# Metaphysical instruments: prototypes for hybrid and live music-making

**Diego Trujillo-Pisanty[1], Heriberto Olguin-Simon[1], Nicolás Spitalier-Tron[1], Paola Ferrari-Garcia[1], Jordi Fragoso-Terreros[1], Alejandro Lobo-Barrera, Ximena Peña-Rios[1], Patricio Pous-Pierson[1], Fabiola Toledo-Galindo[1], Julio Torres-Cazares[1], Roberto Cabezas-Hernandez[1]**

[1]CENTRO, Mexico City, Mexico.
dtrujillop@centro.edu.mx

## Abstract

We present a series of musical instrument prototypes that inquire about how live music can be produced simultaneously in the tangible world and within the metaverse. Our study is centred around a workshop with seven young Interaction Design students and follows a Research-through-Design approach. We invited participants to ask what musical instruments for the metaverse should look like? how they are played? and what affordances do they provide for both tangible and virtual audiences and performers? Participants prototyped working electronic musical instruments that can be played and listened to in both the real world and in virtual space. We took a Critical Design stance and followed a vision-driven design process, foregrounding the non-existent rather than problem-solving or market demands.

The resulting physical prototypes deviate from existing musical instruments and offer novel interactions that affect how music is performed and listened to. Our findings show that hybrid music-making provides possibilities for collaboration, explorations of scale between tangible and virtual worlds, and notions that challenge who is in control of the music-making process. We also analyse how mapping between senses and feedback drive experiences for performers and audiences alike.

## Author keywords

Metaverse; virtual reality; internet of things; music-making; live performance; prototypes.

## Introduction

The digitisation of sound dramatically transformed music, its production, distribution, and consumption. Since the disappearance of the mix-tape in favour of mp3 players and the usage of samples from online files in live performances, digitality has blurred the roles of musicians, distributors and consumers (De Notaris & Savonardo, 2022). As Internet connections grew faster, mobile and broadly available our lives became mediated by online services and social media platforms. Our tangible world is increasingly interwoven with software and the idea of inhabiting virtual environments -the metaverse- has gained momentum with attempts to turn it into reality (Ball, 2021; van der Merwe, 2021). In this work we explore how music can simultaneously be performed and listened to both in-person and within the metaverse. We focus on musical instruments as tangible and virtual objects that emit sound in both of these environments.

With the metaverse beginning to be recognized as a space for musical opportunity, we ask ourselves how live music can be performed and experienced within it. There has been some research around networked music performance (e.g. (Rottondi et al., 2016)) and some companies (e.g. Sensorium Galaxy, Mizic.io) are starting to offer virtual reality (VR) and hybrid concerts, with some of these happening within video game environments (Groux, 2020). Attention has also been placed on how networked music enables collaboration between musicians and enhances audience participation (Carot et al., 2009; Xambó et al., 2017; Yamchareon & Herkenrath, 2005). These studies focus mostly on the technicalities of synchronization or on the social aspects of collaboration and how they exist online. There is however little work around the design of musical instruments for online and VR performance with Serafin and colleagues (Serafin et al., 2016) and Turchet (Turchet, 2019) presenting some ideas and guidelines. The instruments described for VR and networked performances in these works resemble traditional instruments such as guitars, xylophones and assorted percussion instruments. We therefore centre our research on what novel instruments for hybrid performance look like, how they are played, and how they sound; trying to distance our work from existing instruments.

Focusing on instruments as objects allowed us to follow a Research-Through-Design methodology (RtD). Taking ideas from Frayling (Frayling, 1993), Gaver (Gaver, 2012), Andersen (Andersen, 2014) and, Wensveen and Matthews (Stephan Wensveen & Ben Matthews, 2015) we consider the process of discussing and developing prototypes as a form of inquiry. Since our research questions revolve around objects which do not yet exist we find Critical Design (Dunne & Raby, 2001) to be a useful frame for our design activities as its vision-driven approach allowed us to consider possibilities that are neither problem-solving nor market-driven.

## Metaphysical instruments

Using prototypes as objects of inquiry invited us to write a brief guiding the research and development of musical instruments for hybrid performance. We named the brief *Meta-*

*physical* Instruments, a combination of the words *Metaverse* and *physical* that also references philosophical metaphysics. Metaphysics' ideas of *being* were useful for exploring how reality and experience differ within the Metaverse and outside, however our engagement with metaphysics was superficial as an in-depth analysis was beyond the scope of this work.

