The Cochlea Unwound:

a case study for a listening aid using a sonic crystal array

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Introduction

In September 2008, liminal (architect Frances Crow and myself) were awarded a grant from the Wellcome Trust for the research phase of our project Tranquillity is a State of Mind: Listening Aids for a Listening Impaired Society. Working in partnership with Sustrans, the sustainable transport charity, we brought together a research team comprising two acousticians, a computational neuroscientist and a clinical audiologist in order to develop a proposal for a 'listening aid': a device that might facilitate contemplation on the act of listening itself. Our proposal, The Cochlea Unwound, is for a permanent acoustic intervention that would be sited between the weir at Diglis Island, Worcester and the footpath that runs alongside it. The Cochlea Unwound utilises the acoustic technology of sonic crystals to sculpt the noise of the weir into a sound composition that unfolds according to both the speed that the visitor passes the structure and their proximity to it. An overview of the Tranquillity is a State of Mind project as a whole is beyond the scope of this paper, but what follows is a commentary on the thinking behind The Cochlea Unwound and an introduction to the acoustic principles on which it is based.

A Listening Aid

By drawing together a multi-disciplinary team, we were able to address the notion of a 'listening aid' from a number of different perspectives. Collectively, the team represented expertise in the study of sound on its journey from the compression and rarefaction of molecules in the air, through mechanical

vibration in the ear and on into neurological information as it passes through the auditory cortices in the brain. Of the disciplines represented in the team, clinical audiology is most likely to be associated with providing listeners with an 'aid', but significantly, this aid is to hearing, not listening. The notion of 'listening' implies cognition, so an aid to listening requires a response not only to the fact of being able to hear but also to the act of choosing to listen. It is interesting to note that in the visual domain, we differentiate between 'seeing', 'looking' and 'watching', where each of these terms designates a more active engagement than the last. In the aural domain, we differentiate between 'hearing' and 'listening' but lack the terms necessary to define the various modes of listening in which we routinely engage. The deficit in the vocabulary used to discuss aural perception as compared with its visual equivalent is perhaps symptomatic of the relative positions ascribed to the visual and the aural in the sensory hierarchy assumed by contemporary culture. A listening aid, then, challenges this hierarchy, provoking us to listen differently, and by actively framing the act of listening it invites us to reconsider both what it is to listen and help us in finding new ways of engaging with the sites we are listening to.

Locating a Site

Through our partnership with Sustrans, the Tranquillity is a State of Mind project was always going to be about journeys, and so we felt it was appropriate that the means by which we should locate a site for the listening aid would be by undertaking a journey of our own. During April 2009, we cycled from Worcester to Cricklade along Route 45 of the National Cycle Network. On our ride we were joined at various stages by both collaborators on the project and also by members of the public who had signed up for our Diagnosing the Sound of the Landscape sound cycle ride.

liminal sound cycle ride *Diagnosing the Sound of the Landscape*, April 2009
Photos: J. Bewley/ Sustrans

On the ride, we explored various listening techniques; some derived from the 'ear cleaning' exercises developed by R. Murray Schafer, published in his book of the same name (Schafer 1967), while others were devised more recently, including some that evolved directly out of our conversations with the research team. Borrowing techniques for the treatment of hearing loss and tinnitus from clinical audiology, we conducted a 'noise handicap inventory', extracting questions directly from the Tinnitus Handicap Inventory developed in the 1960s as a means of ascertaining the severity of a tinnitus sufferer's condition, and applying them to a diagnosis of sound in the environment. We made sound pressure level readings at the sites where we stopped, and we compared these findings with the more subjective responses gathered through scoring exercises in which participants attempted to transcribe the sounds that they heard. These exercises conveniently illustrated the limits of our aural perception and highlighted the brain's capacity to filter out sounds not usually deemed important. The exercises could themselves be thought of as 'listening aids', functioning as means by which we might listen reflexively, concentrating our attention on the limits of what can be perceived, recognized and remembered.

Journeys

After deciding upon the Worcester site as the location for our proposal, we set about devising an acoustic intervention that might both integrate the themes

explored in our research and also offer a creative response to the site itself. The theme of travel proved to be a useful metaphorical device for drawing together various strands within the project. Travel is implicit in all of the work that Sustrans do and we wanted to create a piece which might itself constitute a journey; something which might require a visitor to move through or along it, on foot or by bike, in order for the piece to unfold. We also saw the journey that we were devising as an opportunity to explore a characteristic of the auditory system that we had become fascinated with. The phenomenon in question is that of so called 'tonotopic mapping' (tonotopic meaning literally: 'a place for tones'); the process by which sound is received by the ear and then processed through our auditory cortices. When sound reaches the cochlea, it is mapped out in space across the length of the basilar membrane, with hair cells at the near end responding to high frequencies and those at the far end responding to low frequencies. This tonotopic mapping of sound frequencies across space is maintained throughout the auditory system, from the cochlear to the primary auditory cortex. In The Cochlea Unwound, we are attempting to replicate this process on an architectural scale, creating a device that would respond to the different areas of the frequency spectrum across space, by means of a journey.

