The sounds of nanotechnology

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Public perceptions of nanotechnology are shaped by sound in surprising ways. Our analysis of the audiovisual techniques employed by nanotechnology stakeholders shows that well-chosen sounds can help win public trust, create value, and convey the weird reality of objects at the nanoscale.

Most research centres and other stakeholders in nanotechnology produce informational videos about their work to help the public understand what they do. Along with documentaries about nanotechnology, these are the main sources of images that people have of what science is capable of at the scale of a billionth of a metre.

But these videos have soundtracks too, and it's worth listening to them carefully. We conducted a survey of 108 videos and other audiovisual experiences from 21 countries in the areas of education, advertising, TV, film and art (**see DOI**). We noted their salient aural characteristics, such as music, tone, voiceover and materializing sound indicators, so that we could identify precisely what aspects of nanosoundscapes are important for achieving key aims in nanoscience education: to envelop the viewer-listener into the scale of the nanocosm, to create economic value, and to induce desirable psychological and cognitive states.

To understand what's going on, we examined what we were hearing with the help of scholarship in the fields of sonic branding, embodied cognition, and film studies. What we found was that these sounds can tell us a lot about the hopes and expectations that are aroused by nanotechnology, as well as the public's niggling unease about this strange new world. Sonic branding research alerts us to the incentive for commercial organizations to associate desirable sounds with their products, while insights from embodied cognition help us understand that human sense perception can be manipulated to give the impression that the nanoscale can not only be seen and heard, but physically experienced. And film studies research provides the best tool for calibrating the various ways that exist to link visual information with sonic information.

The sounds of the nanocosm

So, what do nano-objects sound like? Obviously, the answer is that they make no sound that can be picked up by human ears. We should point out here that we are not

concerned with phonons. What we hear in nanotechnology communication are not real nano-sounds. They are sonic simulations, just as what we are looking at are visualizations of nano-objects that are too tiny to reflect visible light. (For work on visual representations of nanotechnology, see references 1-3.) Nanosound is produced, not recorded.

One type of sound that we find in the great majority of nano-videos is very nearly inaudible, and yet significant. It is what film scholars and sound recordists call 'room tone', a kind of aural fingerprint unique to any location that is caused by the reflection of the faintest source sounds off the boundaries of the space. Our proprioceptive apparatus translates this faintest of hisses, in the range of about 2000 to 8000 Hertz, as evidence that we are sharing an embodied space[4,5].

Room tone plays an important role in giving viewer-listeners the sense that what they are perceiving is real and not some abstract, merely conceptual space. This is a way of overcoming the paradoxical challenge that persistently faces nanoscience communication – how to strike a reassuring balance between stirring our excitement about what is strange in this new world, and making this world familiar and accessible to our imaginations and senses.

In a similar vein, our sample frequently includes music or sounds that give the impression that we can hear individual nano-objects move or being moved. This effect is what the film-sound scholar Michel Chion calls 'synchresis'. When an auditory phenomenon occurs at exactly the same time as a visual one, the viewer-listener assumes the two are inextricably linked. Synchresis is a way of avoiding the potential pitfall that the viewer-listener, upon seeing an object that makes no sound when it moves, will either assume that there is a technical fault or will experience an unsettling feeling that the object belongs to some other level of reality. In mainstream film and television, even apparently silent scenes do still contain the faintest sounds – consider the near-mute soundtrack in *Saving Private Ryan* to convey the characters' shock and dislocation after an explosion, or the eerie hissing stillness in the boxing ring in *Raging Bull*, as the protagonist waits for another punch to land. Total silence, outside perhaps of art films, is never really experienced by viewer-listeners, and that is why there is always something to listen to in nanotechnology videos.

There are many videos that simply use a generic, non-synchretic 'science sound' or 'science music' as a backdrop to the images. This filler sound usually takes the form of echoing electronic music with soft yet rapid beats and descending/ascending arpeggios. The combination is rather bland but can do a good job of providing a non-distracting and yet busily moving soundtrack that allows the viewer to focus on the information being conveyed by text on screen or by voiceover. Its echoing quality conveys, though less effectively, that important sense of spatiality that is achieved by room tone in videos that do not feature music. From the videographer's point of view,

generic sound also has the virtue of being quick and easy to attach to a video track.

