
The death and life of digital audio

JONATHAN STERNE

Department of Art History and Communication Studies, McGill University, W-225 Arts,
853 Sherbrooke St W, Montreal, Quebec, Canada H3A 2T6

For many years now, critics have written of digital audio recording – in its myriad formats – as less ‘live’ or less ‘natural’ than analogue recording. By implication, these critics suggest that digital audio is closer to death. Taking the metaphysical assumptions behind such claims as its starting point, this essay analyses three key elements of digital audio: temporality, definition and mobility. By troubling the notion of time as a continuous linear flow, and by troubling the idea that all analogue media share this continuity with ‘natural’ time, it is argued that digital recordings have as legitimate a claim on sonic experience as their analogue counterparts. The argument about experience extends into a consideration of the problem of sonic ‘definition’: the range of possible pitches and volumes in a given recording. Higher definition does not necessarily make a recording more lifelike. Finally, the contexts in which recordings are generally heard today mitigate against the idea that they must aim to perfectly reproduce a live performance. Rather, their liveliness should be judged by the degree to and manner in which the recordings themselves circulate. Judged by their social lives, rather than by a dubious metaphysics, digital recordings are at least as lively as analogue recordings ever were.

In recent years, the differences between analogue and digital audio have been the subject of great philosophical anxiety – among academics, but also among journalists, audiophiles and communities of fans who exchange audio files on the internet. As audio undergoes an ever increasing series of transformations between the moment of recording and the moment of audience reception, worries multiply about a ‘loss of being’ between the performance and the recording that eventually meets auditors’ ears. In one sense, this is an age-old problem of media, going back to Plato’s critique of writing and painting as containing less ‘being’ than spoken dialogue. But increasingly in the twentieth century, writers accepted the basic fact of mechanical and electronic media, and so the critique that copies lose some essence of the original has been displaced into a debate about the relative merit of one kind of copy versus another.¹ Plato’s original statement of the problem – along with its twentieth-century modification – suggests that mediation is something that can be measured in terms of its distance from life: Is an analogue recording less mediated than a digital one? Is compact disc audio less mediated than compressed formats like mp3 (which deliberately remove data in the quest for better portability)?

Behind these questions lies the premiss that a recording contains a quantity of life, and that as a recording traverses an ever larger number of technological steps, that quantity of life decreases, essentially moving it (and perhaps the listener) toward death. This is not just an academic concern: for instance, many online communities of jam band or progressive rock fans will agree to use only ‘lossless’ audio schemes to avoid ‘degraded’ formats. Some

go so far as to provide software to determine whether an audio file has ever been through a conversion to a compressed audio format, even if it is not possible to tell the difference simply by listening.²

In the following pages, I trouble this metaphysics of recording. While other authors argue that digital audio is ‘further’ from an original performance than an analogue recording, I argue that this is not the case. I proceed first by criticising the notions of time and space that subtend many assertions of digital audio’s proximity to death, and then go on to explore the specific aesthetics of digital audio and the model of listening carried with it. While it is true that digital recordings often sound different than their analogue counterparts, and that mp3s sound different from their counterparts on store-bought compact discs, my argument is that digital audio must be understood within the contexts of its circulation. In other words, aesthetic critiques have largely judged digital audio according to irrelevant criteria, based on a dubious presumption that analogue audio is somehow closer to life. A more robust cultural and aesthetic theory of digital audio must attend more carefully to the ‘mediality’ of recorded audio – its technological consistency, but also the social practices and formations that define its meaning and character.³ Such a move requires that we examine the relevant technologies themselves more carefully, and also that we take seriously the broader cultural formations through which recorded music moves. The question of ‘life’ in a recording is a social question, not an ontological or metaphysical one. Or to put it another way: do the missing data matter when you’re listening on the train?