Journeys feature in many utopian novels. Edward Bellamy's Looking Backwards (Bellamy 1888), William Morris's News from Nowhere (Morris 1890) and Thomas Moore's Utopia (Moore 1516) all include some kind of journey from the chaos of everyday life to the imposed tranquillity of a dreamed utopia. In each case, utopia is achieved via social engineering in which the populous acquiesce to being tranquillized. Although idealized by each of these authors, to many modern readers the positive connotation of the word 'tranquillity' is quickly lost when this state is thought to be imposed upon us by a third party. Our initial title for the listening aid was The Tranquillizer and we explored the possibility of gradually muting the sound of the weir as the visitor approached it, creating an uncanny absence of sound at precisely the point where one would expect to hear it at its loudest. By imposing a reduction of the level of sound coming from the weir in this way, we sought playfully to question the received wisdom, ratified by European Union noise directives (Official Journal of the European Communities

2002)[i], that tranquillity can be measured in terms of sound pressure levels alone, while also examining the role of personal agency in the notion of tranquillity as a state of mind. The Tranquillizer proved to be technically impossible for the Worcester site but it provided a necessary stepping-stone towards the development of The Cochlea Unwound.

Listening to Ourselves Listen

The artist James Turrell often describes his pieces as provocations to the viewer to 'see themselves see' (Andrews 1992: 9). In his Skyspace pieces, such as Deer Shelter at the Yorkshire Sculpture Park (below), Turrell mediates our experience of the sky simply by offering us a frame through which to view it.

James Turrell Deer Shelter Skyspace, Yorkshire Sculpture Park
Photo: Tim Chapman www.2UBH.com

This act of framing something ephemeral, of intervening only in the context of our looking and not in the material of the thing viewed, is important to the reflexive intent of this collection of pieces. Rather than offering us the opportunity to view something new, Turrell offers us the opportunity to view

something already familiar in a new way. He reminds us that the phenomenon we are observing is of course always changing, always new, and in so doing he suggests a reconsidering of the act of looking itself. If the 'readymade' challenged the notion of the 'art object', it nevertheless did so by means of more objects. Rather than presenting us with a 'readymade' object, Turrell turns our attention away from a discourse concerned with authorship towards a corrective of another grand oversight in the canon of Western art culture; the materiality of light itself.

> I feel my work is using the material of light to affect the medium of perception. I'm using light in its material aspect…I try to take light and materialize it in its physical aspects so that you really feel it – feel the physicality; feel the response to temperature and its presence in space, not on a wall. (Andrews 1992: 12)

For our listening aid genuinely to *be* an aid to listening, we felt that rather than designing a device which created new sounds, we needed to design a device which would encourage the reconsideration of sounds already present. Like Turrell, we would intervene only in the context of our listening and not in the material of the thing heard. Of course, all architecture designed with its acoustic behaviour in mind does this, as Steen Eiler Rasmussen wrote in 1959,

> Most people would probably say that as architecture does not produce sound, it cannot be heard. But neither does it radiate light and yet it can be seen. We see the light it reflects and thereby gain an impression of form and material. In the same way we hear the sounds it reflects and they, too, give us an impression of form and material.
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> (Rasmussen 1959: 224)

While there are architectural spaces that draw our attention to the act of listening, architecture designed primarily for the performance of other sounds, whether as music or some other anticipated sounding event, fall outside what we were thinking of as a listening aid – albeit that they might function as one. Unlike a concert hall, The Cochlea Unwound is not so much designed as a frame within which to contemplate sound, the internal relations between sounds, or the

agency of the person making them, but a frame through which to contemplate the act of listening itself.

In his essay Against Soundscape (Ingold 2007: 10-13), anthropologist Tim Ingold observes that much of Western visual art practice, and the analysis of it, has substituted an investigation of what it is to see for what he describes as 'regimes of the scopic'; where art has become artificially divided along sensory lines and only becomes 'visual' (or 'sonic' for that matter) when abstractly rendered as painting, photography or sound recording. 'The Visual', he argues, 'appears to have nothing to do with what it means to see…[and]…scarcely deals with the phenomenon of light.' (Ingold 2007: 10) If examples of visual art from the Delft School to the Luminists or the light sculptures of Turrell or Dan Flavin appear to contradict this assertion, Ingold's central argument that the dominant organizing force in the language of Western art concerns itself with 'the relations between objects, images and their interpretations' holds true.