Synchretic sound design, by contrast, is an excellent way for a nanotechnology video to emphasize the intervention of the scientist or the scientific instrument in a particular process. One widespread technique is what we call the 'sonic-zoom', which is a swooshing, surging sound effect that we hear when we plunge into the nanocosm. It has a stirring, immersive effect, as it dramatizes the capacity of technology to bring us on a science-fiction-like journey from the human scale to the nano in a fraction of a second. In *Nano, the Next Dimension*, a web documentary commissioned by the EU, we hear the rush of the sonic-zoom; when it cuts out, we abruptly find ourselves in this new environment, where we become conscious of a cosmic echo. A kind of accentuated version of room tone, it gives the impression that we are in a hugely cavernous, cosmically big, space. This kind of sound in our sample effectively eases the general viewer-listener past the greatest obstacle to comprehending nanoscience, which is the tininess of objects on the nanoscale.

Such techniques are successful because they exploit our embodied sensation of space. Research in embodied cognition explores the idea that the mind is not exclusively located in the brain, but is distributed throughout the body. Bodily senses don't just guide what we know, but they play a much more active role in modulating our very self-awareness within our environment, usually without our realizing it[6,7]. In this vein, many experiments[8] have demonstrated how physical sounds direct psychological and cognitive states – thus, our bodies (and not just our ears) register some sounds as 'safe' and others as 'thrilling' or 'scary', while inaudible infrasounds have also been shown to influence our behaviour[9-11].

A well-chosen sound, therefore, can engender a positive perceptual-affective effect, and this is a valuable insight for marketers who want to differentiate their product or service. As long ago as 1957, Vance Packard pointed out that the satisfying 'whump' of a closing car door appeals to potential buyers and adds value to a brand[12]. More recent research[13] has found that 'Frosh' – an imaginary brand of ice cream – sounded to consumers to be more creamy and rich than 'Frisch'.

What this means is that, when people come up against something unfamiliar such as a new brand, they will often rely on the sound of the new thing to infer cues on how it will perform or what it will be like. The sounds that are associated with many of the nanotechnology communications in our database exploit this insight, mixing strange auditory experiences with familiar ones but without letting one soundscape dominate. Too much strangeness may induce a sense of dystopia, where the human element is overwhelmed. Too much lightness may come across as flippant, hubristic and even condescending (see Table 1).

We identified a recurring sound, which we call the 'tink-a-link', that in many instances

successfully hits the sweet spot between these extremes. Think of the slightly irregular sound of a teaspoon stirring a drink in a cup, but very slightly muffled. A 'small' sound, the tink-a-link is a digital-sounding chirrup that connotes a cheery friendliness and a good-natured efficient simplicity, for example in *One Boy and His Atom*, or what the makers IBM call 'the world's smallest advertisement'. The tink-a-link is nearly always employed synchretically, mimicking in its rhythm the movement of nano-objects on screen. This makes it a safe sound, and yet its speed and complexity have an ever so slightly non-human edge that effectively keeps us just inside the realm of science-fiction and wonder.

Sounds that make us think of electric current are orchestrated in many different ways. At the quietest level, the faint hum of alternating current can be used as an ingredient of room tone, persuading the listener-viewer that they are in a highly-technologized laboratory environment. Sometimes called 'mains hum' and audible in the range of 50 to 60 Hertz, it can add a sense of vibrancy permeating the nanocosm, as if we can perceive a delicate arrangement of energies below the threshold of the concrete. One step up from this is the hiss and crackle of an overloaded electrical cable (known as 'corona discharge'). This is used sparingly, as it gives an impressive feeling of tiny power but also a sense that things are not quite under control. Several more steps up from this and we reach something akin to the waving and clashing lightsabers in the *Star Wars* films. This sound portrays nanoparticles not so much as three-dimensional solid substances, as arrays over which forces and currents are flowing. It has an estranging effect, in other words, and for this reason we find it used much more frequently in Hollywood films that play on the dangers of nanotechnology, such as *The Stepford Wives* (2004), *Iron Man 3*, and *Agent Cody Banks*.