Our brief considered the divergent experiences of performing and listening to live music within the metaverse versus tangible space and prompted the following questions: How should instruments for hybrid performance be played? how should they sound? What social opportunities are there for live music in VR? And what novel experiences can VR provide for live music? These questions were broad and ambiguous allowing participants to project and use their own definitions of music, instruments, and live performance.

## Workshop

Given the complex skillset involved in making electronics and VR we took inspiration from Bowers and colleagues (Bowers et al., 2016) in organizing an open-ended workshop that leveraged participants' existing knowledge. We invited interaction design students to a 12-week workshop. Seven undergraduate students (authors four to eleven) joined and divided themselves into three groups. Participants were in the second year of the Design for Digital Media and Technology programme at CENTRO University and had knowledge in programming, 3D modelling, animation and digital drawing. The first four weeks of the workshop were spent developing skills in electronics, microcontroller programming (ESP-32 and the Arduino IDE), digital manufacturing (3D printing, CNC mills and lasers) and VR development using the Unity game engine. The final eight weeks were devoted to prototype production.

The workshop started with a launch presentation explaining the brief and an outline of existing experimental musical instruments was provided. We wanted to distance ourselves from stablished categories of instruments such as (Temilola, 2020; Turchet et al., 2022) and encourage participants' definitions of what an instrument is and can be. Following our Critical Design perspective they were also introduced to vision-driven design processes. A short description of each of the resulting prototypes follows.

## CQNC: Community in Quest for Noise Connection

Patricio Pous-Pierson, Alejandro Lobo-Barrera, and Jordi Fragoso-Terreros developed CQNC (pronounced sequence). It bridges the metaverse and tangible reality through real-time sound recording. CQNC uses field recordings to produce music and explores how these can work as an instrument. It requires at least two players, one using a VR headset while the other physically carries a device (Fig.1, left) capable of recording sounds and uploading them to a server.

When a recording is made it is downloaded into VR and represented as a ball. Users can then place sounds into a playback area (Fig.1, right). Sounds in this area are looped and mixed into a single output. A sound's volume is modified by moving it up and down in space and its playback speed and pitch are controlled by rotating the sphere. New recordings increase the samples available for mixing. In VR players compose complex soundscapes from samples recorded live in distant environments.

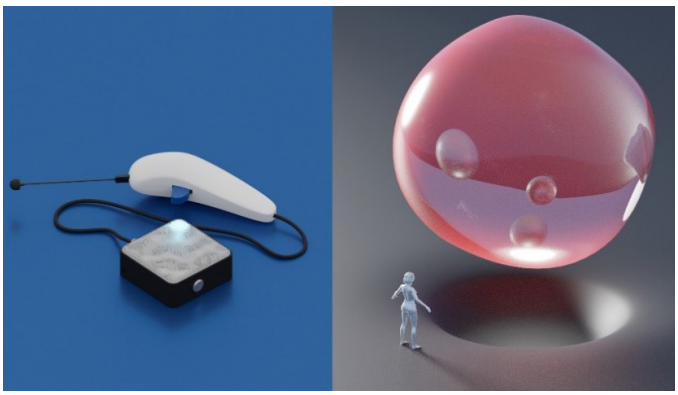

**Figure 1.** The CQNC sound recording controller (left) and its VR environment (right) showing the playback area and the sounds it contains.
Video documentation can be found at https://en.centro.edu.mx/3JC4yd1

## Conditioned Freedom (CF)

In CF Paola Ferrari-García and Ximena Peña-Rios present an interactive sound installation. It provides contrasting experiences for tangible and VR users by placing one of them within a woven structure (Fig 2, left) filled with light beams and annoying sounds. Blocking a light mutes one of the sound channels and makes the space more bearable. Within VR users experience an open landscape (Fig 2, right), an opposite environment to that of the physical installation. Each time a light is covered in the installation a relaxing sound is played in VR accompanied by a visual effect.

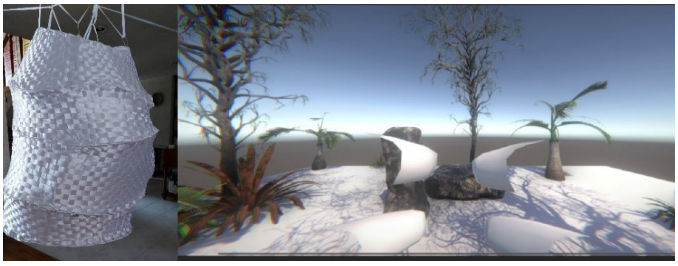

**Figure 2.** The Conditional Freedom installation (left) within which the performer interacts with light to control sounds both in tangible space and within a VR landscape (right)

CF's driving concept was that art is experienced through its end result but we seldom see the struggle of making it. Their title links this struggle with constrains in creative freedom and places the physical user in the role of a creator and the VR audience as spectators of a finished work. In their view the greater the struggles in the tangible world the more beauty is produced in VR.

