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The Sound is the Music - From Shamanism to Quantum Sound

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Introducing Music

If music is organized Sound and sounds are just thoughts, then do we need Sound to make music? Renown avant-garde composer Edgard Varèse (1883-1965), in his text The Liberation of Sound popularized the notion that music is organized Sound;[1] and Andrea Moro a distinguished linguist and neuroscientist, in his book Impossible Languages, suggested that language can also be present in the absence of Sound, like "when we read or when we use words while thinking."[2]

That assumes that we have already learned a language before we can "internalize" the sounds. Similarly, composers and conductors are trained to "hear" the orchestra's sound inside their heads with great accuracy. This training is to prepare for the moment the premiere is performed live on stage in front of the audience. Hearing the sounds in our heads from the manuscript doesn't seem to give the same kind of listening experience. Seating in the concert hall watching the orchestra perform may not be music either. Nina Sun

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Eidsheim wrote, singing or playing an instrument is an action not the sound.[3] So, when does sound become Sound?

What happens when a harp player performs on stage? When a string is plucked, the vibration sets the adjacent air molecules into motion. The sound waves propagate through air entering the ear canal to the eardrum and set into vibration the tympanic membrane. The resulting movements of the eardrum are transmitted through the three tiny bones to the cochlea in the inner ear where sensory hair cells move, creating an electrical signal; the auditory nerve carries this signal to the brain; which finally turns it into the perception of Sound. This process is called auditory transduction and converts the air pressure waves from mechanical to electrical signals that the brain perceives as Sound.[4]

A study from Marco Susino, on musical emotion in the absence of music "demonstrated strong evidence of the prevalence of systematic emotional responses to music genres even in the absence of the music signal."[5] This research aimed to understand how extra-musical cues like lyrics or genre information can affect the musical emotion responses without the need to play any music.

Austrian composer Peter Ablinger takes it one step further, and, in his works, Sehen und Hören (1994–2003) questions the idea of music without Sound. Do we need Sound to make music? Could other sensations or information decouple the music experience from Sound? Ablinger's Sehen und Hören is a series of abstract photographs called Music without Sounds. He says: "if in the beginning, the photos were studies for the concert pieces, they later asserted themselves as an independent and self-sufficient series of works – which, to me, only make sense when I consider them as music."[6]

Only in the last 200 years have almost all music rules broken apart in search of a better understanding of what is music, where it comes from, and how it could get better. The tonality has been weakened almost on the verge of collapse with chromaticism, expressionism, serialism, noise, and sound-based composition to enrich the composition pallet and offer more expressive means to the composer. Today, it is common sense that music can be stochastic, unpredictable, ambiguous, and experimental with approaches that defy categorization by the analysis tools of the Time. Composers continue to ask fundamental questions about the nature of music, what constitutes music, and what makes Sound into music.[7] What is music? Why is it here in the first place? and what are the ingredients to turn something that sounds like music into

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music?

The Three Criteria for Music

The Cambridge Dictionary defines music as “a pattern of sounds made by musical instruments, voices, or computers, or a combination of these, intended to give pleasure to the people listening to it.”[8]

The Merriam-Webster defined music as “the science or art of ordering tones or sounds in succession, in combination, and in temporal relationships to produce a composition having unity and continuity.”[9] The Oxford English Dictionary defined music as: “The art or science of combining vocal or instrumental sounds to produce beauty of form, harmony, melody, rhythm, expressive content, etc.; musical composition, performance, analysis, etc., as a subject of study; the occupation or profession of musicians.” The OED continues in the section of extended uses and further expands its definition to include bird or nature sounds: “The natural sound produced is likened to music in being rhythmical or pleasing to the ear, as the song of birds, the sound of running water, etc. (occasionally used ironically).”[10]

Regardless of how complete the above definitions are, there is a similarity that music affects our emotional and intellectual state by means of organized combinations of musical elements such a melody, harmony, rhythm, etc. On the other hand, organized musical elements or sounds may not be enough to complete the musical experience. In the late 1950s, two separate schools of thought had evolved within the musical avant-garde scene in Europe and the Americas. Their opposition was regarding "order" vs. “chaos” issues, extreme control over the musical elements versus complete indeterminacy. Serial music sounded so complex that an average listener was no longer able to follow. On the other side chance operated music had no control over the combination and order of the musical elements with somewhat similar results for the listener[11]

Although chaos or order in a musical system is also subjective, the definition of music as a continuous organized combination of musical elements doesn’t seem to capture the big picture.

To further explore the musical phenomenon, I propose the criteria that must be satisfied to call something music.

1. Music influences our emotional state
2. Music changes our state of consciousness

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3. Music affects the human body

Although these criteria could be assigned to experiences other than music, in this case the Sound is the medium that enables this experience. Reading poetry could fulfil criteria 1 and 2 but not 3; eating a five-course dinner menu could satisfy all the three criteria but not through music. The three conditions should be combined to have a musical experience to some degree. Music is a subjective experience, and what is a piece of great music for another might not be considered music. The listener can experience each criterion to a different degree. Depending on different intrinsic and extrinsic conditions such as the location of the performance, performance type (recorded music vs. live) with audience or alone, the listener's mental, emotional, and physical condition or other environmental and social conditions. There are so many variables involved which make music such a complex phenomenon.

Music Evokes Emotions

Music evokes a great range of exquisitely different emotions, by the means of associations, memories, images, feelings, thoughts, ideas, values, aesthetics, and fantasies.[12][13][14][15]

Because emotions enhance the process of memory and music evokes strong emotions, music can be involved in forming memories, either about the pieces of music or about the episodes and information associated with a particular piece of music. A recent study in BMC Neuroscience has given new insights into the role of emotion in musical memory[16]

The impact factor to this experience may vary depending on the expectation, cultural background, education, social status, style of the music, the sound quality, the genre, the physical listening, mental and emotional state of the listener.

Listening to music is a subjective experience. There is no way of knowing that what you hear is what I hear. To most people, music is indispensable, but to others it has no place in their life.