Nano-voice and nano-music

There are of course many sound elements that are used across science communication and not just in nanotechnology, such as voice-over and music. In listening to voice-over speech, our focus was not so much on the information that was conveyed as on the rhetorical impact of the sound quality. In our sample, the great majority of voice-overs were of North American males speaking in an informal manner. This reflects to some degree the bias of our sample, which favours English-language videos, but it also of course reflects the cultural reality of high-level scientific research, which is to say that a significant proportion of nanotechnology research and communications stem from American laboratories, and that the gender balance across science of all kinds favours men. The informal tone and language that predominate make for a friendly, disarming experience. A good case in point is the 2011 short animation *Do you Know What Nanotechnology Means?* for the Alberta Science Foundation, which speaks to the viewer-listener as if to a child but without overstepping the line, as some voiceovers do, into infantilizing the viewer-listener. It has been shown in study after study that masculine voice is consonant with two

attributes that are important for science: authority and confidence (see, for example, reference 14). This choice becomes a habit-forming convention in choosing voiceover in everything from commercials to news-anchoring. In fact, over 90% of our sample use male voiceover. On the rare occasions that a female voice is used, it speaks in a more awed register, sometimes almost at the level of whisper against a background of ethereal, choral music. In the absence of the authority and confidence conventionally associated with the male voice, the female voice gives the sense of an admiring, but uninvolved, passive onlooker.

Orchestral music is often scored in a Hollywood style, meaning it keeps the viewer-listener engaged and interested by 'storifying' the nanotechnology on screen. Videos in this style often reach a majestic, climactic point in the narrative, where an unmissable musical feature, such as an imposing chord progression or a booming taiko drum, coincides with some kind of revelation or transformational moment in the procedure being illustrated. An example of this storifying effect is found in the French short animation *Les Nanomedicaments solution contre le cancer*, which dramatically takes us on an acoustic journey from sickness to health through the shift from despondent music to the heavenly, uplifting chords which mirror the nanotechnology-enabled therapy at work.

The harmony of the music almost seems to be transferred to the science of nanotechnology, with the result that the viewer-listener perceives it too as a harmonious process. This kind of orchestral music can take one of two directions: in the first, it begins quite simply and then layers up its instrumentation to increasing complexity. This kind of gradual transformation tracks the way that the video presents us initially with the delicate simplicity of nano-objects and then shows us the amazing capacities of nano-objects when they number in the thousands or millions, as in the video *Multiscale Simulations of Zinc Oxide Nanoparticles* by the Universität Erlangen-Nürnberg.

The other direction for orchestral music is towards minimalism, in the style of composers such as John Adams, Arvo Pärt or Philip Glass. Minimalism is pared back, sometimes meditative, and sometimes but not always harmonious. Its frequently heavenly, mystical style is used to strike a paradoxical balance between strange and familiar, between austere and lush, that has the effect of making the viewer-listener simultaneously experience awe and comfort.

This minimalist effect can also be produced by electronic music, which is the other predominant instrumental mode in nanoscience communication. Ranging from the melodic style of Kraftwerk to the ambient style of Brian Eno all the way to the looser unpredictability of Aphex Twin, its repetitive and relatively unstructured nature means that, as mentioned earlier, it is employed non-synchretically. 'Computer music' such as this lends a technological, computational feel to what is being shown. This is

particularly fitting when the music serves as a kind of aural wallpaper to be semi-ignored so that the viewer-listener can devote his or her attention to the information being conveyed.

The sweet spot between familiar and strange

Paying attention to the music in this way led us to identify a set of correlations across our data set. When a nanotechnology video uses featureless background electronic music, it tends to be relatively shorter in length, to have lower production qualities, to come from one of the smaller institutions in our survey, and to have a lot of detailed, written information to transmit. So, short technical videos pay relatively less attention to the public-outreach aspect of their communication, as they are targeted at viewer-listeners within their field. By contrast, videos that aim to inform the general public about nanotechnology are from larger institutions or corporations (for example, *The Strange New World of Nanoscience*, a non-commercial information film funded by the European Union for the NANOYOU project), and they are more concerned with nanotechnology public outreach. In this category, the main challenges are to convey how small the nanoscale is and to establish an aura of trust and safety around the field. As a result, this category often employs features such as sonic zooms, a paternalistic voiceover, and synchretic sound effects that give aural reassurance.

