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Soundscapes of code: Cochlear implant as soundscape arranger

Meri Kytö

Our relationship with the sensory environment is becoming more and more technologically mediated. Environments are mediated for us or by us every day, often by infrastructures sustained by pervasive technology. The compressed signal of the human voice on the telephone, filtered background-noiseless Zoom meetings, stereo sound radio broadcasts, surround sound movies, and noise-cancelling technology in headphones are all part of everyday listening, rendering the soundscape with layers upon layers of sonic materials. Some layers are more treated or mangled with signal processing and amplification systems, some more with the reverberations of the physical acoustic spaces we are in.

For many, the sonic environment is enhanced and processed by a sound processor located in their listening device, be it an external hearing aid or a neuroprosthetic device like a cochlear implant. A cochlear implant or a CI is an electric hearing aid, a neuroprosthetic in three parts. It is for people with severe hearing loss, one part of which is implanted behind the ear under the skin onto the skull with electrodes curling inside the cochlea. The second part, called the transmitter, is positioned on top of this implant with a magnet, and the third part, a sound processor, on the auricle. The miniscule microphones in the sound processor pick up sounds for the processor to filter according to its algorithmic programmes and the customised calibrations for the individual user. Then, the digital signal is guided through the transmitter to a string of 22 electrodes positioned in the cochlea which stimulate the cells in a way that the auditory nerve is able to transmit this stimulation to the brain. The outcome is a sensation, a perception of sound: hearing. Unlike the external hearing aid, a CI does not reproduce sound waves that have travelled through the sound processor. It skips the parts of the ear that reacts to sound waves and stimulates the cells near the auditory nerve directly.

The history of neuroprosthetic digital hearing aids dates back to early experiments in the 1960s (Mudry and Mills 2013) leading to further development in the 1970s, and finally as wearable technologies entering the consumer market in the 1980s (Levitt 2007). There are about 600 000 people using CIs worldwide (Dietz et al 2018, 574.) Valued at nearly $1,2 bn in 2018, the market for CIs is growing at a healthy pace, with the Australian firm Cochlear Limited dominating this market (Research and Markets 2018).

CIs are prosthetic technologies that extend what the body can do. As Tia DeNora writes, through the creation and use of such technologies, actors and their bodies are enabled and empowered, their capacities are enhanced: “they are capacitated in and through their ability to appropriate what such technologies afford" (DeNora 2000, 103). I am interested in what these affordances offered by CI technology are. People living with cochlear implants hear their environment primarily through microphones and code. These acoustic spaces can be understood as what Rob Kitchin and Martin Dodge call *code/spaces***,** environments that are shaped by and made possible by computer code in many complicated and often invisible ways, which only become noted when the code stops working or a machine breaks down (Kitchin and Dodge 2011). In this chapter I examine these embodied human–technology relationships by asking what kind of listening agency is given to the implant and how a coded soundscape can shape understandings of space and place, that is, our understanding of acoustemology (Feld 2015). These questions are approached with an empirical study: a one-year ethnography with an adult informant adapting and learning to listen with two cochlear implants.

Walking with Helinä – Methodological background

In 2017, I received an email from an acquaintance who, knowing I worked as a soundscape scholar, asked me for information on CI use. She was asking these questions because her sister Helinä had just been implanted with a CI. The sister was going through a lot of “hearing for the first time experiences” with the implant, sounds and acoustic phenomena she hadn’t realised were part of her everyday environment: a visit to a public indoor swimming pool (full of echo), to a supermarket (with background music), to a railway station (with voices over the Tannoy), washing dishes (with the water dripping), and to a coffee shop (where you can hear people sitting in the table next to you, talking). It was clear from the email that the whole family was astonished, excited, and overwhelmed by this novel situation, and wanted to understand it better.

Helinä is an office worker in her 40s, a mother of three adult children. She was born with severe hearing loss to a hearing family, has used hearing aids from the age of four, and is a stellar lipreader. Six years back when her left ear started to be of no use even when using an external hearing aid, she requested an implant. After two years of appealing to the local healthcare authority, her request was accepted and eventually, she got two CIs.

