Symbiophone - Interfaces for unheard communications

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Abstract: Departing from considerations on the meaning of existing in an inherent global symbiosis, as well as, a search for distinct interfaces for inter-species communication, the present investigation combines microbiology and acoustics through an artistic practice, creating a path to uncover possible hidden dialogs and alternative ways of perceiving. As such, this research emerges from three main questions: Do human derived sounds affect the mycelium growth? Can noise pollution from highways, factories or busy areas affect the mycelium, hence affect the forest eco-system? Is it possible to create a dialog through the use of sound frequencies and vibration, producing a sound maze and generating a response though the growth pattern of the mycelium? The first endeavor into set research focuses on the last question, resulting on the development of the audiovisual interactive installation intitled *Symbiophone*.

Keywords: *Symbiosis; Mycorrhizal Network; Sound; Growth Pattern; Bioart;*

Introduction:

The body is an organic plug into the world, a thin two-way shape shifting mirror between myself and the other. It is a permanent conduit through which living organisms experience, store memories and acquire knowledge, while inherently intervening and transforming their surroundings. Calling upon Hannah Arendt, our concept of reality is closely related to the subjective way in which we perceive bodily stimuli coming from exterior appearances, fitted to be known (Arendt H.;1978). As stated by Merleau-Ponty, it is from worldly sensory experience “all meanings are measured” (Merleau-Ponty M., 1976: p.12). As such, I must recognize the relation between body, mind and world as an inherent symbiosis. Knowledge is built upon repeated interactions, which coercively assume movement and exchanges. From this porous relation, the outside world its transformed along with the inside one. The term symbiosis has been used to describe mutually benefiting exchanges between two or more interties, complex organism such as lichens, corals and mitochondria, as well as associations between different organisms such as mycorrhizal fungi and plants (Munzi et al., 2019: p.860). Nonetheless, it has also been an emerging fundamental term to characterize the planet homeostasis between all living and non-living beings, representing a powerful pathway for the future.

The means through which organism perceives the world dictates its subjective idea of reality. Not so long ago, the microscope's invention came to deeply alter people's perception of reality, revealing a layer previously invisible to the naked eye, a world beyond the immediate sensible. Below our footsteps in the forest, there is also an unseen reality affected by our crossing. In the same way neurons allow the communication between different brain areas, the mycorrhizal network, constituted by the symbiosis between mycelium and plants or roots of trees, might be responsible for connecting individual plants together, promoting the transference of water, nitrogen, carbon and other minerals, especially in times of drought (Das S. 2024), creating an interface between mycelium and plants. Although the information on the subject might be too sparse to certainly attribute forest management to the mycorrhizal network (Karst J. 2022), despite lacking a nervous system, fungi transmit information using electrical impulses across thread-like filaments called hyphae, similarly to mammals' nervous systems. The filaments form a thin web called a mycelium that links fungal colonies within the soil, possibly allowing forests interspecies interaction.

Nonetheless, to human kind, these are ghost beings, indifferently pierced by humanity careless drums. These organisms formulate responses in silent dialogues and incomprehensible languages, hidden below the ground, far from sight, but not indifferent to humans' loud way of existence. As such, it might be interesting, as well as of great importance to acknowledge the hidden messages unconsciously sent into the world by the sound of our footsteps in the landscape. On the other hand, this research might be useful to experience a close relation with interconnected processes of coexisting and attaining a deeper understanding on life's inherent symbiosis.

In this experiment is developed an interface between human, machines and mycelium. An interface can be depicted as "a system or device through which unrelated entities can interact", simultaneously presenting "characteristics that are common to each of the entities it connects" (SÁ, 2019, p. 479–482). It coercively detains specific characteristics that produce and shape reality's experiences of each intervening entity. Hence, this research will be useful to better understand if there is a visible link between human activity derived sounds and mycelium growth. We have yet uncovered how invisible sound pollution from major cities, highways and crowded areas can affect the mycorrhizal network and as a result, other forest organisms.

What we perceive as sound can be translated into vibration. Vibration is the periodic back-and-forth motion of particles and is the amplitude, or intensity, of energy. The higher the vibration, the more powerful the energy. The correlation between vibration and frequency is intricately connected, frequency being the rate at which energy vibrates. As such, by introducing different frequencies to mycelium might be possible observe changes in their morphology, as well as, representing a step into unpicking how we have been unknowably communicating with these organisms. Considering the technique coined by Chladni to study the vibration in a sand covered metal plate, in which the patters change symmetrically depending on the frequency of the vibration, it was hypothesized that it might be possible to affect the pattern of growth of the mycelium by exposure to different frequencies.

