provide an answer to interesting phenomena often being missed by current DMI evaluation strategies [39] and enhance research into musical interaction more generally [38].

2.2.2 Autoethnography

Autoethnography is an approach which acknowledges the role of subjectivity and the influence of a researcher's situatedness on the work they do, rather than assuming these issues do not exist [11]. In HCI/design, autoethnography is used for observing, noting and reporting on personal experience with a technology. Some examples of this method in use are the research into removal of self-tracking technologies [24], living without a mobile phone for the span of nine years [30], or horseback riding as a way of investigating bodily experiences [25].

2.2.3 Duo/trioethnography

Duoethnography [34, 42] and trioethnography are based on the juxtaposition of the personal experiences of two or three affined researchers. Howell et al. [28] note "the emphasis is on the dialogical relationship between the lived experiences of the researchers". Often retrospective, this method is used to learn about past projects, rather than reinforce the existing narratives which describe research outcomes. Thus, duoethnography and trioethnography can lead to new insights, by treating subjectivity and emotionality as central to research experience.

2.3 Design Narratives in Recent NIMES

Although Gurevich's [17] findings that NIME papers have skewed towards technical and scientific reporting are now over ten years old, Born [5, ch. 8] noted a displacement of aesthetic by technical criteria. Hayes and Marquez-Borbon [21] add that creative practice research's potential for transforming NIME is "largely unexplored". In this paper, we ask ourselves what kind of design narratives are prevalent in recent editions of the NIME conference. In NIME's latest two editions there are multiple exemplars of physical DMI descriptions combining technical details with other accounts.

The article about the *Kanchay-Yupana*// [6] combines thorough technical detail of the instrument with historical background and description of the decolonial motivations of the project. Although the article about the *Slapbox* [4] recounts the involvement of two percussionists, it focuses on their evaluation of the instrument from a technical point of view, omitting aesthetic decisions. The *Being With The Waves* article [41], which describes an installation, delves into the close entanglement of the listener with

sound phenomena and describes a "materially-guided approach to composition". The *mubone* paper [48] resonates with our discussion, with different perspectives given to describe the augmented trombone. The *Body Electric* paper [8] turns to movements and sensations as materials to design with, complementing technical description with a discussion of how soma design principles were used to develop a more body-centred and aesthetic instrument. The article about *LoopBlocks* [12] goes beyond a description of the hardware and software design to list criteria they found useful when designing with schools for disabled students.

All the above examples contain some form of technical description with varying detail about the hardware and software used, sound synthesis and mapping strategies. Some of them also give importance to aesthetic decisions, compositional processes, sociocultural motivations and historical backgrounds. Inspired by these and other examples, we are motivated to explicitly situate our writing with respect to NIME's multiple disciplines, embracing the opportunity to engage the community with the theoretical and epistemological commitments underpinning our work.

3. METHODS

1. Prior to this study, we published an article about the dialogic design process of the capacitive touch guitar [50]. There, we provided findings from our conversations between the first author and their collaborator, which spanned 18 months, and made contributions regarding the participatory design practices of accessible digital musical instrument design. The first author proceeded to build the guitar without further input from their collaborator due to his unavailability to continue the project.
2. In order to turn the lens on themselves, the first author recruited a methodologically-aligned researcher (second author) to interview them about the guitar design and build. The aim of this was for the first author to attempt at gaining some distance from themselves. The second author had not been involved in the design process.
3. The second author conducted one semi-structured interview and one micro-phenomenology-inspired interview with the first author. In the first, the first author described the design and build processes, and reflected on these. Special attention was given to material and aesthetic choices, and to identifying challenging elements. In the second interview, the first author evoked a specific moment in the build of the guitar which was particularly troublesome and the second author asked questions to help the first author articulate this experience.
4. The first author transcribed the first interview using a combination of automatic transcription and manual correction and familiarised themselves with the data. No formal analysis was conducted. Instead, the transcript helped refresh their memory about the process and aided in foregrounding elements of the experience beyond the obvious.
5. Inspired by the Rashomon effect, the third author suggested the first author describe their experience of building the capacitive touch guitar, writing three accounts through different prisms: (a) an HCI/engineering account, (b) an artistic/practice-based research account, and (c) a social/political account. These were written in the first person and were

not intended to be read as a single narrative. Instead, they should be treated as three different accounts of the same experience, which together provide a more complete picture of the process.