## Llum

The instrument made by Fabiola Toledo-Galindo and Julio Torres-Cazares is played and listened to both from the outside and from within. Llum is a handheld tangible instrument and a large virtual space at the same time. The project explores how the functionality of a tangible object can change when its scale is altered.

The instrument is a 3D-printed cracked sphere that emits light from within (Fig 3, left). Each piece works as a key that synthesizes sound and light in both tangible space and VR. Its virtual counterpart is an enlarged version of the same sphere (Fig 3, right) within which the VR audience exists. The walls of

this space match the object's keys in shape and functionality; That is, if a user touches a wall, it will synthesize the matching sound both physically and virtually. The nature of the instrument blurs the line between audience and performer as they are all capable of contributing to the composition. For this collaboration to work sounds from each key are added together when they are played simultaneously, either physically or virtually. The sounds produced in VR therefore match those emitted by the instrument in tangible space.

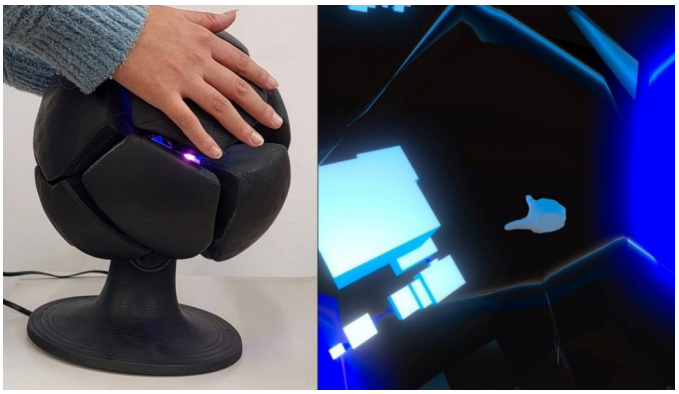

**Figure 2.** Llum, an instrument that is played both physically (left) and virtually (right). VR users experience and play the instrument form the inside while tangible ones hear the sound coming from within the object. Video documentation can be found at https://en.centro.edu.mx/3YSY65z

## Findings

The following subsections analyse how the prototypes function as musical instruments, how they approach liveness, and how scale and control were used in driving users' experiences.

### Mapping and feedback

Serafin and colleagues (Serafin et al., 2016) highlight the importance of feedback and a clear mapping between senses in VR musical instruments. We base our initial analysis on these features. Both Llum and CF map gestures to sound with visual and auditory feedback. In Llum's case, the single sound output that amalgamates inputs from all participants breaks the auditory feedback, as performers increase in number it becomes difficult to recognize sounds triggered by individual users. This collective feedback makes players respond to one another's actions rather than focusing on individual composition, turning the metaverse and live-music into social spaces. This suggests that communal feedback can favour collaborative and improvisational practices.

The CF installation also has a direct mapping between visible rays of light and sound but contrary to other instruments, gestures remove sound rather than creating it. The sounds produced in VR do not provide feedback to the performer to whom the resulting composition is unknown. The contradictory interactions arising from this multiplicity of experiences resonate with Dunne's view that objects working contrary to established logic can be very engaging (Dunne, 2008). In CF the instrument's feedback also takes a narrative role in a story, the performer's attempts to silence the whole installation are contextualised as a creative struggle.

CQNC challenges views of what an instrument and its music are. There has been research presenting field recordings as music (Shaw & Bowers, 2020). However, CQNC provides a novel perspective as it is difficult to decide what the instrument is: Is it the sound recorder as an object or is it the spheres sounding in virtual reality? This difficulty in assessing where the music-making happens and who the performer is suggests that it is truly collaborative and explores musicality in a way only made possible through networked co-creation. Referring back at Serafin and his team's principles for VR instruments we find that CQNC breaks some of these: it has no direct feedback or mapping, it embraces latency and provides no visualization of a player's body. It is yet engaging and rewarding to use, suggesting that current definitions of instruments for VR and the metaverse should be questioned in the field's early days.