Sound can be thought as a universal inter-species kind of communication, common to mammals and even insects, shaping their existence and perception of reality. Nonetheless, perception of a stimuli is shaped by each individual sensorial organs and subjectiveness, hence, the same message can be received and interpreted in incommensurably different ways by different organisms. Consequently, the installation resulting from this initial research looks into how sound might be perceived from the

Figure 1 – Symbiophone installation documentation;

point of view of an organism from a distant kingdom in this case, in the Fungi kingdom, as well as, how can set processes be acknowledge through an artistic expression.

Finally, it invites one to question what can be learned from listening to these hidden dialogs coming from distinct ways of perceiving and existing.

State of the art:

Although the research on the effects of sonic exposure in plants, fungi and bacteria still lacks some dept, it's known that plants have the ability to gather information from certain frequencies emitted by insects chewing on them, "even small environmental stimuli such as touch or wind alter the transcriptional levels of plants" (Jung, et. All, 2018). Playing music or natural sounds to plants can also affects their growth. This has been shown in some studies, such as a 2003 study performed by farmers and scientists in China and South Korea. They implemented a collection of animal and other natural sounds, referred to as "Green Music", which was played to cabbages and cucumber plants in order to observe if there was an improvement in plants health (Qin, et al., 2003). "Both exposures caused significant elevations in the level of polyamines (PAs) and increased uptake of oxygen O_2 in comparison with the controls" (Qin, et al., 2003).

Some studies refer that specific frequencies might bust growth in bacterial colonies as well as strengthen the resistance of a plant to droughts, while other might inhibit growth or synthesis of certain compounds by inducing stress (Bhandawat, et. al, 2022). Other studies found investigate "the effects of traffic noise on growth, hormonal balance, oxidative damage, and activity of antioxidant systems in two urban plant species" (Kafash, et al., 2022) where it was observed that "traffic noise exposure led to significant decrease in growth indices", inducing "oxidative damage and interference with hormonal balance" (Kafash, et al., 2022). In places with high industrial activity and high population density, noise pollution has grown significantly and is now seen as a concern for ecosystems welfare.

In bacteria, the results of a 2016 study indicate that "E. coli K-12 exposed to sound waves owned a higher biomass and a faster specific growth rate compared to the control group" (Gu, et. al, 2016).

As for the object of the present study, is it thought that fungi are induced to produce fruit bodies by environmental vibrations, from falling trees or rain (Kobayashi, et.al, 2023). It has been reported that some species of fungi react differently to specific sound frequencies. Research conducted on *Botrytis cinerea* mold to identify if "frequency-specific sound could be used as a practical alternative to chemical fungicides to control plant diseases", revealed that fungus exposed to wave frequencies of 5 kHz show "significantly inhibited mycelial growth and spore germination". There were also observed "morphological changes, including low mycelial density, swollen mycelial tips, and irregular mycelial surfaces" (Jeong, et al, 2013). It was also observed that different strains of the same species can exhibit distinct growth effects, even when subjected to the same frequency of 250Hz. It was revealed that "applying a frequency of 250 Hz over a period of 10 days proved to be more effective in inhibiting the growth of *A. niger* and *B. cinerea"* while the frequency of 4000Hz enhanced the growth of some of the strains tested but not all of them (Jeong, et al, 2013).

A study on Trichoderma Harzianum, a variation of the Trichoderma used for this first iteration of the installation, applied a frequency of 8Hz at 70dB and 90dB for 14 days and the results "show that the acoustic stimulation treatments resulted in increased fungal biomass, greater decomposition, and enhanced *T. harzianum conidia* (spore) activity compared to controls" (Cando-Ducancela & Robinson, 2024).

The artist Theresa Shurbert in the project *Sound for Fungi. Homage to Indeterminacy* researched on the effects of sound frequencies of 220 Hz, 110 Hz and 440 Hz on *Pleurotus Ostreatus,* a type of arboreal saprophyte which obtains nutrients from dead matter or trees and can be a part of the mycorrhizal network by connecting with the roots of trees. Her choice of frequency was based "on research from plant acoustics where a measurable response in roots occurs at 220Hz" (Schubert, 2020). She reported that there were some species that had strong responses but others were inconclusive. The artist felt there was a contradiction between her "initial idea of facilitating an objective experience for fungi and the unavoidable anthropocentrism where an experiment is always an act of human-imposed control and reduction in contrast to nature's freedom and complexity" (Schubert, 2020). As such, her output was translated into an interactive video installation where the visitor can interact with a 3D rendering of the growth and "complemented with arrangements of photos drawings and diagrams".