6. Finally, the first and third authors engaged in a diffractive approach to discuss the three accounts and argued their complementarity, as well as the implications of this method for NIME.

4. DESIGN RASHOMON

Here, I employ the cultural metaphor of the Rashomon effect to provide three accounts of my (first author) experience as maker of the guitar. These are an HCI/engineering account, an artistic/practice-based research account, and a social/political account. These accounts, written in colloquial style from different perspectives, help paint a more complete picture of the guitar design process. Perhaps the reader will complete the picture with their own interpretation of the whole story.

4.1 HCI/engineering account

After a year and a half of conversations with Victor Chiruta, I had an understanding of the specifications I had to consider in order to build the capacitive touch guitar. What follows is an account of how it was made and the systematic case for why it was made that way.

The instrument was built in order to address several research questions. First, how can a digital instrument approximate the sound and feel of a guitar without using strings? Second, how can such an emulation provide affordances for nuanced control of the sonic output? Finally, what is the best way to retrofit an existing guitar to preserve a sense of instrumentality and skills transfer for those familiar with the original instrument?

The design is based on retrofitting an electro-classical guitar with capacitive touch sensors. This type of guitar was preferred to an acoustic guitar because classical guitar necks are typically wider, allowing for bigger sensor area on the fretboard. In addition, electro-classical guitars have a built-in preamp, with holes for the control panel and jack. This meant drilling additional holes could be avoided.

We specified the fretboard was to be replaced with (a) a layer of laser-cut plywood with a groove down the centre for sensor cables, (b) two custom touch sensors based on Trill Craft¹ (with 30 touchpads each), and (c) a layer of veneer to provide a grid over the sensors (so the player sees/feels where to place their fingers).

The design features a custom 3D-printed panel, designed in Fusion 360, which replaces the existing panel. The new panel has three tone knobs, a volume knob, a graceful shutdown button, and a toggle switch for the amplifier.

The combination of low-latency, high-quality audio and the ability to run custom code in C++ made Bela a good fit for this project, since these features contribute to the nuanced control we set out in the research questions. The Trill sensors were also a good fit because they are open-source hardware and easy to adapt. We tested different ways of powering the guitar, and decided to use a panel-mount micro-USB port for powering the Bela board and updating the software through its IDE. The sound output is provided by a stereo jack, which can be used for headphones or to connect an external amp.

In order to provide a wrist rest for the player (who requested it), the bridge was replaced with a voluminous,

hand-machined piece of wood.

In response to our first research question, two transducers attached to the body of the guitar enhance the guitar-likeness of the instrument by harnessing the resonance of the soundboard. The location of the transducers was optimised by holding them onto the soundboard and moving them until we found the position which sounded best while playing guitar music through.

We worked with the existing braces of the guitar body to attach three laser-cut plywood brackets, which in turn hold the Bela board, the 20W stereo amp and the additional Trill Craft. The brackets are held by a combination of friction-fit with the braces and strips of double-sided tape.

The design also features a sound hole cover with six brass rods attached. These rods, which provide the right-hand interaction, are supplied by a vendor for model train hobbyists. Soldering wires onto the brass rods was challenging because the rods are thick, and one soldering iron was not powerful enough to bring the brass to a suitable temperature. Strips of felt glued to the bottom of the rods prevent the brass from scratching the guitar body or ruining the resonance of the soundboard. The sound hole cover is attached to the guitar body with laser-cut plywood clamps holding it in place. The clamps are screwed together and keep the soundhole cover flush with the soundboard.

In addition to the hardware described above, the following software runs on Bela, in C++. On the control side, an auxiliary task reads Trill sensor data. Also, there is code that runs once per block to rearrange fretboard data into a two-dimensional vector, which over a threshold determines touches (with hysteresis) and keeps track of touches. On the digital signal processing side, a pluck noise sample is triggered when a touch on the brass sensors is detected, with its amplitude determined by touch size. This pluck noise sample is fed as excitation into a Karplus-Strong algorithm. The resulting sound is then filtered according to the tone knobs.