### Virtual and Live

Liveness is central to the resulting prototypes. Not only in the technicalities of device-metaverse communication, but also in overcoming the lacking senses of unity and unexpectedness inherent to remote emulations of live-music as described by Tarumi an co-authors (Tarumi et al., 2017).

Llum's collaborative nature demands that tangible performer and VR audience co-exist. This temporality gains depth when seen from a social perspective. As the virtual audience shares the same space, they must also synchronise their actions in order to drive their portion of the composition. We believe that implementing communication between audience members in a future version would further enhance this social coordination.

In CQNC liveness is less straightforward. Tim Shaw describes field recording as "a practical activity that often requires one to spend long periods of time outdoors hunting for sound" (Shaw & Bowers, 2020). This is seemingly contrary to live performance, waiting for sound samples to arrive could frustrate players in VR. However, receiving a new sample provides an exciting element of unexpectedness. Users were found to restart compositions when a good sample appeared. Simulating this with pre-recorded sounds could be done but knowing that they are being recorded live adds a sense of complicity between tangible and virtual players.

### Control

The prototypes revealed issues of power and control that were not built-in by design. By control we mean people having power over one another and not interface features. In most performances musicians have complete control over what to play, how to play it and when. Our work suggests that the distribution of control is central to the metaverse but difficult to define.

In CF control is approached from an unusual angle, the person within the installation has complete control over sound production but that control is unpleasant to wield and must be endured for the pleasure of the virtual audience. This creates a dynamic in which the person in the installation controls the content but is emotionally subordinated to those in the metaverse.

CQNC and Llum show a different form of control, one in which users react to sounds provided by others. These instruments

allow adversarial or collaborative interactions between participants, where players will conform to what is being provided or try and subvert it. Llum distributes control amongst participants: If few people are attending in VR control shifts towards the person playing physically. In contrast, with tens of VR participants, the notes from the tangible instrument are quickly outnumbered by collective online behaviours. The distribution of control in CQNC is slightly simpler, every player ultimately controls their own composition but VR players have no agency over the received sound and must work within the constraints created by the person recording. It is also possible that the recorder feels pressure to provide adequate samples, despite not knowing what each player is doing, resulting in a self-constrained curation of sounds.

### Scale

All three prototypes incorporate aspects of scale. The digital flexibility of scale has been extensively explored within design; however, we see value in presenting it from a music-making perspective. Llum incorporates shifts in scale by making the tangible instrument inhabitable within VR space. This shows that VR can not only place users in otherwise inaccessible spaces but also alter our reading of tangible objects: The instrument ceases to be to a standalone object and becomes a model of the VR space, therefore containing its audience. This illusion of containment is further reinforced by making the tangible instrument emit sound and light from within while in VR it is spatially emitted from the key that was pressed.

CF uses scale to drive its concepts. The installation as a constrained space is designed to overwhelm the user. Its virtual counterpart is a large, well lit, and calming landscape. The interplay of scales between VR and installation provides an entry-point to the project's ideas, appreciating this difference in scale is sufficient to understand the project.

Both CF and Llum present VR worlds much larger than their physical counterparts. Contrastingly, in CQNC the scale of VR space is fairly small, with minimal movement and interactions restricted to a sphere in the middle. This limited space serves as an interface for an instrument that could be of global scale. Reducing sounds gathered over a large area to such a small space suggests that the metaverse could be not only an alternative world but also a container for parts of our tangible reality.

## Conclusion

Designing, developing and using our musical instruments provoked many questions that were not originally foreseen. We set out to make prototypes that questioned the ontology of instruments in the metaverse, outlining what they are and how they exist. This starting point was however greatly expanded through our process.

Our findings around feedback and mapping do contribute to characterising our prototypes as instruments but they also promted questions about collaboration and improvisation that emerge from the instruments' online nature. When discussing liveness, we were surprised to be focusing on feelings of unity and the unexpected rather than the technicalities of internet communication protocols. The themes of scale and control were not initially identified in our research and were prompted by the prototypes, we find them very relevant when discussing the metaverse and see their emergence as an indicator of how open-ended and protype driven processes can elucidate unidentified questions that contribute to research. We would like to expand on this inquiry in future work by further exploring our prototypes through live performances with a breath of different audiences and performers from various musical backgrounds.