Besides, there are conditions, such as misophonia and acute hyperacusis, which cause increased sensitivity to certain environmental sounds.[17] Marcel Proust's hypersensitivity is legendary, but he hates disruptive sounds. What we would call misophonia, did not prevent him from writing extraordinary letters to Mme. Marie Williams. His letters to her were exquisitely

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polite yet contain painful apologies to keep the noise down, not of music but of ambient sounds like carpet beating, heating boilers, plumbers, and building work, all of which kept him in bed in various states of angst and asthma.[18]

Moreover, about five percent of the world's population has apathy toward music, which doesn't mean they hate or dislike music. It is the inability to feel any kind of pleasure from music. This condition is referred to as musical anhedonia.[19] Although this can have significant implications on the meaning of music and why we have it in the first place, there are still several variants to play. What kind of music in these studies do they refer to, what backgrounds, and importantly, what we define as music and musical experience? If people with musical anhedonia had survived the evolutionary selection process, then the lack of the appreciation of music will appear not to affect their survival.

From Sound to Sound Composition

Composing requires certain skills, knowledge, and talents, but it is a philosophical endeavor in its core. It is relatively easy for a composer to learn instrumentation or orchestration; to learn and master various techniques and compositional methods, yet the most prominent questions are still unanswered, what is music, how it should sound today, who are the audience and what is the purpose of composing new pieces while we have thousands of hours of recorded music. Only in this philosophical discourse, there are no words; there is only Sound. The Sound is the vehicle to something highly complex and multifaceted that is called music.

In sound-based composition, the Sound is the only form-bearing musical element. First, it is essential to emphasize the significance of a single sound only and then its relationship with two or more sounds. John Cage said: "…musicians can't hear a single sound; they listen only to the relationships between two or more sounds."[20] This is somewhat different from the "note-based music," whereas most of the time, a single note has no meaning, but only in relationship to others. Sound does not and cannot replace the musical note because it is a sound. One sound alone can keep the listener engaged for a long time without the need to relate it with other sounds. Musical notes are abandoned in favour of delicately carved gestures, warm fizzing sounds, forcefully distorted sonorous variants, and instrumental acoustic experimentations. The functionality of the diatonic interval, harmony, motive, and melody ceases to exist. Instead, it reconsiders and re-evaluates those

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elements proposing gestures, figures, textures, articulations, postures, symbolisms, and degrees of sound energy often grouped into a single composite sonic entity[21] The thematic idea seeks solutions in Sound objects with a distinctive atmosphere, motion, mood, context, and timbre.

The sound composition develops and manipulates the morphoplastic attributes of the sound object to a great extent. Composing Sound is based on sound-to-sound structures, on transformation strategies from one to another, on functional sound classification, as well as holophonic textures of fused-ensemble timbres.

The musician should first focus on making, not playing, and controlling a single Sound, and then transforming it into another. Sound-based composition requires a different type of virtuosity, a virtuosity of Sound, a concentration not on the precise rhythmic motives at the exact tempo and intonation, but instead on the minutiae details of each sound. It demands the accurate production of variable sound possibilities and the clear distinction between one timbre and another to convey the musical ideas and the structure of the piece. In sound composition, the Sound is the music.

Perhaps, it has always been like that, and it depends on the time and place, the focus might be on different constituencies of the Sound. Sometimes it is the melodic Sound, other times the harmonic Sound. In western classical music, which I know very well, there is a slow development that seems to be more additive than linear. New ideas and realizations are kept added to the mix that each time offers an opportunity for a better and complete experience.

The Mannheim school, a group of composers with a new approach to performing orchestral music in the second half of the 18th century, introduced several novel ideas into the orchestral music of their days, such as sudden crescendos and diminuendos. This was something unheard of before, but after its introduction by composers such as Johann Stamitz and Christian Cannabich it became a standard technique that composers continue to use today[22]
The introduction of new ideas is an ongoing process. Innovations do not cancel the old or prove the more senior wrong. Every time there is a breakthrough in music, it just gets better. Composers understand better how to make music, how to express their ideas better. In the last hundred years, some composers challenged the notions of music, noise, or Sound.

Luigi Russolo in his manifesto the Art of Noise (1913),[23] invited his audience to a new music paradigm where noise and Sound are one. The

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Sound of a machine and the Sound of the violin can coexist in the same musical context. He even developed his musical instruments with the name intonarumori. John Cage also challenged the notion of noise vs. musical sounds, in his text The Future of Music, Credo, written in 1937 for a lecture in Seattle, said: "Whereas in the past the point of disagreement has been between dissonance and consonance. In the immediate future, it will be, between noise and so-called musical sounds."[24] For Pierre Schaeffer, the world's sounds become musical material: any sound that can be recorded is then edited, treated, and manipulated until a composition is crafted from these real-world materials.25Also, composers such as Henry Cowell, Murray Schafer and Edgard Varese, Karlheinz Stockhausen and Iannis Xenakis, could be added to this list.

Electroacoustic composers use the term Cinema for the Ear. To describe compositions that employ esthetical criteria whereby if you listen to the music in total darkness the work will be highly visual. It creates a "cinema for the ear" in which meaning as well as sound become the elements that elaborate these works.26

Composing Sound is all of the above; it is the art of interweaving mental images via Sound and vice versa, it is the manipulation of every recorded Sound, the use of noise as equally applicable musical material, the musical appreciation of our soundscape, the invention or modification of new or existing musical instrument, their use in new experimental ways, and many more innovations that the development of music has heard so far. Sound is a perceived as a whole that cannot be separated. When I compose, I don't hear the Sound; I am the Sound. Being Sound there are no boundaries between logic or creativity, perception or sensation, movement, or stasis; to paraphrase René Descartes "I sound therefore I am."

From Sound Composition to Sound

Sound is a somewhat elusive phenomenon. We cannot hear a sound but its effects. Also, we cannot measure a sound but its constituents. The constituents include pitch in frequency, rhythm in seconds, dynamics in decibels and timbre in a group of descriptors such as a brightness, attack time, formant structure, harmonicity, spectral fluctuation, etc.

