International Journal of Communication 13(2019), 1846–1862 1932–8036/20190005

Jitter: Clocking as Audible Media

OWEN MARSHALL
University of California, Davis, USA

Clocks function as media objects in at least two ways. First, they create shared senses of temporality. Second, they facilitate technologically mediated auditory communication. When clocks fall out of sync with one another, the result is a type of noise that signal-processing engineers call *jitter*. Jitter is, in turn, managed through practices known as *clocking*. Drawing on technical engineering literature and an ethnography of Los Angeles-based recording professionals, I articulate a broader sociotechnical definition of jitter and clocking, which I use to analyze three sites of temporal negotiation in the recording process: (1) the organization of clock signals in the analog-to-digital conversion process; (2) the production of the studio as a heterochrony or "other time," distinct from the world outside the studio; and (3) the reconciliation of human and nonhuman temporalities, exemplified in the interaction between a drummer and a drum machine. I further consider jitter's conceptual affordances for media studies generally.

Keywords: sound, time, temporality, clocks, signal processing, audio engineering, recording, science and technology studies

Clocks and bells, two paradigmatic tools for timekeeping and sound communication, respectively, were at one point virtually synonymous technologies. Historians, philosophers, and media theorists have commented on the fact that the etymology of *clock* is derived from the Latin *clocce*—meaning bell—pointing to their intertwined genealogies (Illich, 2000; Pagani, 2001, p. 20; Peters, 2015, p. 226). The sounds of village bells, as Alain Corbin has shown in the case of 19th-century France, were important sources of temporal and emotional orientation. Long-distance sound communication and temporal standardization can thus be understood as deeply interdependent technological projects whose patterns of constructive and destructive interference need to be analyzed.

Modern digital techniques for producing and transmitting emotionally meaningful sound, such as those used in recording studio equipment and smartphone circuit boards, are similarly dependent on clocking practices. As nodes of temporal production, Corbin's elevated open-air bell towers are now vastly outnumbered by tiny crystal oscillators, soldered into circuit boards and sequestered into black boxes. Instead of sending wide-ranging airborne vibrations to mark events and territories, clocks now generally facilitate communication through square-wave pulses that drive signal processing equipment. Lone central clocks, which loudly ring changes and thereby sound out social spaces, have been displaced by complex

Owen Marshall: omarshall@ucdavis.edu
Date submitted: 2018–10–02

ecologies of clock circuit topologies that quietly mediate technological processes of electroacoustic exchange. The production of time as both an objective social fact and a personal affective experience is mediated through historically specific assemblages of materials and practices. This is true not just for our ability to discern simultaneity and order of events, but also for the ways our feelings of the unfolding "now" or the quality of duration are socially negotiated.

The naturalization and commodification of time have resulted in the embodiment of time as an object and timekeepers as commodities. Sociologist Norbert Elias has noted the modern tendency to treat socially situated time and temporal processes as objects, likening our understanding of clocks as material embodiments of objective time to the use of masks to personify abstract qualities or spirits (Elias, 1992, p. 42). Elias's analysis of temporal reification, or the treating of time as an object rather than a process, is an echo of Karl Marx's famous analysis of commodity fetishism. Marx argued that the value of a commodity is determined by the average, socially necessary labor time required to produce it, but that the process of mass production and exchange of commodities tend to mask the labor process itself. As commodities for keeping time, clocks obscure the temporal processes through which they are produced. In the recording studio, as in other sites of digital labor, clocks thus appear both as tools for time discipline and as objects of consumption, which are thought to add value to the recording process. It is this tension between clocks as standardized, infrastructural objects and as consumer–professional commodities that conditions the various practices of time management with which engineers engage.