I suggested to Helinä that we could do a study together. We had mutual interests in that we realised that we both wanted to learn from each other. I had been interested in situated knowledges (Haraway 1988) in studying soundscapes, and Helinä was curious about communicating with sound. Eventually we ended up working together for one year while she was adapting and learning to listen with the CIs. We did various listening walks in different environments; I accompanied her to the doctors, and she also kept a sound diary which I could then read. We talked regularly, together and with family members and exchanged correspondences. This cooperation resulted in a rich ethnographic body of material of which this chapter presents only a few glimpses at what I learned during the year. To protect her privacy in this study we decided to pseudonymise her name to Helinä. Helinä is an old-fashioned Finnish women's name, meaning the sound of chiming and tinkling. We thought this would be symbolic and descriptive of her newly augmented ability to hear high-pitched sounds.

This study attempts to fill some of the gaps between soundscape studies and technologically-mediated listening. When R. Murray Schafer's classic book "The Tuning of the World" (1977) was re-released in 1994, the name of the book was substantially altered to "The Soundscape: Our Sonic Environment and the Tuning of the World". Soundscape is often understood as "our soundscape", which appears to be constructed of public sonic space, shared listening experience, often surprisingly in open-air space, the outdoors, or in urban settings ("the street"). According to Barry Truax, the model of the acoustic community is one of the main results of the *Five Village Soundscapes* project, carried out by the World Soundscape Project group in the 1970s (Truax 2009, 286). The model emphasises and is predicated on conscious listening, vast amounts of shared sonic information (the basis of acoustic communication), locality, stability and balance in the acoustic environment.

The choice of perspective, or rather the rhetoric of the books written during the era of awakening of environmental and social consciousness, has affected the emphasis of soundscape research during the last 50 years. This has meant that the mainstream of soundscape research still often focuses on a presumption that soundscape is something shared and in common. The "shared" includes cultural understandings of sonic environments and social memory, often represented in a national or geographically local context. The "common" includes the mundane and material environment to which the inhabitants or citizens have a responsibility for, or – in the light of today's global climate – even an obligation. This pedagogical and political stance is laudable until we realise that the so-called shared experience of the soundscape might not be that shared after all, or at least it can't be said that there is a sonic environment that all would perceive in the same way. This leaves the shared understanding of soundscapes with a wobbly perceptual grounding which should be considered carefully when making generalizations of how soundscapes are understood.

Sensory perception is in itself methodologically challenging to study, and hearing through CIs raises even more questions of origins or sources of sound, of knowledge and experience, for both people using them and to people who do not. The presence of a machine should not complicate the issue though; in fact, quite the opposite. As Jonathan Sterne states, everything that is known about the so-called natural state of hearing in itself is a product of an interaction between technology, sound and the ear (Sterne 2015, 116). The presence of this listening technology gives an opportunity to question the very "commonness" of hearing and think of it as a boundary project for knowledge production, to use the term of Donna Haraway. For Haraway, bodies as objects of knowledge are "material-semiotic nodes", the boundaries of which materialise in social interaction. Boundaries of objects are drawn by mapping practices (Haraway 1988, 595). From the very start of our work together, Helinä expressed a need to learn culturally contextual pieces of knowledge concerning sound and spatiality. For this reason, listening walks, walking with a focus on sensing the sonic environment, proved to be the most fruitful method for us to be in dialogue about sound and listening. While moving, we could observe each other's listening while interacting with our surroundings, mapping our understanding in social interaction.