* * *

MP3s and other forms of compressed digital audio have often been singled out as particularly ‘diminished’ forms of recording. Schemes like mp3 are based on a technique called ‘perceptual coding’, which uses a mathematical model of human psychoacoustic response to throw out any portion of a signal that listeners are unlikely to hear. Basically, perceptual coding works on the assumption that people do not hear most of the frequencies that confront their ears (even in the audible range), and therefore, one way to reduce the size of audio files is to eliminate those frequencies beforehand. Of course, the scheme is imperfect: a poorly encoded (or low bit-rate) mp3 has many audible artifacts that a trained listener can easily identify in an experimental setting. However, it is much more difficult – and sometimes impossible – to tell the difference between a CD recording and an mp3 if someone is listening to mp3s in noisy environments, through poor quality speakers or earbuds, or in cases where a high quality encoder or high bit-rate was used to make the mp3 file.⁴ Nevertheless, the fact of the difference between an mp3 and a CD file, just like the fact of the difference between a CD and an LP, is enough to create anxiety among aesthetic critics.

For instance, Aden Evans, who offers a critical account of digital audio that is exceptionally well grounded in knowledge of the technology, writes that ‘with attention turned resolutely away from sound quality, the relationship between the technology and its purpose (to convey music) begins to slur . . . The technology comes to count as much as or more than the music; listeners admire the smallest minidisk player, the most bass-heavy speakers, the mp3 machine with the best LCD display.’⁵ Certainly, the iPod is a triumph of industrial design and consumer marketing.⁶ Certainly, there is a subset of mp3 players

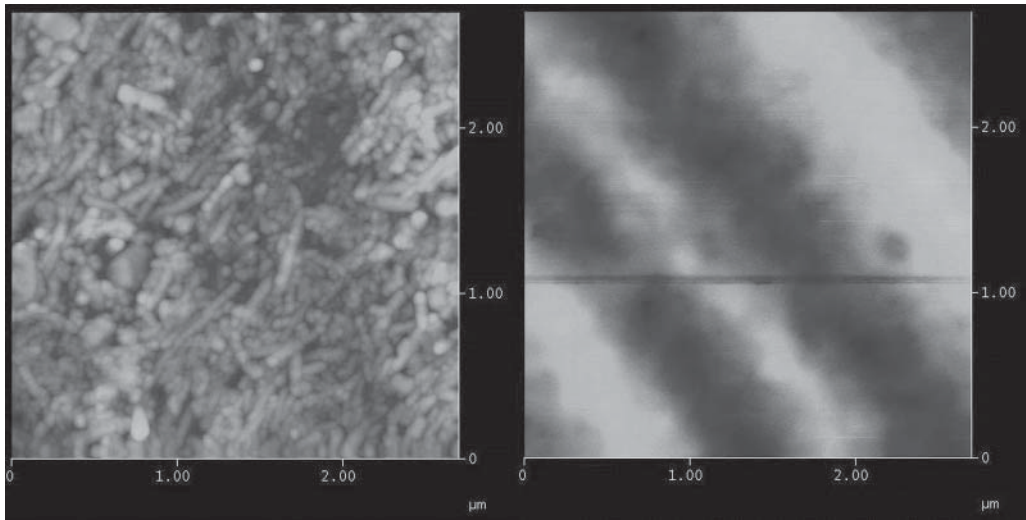
purchased more out of the desire for a status symbol than for their utility, just as with cellphones before them, and email addresses before that. But is the loss of fidelity really responsible for encouraging a consumerist relationship with consumer electronics? Don't audiophiles, who prize fidelity above all else, also submerge the experience of the music to the experience of technology in their pursuit of a beautiful and sublime experience of music?⁷ Perhaps fidelity is the wrong measure of mp3s, or of digital audio more generally.

Fidelity is a metaphysical problem, based on the idea that a copy lacks some of the metaphysical 'stuff' that an original sound once had. In *The Audible Past*, I criticised 'sound fidelity' as a measure of sonic experience. It is worth revisiting that issue in the digital realm because the history of digital audio has largely been read as being about the relationship of originals and copies, and especially about questions of the fidelity of copies to 'original sounds' that exist outside the process of reproduction.⁸ Compact discs, for instance, use a sampling rate of 44.1 kilohertz, which means that for each second, there are 44 100 'frames' of digital audio sampled and then assembled back into a stream when we listen. The process is somewhat analogous to the segmented nature of motion picture film stock, where a series of still images becomes motion before our eyes when projected in a movie theatre. As with cinema before it, some scholars believe that in nature, time is continuous and therefore something is lost when time is cut up into segments, even when we can no longer perceive its segmented nature. Evans objects to digitisation because it segments time and therefore 'loses' some reality:

The digital has a resolution, and detail finer than this resolution is ignored by the digital's ordered thresholds. This suggests that higher resolution and tighter thresholds approach a complete capture of the object, a digital representation adequate to the object represented. But this suggestion effectively treats the actual world as already digital, a world built from parts, irreducible bits and pieces assembled into the familiar objects around us. On the contrary, what distinguishes the actual from the digital is a haecceity, a 'hereness' or singularity, wherein the actual testifies to its generation. There will always be an excess, always more than the digital can capture, because the actual is not fixed and static but creative.⁹

Evans' point is not, however, unique to digital media. Analogue media can store their data in discontinuous formats as well, and resolution can be just as big an issue. Consider the two images of magnetic tape in Fig. 1. One shows particles of ferric oxide on a strip of magnetic tape, magnified through a scanning electron microscope. In tape recording, the recorder takes a sound that has been converted to an electrical signal (for instance through a microphone) and runs that signal through a small magnet that it passes over a moving strip of tape covered with particles of ferric oxide. The particles on the tape rearrange themselves in concordance with the waves given out by the magnet in the recording head of a tape recorder. When the machine passes the tape over the magnet in the reproducing head, the process is reversed, and eventually sound will emanate from a connected speaker or headphones.

Now look carefully at Fig. 1. The particles in the lefthand image are clearly discontinuous. They form a definite pattern on the tape but that pattern is an arrangement of discrete entities, not all that far removed from what we would now call data. The righthand image is the same strip of tape, but scanned for the magnetic patterns it contains. These patterns are continuous, and they are the source of the continuous analogue sound that emerges from the tape recorder. In other words, analogue tape is just as discontinuous as the 0s and



1 Microscopic images of particles of iron (III) (i.e. ferric) oxide on magnetic tape (left), and of the same piece of tape showing the magnetic patterns generated by the patterns of the particles shown at left

1s in digital storage. We can draw two possible conclusions from this exercise: either Evans' critique should be extended backward to include analogue tape (therefore becoming a critique of a certain type of storage media, rather than the digital as such) or we need to rethink the criticism.

In fact, the argument does extend back – it was first applied to media at least a hundred years ago. In his 1907 *Creative Evolution*, Henri Bergson refers to film's ability to create a sense of motion in the viewer as a 'cinematographic illusion'.¹⁰ By this he meant that cinema generates the illusion of continuous movement from a series of still images. Gilles Deleuze would later critique Bergson on this point: isn't the perception of movement as real as any other perception? 'Cinema does not give us an image to which movement is added, it immediately gives us a movement-image. It does give us a section, but a section which is mobile, not an immobile section + abstract movement.'¹¹ One can say the same of the relationship between the sounds one hears listening to a tape recording and the particles of ferric oxide on the magnetic tape. And one can say the same of the data arranged on the platter of a hard drive or the pits on the bottom of a CD. Discontinuous modes of data storage can still provide full modes of sensory experience, and this is a sensory effect, not an illusion. Thus, we cannot say that the segmentation of digital media renders them fundamentally different from analogue media, and we cannot say that their segmentation renders the experience of digital media inherently less full or substantial than the experience of analogue media.¹²

Argument by metaphysics is notoriously difficult to prove, but it is interesting to note that Bergson's conception of time is itself under debate, and that debate has even registered in writings on sound, for instance in *Principles of Digital Audio*, one of the standard textbooks on the subject. At the end of a section on digital sampling of analogue sound, author Kenneth Pohlmann writes:

Time seems to be continuous. However, some physicists have suggested that, like energy and matter, time might come in discrete packets. Just as this book consists of a finite number of atoms and could be converted into a finite amount of energy, the time it takes you to read the book might consist of a finite number of time particles. Specifically, the indivisible period of time might be 1×10^{-42} second (that is a 1 preceded by a decimal point and 41 zeros). The theory is that no time interval can be shorter than this because the energy required to make the division would be so great that a black hole would be created and the event would be swallowed up inside it. If any of you out there are experimenting in your basements with very high sampling frequencies, please be careful.¹³

Granted, today's sampling frequencies are nowhere near this limit-case and are therefore still susceptible to the critique that they might leave some reality behind, but Pohlmann's joke points to the folly of desiring media that simply mimic reality, whether we are talking about the flow of time or the character of the sound itself. Perfect fidelity is a black hole from which nothing can emerge.