Drawing on technical audio engineering literature and participant observation work in Los Angeles recording studios, this article analyzes the specific clock ecologies of modern recording studios. As tools for transmitting electrically encoded audio signals, studio clocks facilitate digital storage, translation, and the communication of commercially preferred sounds, typically the human voice, among other instruments. Studio clocks require skilled sensory attunement to be heard. It thus falls to the trained ears of engineers to recognize when and how things fall out of sync, and to negotiate the differences in timekeeping among the studio's various types of clocks (human and nonhuman, figurative and literal). I structure my analysis around three cases of *jitter*—a term of art in signal processing, referring to the noise produced when clock circuits disagree—which I socially extrapolate into instances when temporal modalities fall out of sync in the studio and require repair.

The first case concerns noise that arises from variations in digital-to-analog convertor clock signals. The second case focuses on the work that goes into making the studio temporally separate from the outside world and the ways that external temporalities can occasionally leak in. The final case involves tensions between a drummer and a drum machine, wherein human and machinic temporalities need to be reconciled. To emphasize the way that artifacts and practices come together in this work, I use the term *clocking* to refer to the general ways in which studio workers materially manage or repair jitter. In this framing, the question becomes how exactly clocking is collectively accomplished in sound production work and how that shapes the way things sound. Jitter and clocking, refashioned as terms for understanding the irruption and repair of noisy temporal disagreements, allow us to think about three important boundaries in modern media production: analog versus digital signals, the inside versus outside of the production process, and human labor versus mechanical activity.

Literature Review: Timescapes, Soundscapes, and Technicity

Sound and temporality have both been usefully analyzed in terms of "scapes." The "timescape" perspective approaches socially specific concatenations of temporal experience as qualitatively distinct frameworks, such that the specific timescapes of industrial production, for example, may be read against ecological or premodern modes of temporal experience (Adam, 1998). Emily Thompson (2002), meanwhile, writes about the particular "soundscape of modernity," which she aligns with the shift from sound understood as a spatially experienced phenomenon to one in which sound "becomes signal" through the rise of electroacoustic practices such as radio and electromagnetic recording. Critics of "scape" thinking, however, have suggested that such an approach risks reifying particular forms of life while neglecting the ways that they are historically and materially constituted (Helmreich, 2011; Ingold, 2011). Partially in response to these critiques, an alternative approach to time and sound research has taken up Gilbert Simondon's concept of "technicity" as a way of thinking ontogenetically about technical mediation: attending to the specific ways in which technical media practices come into being. Adrian Mackenzie (2001) applies this approach to the problem of time, analyzing two definitions of the "second" as a unit of temporal measurement. The technicity of time has similarly been analyzed in the specific context of video games such as Street Fighter (Ash, 2012), as well as the role of sound in casually immersive "timekiller" games such as Flappy Bird (Kassabian, 2015).

Among technical objects, the mobile telephone has emerged as a particularly important site of research into temporal and sonic mediation. Mobile phones, argues Michael Bull (2007), not only isolate users within "auditory bubbles" but also create a sense of discontinuous or "punctured time" (pp. 3, 68). The tendency of information and communication technologies to accelerate and deterritorialize labor processes, particularly those involved in the production and circulation of knowledge, has been analyzed under the rubrics of "iTime" (Agger, 2011) and "network time" (Hassan, 2003). As Judy Wajcman (2008) argues, however, it is important to understand the temporal implications of information and communication technologies not solely in terms of acceleration, but instead as a mutual shaping of timekeeping practices and technological systems. The integration of scape-level analyses with specific technical genealogies also has resonances with the work of critical geographers, who have considered the ways time and space are socially constructed through media, including sound (Harvey, 1980; Revill, 2016). A distinct but complementary perspective can be found in the work of experimental psychology. Researchers working on the problem of time perception have long sought to understand subjective experiences of time in terms of a hierarchy of "elementary temporal experiences," such as the ability to discern simultaneity or order of sense events (Pöppel, 1988). Whereas this literature seeks to quantify and characterize the thresholds between subjective and objective temporal experience, the timescape and technicity literature takes these thresholds to be social and historical products themselves in need of explanation.

