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A Design Continuum for Autographic Sonification

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A design continuum for autographic sonification

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Abstract: Sonification and visualization practices usually take "data" as a given, without considering the complex ways in which data is collected or the complexity of the phenomena that data represents. Autographic design is an emerging field approaching this issue by starting the design process before data collection with the phenomenon itself, treating data as a material trace rather than an abstract reference. An autographic display uses a phenomenon's self-inscription, rather than its mediation and representation in symbolic encodings. While the existing framework of autographic design has a strong relation to the visual domain, a phenomenon may also reveal itself through its sonic trace. The contributions of this paper are threefold. We extend autographic design into the sonic domain, introduce autographic sonification instruments, and propose a design continuum.

Keywords: Autographic Design; Sonification; Design Methods; Design Theory; Field Study; Prototyping

1. Introduction

Data are often treated as a given in processes of representation: researchers and designers begin from datasets, analyze them, and translate them into visual or auditory forms. This practice obscures the complex relationship between phenomena and the data that claim to represent them. The act of collecting or measuring is never neutral, and the abstractions it produces risk concealing the richness and multiplicity of the phenomena themselves. The humanities have long criticized such shortcomings, calling for approaches that attend not only to data but also to the conditions of their generation (D'Ignazio & Klein, 2020).

Autographic design (Offenhuber, 2019, 2023) provides such an approach. Rather than starting from abstracted data, it engages directly with phenomena as they manifest in the world, including the perspective of the observer. Data here are understood as *traces*, material imprints, or disturbances left by events, rather than symbolic representations. The designer's task is to facilitate conditions for a phenomenon to reveal itself, acknowledging that traces are inherently polysemic and can sustain multiple interpretations at multiple scales, in contrast with the typically monosemic nature of conventional visualization (Offenhuber, 2023).

Sonification, the practice of representing data through sound for purposes of 'understanding, communicating, or reasoning' (Scaletti, 2018), offers a timely domain in which to extend this perspective. Since the early 1990s (Kramer, 1994), auditory display research has developed systematic approaches to mapping numerical values to sound parameters, treating sonification as a reproducible scientific method. In recent years (Enge et al., 2024; Lindborg et al., 2024), however, the field has expanded beyond academia, with journalists, artists, and designers employing sound to foster public engagement, activism, and critical reflection across topics ranging from climate change to human rights. Despite this expansion, a persistent challenge remains (Groß-Vogt et al., 2023): listeners often struggle to decode the designer's mapping strategy, limiting their ability to reconstruct the underlying data and to get into the nuances of the phenomena.

Listening, however, is not primarily about decoding abstract signals but about making sense of events and their interrelations in the world. As Bill Gaver noted in his ecological account of auditory perception (Gaver, 1993), everyday listening typically focuses not on sounds themselves but on the events and environments they disclose, for instance, recognizing a car approaching on a narrow street by its sound and echoes. This ecological perspective foregrounds listening as an active, situated mode of interpretation, one that connects sound directly to the dynamics of phenomena.

In this paper, we extend autographic design into the sonic domain by proposing the notion of *autographic sonification*. We first provide a brief introduction to sonification as a method for data display, as well as the emerging practice of autographic design and its design operations. We then introduce autographic sonification through selected examples and the concept of autographic sonification instruments by applying the design operations to the sonic domain. We finish by introducing a design continuum for autographic sonification.

2. Background and related work

Lenzi et al. previously analyzed existing sonification cases through the lens of autographic design and made the case for defining a new sonification technique: autographic sonification (Lenzi et al., 2024). With autographic sonification, they consider sound to be a material trace and focus on its causal, material effect.

2.1 On Data Sonification

Sonification, broadly understood as the representation and communication of data through sound, has historically focused on specifying rules for encoding dataset values into auditory properties. Early definitions emphasized systematic mappings, such as the "mapping of numerically represented relations in some domain under study to relations in an acoustic domain" (Kramer, 1994) or the "transformation of data relations into perceived relations in an acoustic signal" (Kramer et al., 1999). Later refinements required such transformations to be *systematic, objective, and reproducible* for sonification to qualify as a scientific method (Hermann, 2008).