4.2 Artistic/practice-based research account

My collaborator and I built our creative relationship on a common understanding based on (a) his articulated lived experience, needs and goals, (b) my domain-specific expertise and contributed artefacts, and (c) our aesthetic outlooks.

While we set out that the capacitive touch guitar would be a new instrument, it borrows many cultural forms from the guitar. The aim is players will be able to transfer their guitar skills, preserving many gestures which characterise the original instrument. However, the introduction of capacitive touch sensors and this particular setup require the performer relearns the instrument somewhat. It remains to be seen to what extent people will conceive of this instrument as a guitar or not, and what behaviours it will elicit within their practice.

The intended musical context of this instrument is to be used in a small group setting, to play both improvised music and the repertoire of my collaborator's favourite artists. To this end, one of the major design decisions was to use an off-the-shelf guitar retrofitted with sensors and other components. I came to this decision with the third author, who felt like a CNC-machined guitar body—the other option I was considering—would not feel like a *real* instrument. This decision, down the line, meant I could use the guitar body to add resonance to the digitally-produced string sound, placing transducers on the soundboard. Although this was not something I had discussed with my collaborator, it makes a big difference to instrument's sound, and allows it to be

¹<https://learn.bela.io/products/trill/about-trill/>

played out and about without amplification.

The decision to use Bela and design custom sensors was appropriate because I had already been using the platform for five years, building previous instruments and sound art installations. Familiarity in this case justifies the choice of technology. The simplified layout of the fretboard sensors also responds to the aim of playing a certain style of music, building particular notions of harmony with a single touch.

For my choice of materials, I was influenced by designs such as Jack and Harrison's REPLAY instrument². Their combined use of wood and brass gives the instrument a very elegant look. I wanted to emulate that feel and draw from the musical instrument connotations that wood and brass already possess. Having some leftover materials to touch and hold was also an advantage as I could try how they felt before committing to them.

Something peculiar about this instrument is the fretboard sensors sit at an angle. This is due to my collaborator's request, who stressed this would be an important ergonomic feature. We decided on the specific angle by trying out different cardboard mock-ups of the fretboard.

Although my collaborator did not specify he wanted tone knobs to control the guitar sound, I felt it would be a good addition to the instrument. I designed the knobs to be similar to the ones on a guitar, and I also added a volume knob. I tuned the filters behind the tone controls to allow for a desirable range of sounds.

Altogether, this was an open-ended approach to DMI design, where the design decisions were informed by the conversations with my collaborator. I chose components and materials based on our previous experiences with them and evaluated them from an aesthetic point of view rather than a technical one. I also made some design decisions based on my own intuition, which is something that has a tacit dimension to it. In the near future, we plan to evaluate the instrument regarding its musicality rather than its technical aspects.

4.3 Social/political account

Getting to the essence of what we really do in design takes a very political dimension when it comes to disability, as we engage with the wellbeing of marginalised communities. During our conversations, my collaborator and I discussed the politics of disablement under the social model [2], and shared our own views relating to our very different lived experiences of disability and impairment.

One of the perspectives that informed my outlook is that the guitar is an ableist invention that assumes a performer with two highly dexterous hands. As musical interaction is ingrained in society, DMI design has the agency and responsibility of addressing inequalities and normativities which are pervasive in music making ecologies. Instruments (both traditional and new) are largely designed for non-disabled people who can dedicate their lives to learning them. Most electronic music tools (as well as many conventional instruments) are designed with a western-centric view of what music is when it comes to harmony and rhythm. Identifying these biases is part of NIME practice, which acknowledges the need to promote decolonial narratives and engage with the social/political exigencies of our field to improve inclusivity and representation.

For my collaborator, being able to play guitar again after losing the ability to play a conventional guitar due to impairment has become a major life goal. During the build process, this was a very important and motivating factor to

²<https://www.cwplus.org.uk/blog/2020/04/03/the-replay-study/>

keep in mind, as I was not only building a guitar, but also a tool that would help him achieve his goal. The design decisions that I made during the whole process were informed by our discussions on the musical and extra-musical aspects of playing guitar, and the importance of preserving the cultural cues that are associated with the instrument.