The theme of temporality as a material–semiotic construction is similarly well trod in broader sociohistorical accounts of technoscientific life, such as those found in the areas of science and technology studies and its cognate field actor–network theory. Work in actor–network theory has aimed to trace how networks mediate all aspects of life, including time. Actor–network theory founder Bruno Latour (1987) suggests that "different times may be produced inside the networks built to mobilise, cumulate and recombine the world" (p. 228). In this view, instances of sociotechnical delegation between humans and

nonhumans appear as ways in which "time is folded" (Latour, 1992, p. 231). Related work in science and technology studies has described how multiple temporalities are woven together in scientific and engineering work. Ethnomethodologist Michael Lynch (1985) shows how work in a scientific laboratory proceeds in terms of projects and their constitutive local tasks, the proper sequencing of which is made accountable retrospectively over the course of a writing-up process. Rachel Prentice (2013, p. 196) shows how the cultivation of skilled practices such as those involved in surgical procedures form a "temporal joint" wherein past experiences shape future actions. The multiple histories and temporalities of scientists and how the materials they use intersect and combine have been shown in such works as *Beamtimes and Lifetimes* (Traweek, 1992) and *The Mangle of Practice: Time, Agency, and Science* (Pickering, 1993). Postcolonial scholar Dipesh Chakrabarty (2000) explores the ways multiple histories and temporalities can come together in a "time knot," a transliteration of a Bengali figure of speech. The time knot, for Chakrabarty, is a way of getting at the "plurality of the present" (p. 112) that characterizes the colonial encounter and its play of power-knowledge. In different ways, these articulations of knotted, folded, jointed, and multiplied forms of time express the qualitative mediations that sociotechnical systems entail. Historians and sociologists of science, meanwhile, have helped to culturally and historically situate the various ways that we conceptualize and keep time (Galison, 2003; Landes, 1983), as well as how practices of temporal ordering are deployed metaphorically (Lakoff & Johnson, 1980; Shapin, 1996).

Sociologist Susan Leigh Star (1999) points to the hidden-in-plain-sight quality of infrastructure as a reason for attending to its social significance. The standards, structures, and practices that support and configure everyday life are so taken for granted as to become imperceptible. For Star, this also includes the question "When is an infrastructure?" pointing to how systems of material and conceptual support are maintained over time (Jackson, 2016; Star, 1999). Similar themes have emerged in the area of experimental sound work. In the 1960s, American composer La Monte Young built much of his ongoing compositional practice around the observation that two sine waves of slightly differing frequencies will only reveal their difference over time. The degree to which things are in tune, then, is as much a temporal as it is a spatial question. Young explored this concept most famously through his Dream House installation in Manhattan, which for several years consisted of sustained tones in simple harmonic relation to the 60-cycle hum of the building's alternating current supply. Young's intervention into musical practice opens questions of how relationships of in-tuneness (taken both in its specifically musical meaning and also in its meaning of social attunement; Schütz, 1951) can be understood as infrastructurally rooted and temporally unfolding accomplishments.

The Field Sites: Studios A and B

Previous ethnographic accounts have demonstrated the importance of the recording studio as a site of social and material mediation. Antoine Hennion (2013) shows how the work of mediation between production and consumption characterizes the role of the record producer. Thomas Porcello (1998, 2004) shows how communication regarding particular sound qualities is accomplished through metaphorical negotiations among engineers and artists. Susan Schmidt Horning (2004, 2013) emphasizes the importance of unspoken or "tacit" knowledge in the work of the recording engineer. Louise Meintjes (2003) shows how perceptual differences in studio work are negotiated across cultural boundaries. In considering the interplay of time and sound, I draw primarily on an ethnographic study of two recording studios in Los Angeles

conducted during the latter half of 2013. I refer to these as Studios A and B. Both studios are in the middle range in terms of size and cost of service. This means that they are considerably better equipped than the home studios that have proliferated with the increasing availability of inexpensive computer-based recording technology. However, they are not as large or expensive as more famous studios such as Capitol, Henson, or Paramount, which draw financial and infrastructural support from large media conglomerates. Midrange studios have taken on increased importance in recent decades, as major labels have sought independent facilities for their projects and artists who started in home studios have sought more professional facilities. Hip-hop artist Kendrick Lamar, for example, recorded his acclaimed platinum-selling debut studio album *Good Kid, M.A.A.D. City* at four different studios. These included his mother's house; the suburban home studio of the owner of his label; an independently owned midrange studio in Atlanta; and Dr. Dre's No Excuse Studio, which is owned by Interscope, a subsidiary of Paramount Studios. Paramount itself is a subsidiary of the Universal Music Group, one of the current "Big Three" major labels, alongside Sony Music and Warner Music Group.