## References


Andersen, K. (2014). The deliberate cargo cult. *Proceedings of the 2014 Conference on Designing Interactive Systems (DIS '14)*, 627–636. https://doi.org/10.1145/2598510.2598596

Ball, M. (2021, June 29). *Framework for the Metaverse*. Matthewball.Vc. https://www.matthewball.vc/all/forwardtothemetaverseprimer

Bowers, J., Richards, J., Shaw, T., Frize, J., Freeth, B., Topley, S., Spowage, N., Jones, S., Patel, A., Rui, L., & Edmondes, W. (2016). One Knob to Rule Them All: Reductionist Interfaces for Expansionist Research. *New Interfaces for Musical Expression*, 7.

Carot, A., Hohn, T., & Werner, C. (2009). *Netjack – Remote music collaboration with electronic sequencers on the Internet*. 5. Na.

De Notaris, D., & Savonardo, L. (2022). The Digitalization of Sound: How the Consumption of Music Changed from Vinyl to Hybrid Experiences. *Italian Sociological Review, 12*(1), 159–183.

Dunne, A. (2008). *Hertzian Tales: Electronic Products, Aesthetic Experience, and Critical Design* (1st ed.). The MIT Press.

Dunne, A., & Raby, F. (2001). *Design noir, the secret life of electronic objects*. August.

Frayling, C. (1993). Research in art and design. Royal College of Art, *Research Papers, 1*(1).

Gaver, W. (2012). What Should We Expect from Research Through Design? *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. CHI '12, New York, NY, USA. https://doi.org/10.1145/2207676. 2208538

Groux, C. (2020, May 9). "Fortnite" Party Royale May 8 Event Recap. *Newsweek*. https://www.newsweek.com/fortnite-party-royale-event-steve-aoki-deadmau5-tracklist-what-happened-1502909

Rottondi, C., Chafe, C., Allocchio, C., & Sarti, A. (2016). An Overview on Networked Music Performance Technologies. *IEEE Access, 4*, 8823–8843. https://doi.org/10.1109/ACCESS.2016.2628440

Serafin, S., Erkut, C., Kojs, J., Nilsson, N. C., & Nordahl, R. (2016). Virtual Reality Musical Instruments: State of the Art, Design Principles, and Future Directions. *Computer Music Journal, 40*(3), 22–40. https://doi.org/10.1162/COMJ_a_00372

Shaw, T., & Bowers, J. (2020). Ambulation: Exploring Listening Technologies for an Extended Sound Walking Practice. *New Interfaces for Musical Expression*, 6.

Stephan Wensveen & Ben Matthews. (2015). PROTOTYPES AND PROTOTYPING IN DESIGN RESEARCH. In P. Rodgers & J. Yee (Eds.), *The Routledge companion to design research*. Routledge, Taylor & Francis Group.

Tarumi, H., Nakai, T., Miyazaki, K., Yamashita, D., & Takasaki, Y. (2017). What Do Remote Music Performances Lack? In T. Yoshino, T. Yuizono, G. Zurita, & J. Vassileva (Eds.), *Collaboration Technologies and Social Computing* (Vol. 10397, pp. 14–21). Springer International Publishing. https://doi.org/10.1007/978-3-319-63088-5_2

Temilola, I. (2020). A Formalised Ontology of Musical Instruments. *International Journal of Computer Applications, 176*(24), 28–32. https://doi.org/10.5120/ijca2020920235

Turchet, L. (2019). Smart Musical Instruments: Vision, Design Principles, and Future Directions. *IEEE Access, 7*, 8944–8963. https://doi.org/10.1109/ACCESS.2018.2876891

Turchet, L., Bouquet, P., Molinari, A., & Fazekas, G. (2022). The Smart Musical Instruments Ontology. *Journal of Web Semantics, 72*, 100687. https://doi.org/10.1016/j.websem.2021.100687

van der Merwe, D. F. (2021, October 22). The metaverse as virtual heterotopia. *Proceedings of The 3rd World Conference on Research in Social Sciences*. 3rd World Conference on Research in Social Sciences. https://doi.org/10.33422/3rd.socialsciencesconf.2021.10.61

Xambó, A., Shah, P., Roma, G., Freeman, J., & Magerko, B. (2017, August). Turn-Taking and Chatting in Collaborative Music Live Coding | Proceedings of the 12th International Audio Mostly Conference on Augmented and Participatory Sound and Music Experiences. *Proceedings of the 12th International Audio Mostly Conference on Augmented and Participatory Sound and Music Experiences*. 12th International Audio Mostly Conference on Augmented and Participatory Sound and Music Experiences, London, UK. https://dl.acm.org/doi/10.1145/3123514.3123519

Yamchareon, O., & Herkenrath, G. (2005). *Remote Music Collaboration*. 15.Na.