Literature typically distinguishes between several main techniques: **Audification** directly converts data waveforms into sound, often processing the original signal (e.g., by shifting it in frequency, or applying filters) to make them audible (Walker & Kramer, 2004). Dombois and Eckel (Dombois & Eckel, 2011) extend the concept to all datasets that can be listened to, including sound recordings themselves. **Parameter mapping**, the dominant approach, systematically links data dimensions to auditory parameters such as pitch, timbre, or rhythm (Grond & Berger, 2011). **Model-based sonification** treats data as the foundation for interactive, sound-capable objects that produce audio through user engagement, effectively turning data into an instrument to be played (Hermann & Ritter, 1999).

Although sonification has been recognized as a design-driven practice intended to support user information processing (Vickers & Barrass, 2011; Jeon et al., 2019), in practice, a top-down approach defined by the designer's conceptual model, embedded in mapping strategies, tends to prevail (Lenzi et al., 2024). Listeners are then expected to reconstruct this model from the affordances of the auditory display, a task that frequently proves challenging. Consequently, debate has long centered on the so-called *mapping problem* (Stephen & Bridges, 2016): the tension between encoding data into seemingly objective acoustic parameters and the inherently subjective and situated nature of auditory perception.

More recent contributions have begun to shift attention to the role of listeners, investigating how they develop listening practices and construct meaning when encountering unfamiliar sonifications (Lenzi & Ciuccarelli, 2020; Wirfs-Brock et al., 2021). Yet, in sonification literature, an ecological approach that foregrounds the human capacity to understand the world through listening remains underexplored. Leveraging listening as an *act of knowledge production* could provide the paradigm shift needed for sonification to enrich human engagement with complex phenomena. An autographic approach can take this direction further: Rather than treating sonification as the symbolic encoding of data, we approach it from an inscriptional perspective in which sounds emerge as *audible autograph*s of phenomena, hence material traces through which listeners construct meaning. From this broader perspective, data can also be treated as inscriptions caused by material processes.

2.2 Autographic Design

The "design operations" of autographic design aim to make the process of data generation from physical phenomena to symbolic data more legible and accountable. To this end, they provide both sensory techniques for attending to phenomena as well as techniques to transform them in ways to make their imprints perceptible and measurable as data. In the following, we briefly introduce the high-level design operations of "focus," "tune," "inscribe," and "encode" (Offenhuber, 2023, p. 49).

2.2.1 Focus

Focusing means directing the user's attention to a particular aspect of a phenomenon, direction, or location. In visual terms, focusing guides not only "where to look" but "what to look for." Focusing involves techniques of *framing* (Hullman & Diakopoulos, 2011) as well as more interventionist approaches of *constraining* certain aspects of a phenomenon to make others more prominent. The same principle extends to auditory phenomena. Auditory perception enables us to isolate specific qualities of a sound from others through techniques such as reduced listening (Chion, 1994). In autographic sonification, the design objective is not primarily identifying the source, which would lead us back into the space of representation, but to focus on the auditory qualities of the sonic trace itself.

2.2.2 Tune

With this operation, a designer is "tuning the intensity and arrangement of the trace-phenomena" until they become perceptible (Offenhuber, 2023, p. 56). While the term 'tuning' has a musical meaning, here it is used differently: to tune an autographic sonification instrument (introduced below) means to prepare it so that it can respond optimally to a phenomenon. In the visual manipulation of traces, tuning can involve aggregating material to increase the intensity of a trace, or conversely, separating its components, e.g., through filtering.

2.2.3 Inscribe

Inscription is a second strategy to make an imperceptible phenomenon perceptible, in this case, through its interaction with another medium (Offenhuber, 2023, p. 56). In the wind tunnel, moving air becomes visible through smoke trails or its interaction with strings. This is understood as a process of *coupling*. The operation of *registering* leads to a more permanent trace, e.g., by attaching pens to the arms of a clock.

2.2.4 Encode

Finally, the design operations of encoding are at the boundary between traces and symbolic data. This includes manual *annotation*, such as those made by physicians on top of MRI images, which are forms of qualitative data. It also includes practices of *coding*, i.e., measuring a trace by comparing it to a quantitative scale.

3. Autographic Sonification

We begin this section by introducing a selection of autographic sonifications. In a second step, we introduce the concept of an autographic sonification instrument and present four examples. Finally, we will position the mentioned examples on an "Autographic Sonification Design Continuum."