As such, the rage of the frequencies and species tested its large, but there is not much information analyzing the visual effects on the growth pattern created by the mycelium on agar solutions. On the other hand, this area of investigation is lacking a deeper analysis on arboreal fungi and different species present on the mycorrhizal network, such as saprophytes as *Armillaria Mellea,* which is one of the main species this research will investigate. It might also be interesting in a further investigation to analyze how certain saprophyte species connected to the mycorrhizal network can be affected by noise pollution in comparison to the effect on other species of fungi nearby. This eco-acoustic approach might have the potential to restore damaged ecosystems and out to use instead of pesticides, as well as to make heard these hidden dialogs. There's still much left to uncover.

Methods, development and result analysis:

This preliminary research and integrated installation focus on the hypothesis that, through mycelium exposure to specific sound frequencies, it might be possible to generate a response visible in the growth pattern. As such, this initial investigation required a combination of experimental methods has well aesthetic considerations and decisions. Therefore, it results of an intersection of three main areas of exploration and development: the microbiology investigation, electroacoustic considerations and system design and the aesthetic considerations which influence decisions made both previous areas.

The electroacoustic considerations and system design:

For this experiment a system was built with five 165mm speakers connected to five mini audio amplifiers which were plugged into a Focusrite soundboard connected to a computer. The frequencies were played from a Max patch with six different possible sinewaves played continuously, but only five channels were used. The sixth speaker is separately connected to a mini audio amplifier with a headphone output in order to be able to connect any portable device and be used freely by the installation visitants. It was also used a dino lite digital microscope placed above the last speaker connected to a projector which displayed the live imagens on the front wall. Visitors were invited to pick samples from the table left outside the installation room and see different samples created during this experiment as well as some of the contaminated samples.

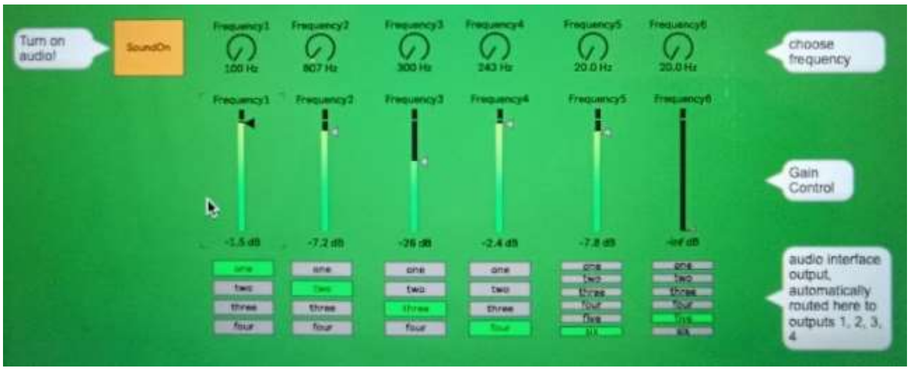

Figure 2 – Max patch with frequencies and dB (created by Guy Fisher and adapted for the experiment);

The selected frequencies selected where 20Hz, 100Hz, 243Hz, 300Hz and 807Hz. The slight variation from the even numbers and different dB was due to a consideration on the sonority of the frequencies when played together. The experiment was left running from the 05/07/24 at 16h:45min and was terminated on the 12/07/24 at 13h00min. There was a malfunction on the mini sound amplifier of the sixth speaker which was reserved for interactivity, as such this part of the installation wasn't running, so it served has a control sample.

Experiment observations and results:

Upon inoculation of contamination samples from *Trametes* (powder+water), on the 06/07/24 the 20Hz frequency sample was found to have larger water droplets than any of the other samples.

Figure 3 – Control sample (06/07/24);

The 100Hz sample seems to follow in water bubble size, being noticed a decrease in size with de decrease of the frequency. No growth visible in any of the samples.

Figure 4 – 20Hz; 100Hz, 243Hz, 300Hz and 807Hz respectively (06/07/24);

On the 07/07/24, the second day it was a Sunday, hence, there was no observation, and therefore, the further documentation was be done every two days. This was also possible due to the growth rhythm of the samples.

On the 08/07/24, the third day, when the system was revisited, one of the sound amplifiers had fallen and altered the sound produced by the third and fourth speaker, which disturbed the experiment. All of the samples show some signs of growth;

Figure 5 – Control sample (08/07/24);

Figure 6 – 20Hz; 100Hz, 243Hz, 300Hz and 807Hz respectively (08/07/24);

On the 10/07/24, fifth day here was a further increase in the water content in the frequencies of 20Hz, 100Hz, 243Hz and 300Hz. For documentation of the growth to be possible some of the water was shaken off the top of the petri dishes for better observation. There was no noticeable water present on the 800Hz frequency or the control; The 807Hz speaker shows some signs of growth with the less colonies spread and more circular. The control also had fewer colonies than the remaining samples, but more than the 800Hz, which might be only from dissemination during inoculation. 100Hz sample has a lot of water and the inoculation seem to have shrunken; The 20Hz speaker has the most water and some irregular growth. The number of colonies present makes it difficult to analyze the pattern of growth.