It doesn't stop there. Psychoacousticians believe that the brain processes signals from the auditory nerve at a rate much lower than the speed of sound. The coupling between the inner ear and the brain is such that the brain can't keep up with sound as it actually happens. Yet somehow, between the cochlea, the auditory nerve and the brain, people get a sense of the detailed rise and fall of sounds. There are a number of proposed analyses as to why the ear works the way it does, but no one theory is dominant.¹⁴ The key point, though, is that while sound reproduction technologies have traditionally been theorised in terms of their relation of absolute fidelity to a sound source, current research suggests that auditory perception has at least as much to do with what happens inside the brain as what happens outside of it.

Even if the brain were capable of such distinctions, the question as to whether there is a loss of being in recording also ignores the fact that the so-called 'original' in most cases was fabricated for the specific purposes of reproduction. This is true of both casual and serious cases of sound reproduction. Telephones do not 'capture' conversations that happen in the room and send copies of them down the line; people speak into phones in order to have their voices reproduced. The same can be said of the CD I'm listening to right now: the label paid a lot of money for the musicians to go to a studio and perform their music over and over (and piece by piece) into microphones and mixing boards so that the music could eventually be put on a CD to be sold. The recording process didn't capture a 'live' performance. If anything, the performance was designed to capture the recording.¹⁵

So what of the actual differences between analogue and digital media? When people write about the missing frequencies in an mp3 or the picoseconds of sound lost between the digital samples on a compact disc, they are really writing about definition, not fidelity. *Definition* has to do with the frequencies reproduced by sound equipment. Michel Chion calls definition a sound recording's 'acuity and precision in rendering of detail', which can be measured in terms of how much of the audible range of frequencies (from lowest to highest) the recording produces, and its dynamic range, which is the distance between the loudest and quietest sounds in a recording measured in decibels:

In the 'natural' world sounds have many high frequencies that so-called hi-fi recordings do capture and reproduce better than they used to. On the other hand, current practice dictates that a sound recording should have more treble than would be heard in the real situation (for example when it's

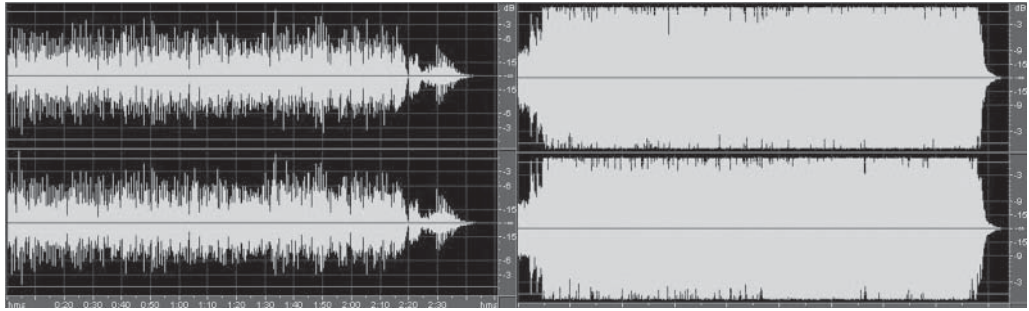
the voice of a person at some distance with [his or her] back turned). No one complains of nonfidelity from too much definition! This proves that it's definition that counts for sound, and its hyperreal effect, which has little to do with the experience of direct audition.¹⁶

Definition is the metric by which people tend to compare copies to copies. For our anxious hordes of critics and sound engineers, metrics of definition suggest that one copy has more of the stuff of sonic life than another. As Chion points out, the connection between definition and the 'reality' or 'liveness' is largely metaphoric, since it has as much to do with aesthetic conventions of sound mixing as it does with how something might sound in a room to the 'naked ear'. To turn it around, audiophiles worry that the mp3 is a little closer to death than the CD, which is a little closer to death than an LP or audiotape, which is closer to death than the people on the recording.