Both owners of Studios A and B have more than a decade of experience working as in-house and freelance engineers at a number of major label studios in and around Southern California prior to starting their own studios. Each serves as chief engineer and proprietor of their respective studios, while also employing assistant engineers, runners, interns, and project-specific guest engineers as needed. Studio A, whose owner and chief engineer I call Carl,[1] is the smaller of the two. Carl specializes in the genres of rock, pop, and hip-hop. Much of his studio's work involves bringing in projects that were begun or may continue to be worked on at other studios. Studio B, whose owner I call Harold, is larger both in terms of physical space, employees, and number of clients. In terms of genre, Studio B specializes in heavy metal, experimental, indie rock, and pop music. Studio B also occasionally hosts recording sessions for advertising music, which are usually helmed by nonresident engineers who simply want to make use of the equipment and recording space.

Having briefly sketched the ways Studios A and B are geographically, professionally, and practically situated, we can now consider the ways they are temporally constituted with respect to these situations. Using the dialectical categories of jitter, meaning noise that arises from temporal disagreement, and clocking, meaning the practice of managing these temporal disagreements, I analyze three moments of temporal negotiation in-studio. The first case involves the process of analog-to-digital/digital-to-analog (AD/DA) conversion, an essential part of audio signal processing work, and the moment when jitter, in its most narrow technical definition, is most likely to occur. Engineers have to learn to hear jitter in order to silence it, a paradoxical state of affairs that occasions debate within the profession itself. The second and third cases extend the jitter/clocking dichotomy to more clearly social moments of temporal disjuncture in studio work. The second case involves the production of the studio as an "other time" or heterochrony, differentiated from the mundane temporality of the outside world and internally differentiated through artifacts and practices that can seem to both transcend and crystallize particular forms of time.[2] The third

[1] All ethnographic subjects have been given pseudonyms, in accordance with this project's institutional review board approval.

[2] The effect of a homogeneous "mundane" external time is itself a product of this process.

case concerns disagreement between human and nonhuman temporalities in studio work, as illustrated by an encounter between a drummer and a drum machine as mediated by the session's engineer.

Digital-to-Analog Conversion

Visible timepieces are often hard to come by during a recording session, but the studio is, in fact, full of clocks. Clock circuits inside the AD/DA converters, electronic drum machines, and midi equipment keep their own time. Some clocks are more reliable than others, and they can drift apart if they are not coordinated regularly. Harold runs Studio B on a Grimm CC1, an expensive Dutch-made master clock, which is designed to have extremely precise and "clean" timing signals. He runs the Grimm's master signal to a variety of "slave" clocks that drive specific pieces of gear. For clocks to work properly, they have to be put into the proper hierarchy, or as engineer Lucille puts it, you have to identify "which one is the master and get everything else to understand that that's the master." In this way, the clock signal chain echoes the studio's own hierarchical structure. As a Nashville-based engineer puts it, for lower-ranked studio workers "the Engineer's word is gospel" (Hughes, 2003, p. 5). When clocks are not synced properly, signals tend to degrade. The imaginary mathematical perfection of the digital disappears when pieces of equipment malfunction or simply fail to get along with one another.