3.1 Examples of Autographic Sonification

Most are familiar with a large number of sound traces that indicate physical processes and causalities. Imagine *filling up an empty bottle under the faucet*. Most people will not have any difficulty predicting when the bottle is full, even when the bottle is opaque, as the sound of water splashing inside rises in pitch. No explicit measurements are necessary to make this prediction. The pitch of the water splashing inside, reflecting and resonating in the shrinking space of air in the bottle, becomes a mode of measurement. In a similar manner, before we drive a nail into a wall, we will often *knock on the wall* to identify regions with pipes or other hidden obstacles. In such cases, we have learned to direct our auditory attention towards sonic traces to collect information.

Sound also indicates *material composition*. To check whether an empty plastic bottle is made from PET (polyethylene terephthalate) or PP (polypropylene) for selecting the proper recycling procedure, one only needs to slightly crumple it. PET is stiff, producing a crisp and sharper sound, while PP sounds duller, more muted. Another example is to knock on an object, e.g., a table, to learn about the material it is composed of.

Furthermore, *sound tells us something about the room*. When we hear an announcement or signal at the train station, a large part of what we hear is produced by the reverberation and the echoes produced by the floors, walls, and ceilings of the space. Also, if one were lost in a dark cave, clapping and listening to the reverb of the space could be used to estimate the direction of the exit. All of these phenomena can be described as sonic traces. They let us instinctively experience causality.

An autographic perspective involves a figure-ground shift: instead of trying to recognize what the sound represents, such as a fire truck or an error signal, it focuses on how the sound presents itself, for example, by its frequency composition or how it resonates in a room, without immediately taking it as a sign for something. *Noticing an unfamiliar sound in the engine of a moving car* prompts the driver to conduct a close examination of how it sounds, where it comes from, when it appears, etc. In other words, before the sonic trace represents (e.g., a mechanical problem), it presents itself.

All of these effects can be applied to digital data and sound sources. It involves bracketing, or postponing consideration of the data "content" and focusing on its materiality and spatiality. *Audible glitches and distortions*, for example, may be considered defects when foregrounding the content. From an autographic perspective, they are part of the trace that indicates the material origin of data. Whenever we hear an aliasing effect, we essentially hear the sonic trace of a digital system that is trying to reconstruct an analog signal containing frequencies above the Nyquist frequency. Whenever we hear the audio clipping, we are listening to the sonic trace of a digital system that ran out of bits to represent the amplitude of an analog signal. In this sense, what is considered an error to the designer of a conventional sonification is identified as informative by the autographic sonification designer.

Also, the absence of a trace can be a trace, for example, considering the *18 minutes of silence* in the Watergate tapes telling the story of the deliberate erasing of the recordings in the Oval Office during Nixon's presidency (Schuppli, 2020, p. 104) or the *missing animal voices* in areas with formerly rich biodiversity (Krause, 2025).

Finally, the relationship of autographic design to the practice of forensics can be demonstrated through the *killing of Nadeem Nawara and Mohammed Abu Daher*, an example of autographic sonification. In the incident, presented in detail in a report by Forensic Architecture (Weizman et al., 2014), an Israeli policeman fired live ammunition that killed two Palestinian teenagers in 2014. While the rifle was equipped with an extension for firing rubber bullets, live ammunition can still be used with it. When the two shots that killed the teenagers were fired, their sonic traces self-inscribed into the microphone of the CNN camera, allowing for a rigorous spectral analysis of the shots at a later point. These captured sonic traces would then prove that the bullets were live ammunition and not rubber bullets. Utilizing our terminology, the bullets "autographically sonified their quality as being live ammunition by self-inscription into their sonic trace."

3.2 Autographic Sonification Instruments

While some phenomena reveal themselves once a listener "opens their ears," others will benefit from or even need a designer to help them emerge. We introduce "autographic sonification instruments" that are intentionally designed as a material object used by a phenomenon to reveal itself sonically. Differently put, it is the phenomenon that "plays" the autographic sonification instrument, using it to express itself to a listener.

From the listener's perspective, an autographic sonification instrument must not be confused with a musical instrument. Its purpose is rather to "measure" a phenomenon. Hence, it can be compared to a measuring or probing instrument. In what follows, we introduce four different instruments and describe how different design operations relate to them. Only the first one, the Rain Drum, is designed by the authors with autographic theory in mind. The other examples are designed by others, but are described here through an autographic lens.