Within music – the art form that until very recently held a monopoly on the creative organization of sound – the relationship between sounding objects and their interpretation could certainly be seen to have been the dominant organizing principle in the West. An interest in sound for its own sake and a fascination with its internal character has been slowly in the ascendant since the middle ages however, and we can trace this trajectory through the growing sophistication in both notation and instrumentation as well as developments in the design of instruments themselves. If these developments find their nexus in the nineteenth century cult of orchestration, it wasn't until the middle of the twentieth century, with the rise of electronic music (and musique concrète and acousmatic music in particular) that the status of the 'note' as the primary unit of organisation was challenged.

John Cage offered a more radical slant on this development, challenging not only the status of the note but also the role of the composer as an organiser of sounds.

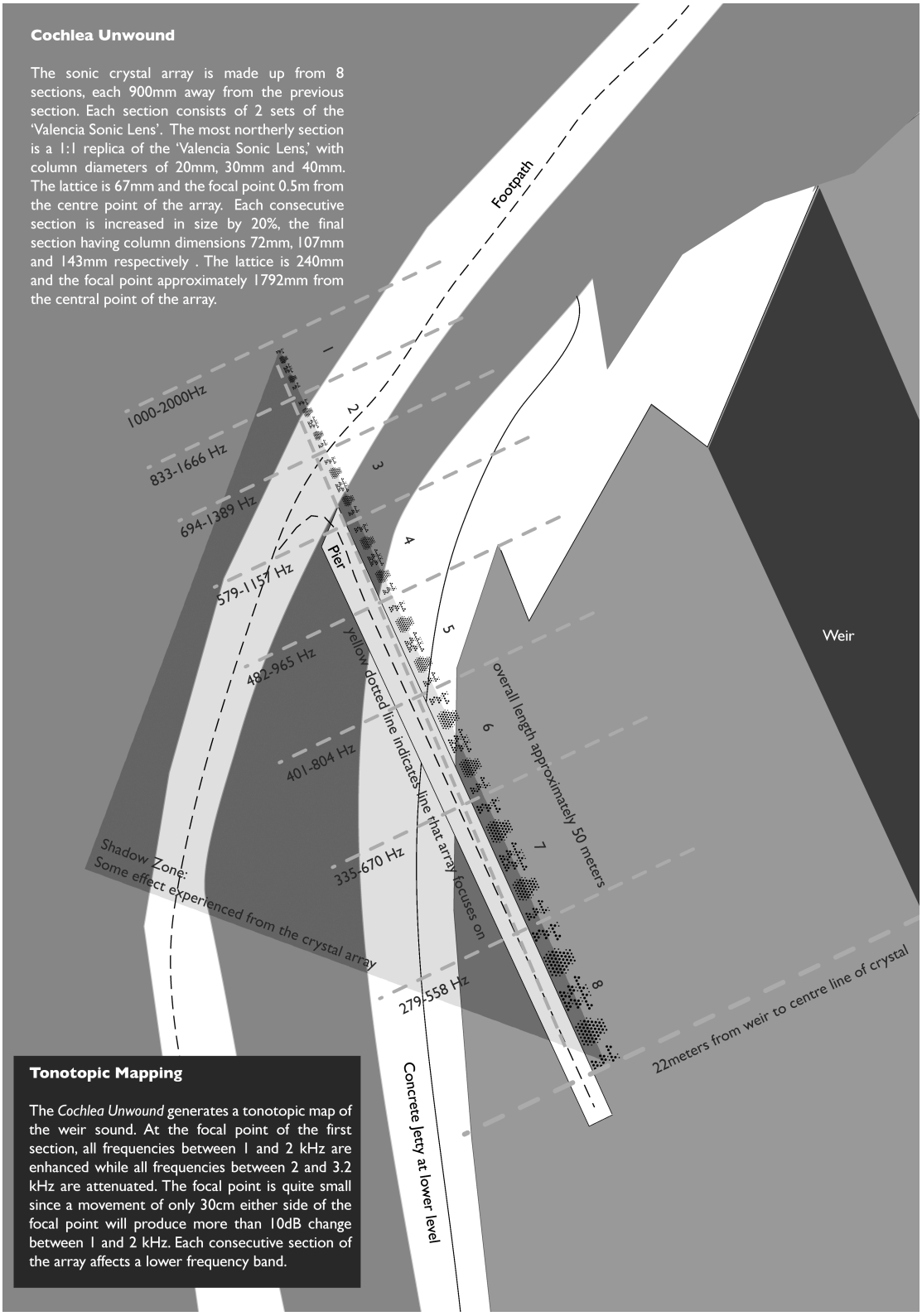
His framing of 'silence' in 4:33" (1952) is often read either in terms of the statement it makes about notions of authorship and the cessation of the composer's ego, or as a meditation on the relative nature of silence, but it could also be read as a listening device; a frame which invites contemplation on the act of listening. Alvin Lucier, too, offers numerous pieces; notably I Am Sitting In a Room, Vespers and Music on a Long Thin Wire, all of which establish a complex interplay between the material of the sounds produced and the acoustic context of the place in which they are heard and, in so doing, serve as a means by which to contemplate the act of listening. It is from this tradition of thinking about sound that The Cochlea Unwound emerges, eschewing not only the note as the primary component of musical organisation, but also the production of sound.

