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The Hearing Test

Evidence of a Vegetal Entity

LAURA BELOFF

ABSTRACT

The author's artistic experiment *The Hearing Test* focuses on detection of high frequency clicking sounds that are emitted by the tips of plants' roots. Scientists have claimed that plants' roots produce high frequency clicks between 20 and 300 kHz by bursting air bubbles. But while the phenomenon has been described, its cause remains unexplained. This lack of knowledge opens up possibilities for multiple interpretations and invites experimental approaches as well as speculation concerning plant intelligence, the role of species-specific hearing and sound as evidence. The article is an extended reflection on the experiment.

DEPARTURE

The recent decade has witnessed palpable interest among the general public to observe, understand and connect with our co-organisms on the planet. This is visible also in the increase in theoretical publication on humanistic perspectives on multiple species and their projected evolution, as well as on the division between humans and nonhumans [1–3]. It seems obvious that this increasing interest and the popular urge to add to understanding is partly motivated by our helplessness in the face of environmental and climate change. This situation and our growing desire to reconnect with our planet and its creatures, as well as the hypothetical but often-articulated aspiration for interspecies communication, underlies my artistic experiment, discussed below.

A desire to connect with the earth is visible also in earlier art experiments and practices that focused on sound as a phenomenon of terrestrial energies and signals. Artists and musicians such as Alvin Lucier in the 1960s, Christina Kubisch in the 1980s and Joyce Hinterding in the 1990s have tapped into electromagnetic fields, e.g. in the form of brainwaves and natural radio, as raw material for their projects [4]. In their artworks, sound in the form of signals evidences the movement of energy produced by the planet Earth. While the scientific and artistic exploration of the above-mentioned earth sounds is already well documented, the new field of plant bioacoustics and plant intelligence is currently gaining momentum.

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PLANT INTELLIGENCE?

A subtle carpet of clicking sounds is heard from speakers in the studio—this continuous and irregular sound creates an image of how a forest may sound to an organism whose faculties enable hearing high frequency clicks emitted by roots of plants.

Are plants intelligent and do they communicate and sense the world? Such questions have been posed within the field of plant biology throughout the last century and before: Darwin in 1880 published *The Power of Movements in Plants* with his son Francis, reporting on numerous experiments they performed on plants. The book departed from the then-dominant view of plants as organisms with no need of movement and proposed the roots as a brain-like organ receiving sensory inputs [5,6]. Indian scientist Jagadish Chandra Bose was one of the first to investigate plant physiology, publishing findings around 1900 based on various experiments using self-designed scientific instruments. For example, his "crescograph" measured the growth and movement in plants [7]. The term and idea of actual *plant intelligence* was proposed by Anthony Trewavas in 2003—that plants can hear, communicate, remember and, in general, sense their environment and other species to a degree exceeding current human presumption [8]. His proposal led to debate on understandings of the concept of intelligence and its appropriateness in talking about plants. According to Trewavas, plants' abilities to compute complexity in their environment have previously been judged inaccurately. This misunderstanding has been largely due to plants' sessile existence, which differs from that of humans and mobile animals [9]. Trewavas asks whether plant behavior could be described as intelligent and how plants achieve intelligence in the absence of a brain. Trewavas claims that plant behavior is an emergent property that results from cellular interactions, in a manner comparable to that in the brains of animals [10]. Similar research and discoveries have been made in recent years by other plant scientists. One proponent of plant intelligence, Monica

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Gagliano, has investigated plant communication and plant cognition. She claims that plants are sound sensitive and can "hear" sounds [11]. Gagliano, together with Stefano Mancuso, has investigated and claimed that plants also produce clicking sounds on the tips of their roots [12]. Although they have detected these, they do not yet know why plants produce these clicks. The scientists' hypotheses suggest that the phenomenon may be a type of communication in plants. This suspicion and hypothesis attracted my attention. That scientists don't know the cause of this phenomenon opened up a space for possibilities and speculation.

Karl Popper's definition of verisimilitude, "truthlikeness," proposes a perspective on scientific truth that has been critically scrutinized by Pavel Tichý, who defines it as an optimistic skepticism.

> It is a scepticism since it affirms that no non-trivial theory can be justified and that more likely than not all the theories we entertain and use are false. The position is optimistic in contending that in science we nevertheless make progress: that we have a way of improving on our false theories. Progress, however, hardly ever consists in supplanting a false theory by a true one. As a rule, the new theory is also false but somehow less so than its antecedent [13].