Chion's point can be expanded further, because high definition is not the only or even the main goal of most recording. While it is true that at the level of formats, mp3 has less potential definition than .wav (which is the format used on a commercially pressed compact disc), it is also true that few if any commercially released CDs take full advantage of the format's capabilities. This is especially true in the case of dynamic range, which has been steadily decreasing over the past decade's commercial popular releases. Professional engineers, mixers and broadcasters have for years worked hard to reduce the dynamic range of recorded signals. Recorded voices in rock, rap, blues, folk, country, reggae, and countless other genres gain their power from a process called audio compression, where the dynamic range of the voice is reduced and the overall, average volume of the voice is therefore increased. Audio compression is an essential process in shaping the sound of modern recorded music and if a commercial recording were released without it, most listeners would say that it sounded 'wrong' even if they could not explain precisely what was missing. Unfortunately, this can lead to some confusion because the *audio* compression used to reduce dynamic range in studios has no necessary relationship with the *data* compression that occurs when people convert files on a CD to mp3 format. They are two completely distinct technological processes. (If it helps, think of audio compression and data compression as proper names rather than descriptive nouns: they each name completely different processes, just as the author name 'Jonathan Sterne' has a different contextual meaning depending on whether you are referring to an oeuvre on communication, culture, sound and technology or an oeuvre on medical statistics, sampling methodology and diagnostic practice.)

Compared with vinyl records, compact discs theoretically allow for a much wider dynamic range. But digital formats can also go the other way: they allow engineers to create recordings with much narrower dynamic ranges than was possible with vinyl records or magnetic tape. In other words, if you play any commercial CD in a popular genre, odds are that the average distance in decibels between the quieter and the louder sounds on the recording will be smaller than it would have been with a similar CD pressed twenty years ago. The effect is visible in waveform representations of songs. Each of the images in Fig. 2 represents the variation between the loudest and softest sounds in a recording; their scale is identical. For those unfamiliar with these two recordings, they are both guitar-oriented pop songs with prominent male vocals.

As the anonymous author of the article from which these images are taken points out, only a single peak reaches the maximum possible volume of the recording in Brian Adams'



2 Graphs showing dynamic range of recordings of Brian Adams, ‘Cuts like a knife’, released in 1983 (left), and The Rembrandts, ‘I’ll be there for you’, released in 1995

case, whereas the Rembrandts song is *mostly* at the maximum possible volume. If you put both in your CD player, set them to play one after the other, set your volume dial to ‘3’ and walked away, the Rembrandts song would sound much louder because its average sound level is much louder. This happens because while the loudest parts of the Rembrandts song are a *little* louder than in the Adams song, the quietest parts of the Rembrandts song are *much* louder than in the Adams song. Most commercial releases today (with some notable exceptions, like the band Tool) look more like the Rembrandts song than the Adams song. The net effect of this shift is that there is considerably less dynamic range in today’s popular music than there was twenty years ago.¹⁷ To be sure, the quest for ‘louder’ music can probably be traced back through all of musical history, but the issue has become particularly acute in the past ten years or so for a variety of reasons.

Engineers reduce dynamic range because to do so makes the recording ‘seem’ louder when compared with other recordings with more dynamic range. Some compression is necessary for the song to sound ‘right’ in many genres; more is added for commercial and competitive reasons. Psychological studies have claimed that all other things being equal, a ‘louder’ song will sound ‘better’ to listeners than a quieter song. Whether or not this is actually the case, it is taken as gospel in the recording industry, especially because the effect seems most pronounced upon first impression. The theory is that if two songs on the radio are otherwise of the same quality, the ‘louder’ song will be more likely to catch a listener’s attention. In practice, musicians and producers have come to measure the loudness of their own CDs – whether or not they will appear on radio – against other commercially released CDs, and the result has been a sort of loudness arms race, fuelled by new software developments in ‘loudness maximisation’.¹⁸

In the vinyl era, records put a limit on the ‘loudness wars’, as engineers have dubbed them. That’s because of the limits beyond which vinyl records and electromagnetic tapes could not be pushed (digital audio files have limits too, but they are different kinds of limits). For instance, when mastering engineers cut master records with lathes, they could not put too much low-frequency sound on the records or the lathe would literally cut through the groove and destroy the record in the process of making it. While records could be played in noisy environments like parties or bars, they could not be played in cars or carried onto mass transit the way tapes and digital media can, eliminating two key situations where wide dynamic range would be a problem (note that radio stations have been

heavy users of audio compression since at least the 1930s, so this is not an issue with records played over the radio). Those and other practical limitations were eliminated in digital audio, and the result was that the possibility for a narrower dynamic range became much more important than the possibility of a broader dynamic range in most fields of recording, with a few notable exceptions like classical music, where dynamic range in recordings is still valued (and commented upon) by reviewers.¹⁹