A sense of code/space

During our first walk together, Helinä had been using one CI for a few months. This machine was a so-called hybrid, an implant combined with an electroacoustic hearing aid that enhances lower frequencies acoustically, in her case sounds below 400 Hz, while higher frequencies were generated by the CI. While out and about she would keep me walking on the “CI-side” of her (left) so that we could talk. On her right ear which had been “the better one” before the operation she was wearing a hearing aid. The right ear was also to be operated with an implant later in the Autumn. During this walk I would ask her to tell me what she hears. She would indicate an acoustic phenomenon, I would listen for it and try to locate it in space, and then we would discuss the possible sound sources and their various meanings and ways to describe them. For example, we would discuss airplanes flying by. She would first say “okay, now I hear a faint rumble descending in pitch… it is not a car… it might be an airplane, as I know there is an airfield near by”. She would then look up and try to locate the airplane, and as she didn’t in this moment have any spatial hearing (as she would later), she would turn until she saw one. Then, as the plane disappeared, asked if an airplane makes a different kind of noise when it flies in a cloud, if that would be the reason for the descending pitch. We then discussed acoustics of different spaces, of how far sound moves in spaces, how it changes in volume, what reverberation feels like, and how it sometimes defines how people use their voices, talking softly or loudly. She would also search for descriptive words imitative of high-pitched sounds, asking me if I would use the same, for example: “the light switch clicks up, paper rustles, trousers swish, brakes of buses screech, knitting needles click”, this all in Finnish of course. Finnish being an onomatopoetically flexible language, these descriptions of qualia would sound like *naksuu, rapina, kahina, vinkuu, kilinä,* respectively. The outcome of the discussions was never very clear; mostly tentative thoughts, doubt, and above all, wonder.

The CIs have changed Helinä’s relationship to her sonic environment in various ways. But one of the more drastic changes seems to be the sense of space gained with the second implant. Helinä described the difference between the external hearing aids and the implants as being enormous, like between black & white and colour. She writes in her sound diary:

> “There’s depth. Before, [the soundscape] was flat and dull, now there are all kinds of elements. Before, everything was the same volume: steps, talking, everything was the same volume. Now I can differentiate between what is near and what is far. First, I need to learn to recognise the source, but after that I know. And directions; I couldn’t tell if [a sound was] coming from behind me or where, but now I can.”

As Don Ihde states, people invent technologies but while using them technologies re-invent people (Ihde 2007, 243). From the very beginning Helinä has wanted an embodied relation to the machine, in Ihde's words the CI should become "incorporated" as Helinä's medium of perception, become parts of her very self. She often noted how exhausting attentive listening was, writing in her sound diary that, "I'm going to work on Monday [the first time after the second surgery], and we'll see how tired I will be after the working week or if I feel the need to switch the implant off." At the same time she explained how she felt dependent on the CIs and feared she would someday lose them, saying, "at the moment I'm actually quite horrified about the thought that I couldn't hear anymore. That's why I say that if go unconscious I want my implant to stay turned on."

It is evident that for Helinä learning to listen with the CI is both arduous and rewarding as sensory labour, that is, recognizing, interpreting, enduring, handling and responding to different sensations carrying information and mediating affect. But this process has also changed her perception of self. She can't hear her own voice without a device, and ever since the age of four she has had to get used to hearing her voice differently every time the hearing aid was updated, every four years or so. For her the microphone and the code render an interface of self. Before the CIs, she heard her voice with the external hearing aids as if "from the bottom of a well". Now the voice is much more clear, present and closer, and it has done a great deal for her self-confidence in social situations.

The listening technology transforms Helinä's bodily human experience of the sonic environment into a code/space she both depends on and needs to manage by occasionally turning it off. She feels the machine demands a lot from her but her expectations for it, for medicine and the science behind it are also very high. The difference between the external hearing aids she had before and the CI sound processors are in the complexity of its automated algorithms and how they produce a sense of space. Using tools and machines to accompany the external hearing aids have been part of her everyday life, like audio induction loops, FM devices, wireless microphones (Roger Pen), and alarm clocks, doorbells, fire alarms and baby monitors with lights or vibration, not to mention sign language as a tool; even after the CIs they are useful. But the CI sound processor is more comprehensive in its scope, more incorporated in her body, and producing soundscapes of code, that is, heard "landscapes of code", to use the term of Minna Saariketo (Saariketo 2020). This opens up the question of what is meant by listening and learning to listen in situations where the sonic environment is technologically generated by a CI. Or, to be more precise, does the machine have listening agency? What kind of agency? Given by whom?