On the other hand, Sound is just air molecules propagating in mid-air. Only when they finally reach the primary auditory cortex in the temporal lobe,

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that become perception; then voila, we have sound; that is frequencies, harmonies, timbres, images, memories, words, anticipations, and emotions, fantasies or even smells. Composers such as Denis Smalley[27] and Trevor Wishart[28] have discussed the potential of Sound in invoking extramusical meaning, connotations, and associations in addition to the abstract comprehension of the Sound features themselves and their relationships (high low, quite loud, fast-slow, etc.). Sound can also evoke memories directly like the sound of windmill or indirectly via a sequence of associations such as firework sounds that evoke memories from a special day years ago. It could also bring images, emotions and smells related to these memories. Others could perhaps experience similar effects by abstract realizations such as symmetries or geometrical relationships, aesthetics, or technical accomplishments. The brain is selective, and the first hearing might be incomprehensible, another hearing of the same piece could reveal new insights. In Sound composition there is a multiplicity and layers of information that cannot be observed in a single timeline.

If the distinction from one Sound to another is so critical then how is the borders from one sound to another defined, when the sound of a bird calling, becomes different from a slide whistle and from a high octave *sul ponticello* passage on the violin's first string? How the extramusical connotations of the sound "trick" our mind, and what are the perceptual limitation? Erick Robert in his book *Sound Structure in Music*[29], refers to the term subjective constancy with Sound, which is our ability to recognize objects as the same, even though our sensation of the object changes.

In music, subjective constancy identifies a musical instrument as constant under changing timbre, pitch and/or loudness, in different concert halls and by other players. On one hand subjective constancy blurs the distinction of one Sound to another, but on the other hand in sound composition can open aesthetic and artistic avenues that allow original and personal expression.

In Ai Phantasy[30] for electroacoustic sounds, the end of the piece creates a timbral and contextual transformation that moves from a panpipe-like sequence of pulses to a bicycle reverse pedaling to an old clock "tick-tock" sound to footsteps on the water. These sounds are connected timbral and rhythmically but also trans-contextually. As they change their extramusical context, they also create a zone of ambiguity that allows for multiple interpretations and associations to occur.

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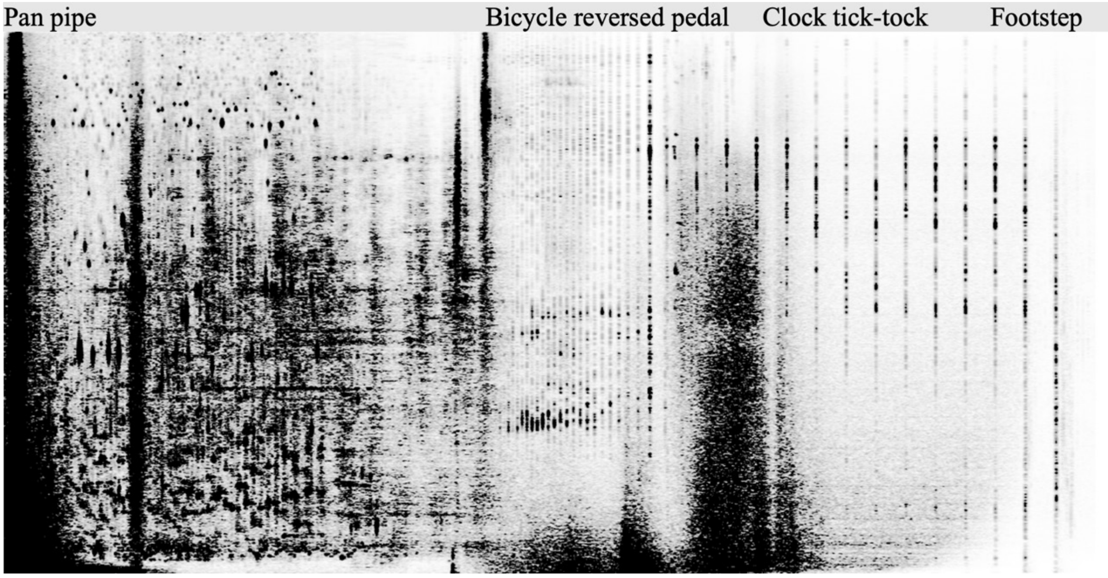

Figure 1: Sonogram extracted from the last section of AI Phantasy, a section from 10:26-11:10 minutes.[31]

The Sound is the medium and the message; I do not need a snake to generate its hissing Sound. I can resynthesize it with the proper instrumentation and performance technique. All I need more sounds, so I am constantly searching for new sounds. The more sounds I have, the better I can express myself. To that extend, many instruments have limited sound pallets, and the challenge for me is to see how many different Sounds I can make out of it.

In Viper Snake[32] for two percussion players and electronics, I designed a bow stick, modified a ratchet percussion instrument, and created an amplification system suitable for the composition's needs. I cannot identify my role as a composer if I sit on a chair with a pencil and paper or in front of the piano and notate on a musical page. Composing Sound is a unique endeavor, and it is informed by various disciplines and involves a diverse range of skills. To reach these new levels of sonic innovation that will allow me to express better my musical ideas, I need to go beyond the Sound. I need to design the bow stick and modify the ratchet; for that I become a carpenter to shape the wood, designer to digitally fabricate 3d printing objects; performer to test the bow stick and the modifications, audio engineer to record the sounds and the list goes on. The classic triangle that a piece of music needs three kinds of people to exist: composer, performer, and listener even in different times and places, is broken.[33] In sound composition, it is more like a circle that embraces the composer, the designer, the performer, the listener and the space, all at the

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place and time and in no particular order. However, the objective remains, the search for new sounds that will be more, beautiful, bizarre, or ugly, malleable, controlled, and organized.