Figure 1 The first prototype of the autographic sonification rain drum.

3.2.1 The Rain Drum

Is an autographic sonification instrument that provides a resonating surface for rain droplets. Rain is a phenomenon that can come in various forms: From a very subtle kind that can hardly be seen or felt, to a thunderstorm. The rain drum is designed to reveal different qualities of rain in a nuanced way by facilitating its sonic trace.

For initial experiments, and as a prototype, we used a simple drum with a plastic drum head and a metallic drum shell (see Figure 1). We adopted an autoethnographic approach adapted for soundscape research (Chamberlain et al., 2017). We experimented with the instrument in the field and documented the explorations via video (available in the supplemental material via https://doi.org/10.5281/zenodo.19113851), photographs (Figure 1), audio recordings, and annotation. In the following paragraph, we report on the diary notes taken by the first author during the process.

> "First, placing the drum in the rain, I noticed a difference between my expectations for the amount of audible rain and the actual number of raindrops hitting the drum. Feeling the rain on my head and jacket, and seeing the drops in front of me, I had expected many more individual hits. Once I started listening, I realized far fewer drops struck the drum than anticipated. Second, I could hear and distinguish drops of different sizes, from small to large. Without the instrument, my attention would likely not have been drawn to the different qualities of droplets. The drum offered a more nuanced way of perceiving the phenomenon, allowing it to present itself with greater granularity. Third, the instrument triggered an exploratory mindset, encouraging me to try different interactions. One way of "tuning" was to change the angle between the

> rain and the drumhead. Tilting the drum reduced its probing area from a circle to a smaller ellipse, resulting in fewer hits and allowing me to study smaller areas. The instrument also led me to compare rain in various locations. Questions arose, such as: How does rain sound under a tree? Do droplets differ in size here? How does the sound change at different distances from a facade?"

Instead of looking at the rain or feeling it on our skin, the instrument *focuses* our attention on its sonic trace to assess its quality. Opening our ears to the nuanced differences in droplets, we develop an understanding of the phenomenon that goes deeper. On the one hand, the literal tuning of a drum will influence the audibility of the rain. *Tuning* the drum to an appropriate pitch can be considered as adjusting intensity. On the other hand, tuning in an autographic manner can also mean designing the size of the drum, for it to optimally register the phenomenon of interest. The size of a drumhead will directly affect the area that is available to the rain to leave a sonic trace. Smaller probing areas will result in fewer droplets hitting the surface, while, at the same time, providing a finer-grained spatial probing of the phenomenon. With the rain drum, each droplet *inscribes* itself into the drumskin in a material way. Each droplet mechanically excites the instrument, resulting in a sonic trace that is comparable to the sounds of other droplets. Different rain qualities become comparable through *encoding*. This can be done quantitatively, for example, by counting the number of droplets per minute in various locations or at different times, or qualitatively through a written report on the sonic impression facilitated by the drum.

3.2.2 The stethoscope

Is an instrument commonly used by physicians, for example, for the auscultation of a patient's heartbeat. Essentially, the device augments the sonic qualities of natural processes occurring inside the body. Its intentional material design, consisting of a membrane and a tube that channels sound to the physician's ears, amplifies a phenomenon to become audible to the listener. The phenomenon itself, in this case the heartbeat, has audible potential but is not loud enough for the human ear to perceive as such (not considering placing one's ear directly on another person's chest). The instrument directs the listener's attention to *focus* on the sounds inside the body, listening for irregularities. The device also allows for exploration by being placed on different parts of the body. The instrument is *tuned* in such a way as to serve this purpose best, neither being too sensitive nor too insensitive. The heartbeat as a phenomenon *inscribes* itself in the form of a sonic trace. The stethoscope registers and augments that sound so that it can be heard. The last step of autographic design, *encoding*, is done by the listener, who uses their domain knowledge to transform what they hear into a report on the patient's health.

3.2.3 The Geiger Counter

Is intentionally designed to sonify radiation density in a specific location. When radiation enters the Geiger–Müller tube, the gas inside the tube becomes ionized, making the environment momentarily conductive. During this brief moment, an electrical charge is exchanged between a metal rod and the tube. Since the rod and the tube are connected to the two poles of a loudspeaker, this voltage drop produces a clicking sound audible to the listener.