Resulting timing differences might be miniscule, but they tend to accumulate as they run in parallel. Discrepancies in clocking are especially problematic in processes of analog-to-digital or digital-to-analog conversion (ADC or DAC, respectively) in which the rates at which sounds are sampled or played back need to be closely matched for faithful transductions to occur across media. Discrepancies in clocking can produce jitter. Mastering engineers, who are tasked with producing extremely polished versions of stereo mixes before they are sent out for production and distribution, are particularly concerned with the potential effects of jitter. Grammy-winning mastering engineer Gavin Lurssen explains how he goes about keeping clocking problems from creating artifacts in his work:

> When we record it back to digital, we have a raw file. That file needs to be scoured for any little tics and clicks because, in today's world, most of what comes in needs cleaning up. Very rarely, if ever, does it happen here that we add tics and pops, because we pay such close attention to our clocking and all that. But in the mix environment, particularly in the new generations of people who are working with plug-ins and all that, all kinds of clocking issues can happen. (Crane, 2016, p. 9)

Engineer Ted Smith describes his experience of jitter (or lack thereof) as "touchy-feely": If people are tapping their toes, for instance, it has to do with all of the timing being perfectly lined up because jitter is not present (McGowan, 2014). In his book *Mastering Audio*, mastering engineer Bob Katz begins his discussion of jitter with the caveat that "in this topsy-turvy digital audio world, sometimes you have to abandon the evidence of your senses and learn a totally new sense, but one that is fortunately based on well-established physical principles" (Katz, 2007, p. 227). He describes the symptoms of jitter as "blurred, unfocused, harsh sound, reduced image stability, loss of depth, ambience, stereo image, soundstage, and space" (p. 227). Jed, an Oakland-based mix engineer, suggests that "jitter is kind of an onomatopoeia. . . . It can manifest in a number of ways."

Not everyone agrees that jitter is a real problem, however. To Carl's ears, Studio A works fine without a fancy master clock presiding over its signal chain. Ethan Winer (2014), a specialist in architectural sound treatments and self-styled crusader against "voodoo" techniques and beliefs in audio engineering, dismisses jitter and related temporal artifacts as being real but practically imperceptible because they occur below the threshold of audibility. Winer's debunking argument concerns the discrepancy between the decibel level of jitter-based noise and the decibel level at which humans have been shown to be able to reliably perceive differences between sounds. This claim is rooted in a particular epistemic ritual: the "ABX test." First employed by Bell Labs in the 1950s (Munson & Gardner, 1950), the ABX test presents a listener with two known sound sources; for instance, two different AD/DA converter circuits. It then randomly presents either *A* or *B* again (as *X*) and asks the listener to identify it. If the listener can correctly identify *X* at a rate higher than one might expect from random guessing, the difference between *A* and *B* is said to be "perceptible."

In a critical response to the ABX argument, engineer Allen Farmelo (2012) points to the temporally emergent quality of skilled perception. Although Winer may be correct to say that, when presented with a jittered and unjittered signal, most people, most of the time, would not be able to discern the difference, Farmelo notes the unspoken assumption "that because two things are close enough in a quick test that the difference will also be indistinguishable over long stretches of time" (Farmelo, 2012, p. 8). This assumption, he notes, ignores the way that,

> if given enough time, subtle differences will reveal themselves to us. Subconsciously at first, and eventually consciously, we become aware of new details, subtleties, nuances. We humans need time to truly come to perceive things in full detail. But details, once revealed, become important features in the big picture. (Farmelo, 2012, p. 13)

Jitter is not only a result of temporal references (e.g., clocks) falling into disagreement within a particular signal path. Jitter's social phenomenology—its very status as a thing one can actually hear—depends on the kinds of timeframes being considered. This is to say that temporal practices such as repeated listening help constitute the *acoustemology*, or sonic way of knowing specific to signal processing engineers (Feld, 2015).[3]