Popper's point was that among various theories, science subscribes to that closest to truth, even if it is false. Popper's perspective has been extensively criticized throughout the years; however, it is clear from his arguments that we learn and generate knowledge through trial and error, and that at the core of scientific statements is the fact that they can be tested and contested [14]. The point of view that no scientific theory or statement is necessarily true resonates with the uncertainty of my experiment aiming at recording clicks produced mechanically at the roots of plants.

THE EXPERIMENT

The Hearing Test project has proceeded in limited periods over a three-year timespan [15], conducted within a framework of an artist's studio. Parallel to this experiment, I have carried out other investigations on plants in my lab and studio space [16]; these triggered the inspiration for this experiment. Throughout the recent decade my artistic investigations have focused on the intersection of nonhumans, humans and technological agency. I am searching for new ways to reintroduce our connection to the natural environment and nonhumans—potentially with technological support. Also, I perceive a gradual merger of biological and technological realms, driven by human intentions. I aim to make this process visible and offer insights on our evolving relationship across technological structures, nonhumans and natural environment.

Plant scientist Gagliano claims that "recent evidence now indicates that plants generate sounds independently of dehydration and cavitation-related processes" [17,18]. Inspired by the research by Gagliano, Mancuso and others [19], I began artistically investigating the sounds emitted by plant roots. Gagliano claims that plant cells can emit minimal sounds—but if they work in concert, they should be able to produce observable effects [20,21]. She writes: "If such mechanical vibrations or sound waves can extend over large distances within the organism and also outside the organism, then there is a real possibility that plants may indeed use these means to communicate with other plants or organisms" [22].

My experiments used fairly low-cost equipment: contact microphones, a sound card designed for appropriate frequency levels and free or open source software. I worked on the first experiments together with Danish artist Christian Brems and later continued on my own. Beginning the experiments was exciting; we had no idea if we would find any clicking sounds with our system. After some adjustments of microphone connections, we started receiving clicking sounds from roots within high frequency levels. The recordings were conducted with the plant out of the earth and its roots exposed and placed over the contact microphone (Fig. 1). We also systematically tested the difference between recording sounds from roots of plants that were freshly taken from the earth, recording roots that were recently cut off from

Fig. 1. Recording plant roots with contact microphone. (© Laura Beloff)

the plant and, as a comparison, recording without any roots with the same set up and location and with the same microphone. The greatest number of clicks were received from the living roots and the recently cut roots. The clicking sounds were recorded, sampled down to human hearing range, between 40Hz–15kHz, and listened to. As one analyzes the recordings, one can notice two frequency clusters where the majority of sounds appeared. The highest amount of clicks occurred between 1 and 20 kHz, and the second clear cluster was around 40–55 kHz—occasionally even higher. After our initial success, the experiments became more challenging as we started asking questions and finding uncertainties; as a result, we tried to systematize our methods. From an artistic perspective, I was especially interested in long-term observations of clicks, which were first done through several hour-long recordings. Later, I developed a real-time system that could detect the clicks continuously.

The experiment involved many challenges; handling of the fragile plant roots for example demanded gentleness and patience. Some recordings were made with roots exposed and another set was made with roots in close connection to the soil—although the contact microphone was isolated from the soil as much as possible. Nevertheless, it was impossible to say with certainty what one was hearing—roots clicking or action by soil microorganisms. By that time, it was clear to us what kinds of sounds and frequencies we expected to receive based on previous experiments—which made it easier to believe that we were hearing the roots.

Other challenges, especially with the real-time system, included changes in the moistness of the roots and other matter touching the microphone. This affected the sound conductivity and impacted the system's settings. It became obvious that the software system should be developed to change dynamically based on detected moistness values. Among other factors causing challenges were selection of plant species and natural movement of the roots in relation to the size of the contact microphone. Also, although ambient noise was fairly easy to eliminate, physical vibrations of the building seemed to cause the microphones to react.

My interest in long-term observation of the clicks was based on the possibility of seeing them as a type of communication, to observe the potential changes in the frequency or rhythm of the clicks impacted by external factors such as time of the day, watering frequency, presence of other plants, presence of humans or weather conditions. The challenge of wanting to consider these clicks a type of communication, as proposed by Gagliano, is to understand what and how plants communicate. In other words, how to interpret the clicks: Are they reactions, sounds from biological processes or a type of language with potentially reciprocal exchange with other organisms? What am I actually hearing?