A Geiger counter *focuses* the user's attention on the presence of radiation in a specific location. In this specific case, notifying a user of radiation can even be health-critical. The instrument is *tuned* in a specific manner, such that it can facilitate different kinds of radiation. The phenomenon (radiation) self-*inscribes* into a sonic trace through its coupling with a sonic click. A Geiger counter *encodes* the radiation into the number of clicks per minute, which transforms the phenomenon into actionable data that can be further processed.

3.3.4 The "Signing Ringing Tree"

Sound installation in Burnley, England, designed by architects Mike Tonkin and Anna Liu of Tonkin Liu, is another example of an autographic sonification instrument (Tonkin & Liu, 2007). The installation facilitates the sonic trace of wind. Wind is a phenomenon that sounds through its interaction with a material, such as leaves or grass. The Singing Ringing Tree is constructed from metal pipes of various lengths and orientations. The vibrating air columns inside the pipes, *coupled* to the wind, will result in an autographic sonification of the wind strength and direction. While one could also listen to the leaves of a regular tree in the wind, with this installation, a listener might hear nuances that stay hidden otherwise.

3.3 The Autographic Sonification Design Continuum

In previous sections, we introduced several examples of autographic sonification and the concept of autographic sonification instruments, which are intentionally designed with specific operations in mind. In the following, we introduce a model that places different qualities of such autographic designs on a continuum (see Figure 2). The continuum spans from "Focusing Attention towards an Audible Phenomenon" to "Designing Instruments to Facilitate a Non-Audible Phenomenon."

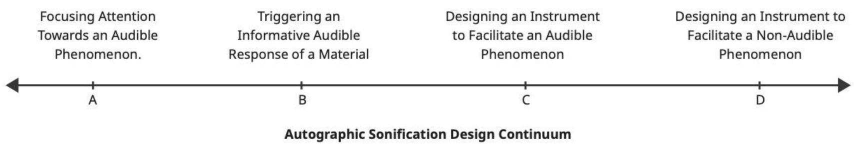

Figure 2 The Autographic Sonification Design Continuum with four positions. On the left-hand side, the continuum starts with "simple" forms of autographic sonification, where a listener needs to focus their auditory attention on a specific phenomenon. The continuum ends with the design of elaborate instruments that help non-audible phenomena reveal themselves sonically to a listener.

A – Focusing Attention Towards an Audible Phenomenon

Guiding a listener to focus their auditory attention on the informative qualities embedded in found sonic traces is the most basic form of autographic sonification. In such cases, the designer's role is to support the listener with "opening their ears." Among the previously discussed examples, the following fall into this category:

- Filling a water bottle under the faucet.
- Noticing an unfamiliar sound in a car's engine.

- The 18 minutes of silence in the Watergate tapes.
- Missing animal voices in formerly vivid natural ecosystems.
- Digital audio artifacts, such as glitches, aliasing, or clipping.
- The bullet sounds in the killing of Nadeem Nawara and Mohammed Abu Daher.

B – Triggering an Informative Audible Response of a Material

In some cases, a phenomenon reveals itself only after being triggered through an interaction. Previous examples that fall into this category are:

- Crunching a plastic bottle to learn about its material composition.
- Knocking on a table to learn about its material composition.
- Clapping one's hand to learn about the size and shape of a room.

In sonification literature, examples such as these are commonly used to make a point about how we utilize auditory information in our everyday lives. They are mentioned as inspirations for the design of sonification with ecological validity in mind, but they are not considered sonifications themselves. We propose to consider them to be sonifications, namely, autographic sonifications.

C – Designing an Instrument to Facilitate an Audible Phenomenon

Some phenomena are audible as such, but can be facilitated by providing them with a dedicated environment. Examples that fall into this category are:

- The Rain Drum
- The Stethoscope

Rain, for example, is audible as such whenever it hits the ground or the leaves on a tree. Nevertheless, a surface such as a drum head provides an environment that helps bring out different nuances in droplet quality. Furthermore, a drumhead can be tuned in surface tension, size, and material, allowing for various designs. Some phenomena have an audible potential, but are, for example, too quiet to be audible to the human ear as such. In such cases, an autographic sonification instrument such as a stethoscope may amplify the sound of the phenomenon to make it audible.