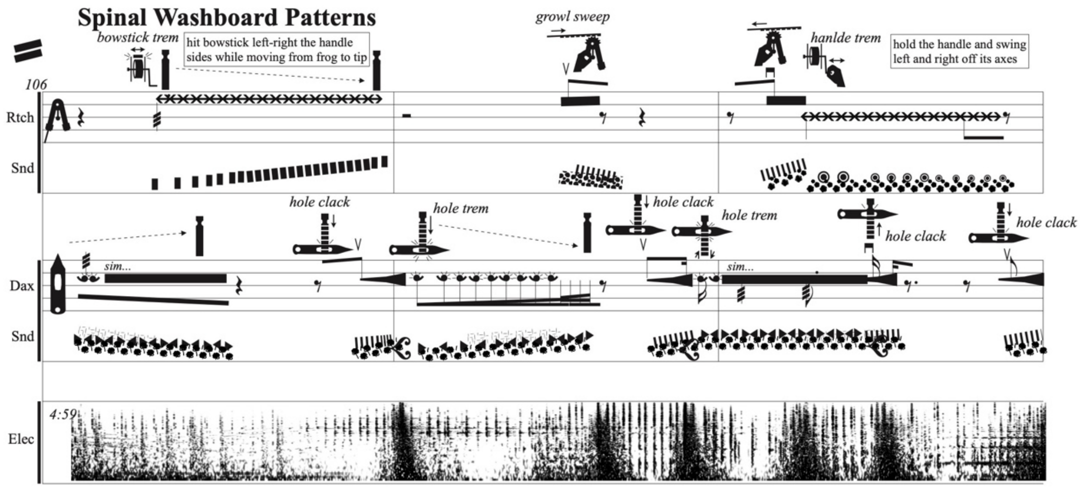

Figure 2: Viper Snake measures 106-109

All these facets are part of the composition process; in sound composition, the movements and the gestures that produce the various sounds are not disconnected from the sounds. This is not the reason for the sounds they are the sound altogether.

Conscious Sound - the sub/conscious musical mind

Does music change our state of consciousness and alter the way we perceive time and space? Is it possible that music stimulates a part of the subconscious mind?
Alan Moore an English writer known primarily for his work in comic books describes magic as the art of manipulating words in a documentary interview. He says, "To cast a spell is simply to spell, to manipulate words, to change people's consciousness."[34]

Shamanism – and the Origins of Music

Indeed, these phenomena have been utilized in shamanic practice for ages. Rouget suggested: "To shamanize, in other words, to sing and dance, is as much a corporeal technique as a spiritual exercise. Insofar as he is at the same time singer, instrumentalist, and dancer, the shaman, among all practitioners of

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trance, should be seen as the one who by far makes complete use of music."[35]

Similarly, I see composers as sound alchemists that use Sound to change people's consciousness. They manipulate sounds that can transcend the listener's state of consciousness and allow them to have a subjective experience. Shamans, tribe chiefs, warriors, hunters, and ordinary people have used Sound to their advantage. In the ceremonies, gatherings, or ritual, they will incorporate nature and animal sound imitations to scare the evil spirits; to bring the animals close and hunt them down; to heal diseases or make it rain.[36]

When I compose, I am inspired and use all of the above; I compose sounds that imitate natural phenomena, animal calls, human activities, and machines. In *Hippo*[37] for clarinet in Bb, piano, and violin, which is part of a series of compositions under the theme Zoomusicology, begins with a transcription of a recording from 1976 of two hippopotamuses making sounds nearby the river in Luangwa National Park, Zambia.[38]The first minute, measures 1-20, has been analyzed and resynthesized for clarinet, piano, and violin. The recording functioned as the acoustic model that I used to re-synthesize with the three instruments. The score below shows the first system of Hippo and two waveforms that represent measure one. The waveform to the left shows the model, the original recording 1976 and the waveform right the resynthesized version for the trio.

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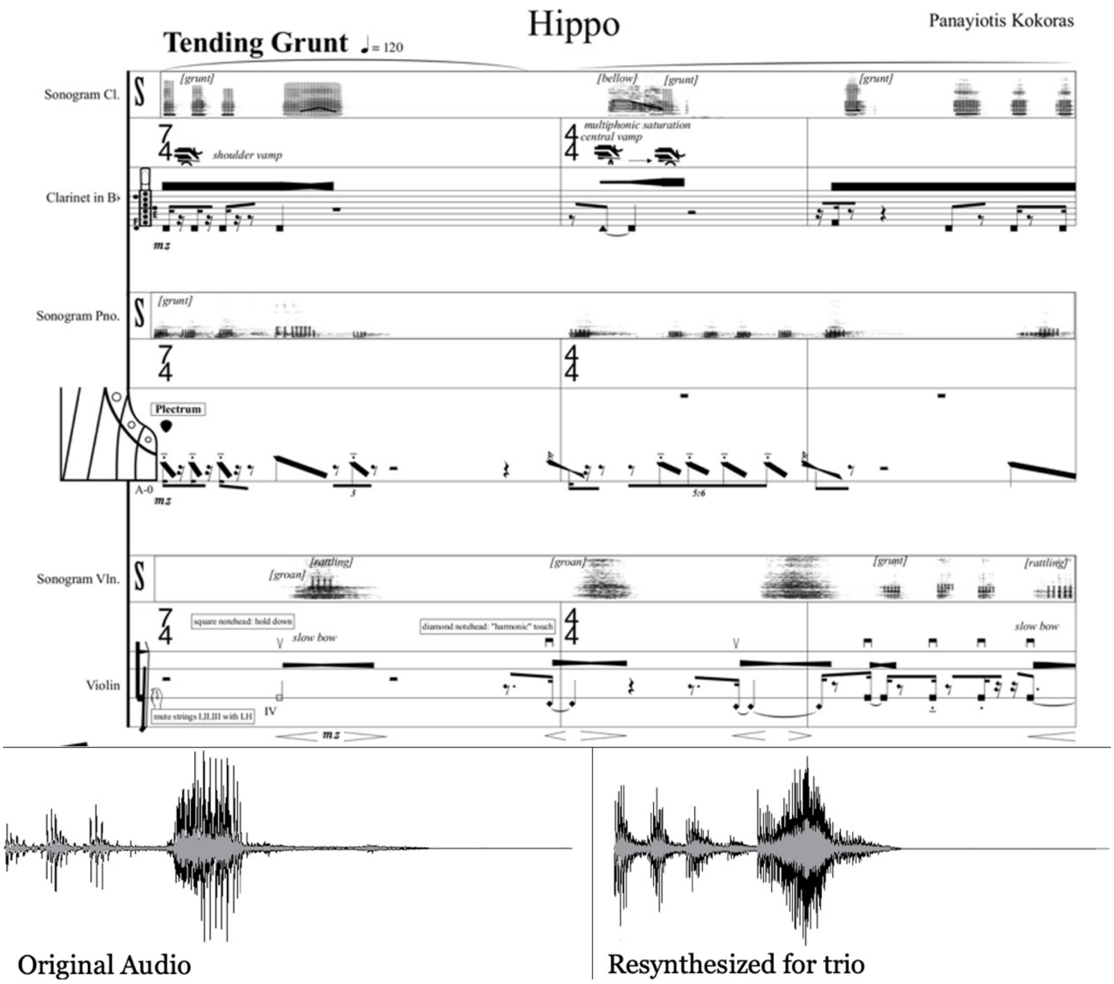