The sound processor as a listening machine

In the social sciences, interest in code and algorithms is based on their abilities to make things happen and produce ways to see, know and do. In critical studies of algorithms and software the focus is often on the performativity of the code and algorithms, the choices, values and intentions that are inscribed in them. The premise is that programmes are born in political, technical, cultural and social constellations and are thus saturated with disputes, emotions, intensities, meanings, power formations and imaginaries (Saariketo 2020, 29. See also Mackenzie 2006, 19, Kitchin and Dodge 2011, 37). In her study on the technological history of the CI sound processor, Mara Mills states with unquestionable clarity, that:

> "CI signal processors embody a range of cultural and economic values, some of which are deliberately "scripted" into design, others of which accrete inadvertently. These scripts include the privileging of speech over music, direct speech over telecommunication, nontonal languages over tonal ones, quiet "listening situations" over noisy environments, and black-boxed over user-customizable technology" (Mills 2013, 323).

The complexity of algorithmic programmes often mythologises data technology making it unobtainable for people living with them. To prevent this kind of interpretation and give the machine no more algorithmic power (Bucher 2018) than necessary, I will describe briefly how the sound processor works.

The processor in Helinä's CI model Cochlear CP910 is called SmartSound iQ. For the signal to be optimal for the electrical stimulation of her cochlear nerve the processor uses dozens of algorithms to filter and denoise digital information. The basic sound processing algorithms of the processor deal with wind noise reduction, compression, adjustment of the directional microphones' sensitivity, and volume control. The device uses 22 channels to create stimulating pulses. The input of these channels is individually processed with several algorithms and when combined they can be used as selectable programmes, although most of the time the machine does this detection automatically. These automated processes are also called adaptive processes, a choice of words that emphasises the machine's ability to respond to changes in input, not only react to them. The complexity and meticulousness of the pulses generated can be visualised with an electrodogram. Here is a graph depicting a timeline of a half-second, the word "choice" under one algorithmic strategy (electrode 1 is the highest pitch-wise, 22 the lowest).

[Picture: Electrodogram of the word "choice", *Clinical Guidance Manual* (2018, 32). © Cochlear Limited 2021. This material is reproduced here with kind permission of Cochlear Limited.]

The main challenge for the designers of processors is to get a good signal-to-noise ratio, or to get speech and other desired signals clearly audible and to tone down noise. The Cochlear Clinical Guidance Manual describes the main data programmes (Clinical Guidance Document 2017, 13–14). These include the *ADRO* – Adaptive Dynamic Range Optimisation (a digital pre-processing signal algorithm designed to improve audibility of low-level sounds and reduce the gain on higher-level sounds to keep the signal level at the desired point), the *Whisper* (a fast-acting compression circuit that makes soft sounds easier to hear), and the *Beam* (a beamforming algorithm that uses spatial input processing and intelligent noise cancelling to automatically adjust microphone directionality depending on the presence and type of noise sources), just to mention a few.

Combination programmes can be selected using a personal remote control (and in the newer processor model, with a mobile app). When activating the second implant, Helinä's doctor took up the use of the remote control and emphasised the good qualities of the available programmes, demonstrating that they are helpful for those who just want to pop the gadgets on to their ears and take them off, that is, people who strive for an embodied relationship with their implant. The default combination programme in SmartSound iQ for everyday use is *SCAN*, which classifies incoming signals into six "scenes": quiet, speech, speech in noise, music, noise and wind. Based on these classifications, the SCAN programme automatically selects and turns on the most appropriate input processing algorithms. During the appointment the doctor added the SCAN programme to the programme slot 4:

> Doctor: The scanner is a programme that – what it does is that it sniffs around your sonic environment and tries with the help of its artificial intelligence to find the best operating settings for that situation, and I think then… like, if you are a normal person you really should try it because it's this kind of "switch on and forget it" system. The only problem is that it pumps the sound a bit
> Helinä: Yeah, and then, I think it has, there is a delay
> Docrtor: Yes yes
> Helinä: So, I kind of feel that I miss something
> Doctor: Yes, in a way, it is a problem, or it is a disadvantage, the pumping, but you just need to know it does that
> Helinä: Yeah, I guess
> Doctor: [- -] With the other programme you can decide for yourself but with the adaptive programme you won't know because it can skip a bit, like when two people are talking and the other is louder than the other, it will jump to listen to the louder one even though you would like to listen to the more quiet one but then if a motorcycle buzzes behind you it will try to cut it off. So that's why programme number three is "outdoor" and number four the scanner, okay?
> Helinä: Yeah

As the implant bypasses most of the hearing organ's abilities to react to loud noises from the environment, this needs to be done automatically by the machine. This results in a "pumping" that is heard in the volume of the sound. In describing how the processor "pumps", delays and goes quiet between changing programmes, Helinä voices a concern of the machine being too noticeable. The doctor is trying to help her adapt to the workings of the machine by explaining its internal logic in choosing foci for Helinä to hear, and at the same time participating in legitimising and sustaining its configurations.