Many audiophiles read this development tragically, since it appears that one potential of digital recording has been realised at the expense of another. This may be so. But it is a little more complicated than that. Bob Katz, who is well known among other mastering engineers for his published advocacy of audiophilic standards, makes an important qualification to his claim that the compact disc has become 'its own worst enemy': 'there are, of course, specific places where heavy [audio] compression is needed: background listening, parties, bar and jukebox playback, car stereos, headphone-wearing joggers, the loudspeakers at record stores, headphone auditioning at the record store kiosk, and so on [. . .] I dream of a perfect world where all the mp3 singles are heavily compressed and all the CD albums undamaged.'²⁰ The striking thing about Katz's list of listening environments is that they are far and away among the places where people are most likely to hear or listen to music (at least in industrialised societies). When we add other playback arrangements, like the speakers on computers, hold music on telephones, and programme music on televisions, Katz's list of environments where heavy audio compression is appropriate quickly outpaces a list of environments where recorded music should be heard with maximum dynamic range. In fact, beyond recording studios and living rooms, there are relatively few environments where people can hear the edges of a recording's definition. Distracted listening in non-ideal circumstances is the norm for music listening and has been for some time. It is very rare for people to sit quietly in a room and just listen to recorded music coming out of speakers.²¹

The history of sound reproduction in the twentieth century is not, as sales literature might suggest, a story of ever increasing fidelity, and it may very well also not be a history of audiences who really care about greater fidelity. Even the quite notable increases in sonic definition are really a side-story. Recording has both space- and time-binding characteristics.²² And the more remarkable story of sound reproduction in the last hundred years is a spatial story, about how recorded and transmitted sound became more portable and suffused an ever growing segment of people's everyday lives, both during hours of waking and during hours of sleep. The point to take here is simple: at the psychoacoustic level, as well as the industrial level, the mp3 is designed for easy exchange, easy storage and maximum portability. This has been a long-term goal in the design of sound reproduction technologies. If technologies had essential characters, the mp3 would be essentially promiscuous.

Audiophiles may consider digital audio – especially in its compressed form – as a giant step backward in a story of ever increasing sonic definition, but that story of progress never really quite happened. Every time the signal got clearer, artists, musicians and engineers sought out new methods of distortion.²³ And every time the bandwidth grew, engineers looked for new ways to make recorded or transmitted sound more mobile, more flexible and more ever present. The history of digital audio is only partly a story about the definition of sound. It is also a history of transmission. Indeed, current corporate

experiments with digital rights management are aimed precisely at making it more difficult for people to move digital recordings around.

To generalise about the nature of digital audio (as a whole) is a fraught enterprise in the best of conditions. But if we were to do so, we would have to up-end the hypothesis that digitisation kills audio bit by bit. Regardless of whether potential definition is increased or compromised in a particular form, digital audio is incredibly mobile and incredibly social. Where critics have found the chasm of death in the spaces between frames of a digital recording, they should have found vivacious life instead.

ACKNOWLEDGEMENTS

Many thanks to Carrie Rentschler, Jeremy Morris and Didier Delmas.