A surprising incident occurred in the course of experimenting. I had a long-term real-time system hooked up with two microphones onto the roots of a single plant. The system was producing a sound cue every time it received a high-frequency peak from a microphone. One day I was sitting alone in the studio close to the plant when it suddenly began clicking in more or less regular intervals. I continued working on other things as the plant clicked beside me when another person entered the space and came to talk with me. I was about to point out that we could hear the plant clicking in real time when I realized that the plant had suddenly stopped clicking. Later that day, others working in the same space went for lunch, but I stayed. After 10 minutes in the quiet room, the plant started clicking again and continued until the others returned. From this situation questions emerged: Did the plant react to the presence of other humans or general noise in the room? Or was the heard clicking just a technical error caused by the hardware? Or is this my own interpretation of the event, because I want to believe that the plant sensed the environment and communicated with me? Also, I realized that in the case that the plant actually reacted to the presence of humans or sounds made by them, it would be quite challenging to create an art installation with plants in an exhibition setting with the expectation that the audience can hear the clicks. What if the plant were silent when the visitors enter the space; would that be considered a broken installation?

One can speculate upon the causality behind the root clicks and their possible interpretations. I think either a scientist or an artist would like to know if their hypotheses on why plants emit these clicks were correct. The artist's focus would be on the meaning of the clicks for the plant and for the listening human, including a critical reflection on a human observer for whose faculties the setup is designed and whose desires the interpretation of the meaning fits. One can also ask if the clicks should be interpreted as a type of evidence—but evidence of what?

EVIDENCE

The hypothesis concerning the meaning of the clicks can potentially be tested in the future within science. The first step in my experiment was to evidence the existence of the emitted soundwaves. This points to an interesting question of why and how one claims evidence in art.

Olaf Dammann has clarified the meaning of data, information, evidence and knowledge within the health sector [23]. Based on his description, *data* is numbers, text, recordings collected from field research, measurements or databases. Data is used for the generation of *information*, often for specific tasks and contexts. Information is aimed at answering questions, whereas *evidence* is information in context that is used e.g. for testing a hypothesis. Dammann locates *knowledge* on the top of this hierarchy as evidence-based belief and consensus, which has been produced through reasoning and discussion [24]. Even if Dammann's definitions are produced with the health sector in mind, they fit other areas well. For example, scrutinizing the above-described experiment in these terms, one can claim that the produced clicks are raw data, but, at the same time, these clicks can be seen as evidence that supports the suggestion of the plant scientists about the plant roots producing clicks beyond the range of human hearing. However, based on these definitions and science traditions, we can only conclusively confirm the ex-

istence of the clicks—not what their purpose is nor if they are some kind of communication. These might be important concerns, because what actually makes this sound intriguing is its production by the plant and the hypothesized possibility that we might be tapping into plants' communication channel.

The *Umwelt* concept of Jakob von Uexküll, which in recent years has received a fair amount of attention from arts and humanities scholars, is based on the idea that each species will see and hear what is necessary for its species-specific existence [25]. One of Uexküll's experiments involved a fighting fish, which is able to see fast-moving prey in slow motion [26]. Conversely, it is quite clear that hearing root clicks has not been necessary for the survival of the human species, nor has the capability of hearing electromagnetic energy within artworks by the artists mentioned in the introduction of the article. However, one could ask how the technologically assisted ability to hear terrestrial electromagnetism and clicks from roots impacts our connection to the planet. And more importantly, one can ask how this possibility to hear things we normally would not hear will impact the evolution of the human species.

CONCLUSION

The above-described experiment concluded without a final result in the form of a finalized artwork. Rather, it is part of my ongoing artistic investigation following Popper's suggestion on learning through trial and error. The experiment began with a desire to attempt an understanding of the root clicks as communication. But thus far, the experiment has mainly pointed out many challenges embedded in this desire: Even when we are able to hear the clicks, we perceive them merely as "raw data," which does not tell us anything about their purpose nor give clues how we should interpret them.

Nevertheless, I have planned further steps in the experiment. These include using machine learning to recognize possible patterns within emitted clicks. This data would be compared to environmental and atmospheric measurements and potentially could generate another interpretation of the clicks—but only within the limits of human understanding.

While it is hard to draw any clear conclusions about the experiment itself and its factuality, one could instead point toward the question posed by Mariana Perez Pobadilla: What does it mean to hear? [27] I would like to ask in addition: What does it mean to hear through technological mediation?

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