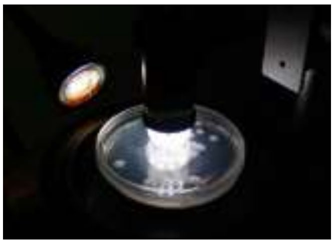

Figure 7 – Control sample with dino light installation (10/07/24);

Figure 8 – 20Hz; 100Hz, 243Hz, 300Hz and 807Hz respectively (10/07/24);

On the 12/07/24, the last day of the experiment there was a noticeable growth in all samples. All of them had multiple colonies possible due to the water droplets spreading the spores or due to spore dissemination in the process of inoculation. Nonetheless, it was visible that the 100Hz sample had the least

Figure 9 – Control sample (12/07/24);

growth. The 20Hz sample had the widest spread colonies followed by the 243Hz sample. The 807Hz sample has the lower number of colonies and a clearer pattern of growth.

Figure 10 – 20Hz; 100Hz, 243Hz, 300Hz and 807Hz respectively (12/07/24);

Results discussion:

It was yearly noticed that the experiment would have to be further repeated, once there was a malfunction of the system on the second day. Nonetheless, it was decided that the experiment would still run for the seven days expected. This time gap proved to be insufficient for the full growth and maturation of the colonies, hence their size was still too small for analysis on the project end date. This clearly highlights the importance of respecting organisms' development time.

Regardless, from the observations it was noticeable a clear growth difference in the samples. With the most growth similar in the 20Hz, 243Hz and 300Hz frequency samples, due to their many present colonies possibly caused by the augmenting of water content. There was an unexpected inhibition of growth from the 100Hz frequency sample which might suggest a nonlinear change with the increase of frequency. The 807Hz frequency sample seems most similar with the control sample, but with a more central, larger growth and less colonies. This might suggest growth stimulation, even though the data is not enough to certainly conclude it. The growths didn't get to maturation point and therefore the green spores weren't yet visible, as such, it was only possible to formulate a general analysis.

From the aesthetical point of view, the resulting installation conveys a shift from a micro to macro perception, present when the microscope amplifies the samples or even when the effects of sound stimuli manifest interferences in the live matter, becoming visible to human naked eye. A visually absent communication, a non-pictorial form of language is interpreted through vibration, the input passable to be received by these organisms, which deliver their response in a visible pictorial output, allowing different species to interact and communicate information. Inevitably, *Symbiophone* invites one to consider how invisible forces, as sound, can affect matter and organisms.

On the other hand, collecting, isolating and manipulating organisms are processes that carry strong ethical concerns, discussing the meaning of affecting the growth of a living being and wile aware of it. As such, this installation questions human self-awareness towards other life forms, as well as, the ecological application of the present and further research might represent a possible solution for ecosystem restoration.

Lastly, drawing away from the specific concepts of this experiment, this investigation inherently places into contrast the laboratorial work flow and mind set with the creative mind set, where the first one is coercively precise and rigorous and the second one, intuitive and spontaneous. Nonetheless, both mind sets share an experimental methodology and as such, set installation presents one of many possible solutions to communicate scientific and artistic research in an artistic installation context.

Conclusion:

In a next experiment, it will be important to continue an investigation into arboreal mycorrhizae, as well as, in saprophytes, as *Armillaria Mellea*. From the results it would be beneficial to extend the experiment duration time to fourteen or more days, to better encompass the full growth and maturation of the mycelium.

Due to being difficult to analyze clearly the growth patterns due to the many different colonies in each sample, even on the control sample, it was concluded that, in a next trial, would be preferable to inoculate from a younger mother sample with less spores, to facilitate a clean inoculation and enable pattern analysis. Furthermore, from a scientific point of view, it would be useful to develop the experiment in a more controlled environment and with better process documentation, including some continuous video recording, for a detailed growth analysis. It might also be useful to test less samples at the same time, to increase control over the experiment and simplify the documentation, has well as, to enable a more direct and rigorous comparison method. It would also be beneficial to keep one sample in a complete silence environment, for a more exact control sample, and to perform the future experiment in a temperature-controlled environment, in order to understand why there is such a big difference in water content on each sample and what is happening to the samples. It could also be important to understand if the effects are due only to direct contact vibration or can be also observed only by sound stimulation.

From the aesthetical point of view, in a future installation would be interesting to explore different speaker and projection dispositions, experimenting with different heights and the distance from the visitant to the petri dishes, inviting to lean towards the experience by moving closer. It could also be explored a more harmonious set of frequencies as well as ultra sound frequencies, completely invisible to humans, but made observable by the possible different patterns on the mycelium growth.

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