NOTES

1. J. D. Peters: *Speaking into the Air: A History of the Idea of Communication*, 1999, Chicago, IL, University of Chicago Press; Plato: 'Phaedrus', in *The Collected Dialogues of Plato*, (ed. E. Hamilton and H. Cairns), 475–525; 1961, Princeton, NJ, Princeton University Press; E. W. Rothenbuhler and J. D. Peters: 'Defining phonography: an experiment in theory', *Musical Quarterly*, 1997, **81**, 242–264.
2. C. Anderton: 'Beating the bootleggers: fan creativity, "lossless" audio trading, and commercial opportunities', in *Cybersounds: Essays on Virtual Music Cultures*, (ed. M. Ayers), 161–184, at 168–169; 2006, New York, NY, Peter Lang.
3. See the translators' introductions to F. Kittler: *Discourse Networks, 1800/1900*, (trans. M. Metteer and C. Cullens); 1985, Stanford, CA, Stanford University Press; F. Kittler: *Gramophone, Film, Typewriter*, (trans. G. Winthrop-Young and M. Wutz); 1999, Stanford, CA, Stanford University Press.
4. See K. Brandenburg: 'MP3 and AAC explained', Paper presented at the AES 17th International Conference on High Quality Audio Encoding, Florence, Italy, 1999; J. Shiga: 'Translations: artifacts from an actor-network perspective', *Artifact*, 2006, **1**, 19–34; J. Sterne: 'The MP3 as cultural artifact', *New Media and Society*, 2006, **8**, 853–870.
5. A. Evans: *Sound Ideas: Music, Machines and Experience*, 121–122; 2005, Minneapolis, MN, University of Minnesota Press.
6. M. Bull: 'Iconic designs: the Apple iPod', Paper presented at the Third International Workshop on Mobile Music Technology, University of Sussex, UK, March 2006.
7. M. Perlman: 'Consuming audio: an introduction to tweak theory', in *Music and Technoculture*, (ed. R. Lysloff and L. Gay), 346–357; 2003, Middletown, CT, Wesleyan University Press; E. W. Rothenbuhler and J. D. Peters: 'Defining phonography' (see Note 1).
8. J. Sterne: *The Audible Past: Cultural Origins of Sound Reproduction*, 215–286; 2003, Durham, NC, Duke University Press. See also J. Corbett: *Extended Play: Sounding Off from John Cage to Dr. Funkenstein*, 1994, Durham, NC, Duke University Press; J. Mowitt: 'The sound of music in the era of its electronic reproducibility', in *Music and Society: The Politics of Composition, Performance and Reception*, (ed. R. Leppert and S. McClary), 173–197; 1987, New York, NY, Cambridge University Press; E. W. Rothenbuhler and J. D. Peters: 'Defining phonography' (see Note 1).
9. A. Evans: *Sound Ideas*, p. 70 (see Note 5). Evans' analysis of digital audio is predicated on a rich description of the technology itself. While this is quite refreshing, I differ with his methodological premiss that one can make ontological claims from the workings of the equipment and software itself.
10. H. Bergson: *Creative Evolution*, (trans. A. Mitchell), 322; 1944, New York, NY, Modern Library.
11. G. Deleuze: *Cinema 1: The Movement Image*, (trans. H. Tomlinson and B. Habberjam), 2; 2001, New York, NY, Continuum.
12. Lev Manovich also covers this issue, pointing out that beyond a certain level, resolution doesn't matter, and neither does segmentation. See L. Manovich: *The Language of New Media*, 52–55; 2001, Cambridge, MA, MIT Press.