Helinä longed for a background relation with the CI, for it to fade into the background of conscious experience. She wanted the machine to be as easy to use as possible. That is why she also shunned using a remote control. Her aim was to learn to focus beyond the machine, which of course demanded quite a lot of upkeep and calibration in the beginning. For her the device needed to be fully domesticated; she spent a lot of time describing to me how she understands what is "real" (what others without hearing-impairment hear) and what is machine interface. She didn't trust the adaptive programme because it felt fake, compared to what she felt was a neutral default setting. In a way, it was important for her that there would be a “neutral” setting for her to choose and learn to predict so that the ability to choose the levels and foci of attention would be more hers than the machine’s.

Arranging the soundscapes of code

This interface between the audio signal and the self bring forward the challenges of regularising sonic phenomena to signal-to-noise automation. Regularizing phenomena for the purposes of automation is in the core of data practices. This regularisation automatically drops out features that are not contributing to data class predictions. Regularisation changes the object, sometimes radically, and should thus be confronted as a technique of disciplinary power (MacKenzie 2017).

The secondary agency given to the CI – by Helinä, the doctors, the developers, the health care services – resembles that of a mediator. According to Bruno Latour, a mediator has the power to transform and translate meanings, whereas an intermediary merely transfers meanings without transformation (Latour 2005, 39). It is obvious that the CI is not merely an intermediary but an arranger of soundscape, arranging sound in order and, as such, working on a model that is both communicatively relevant and culturally situated. As with machine seeing, machine listening is a similar a type of automation that is integrated into the everyday lives of their users, but recedes into a “technological unconscious” (Thrift 2004). In the background of mundane practices there are complex programmes and certain representations to which people do not cognitively invest in, the taken-for-granted processes that keep the corporeal body in the recursive loop of code-based technological infrastructure (Parviainen and Ridell 2021).

The agency of the CI sound processor extends its physical presence and the closed calculations of the individual processor in a similar fashion to other wearable tech like smartphones and fitness trackers that generate, collect and circulate relational data. While being experienced as intimate technologies, these wearables at the same time render corporeality into an external object to be (self-)surveilled, and the data generated delivered to global technology companies for analysis and profit. CI users participate in the generation of big data, thereby assisting in cybernetic feedback mechanisms (See Parviainen & Ridell

2021), in Cochlear Ltd's case at least in maintenance and the development of future products. It should be noted that there is a difference between wearables and neuroprostheses. The sense of body-ownership, the desired feeling that the prosthesis is a part of the body, something belonging to the beholder, makes the issue of data generation and surveillance more complicated in the broader socio-technological frame.

Laura Mauldin claims that with the emergence of CIs, deafness has been redefined from a sensory (hearing) loss to a neurological (processing) "problem"; the CI is recast as a device that merely provides access to the brain. Mauldin sees this redefinition shifting responsibility from the device to the individual, subsequently displacing "failure" in habilitation from the device onto the individual's ability to train their brain (Mauldin 2014, 131–2). This pressure and weight of a successful domestication of the CIs is also present in Helinä's experience although her take on the machine is very pragmatic overall. During the long and ongoing process, different emerging agencies are weighted, contested and questioned. The combined programmes have eventually proved useful in extreme situations. The doctor has hinted that she could in the future calibrate the processors herself through bespoke software. The idea that the implant would categorically not be turned off has turned into an empowering choice. One year after the second implant was activated Helinä wrote to me: "At night I rest. Before, I seldom was alone at night. Now I don't feel the need to have a hearing person nearby. I feel it's more of an advantage that I can take these off. I don't need to hear anything at night."

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