Figure 3: Left - full score of measure 1 from Hippo. Right - waveform representation of the original hippo's sound and resynthesized for trio.[39]

In the first measure both the clarinet and the piano start with the three iterations and the longer quarter note as a result of the re-synthesis of the acoustic model, the first two seconds in the original 1976 recording. Besides the rhythmic pattern and the dynamic contour, the re-synthesis of the "grunt" sounds has been achieved using various instrumental sound techniques and instrument modifications. Using sonographic analysis, I studied the rhythmic iterations, the way they are sequenced as well as the temporal timbal changes, their envelope and spectral intensities. Next, I reproduced similar instrumental sounds by modifying various acoustic aspects of the instruments (reed, strings, and found objects) and by developing the appropriate performance techniques and temporal articulations. While experimenting with the different instrumental sounds to match my acoustic models, I recorded hours of sound materials.

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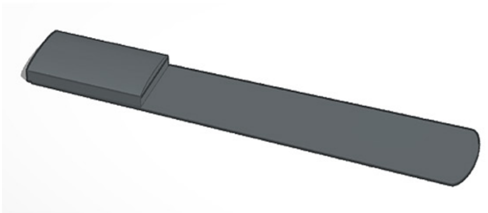
The clarinet uses an ultra-thin synthetic reed that I developed in 2014. This reed allows me to explore entirely new timbres and sound gestures. The piano is played inside the harp on the lowest string using a guitar pick and moving longitudinally to the coils of the string. The violin simulates the hippo-like grunt sound by extreme detuning of the IV string. The fourth string should be detuned almost two octaves down and bowed with a slow and short down-bow gesture.



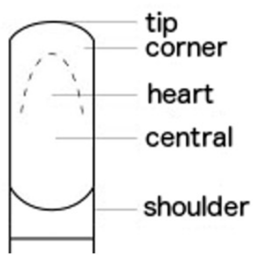


Figure 4: Left- Early 3D printed prototype of the ultra-thin synthetic reed for clarinet; Right- Reed Anatomy, the vamp of the reed is notated in five distinct areas: tip, corner, heart, central, and shoulder. Each area on the reed can produce a wide range of sounds.

The Sonogram or Sound staff (S) (figure 3) provides a visualization of the Sound to be produced. In sound composition, the performance action and the Sound have been decoupled. The performer may open the clarinet keys from bottom to top but they may not sound as “expected”. The representation of the resulting performance sound aims to fill this gap and provide the performer the missing information. How this Sound should sound after all. The vertical axis represents frequency and the horizontal axis time. The greyscale coloring represents loudness in terms of frequency (from black for the loud frequencies to white for silence). Also, I often draw different shapes and patterns to represent the sound characteristic.

The clarinet staff has six spaces and seven lines, instead of the five lines traditional staff, because it represents the clarinets fingering. The thick black horizontal stripe to the top displays the position of the lower lip and the pressure on the reed. The wider the line, the looser the lip, the thinner the line, the more pressure is applied to the reed. The more pressure the higher the pitch and less roughness to the Sound. The less the pressure the lower the pitch and additional roughness to the Sound. A similar approach is applied to the piano and the violin staff. The score instructs the performer on how to

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perform each Sound and how the Sound should sound.

The music in Hippo can be experienced as an abstract organized sequence of sound gestures and/ or associations with extramusical ideas, mental images, and trans-contextual strategies. Trans-contextuality in music is a method by which the extrinsic meanings of a sound can have a profound impact on their musical surroundings.[40] Associations such as the sounds of the hippo, their habitat, perhaps memories related to it from zoos, documentaries, books etc.; thoughts about environmental awareness and wild animal protection; smells or other sounds, even tactile sensations. This experience maintains a connection from the most concrete experience of music to the most abstract manifestations of sound imagination.

Although zoo musicology was only established as a subject in the 1980s, even in the 17th century musicality was inherent in the vocalizations of animals.[41] One of the known engravings from Athanasius Kircher's *Musurgia Universalis is* a selection of domestic bird songs in musical notation. The nightingale's song is first, then the cock, the hen laying eggs and calling her chicks, the cuckoo, the quail, and the parrot. In their birdsong, birds were also seen to reveal links between music and nature. The parrot however is depicted to be imitating humans. It says "hello" (in Greek!). On another page, Kircher claims that the sloth (a type of ape) "perfectly intones the first elements of music," by which he meant the musical scale. Alongside that can be seen is the scale of six notes believed to be sung by this ape. For Kircher, the notion that an animal could do this confirmed the naturalness of music. Thus, he believed that music enshrined elements central to the creation of the universe and the "sound of nature" itself.[42] In *Athenaeus Deipnosophistae*, Chamaeleon of Pontus (c. 350 – c. 275 BC) has said: "the men of old devised the invention of music from the birds singing in solitary places; by way of imitating them, men instituted the art of music" (Deipnosophists ix.390a). Sakadas of Argos (c. 585 BC) aulos player and composer, in performing his *Pythikos Nomos* he imitated the sounds of gnashing teeth and hissing serpents on the pipes when narrating Apollo's battle with the snake Python."

One can imagine that imitations of animal songs may not only have been present in the earliest human music but may even have been their origin. A possible route from animal imitation to the musical song might have been from direct imitation for practical purposes; ritualized reproduction for symbolic or magical purposes; symbolic imitation; to abstract music. A more recent

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example is the *Caccia*, (Italian: "hunt," or "chase"), one of the principal Italian musical forms of the 14th century. *Caccia* texts were typically realistic, animated scenes such as the hunt or the marketplace, and horn calls, bird calls, shouts, and dialogue frequently animated the musical settings.