D – Designing an Instrument to facilitate a Non-Audible Phenomenon

In some cases, autographic sonification may even reveal the sonic trace of a phenomenon that is not audible as such. Examples that fall into this category are:

- The Geiger Counter
- The "Singing Ringing Tree" sound installation

The Geiger counter is an example of an instrument that exploits a physical process to make the presence of radiation audible. It does so by providing an environment that *couples* the radiation to an electrical discharge and, with that, a click sound. The instrument can be *tuned* according to the type of radiation that the listener wants to detect. The Singing Ringing Tree provides an environment where the wind, being inaudible on its own, can leave a sonic trace audible to the listener.

The designer of an autographic sonification creates conditions for a phenomenon to reveal itself sonically. Different phenomena require different designs, and the continuum presents various high-level approaches that will result in an autographic sonification. Moving across the continuum, sonification designers can act as facilitators, guiding an audience's listening intention toward a specific phenomenon and its acoustic manifestations, or build their own instruments to interact with and make sense of the world through its sonic traces.

4. Discussion and Future Work

Sonification design is often inspired by everyday skills of analytical listening, but overlooks the gap between such everyday listening and the ability to decode the meaning of an abstract auditory display. There is an unresolved design tension between the sophisticated albeit mundane capacity of humans to gain knowledge from listening (often a grounding argument to justify the use of sonification) and the widely recognized difficulty of audiences to interact with sonification artifacts in an efficient and engaging way. This tension has hindered the transition of sonification from a niche method to a mass medium of information communication. Autographic sonification takes a radically ecological approach: instead of using abstract mappings, it facilitates 'natural' ways phenomena present themselves in the world. Taking this approach also avoids the double abstraction from phenomenon to data to sound by preserving relevant characteristics of the phenomenon. Through an autographic approach to sonification, we want to suggest a 'return to things' in a phenomenological perspective, and a focus on the centrality of listening and the listener's needs (Monache et al., 2022). In a data-intense society, we believe, as designers, that this contribution supports a much-needed critical approach to the role of digital data in our lives. The ultimate goal of autographic sonification as a 'counter model' is to foster an ethical approach to data representation and, conversely, a more inclusive access to *sensemaking through data* methods for a lay audience.

We position autographic sonification as a sonification technique that has not been suggested in the literature. The core reason for us to consider it a technique of its own is that all other sonification techniques start with data and propose mappings from data to sound. Audification is the technique closest to autographic sonification. Nevertheless, the lived practice of audification, hence recording and pitch-shifting a sound for it to become audible during playback, is distinct from an autographic approach. While audification relies on a recording, an autographic approach may (or may not) end with recordings or visual annotations. First and foremost, an autographic sonification is produced by a phenomenon in a given time and space. As such, it is inherently ephemeral, and the sense-making process relies on listening in situ rather than recording a sound to be analyzed later.

We presented a design continuum for autographic sonification and how autographic design operations may apply to the sonic domain. However, an established autographic design space is best understood as provisional and evolving. Future research will focus on exploring and defining:

- Design operations that are specific and unique to autographic sonification.
- Design methods that can expand the understanding and reach of an autographic approach in sonification. For instance, other sensory modalities could be engaged with to define a multimodal autographic design where auditory, visual, or olfactory traces are needed to explore and make sense of a phenomenon (e.g., the distance of a thunderstorm by sound and light, or animal movements by their smell and sound).
- Implications of autographic sonification for topics such as learnability, intuitiveness, and literacy in the field of sonification.

5. Conclusion

With autographic sonification, we argue for the importance of opening our ears to the sonic traces of the real world. The dominant practice in sonification research is to accept "data" (mostly digital) as a given, without acknowledging that such abstractions often fall short of telling the whole story of the phenomenon of interest, its complexity, and entanglements. In contrast, autographic sonification offers designers an approach that facilitates a phenomenon's sonic self-inscription and, consequently, its revelation to a listener in a relational sensemaking process. In doing so, it is ecologically rooted in the ways we have learned to listen to our everyday environments, which is a quality of sonification that the community has repeatedly called for. Ultimately, autographic sonification offers a counter-model that re-centers listening as a mode of understanding, opening pathways to more ethical, inclusive, and phenomenologically grounded ways of making sense of our surroundings.

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