Jitter is an example of how the medium through which data is stored and transported leaves traces on the information itself. Time-based artifacts of audio storage are not unique to digital recording, however. Until the late 1990s, magnetic tape was the go-to medium for mainstream popular music production. Tape can be thought of as a "literal" spatialization of musical time (Weeks, 2002, p. 363). It is also an important element in what Jonathan Sterne (2012) calls sound technology's "compression history" whereby sonic recording and reproduction are not simply about accuracy of representation, but also of increased efficiency of storage and transmission. One of the reasons that tape is useful is that it can, for example, be wrapped around a reel and stored for years without fear of it being rendered obsolete by a software update. Compression, Sterne argues, always entails artifacts. One major artifact of magnetic tape, as Thomas Porcello (1998) elegantly describes in his ethnography of an Austin recording studio, is the "print through"

[3] To the extent that the engineer's acoustemology is mediated by technical practices, we might employ Greene and Porcello's (2010) variation on the term: *techoustemology*.

that occurs when magnetic interference causes sounds to leak across layers of the tape reel. The audible effect of print through is to have sounds appearing faintly several seconds before or after they actually appear on tape. Practices such as storing tape "tails out" help minimize the audibility of this sort of material boundary jumping. Jitter is not the only type of temporal bleed-through in digital audio, either. MP3 compression codecs, for example, are notorious for having "pre-echo" artifacts, in which one is occasionally able to hear echoes of sounds before they occur (Sterne, 2012). As a technique for data compression and transmission, AD/DA conversion is similarly at risk for temporal leakages.

In its narrow technical definition, clock jitter is a specific kind of noise that indexes a particular process: the conversion of analog sound pressure waves into digitally legible bits of sampled data. Although improved clocks and converters have made jitter less of a problem over time, there was still a learning curve early on for engineers to even be able to hear jitter. As musician and engineer Alan Parsons recounts, his first impression of early digital audio was that there was no noise at all:

> There's no sound of crackling and we don't think there's any distortion . . . there's something a little bit strange but we don't know what it is. The words dither[4] and jitter didn't exist then. (Baccigaluppi & Crane, 2004, para. 88)

As another engineer explains, in a review of an external master clock, that the limitations of digital clocking were indistinguishable early on from his own subjective demeanor:

> I used to think my ears needed to "settle" into my room whenever I'd first sit down at my console because things wouldn't sound as good as they would a half hour or so later, but . . . it's the DMX-R100 [digital mixing console]'s internal clock that's doing the settling as it's warming up. (Hong & Jasper, 2006, para. 10)

As another engineer explains his experience of jitter in terms of the rhythmic interference or "beating" of clocks within a circuit:

> The realities of the outside world are not perfect and that is what we need to deal with. Another thing to avoid is beating clocks within the same unit. The results of that can be really nasty. In our design everything is synchronous. Which is also the reason why we do not make a converter card for inside the computer—it is full of beating clocks. Some of the audible results of jitter are a flatter soundstage, a certain fuzziness in the top end and a less pronounced center—in other words, everything we have come to hate about digital audio. So the goal needs to be to attack it vigorously and make it as inaudible as possible. (Silverstein, 2006, para. 11)

The translation of digital and analog signals, mediated by clock circuits, thus becomes audible to trained ears over time. As the next section shows, similar problems arise at the boundary between the inside and the outside of the studio.

---

[4] Regarding the related phenomenon of *dither*, see the work of Melle Kromhout (2017).

Studios as Other Times

Particular elements of the studio shape the labor process in ways that can seem to accumulate the past or offer access to other temporalities. This is, again, well illustrated by the use of magnetic tape, as opposed to digital hard drives, as a recording medium. Digital recording is described as "nondestructive" because it is possible to undo a take or record multiple takes, putting off the final decision regarding which one is the "keeper" until later. When tracking to tape, the irreversibility of the process is emphasized, and time becomes destructive once again. Engineers such as Steve Albini or John Vanderslice, who work exclusively in analog tape, are sometimes criticized as being "stuck in the past" or fetishizing the sound of an obsolete format. Albini's rationale, however, is actually future-oriented: Magnetic tape and the machines that play it do not seem to degrade or go obsolete as rapidly as recording software tools and digital audio formats. Neither Studio A nor B uses tape primarily, although both reserve the option to bring in a tape machine in case it suits the client's needs. Often tape will only be brought in at the end of the mixing process. The entire finished mix may be printed to tape and then redigitized to lend a touch of "analog warmth." Tape is considered desirable not just because of its sound, but because of how it structures the session temporally. Tape requires a performer to "commit" to a take in a way that digital recording does not, because when you decide to reperform a take, you need to either record over the last one or employ a new track. For engineer Jed, it is the commitment demanded of tape that makes it a "beautiful" recording medium.