I can reconnect these lost links with the old music, the animal, and the natural world by composing sound. In Sound composition, classical music instruments, birds, wind, and machine-made sounds are all equal; they are all sounds in a vast sound world. Listening to nature, live acoustic performances or high-resolution recorded music, add more dimensions to the experience. It is known that there is sound above 20KHz which is the upper limit of human hearing. Most of the orchestral instruments can produce frequencies above the 20KHz. Although we cannot hear them with our ears they do exist.[43]

Microtubules - Quantum Listening

Where do we listen to, and how does our body hear with more than just our ears? How does music interact with our mind and our state of consciousness? Where Music Does Exists?

Our body is sensitive to pressure waves like sound. As the pressure wave hits our scalp or skin, it turns into an electrical field that then vibrates deeper tissues that turn into electrical fields and so on until it reaches molecular, atomic, and perhaps subatomic levels. Sounds at very high frequencies can penetrate human tissues and set them into vibration. Like in an ultrasound exam, when a transducer is pressed against the skin, it emits ultrasound waves into the body and records the tiny changes in the Sound's pitch and direction as it reflects. Then, the data are processed by a computer that generates real-time images of internal tissues.[44] Another example is the classic demonstration of resonance, using a loudspeaker playing back a sound whose frequency is tuned to match the natural frequency of a wine glass that brakes as the speaker's volume increases at the glass's resonant frequency.[45] A similar principle is used in imaging machines like MRI (Magnetic Resonance imaging) to generate images of different tissues. There are also other acoustic phenomena happening when sound is played, such as interference and harmonics. In acoustics, when two sound waves of slightly different frequencies are combined, this creates an interference pattern that causes the Sound to be alternatively soft and loud - a phenomenon called "beating".[46]

Dr. Stuart Hameroff anesthesiologist and professor at the University of

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Arizona, conducted a pilot study on Transcranial ultrasound (TUS) effects on mental states. They applied transcranial ultrasound to the frontal scalp and brain, and they found improvement in subjective mood 10 min and 40 min after TUS compared to placebo. The study also suggested that TUS acts via intra-neuronal microtubules, which resonate in TUS megahertz range.[47]

In the late 80s and 90s, Dr. Stuart Hameroff collaborated with Sir Roger Penrose, Oxford physicist and Nobel Laureate in Physics, on a theory of consciousness called the "orchestrated objective reduction" (Orch OR).[48] Prof. Hameroff suggests: In Orch OR, consciousness is derived from deeper-order, finer-scale quantum computations in microtubules inside brain neurons which, 1) regulate neuronal membrane and synaptic activities, and 2) connect brain processes to fundamental space-time geometry, the fine-scale structure of the universe.[49] Microtubules are hollow cylindrical lattice polymers of the protein tubulin, with spiral geometry matching the famous Fibonacci sequence (3, 5, 8, 13, etc.);. They have a diameter of about 25 nanometers (nm), and among other functions, they are like the skeleton of our cells; human brain neurons have a particular dense network of microtubules.[50] In 2009, Prof. Anirban Bandyopadhyay a senior scientist in the National Institute for Materials Science (NIMS), Tsukuba, Japan, joined the team and offered some experimental evidence supporting Orch OR. He was able to stimulate the microtubules at specific frequencies detecting quantum vibrations in microtubules like the ones we have inside the brain neurons.[51] Hameroff continues: With resonances, orchestration beats, and different scales, or octaves, microtubules look like musical instruments, at least metaphorically. In Orch OR, microtubule vibrations also correspond with fluctuations in the fine-scale structure of space-time geometry, so in some sense, consciousness is the "music of the universe".

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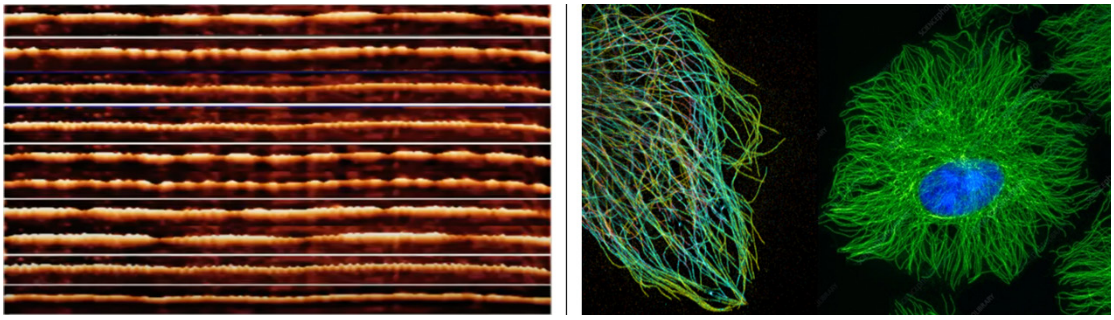

Figure 5: Left- Quantum mechanical picture of Actin protein vibrating at a range of 100kHz-15GHz.[52] Right- the green "wispy" looking strands are the microtubules that give the cell shape and help in the transportation of materials throughout the cell.[53]

In the most traditional sense, hearing is the ability to perceive Sound by detecting vibrations through the ear. The Orch OR theory and the vibrating microtubules suggest that "Quantum listening "is also possible. We also "hear" with our brain cells which are potentially responsible for consciousness. This could suggest why music affects us so profoundly and why it changes our state of consciousness. It could also relate to cosmic frequencies and other frequency patterns at a planetary level that may interact with the musical frequencies outside and inside us. These tiny structures, the microtubules, vibrate at extremely high frequencies at MHz ranges. Musical instruments can reach high frequencies too but not as high. However, an instrument or an ensemble or orchestra creates very complex sounds with many frequencies; it might be possible through acoustic and/or electromagnetic interference, resonance, transduction, or other phenomena causing these vibrations reach the microtubules and set them into vibration. In such case, Dr. Hameroff's study on transcranial ultrasound effects on mental states should also be true when listening to music.