An important social aspect of playing guitar for my collaborator is the role it has in social interactions. He mentioned that he would like to be able to play guitar with his friends, as he already did before acquiring his impairment. In our conversations, he had reminisced about playing out and about, on a roof terrace, on the beach, etc. For this reason, it was important to make the instrument as portable as possible, and this was permitted by using a large-capacity powerbank to power the Bela and the amplifier.

A final aspect of the capacitive touch guitar is that it looks and feels largely like a conventional guitar, but it has its own personality. The right-hand interaction with brass rods allows for a different kind of playing experience, and can be played with tapping gestures using the fingertips as well as typical strumming and plucking. This, as well as the aesthetics of the sensors, make it stand out as a novel instrument that is not just a conventional guitar with sensors attached. It has the potential of affirming the player's identity as a disabled musician.

5. DISCUSSION

The aim of providing these different perspectives is to go beyond a technical description to include the aesthetic and political dimensions of design decisions. With these complementary accounts, we affirm our method and the Rashomon effect metaphor as productive towards understanding the messiness of shifting roles in NIME.

Which type of account do we tend to trust more than others? What are the ways to combine them to paint a more complete picture? Do the descriptions go beyond the *what* and the *how* to engage with the *why* of design decisions?

Without meaning to generalise, I argue the first account is more akin to instrument design descriptions we find in some NIME papers. I suggest this is due to positivist tendencies, which characterise earlier waves of HCI tradition and which our field has inherited, as well as outside economic pressures which lead to certain narratives being tied to certain funding streams. The other two accounts are perhaps more useful in understanding the design process and design decisions. Nonetheless, any of the accounts would be incomplete on their own [21, 33, 3].

As an example, I talk about brass sensors in the first account, but it is not until we read the second account that we understand why I chose that material. Similarly, the third account is the only one mentioning the social model of disability, and the importance of preserving the instrument's cultural cues. The second account mentions the importance of ergonomics of the fretboard, but there is no mention of the social aspect of instrument portability until we reach the third account. This raises a point about the possibility of merging the accounts, something which we avoid due to the difficulty of translating political factors or experiential issues into concrete engineering specifications. Merging the accounts would be a more artificial process than leaving them as parallel but interacting layers.

I argue it is more useful to know how the guitar becomes different things and the different ways in which it has been produced, than what makes it work³. The guitar is a digital musical instrument, with its control interface, sound gener-

³see Harrison et al. [19] on this topic.

ator and mappings, but it is also a physical object with a particular shape and materiality. It is also an artefact to be used in social interactions, and draws on cultural cues connoting a particular history and meaning. The different accounts provide complementary perspectives on these different aspects.

As we put forward in the introduction, this Rashomonian telling of the design story not only helps understand the messiness of shifting roles in NIME practice, but forces us to engage with the plurality of perspectives that exist in our field.

A limitation of this work is it would have been useful to have further perspectives from the principal collaborator, who was unable to participate at this stage. Also, in contrast with the original Rashomon, other than by some elements of friction, these accounts are not irreconcilable, but rather complementary. Nonetheless, engaging in this approach has provoked a way of providing multiple perspectives which are intertwined in practice. We argue that attempting to adopt different voices is the best way of productively laying out these perspectives, rather than siloing them a posteriori.

On a final note, I would like to highlight the emerging friction between the accounts, characteristic of the Rashomon effect. Preserving the feel and familiarity of the guitar (as seen in the first account), and challenging the guitar as an ableist invention (as expressed in the third) point to different directions. Another point of friction is the contrast between supporting a particular style of musical practice (as seen in the artistic account), and arguing against the western-centrism of music technology.

One needs to understand all the perspectives given above to understand what happened, and there is a particular authenticity to each account which would be lost if forced into a single overarching narrative. The three accounts—working as nested layers of perspective—describe the *what*, the *how* and the *why* of the instrument designed, although more intricately bound up than that. Ultimately, the accounts respond to different disciplines and paradigms, something which is not uncommon in the writing found in NIME papers. Interdisciplinarity is important, but we should find the different ways in which it happens for our epistemological claims to flourish.

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7. ETHICAL STANDARDS

The instrument described in this paper was designed in collaboration with Victor Chiruta, who expressed a preference for including his real name, and who consented to our conversations to contribute to a research publication such as this one. The study was reviewed and approved by the authors' university's ethics board. We observe no potential conflicts of interest.

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