13. K. C. Pohlmann: *Principles of Digital Audio*, 5th edn, 50; 2005, New York, NY, McGraw-Hill.
14. M. Mathews: 'The auditory brain', in *Music, Cognition, and Computerized Sound: An Introduction to Psychoacoustics*, (ed. P. R. Cook), 11–20, at 16–17; 2001, Cambridge, MA, MIT Press.
15. Conceptions of sound fidelity and descriptions of sound recording as separating 'originals' and 'copies' have come under heavy criticism in recent years. For more on sound fidelity, see P. Auslander: *Liveness: Performance in a Mediatized Culture*, 61–111; 1999, New York, NY, Routledge; J. Lastra: *Sound Technology and American Cinema: Perception, Representation, Modernity*, 123–153; 2000, New York, NY, Columbia University Press; J. Sterne: *The Audible Past*, pp. 215–286 (see Note 8); A. Williams: 'Is sound recording like a language?', *Yale French Studies*, 1980, **60**, 51–66; A. J. Zak: *The Poetics of Rock: Cutting Tracks, Making Records*, 1–23; 2001, Berkeley, CA, University of California Press.
16. M. Chion: *Audio-Vision*, (trans. C. Gorbman), 98–99; 1994, New York, NY, Columbia University Press.
17. Anon.: 'The death of dynamic range', available online at www.mindspring.com/~mrichter/dynamics/dynamics.htm.
18. B. Katz: *Mastering Audio: The Art and the Science*, 187–188; 2002, New York, NY, Focal Press. Research on the effects of loudness goes back to Harvey Fletcher and Walter Munson's studies of loudness curves, which showed that the frequency sensitivity of hearing changed as the volume of a sound increased (the so-called 'Fletcher–Munson effect'). See H. Fletcher and W. A. Munson: 'Loudness of a complex tone, its definition, measurement and calculation', *Journal of the Acoustical Society of America*, 1933, **5**, 65; 'Loudness, its definition, measurement and calculation', *Journal of the Acoustical Society of America*, 1933, **5**, 82–108; 'Relation between loudness and masking', *Journal of the Acoustical Society of America*, 1937, **9**, 1–10. Aesthetic studies of loudness appear to have caught on in the 1960s. By the end of the 1970s, psychoacousticians were arguing that increases in loudness could lead to improvements in perceptions of fullness, space, nearness and brightness. Turning down the volume had the opposite effect. See A. Gabrielsson *et al.*: 'Perceived sound quality of reproductions with different frequency responses and sound levels', *Journal of the Acoustical Society of America*, 1990, **88**, 1359–1366; A. Gabrielsson and H. Sjogren: 'Perceived sound quality of sound-reproducing systems', *Journal of the Acoustical Society of America*, 1979, **65**, 1019–1033.
19. For an account of engineers discussing this phenomenon, see S. Jones: 'The big squeeze', *Mix*, 2005, **29**, 34–36, 38, 40.
20. For further discussion, see B. Katz: *Mastering Audio*, p. 18 (see Note 18); J. Sterne: 'What's digital in digital music?', in *Digital Media: Transformations in Human Communication*, (ed. P. Messaris and L. Humphreys), 95–109; 2006, New York, NY, Peter Lang.
21. Interestingly, scholars are much more likely to assert that this is the condition of musical listening than to actually demonstrate it in any systematic fashion. Ethnographies of music listening in everyday contexts illustrate this to be the case for their subjects, and new work in the psychology of music has also moved to a model that privileges distraction over attention. M. Bull: *Sounding Out the City: Personal Stereos and Everyday Life*; 2000, New York, NY, NYU Press; S. D. Crafts *et al.* (ed.): *My Music: Explorations of Music in Everyday Life*; 1993, Hanover, NH, Wesleyan University Press; T. Denora: *Music in Everyday Life*; 2000, New York, NY, Cambridge University Press; D. J. Hargreaves and A. North (ed.): *The Social Psychology of Music*; 1997, New York, NY, Oxford University Press; V. Konecni: 'Social interaction and musical preference', in *The Psychology of Music*, (ed. D. Deutsch), 479–516; 1982, New York, NY, Academic Press; J. A. Sloboda, S. A. O'Neill and A. Ivaldi: 'Functions of music in everyday life: an exploratory study using the experience sampling method', *Musicae Scientiae*, 2001, **1**, 9–32; R. S. Wolpert: 'Attention to key in a nondirected music listening task: musicians vs. nonmusicians', *Music Perception*, 2000, **18**, 225–230. How much this has changed from earlier periods, however, remains to be seen. While there is much anecdotal evidence for people sitting in their living rooms and listening to records or radio, there aren't good data to determine whether this was ever the dominant form of listening, since distracted listening is already a category in early radio research. See, e.g., T. Adorno: 'A social critique of radio music', in *Radiotext(e)*, (ed. N. Strauss), 272–279; 1993, New York, NY, Semiotext(e) (first published 1945); H. Cantril and G. Allport: *The Psychology of Radio*; 1935, New York, NY, Harper and Row.
22. H. Innis: *The Bias of Communication*; 1951, Toronto, University of Toronto Press.
23. J. Mowitt: 'The sound of music' (see Note 8); R. Poss: 'Distortion is truth', *Leonardo Music Journal*, 1998, **8**, 45–48; S. Waksman: 'California noise: tinkering with hardcore and heavy metal in Southern California', *Social Studies of Science*, 2004, **34**, 675–702.

Jonathan Sterne (jonathan.sterne@mcgill.ca, <http://sternetworks.org>) teaches in the Department of Art History and Communication Studies and the History and Philosophy of Science Program at McGill University. He is author of *The Audible Past: Cultural Origins of Sound Reproduction* (2003, Duke University Press) and numerous articles on media, technologies and the politics of culture. His next book is tentatively entitled *MP3: The Meaning of a Format*. He is also an editor of *Bad Subjects: Political Education for Everyday Life* (<http://bad.eserver.org>), one of the longest continuously running publications on the internet.