In *Magic*[54] (2010) for electroacoustic Sounds I recorded all sounds at very high resolution, 192KHz Sample rate,[24] bit which extends beyond the audible range. In humans, the audible range of frequencies is usually 20 to 20,000 Hz. Recording everything at that range means that a much broader frequency spectrum is captured in the first place. We are surrounded by natural and mechanical sounds that we cannot hear in their full range due to their extreme frequencies, beyond our perceptual capabilities. An elephant can hear sound waves well below the human hearing limitation, between 10 and 35 Hz, and mammals like the Atlantic bottlenose dolphin can go as high as 150KHz. Insects like the Noctuid moth have a frequency response of 1,000 to 240,000 Hz, or a trumpet that can produce frequencies above 100KHz[55] and although we are not able to confirm if these 80KHz above 20KHz add to the experience, we cannot deny it. The idea of recording *Magic* at such a high resolution is that this brings the sounds closer to their true nature which often has frequencies above 20KHz. Therefore, the playback experience, with properly calibrated loudspeakers, will be closer to the experience we have in music concert halls or in nature. It is known that the audience experience unusual sensations in concerts with church pipe organ[56]. It can cause sensations of sorrow, coldness, anxiety, and shivers down the spine. Scientists have hypothesized that the infrasonic signals produced by church organ pipes can cause similar feelings in parishioners. They attribute this feeling to metaphysical causes as the natural result of the brain's effort to contextualize environmental input.[57]

One can suggest that church pipe organs can produce high and low frequencies at high volumes that, although we cannot hear them with our ears, they can travel through our scalp to the microtubules inside the neurons.

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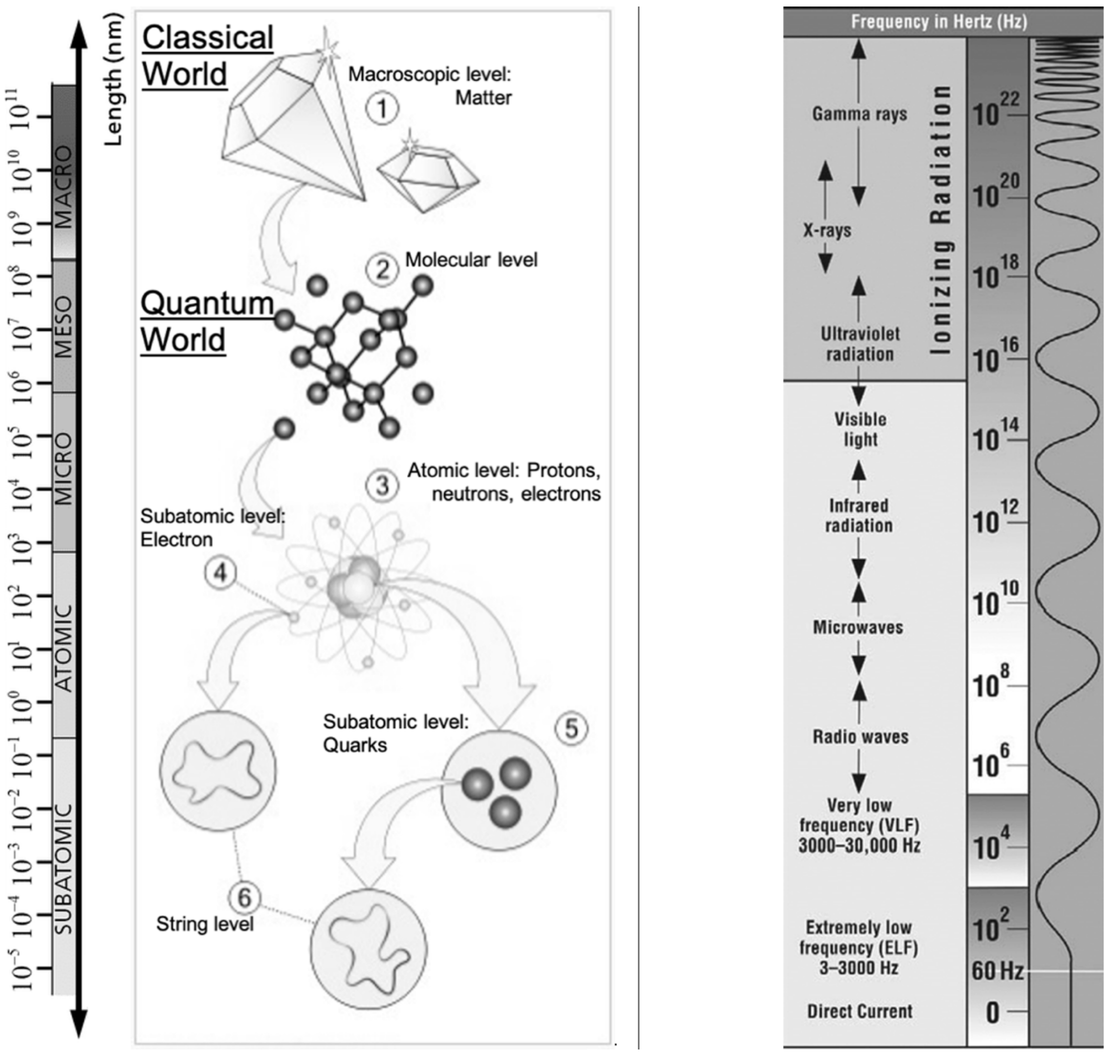

Figure 6: Left- Schematic showing the relevant length scales in material science from Classical world to Quantum world. Right- Diagram of the entire electromagnetic spectrum [58] the electromagnetic (EM) spectrum is the range of all types of EM radiation.

Perhaps there is a kind of music whose frequencies expands across the electromagnetic spectrum. The low frequencies interact with the classical world including the musical instruments, and the high frequencies interact with the quantum world, including the microtubules. This would require a new type of instrumentation and orchestration paradigm that considers both the classical and the quantum world musically.

Music Affects Us – The Energy You Can Feel

In her TEDx talk, American composer Pauline Oliveros said, “The ear hears, the

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brain listens, and the body senses vibrations."[59] Indeed, music affects the human body in various ways; research has shown that blood flows easily when music is played. It can also reduce the heart rate, lower blood pressure, decrease cortisol (stress hormone) levels and increase serotonin and endorphin levels. Also, music can boost the brain's production of the "feel-good" hormone dopamine[60] and give us goosebumps.[61] It is the vibrations and physical sensations we feel in our chest, stomach, skin, or joints.