Sonic Crystals

In our quest to find a means of muting sounds in the landscape, we came across the relatively new research field of 'sonic' crystals. The term describes a structure in which an array of spheres or cylinders is arranged so as to guide sound waves through the structure along routes that can cause the subtle attenuation or accentuation of certain frequency bands. This is achieved by sound waves being scattered by the components of the array, literally altering the speed of sound within the structure and thus inhibiting or facilitating the propagation of sound waves as they pass through the sonic crystal array. The periodic distribution of the spheres or cylinders in the array is reminiscent of the atomic structure of a crystal, albeit in an idealized form, hence the name.

Testing the sonic crystal prototype the sonic crystal scale model
photos, David Prior, liminal

Using the Diglis weir in Worcester as a source of broadband noise, we propose to install an array of sonic crystals located between the weir and the cycle path which runs alongside it. The effect of the sonic crystal array will not be dramatic until the visitor comes quite close to it, but in our proposal the sonic crystal array juts out into the river, diverting the path so that the visitor travels alongside the weir maximizing their exposure to its noise and providing a length of the path with a relatively stable sound character which could be used as the basic sound material for the intervention.



Image, Frances Crow, liminal

Our title for the piece, The Cochlea Unwound, makes reference both to the visual similarity between the sonic crystal arrays with the outer hair cells of the

cochlear membrane in the inner ear and also the function of the sonic crystal array as a tonotopic map. Working with Keith Attenborough, a Professor of acoustics at Open University and a leading expert in the development of sonic crystals, we sketched the design for The Cochlea Unwound as a series of differently tuned arrays, so that as the visitor moves along the length of the array the effect of the sonic crystal changes, starting with low frequencies and moving up through the spectrum of our hearing. Taking its cue from the basilar membrane, the effect of the sonic crystal array is tonotopically mapped across its length, sculpting the sound of the weir as the listener interacts with it.

One of the characteristics of sonic crystal arrays is that where a band of frequencies is attenuated (made quieter), there can be an accentuation of a narrow band of frequencies either side of the attenuated area. If applied to an application such as a noise barrier on a motorway, this would be a problem and, indeed, one of the primary tasks for the acousticians working with sonic crystals is to find ways of minimizing this effect. However, this phenomenon fascinated us for two reasons. Firstly, a common cause of tinnitus is hearing loss. Due to the tonotopic nature of the cochlear, damaging a portion of hair cells on the basilar membrane results in hearing loss at specific areas in the spectrum of hearing. Where this occurs, the brain often over-stimulates the neurons connected to the hair cells either side of the damaged portion of the basilar membrane in an attempt to find the missing neurological information. This can lead to a perceived ringing in the ears of the sufferer at the frequencies either side of the damaged area. Like the pain sometimes experienced in the missing limb of an amputee, this ringing has no source in the material world but is produced by the body itself. This link between audiological and acoustic behaviour was seductive in itself, but the second reason for our being drawn to this characteristic of the sonic crystals is that if the sonic crystals could be used not only as means of attenuating portions of sound in the environment, but also as a means of amplifying others, the potential for sculpting the incoming noise source of the weir was greatly increased. The Cochlea Unwound, then, might work much in the same way as subtractive synthesis in the electronic domain, where a synthesist

starts with a block of noise and then uses a combination of filtering and 'resonant filtering' to sculpt the desired sound.

The Cochlea Unwound, however, is entirely passive, using no electrical technology. Neither does it make any sound of its own, but rather it attempts to draw our attention to the sounds already present by framing them in a new way. We very much hope that this listening aid might be a device that rematerializes our experience of sound. In contrast to the therapeutic technique of habituation used in audiology to treat tinnitus, it might serve to dehabituate us to the sounds which surround us in much the same way as Turrell's Skyspace pieces dehabituate our experience of light: framing serendipity, reminding us of what we already know but might have forgotten.

In a world saturated with sounds, we wanted The Cochlea Unwound to question whether we need any more noise. By recycling surplus sounds from our environment, The Cochlea Unwound challenges expectations of what might constitute a piece of music by adding nothing to the existing soundscape, but rather offering new ways of listening to what is already there.

The Cochlea Unwound, Diglis Weir, Worcester
Visualization by Jim Morris

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Notes:

[1] Directive 2002/49/EC of the European Parliament and the Council of 25 June 2002 relating to the assessment and the management of environmental noise. L189/12 Official journal of the European Communities 18.7.2002

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