And so we can see that a carefully calibrated soundtrack is vital for creating brand value, especially for larger organizations. We know from research in sonic branding that economic value is enhanced when sound is used to create unique and differentiated brands0[15]. Think of the Apple computer startup chime, the muted crinkle of a Petit Camembert wrapper, or the reassuring solidity of the sound of a Cadillac car door closing – all of these well-designed sounds, like well-designed products, occupy a distinctive place in our minds and ultimately command a price premium – the holy grail of marketing. This helps us understand why the generic science sound that we discussed earlier is more typically used in nanoscience videos that are not primarily focused on enhancing economic value or public awareness but are instead engaged in technical communication or education.

Any single sample from our database can illustrate only a few of the aspects described here. With this in mind, we recommend to readers who are interested in listening for themselves that they go online to www.nanoreisen.de and explore the interactive Flash animation, which was sponsored by the German Ministry for Education and Research. It illustrates well five sonic characteristics: the tension between the familiar and the strange, sonic zoom, synchresis, room tone, and electric current. Starting at the scale of 10^0 m (an airplane announcement, a café), the animation offers the traveller several possible paths of exploration down to 10^{-9} m, the nanometre. The café soundscape envelops us in a familiar, open-air environment of chatting voices and bassy music. There are three clickable exit points from this place. Simply moving

the mouse over any of them immediately disturbs this human scale with an electrically-charged trilling twang. Clicking on any of them provokes a synchretic bleep followed by the rush of a sonic zoom down to the next level, 10^{-1} m. When the scale-shifting commotion subsides, we become aware that the café sounds have been replaced by an entirely new room tone. The room tone varies according to which exit point we have clicked on, but in all cases we are surrounded by a dull, enclosing thrum, often with a strong connotation of mains hum. As we mouse around, the environment synchretically shivers and hisses into life, offering information boxes and clickable paths downwards towards 10^{-2} m. With each exploratory click, the journey continues in the same way – twang, bleep, zoom, thrum — until we reach 10^{-10} m, where all the paths join for the final plunge down to the 10^{-15} m level of quarks. The many sound environments on the way are too numerous to describe and are best experienced directly, but whether they bring us into seemingly arid or underwater spaces, desolate or teeming with unusual activity, inert or buzzing with barely contained forces, they all feel like places where the human scale does not apply. This potential estrangement is at every level counterbalanced by the feeling of control that the interface gives us, giving us sonic reassurance that we, and nanotechnological science, can measure, comprehend, and navigate this space.

It is possible, then, to identify the sounds of nanotechnology. But it takes a degree of conscious effort, as humans devote so much of their cognitive attention to the visual when watching a screen. Because sound often approaches us unawares, we have to engage our critical faculties in a deliberate way to hear it properly. It is not a simple challenge, especially with the enormous development of digital sound technology since the 1980s, such as Dolby surround sound and sampling, which increases the capacity of the soundtrack to give us what Chion calls ‘an acute feeling of the materiality of things and beings’[16].

What this means for nanotechnology stakeholders is that they also need to pay attention to the sounds that they emit in their communications about themselves. It is easy, even fun, to wow people with the wonders of the nanocosm, but it is also easy to speak down to them in the process. It is tempting to emphasize strongly what is strange and non-intuitive about nanotechnology, but this brings with it the danger of alarming people wary of the negative side of other new technologies. Music can be distracting or disconcerting. Sonic zooms can be thrilling the first time but tiring a few short minutes later. Room tone can establish an atmosphere of how much room there is at the bottom but can sound overwhelmingly cavernous. Throughout our analysis we repeatedly find that nanotechnology communication at its best strikes a delicate balance between the familiar and the strange, and we hope that our description here can serve as a set of signposts for stakeholders thinking about their next video project.

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Caption for the Table
General typology based on our sample of nano-sounds and the ranges of effects they produce, plotted on a spectrum ranging from sounds that feel familiar to the viewer-listener to those that are potentially alienating.