A listener exposed to low-frequency music perceives vibrations at the chest or abdomen by sensing the mechanical vibration that the Sound induces in the body.[62] We may have physical sensations through our body by emitting various frequencies; music therapy and other practices are using such methods to improve various conditions. Oliveros wrote in her book "*Deep Listening* is the acoustic space where time and space merge as they are articulated by sound; it is learning to expand the perception of sounds to include the whole space/time continuum of Sound — encountering the vastness and complexities as much as possible."[63]

Has it ever occurred to you, when listening to a great piece of music, you feel a shiver run through your body to your spine or a shiver that tickles your arms and shoulders? This experience is called frisson, a French term meaning "shiver of aesthetics," and it looks like waves of pleasure running across the skin. Some researchers have called it "skin orgasm."[64] In a classical live music concert, a cello performer feels the vibration of the cello on various points of contact with the body; the upper body touches the chest, and the left bout wraps behind and above the left knee, the fingers on the left hand touch the strings and fingerboard, the right hand touches the bow that moves up and down on the strings, and the end pin of the cello touches the floor which in turn transfers vibrations to the sole of the feet. Only the performer has the privilege to enjoy this experience in full. Most of these tactile sensations will never reach the audience.

In 2013, I composed a piece with title *Sense*[65]; it is part of an ongoing project that explores tactile, infrasonic, and ultrasonic sensations where a holistic listening experience is expanded beyond aurality. It aims to examine the use of tactile vibrations as an extension and counterpart to the audible Sound. Besides its stereo version, the piece was initially composed of twelve discrete channels. The first six channels are audible and diffused through a 5.1 surround system. The other six channels are "inaudible" but composed in such a way that a system of tactile transducers is controlled. It demonstrates a synesthetic experience where on the one hand the listener can hear the sound, and, on the other hand, can feel it through the body.

Sense, Hearing Without Listening

In *Sense*, the tactile stimuli are composed explicitly in a musical context and aligned, or not, with the audible part extending the listening experience far beyond our traditional confines.[66]

The project proposes the conversion of these extreme frequencies into tactile stimuli the body receives. In addition to the sound perceived through our ears, experiments by Bolanowski[67] and others[68] [69] have identified four channels that mediate tactile (mechanoreceptive) sensation. Besides the Sound perceived through our ears, I also used three more paths to perceive Sound, such as the cochlea via bone conduction, through the joints and muscles via movement, and through the skin via tactile sound reception. Particular transducers have been used at specific frequency range for each path.

Pathway	Transducer Type	Range	Sense
Through the Cochlea via bone conduction	Cochlear Transducer	Audible range	Conductance
Through the skin via tactile sound reception	Ultrasonic Transducer Tactile Sound Transducers	Inaudible Infrasonic	Tactile Vibrotactile
Through skeletal joints and limps movement	Tactile Sound Actuators	In/Audible range	Kinesthetic
Through the ears via air-transmission	5.1 Speakers or stereo headphone reduced version	Audible range	Hearing

Table 1. The table above shows the four pathways for perceiving Sound, the type of transducer implemented in each case for the *Sense* chair project, the frequency range, and the sense involved.

I investigated different compositional strategies to inform the listener's brain using all the sensory paths to feel the sound.

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Figure 7: Visitors listen to a demo piece on the modified chair at the Perot Museum in Dallas, Texas/ USA, 2014.

While composing with the modified chair as the sound projection apparatus, I realized the complexity, depth, and endless possibilities available in integrating auditory and vibrotactile stimuli. Following the paradigm of Rovan and Hayward[70] of Time dependent and Space dependent types of tactility I expanded by adding texture and amplitude dependent types and further refined the existing ones. My main aim was to develop a balanced ecosystem that can holistically integrate both audible and tactical sensations into a single listening experience.

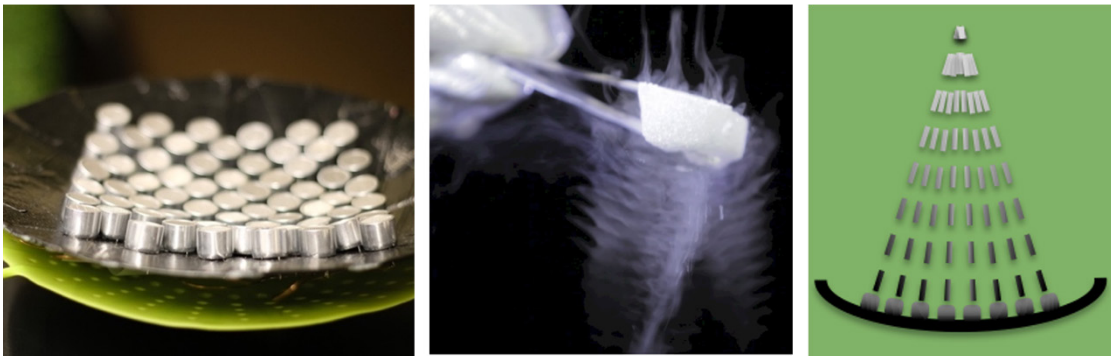

Figure 8: From left to right- ultrasonic transducer array arranged in a parabolic dish, mid-air ultrasound waves become visible with a bit of dry ice, a representation of the ultrasonic transducers aligned to create a strong mid-air force field in the focal point.

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The ultrasonic haptic feedback provides tactile sensations in mid-air. The pressure field resembles the frequency structure and rhythmic characteristics of a part of the composition that is not audible otherwise. The ultrasound transducers allow feeling the Sound in the mid-air. The listener places the palms under the force field of the ultrasound transducers. When a focal point is reflected off the skin, the force produced creates a localized tactile sensation that is similar to “air”, “breeze” or “wind” and can make the sound waves on the palms feel like pulses, textures, waves or different shape sensations without any gloves, attachments or in direct contact with the transducers.

Potential uses of the *Sense* project include experiments with deaf or hearing-impaired individuals, setups for immersive sonic environments like sound installation, video game, and experimental intermedia artworks. Another development of the project is using the chair with ultrasonic and infrasonic specialized microphones to playback the ultra/infrasound from the natural environment and converted to tactile stimuli. This way one can have a real augmented experience of a soundscape closer to its full frequency range.

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