As with musicians, equipment can acquire experience and develop new habits with age. Often these take the form of bugs that become features. The Roland TR-808 drum machine sound, for example, was initially a commercial failure because it so poorly imitated the sound of an acoustic drum kit. Now it is that very distinctiveness—the way it separates itself from "real drums"—that makes the 808 a classic instrument. Engineers often speak about "legendary" pieces of equipment, which may be high maintenance and behave in ways that are not deterministically accountable. As Seattle-based engineer Randall Dunn puts it, "Opinions about gear are really beautiful superstitions" (Kostelnik, 2016, p. 28). These beautiful superstitions are often articulated in ways that position the piece of gear in a particular point in time or situate it outside time altogether. Gear might be valued on the basis of its sheer newness, its ability to capture a particular era, or its "timelessness." This quality of timelessness, in particular, needs to be understood as an implication of commodity fetishism in that it masks the labor that constitutes the gear through production and use. Temporal categories, such as era or decade, also serve to index particular sounds or feelings, which are in turn understood as important value-adding elements of the recording process. The affective or authoritative qualities of certain eras become sedimented into "retro" or "vintage" pieces of equipment, which need to be rigorously maintained to evoke the particular sound of a given era. Engineer Mick Guzauski, for example, describes his mix for Daft Punk's 2013 album *Random Access Memories* as being inspired by the "sound of late 70s disco, definitely keep[ing] 80s sounds out of it, and… us[ing] a modern approach at the same time" (Pensado, 2013, 14:19–14:29 [video]). For Guzauski, this meant the use of certain pieces of equipment and techniques from that era, as well as a general aesthetic orientation. Decades become useful shorthand and mnemonic devices for specific hard-to-articulate sensory and affective qualities. Studio A Engineer Bob, for example, says that whenever someone asks for a "warm" sound, he thinks of the 1990s, the last decade to see tape as a dominant recording format.

Recording studios are examples of what Michel Foucault terms "heterotopias," or spaces that contain multiple settings. Heterotopias function as "other spaces" to the extent that they facilitate the production of heterogeneous representations. Examples may include archives, theaters, or laboratories. Foucault further suggests that heterotopias are often also linked to specific temporalities, which he calls "heterochronies." These are constituted by an "absolute break" with time as traditionally experienced (Foucault, 1984, p. 6). Some heterochronies, such as those of libraries and museums, are engaged in the accumulation of time. Others, such as examinations, medical interventions, or festivals, are more temporally precarious, oriented not toward eternality and the overcoming of time, but rather a temporality defined by its fleeting quality (Foucault, 1984, p. 7). The studio straddles these chronological modes, being both a place where temporary performances are made to "endure" over time and also being a place that, for the client, is occupied for only a limited period of time.

The "absolute break" that defines Foucauldian heterochrony is only one of many temporal disjunctures that characterize studio life, however. Reconciling audio production's diverse modes of timekeeping, and the productive ways in which they conflict, means understanding them polyrhythmically and in terms of maintenance. Writing about the relationship among infrastructure, repair, and temporality, Steven Jackson (2016) argues that attending to breakdown highlights the "irreducible presence of embedded materialities with rhythms and propensities all their own, which can only ever be sometimes, and for a while, slowed, arrested, and aligned" (p. 173). Reading heterochrony in terms of repair adds nuance to the concept of a sphere of action marked by a break with conventional time. In place of a single disjuncture between the studio and the outside world, there instead appears a complex ecology of partial attachments and temporal tears both within the studio and between the studio and the world around it. The recording studio can thus be understood as inter- and intraheterochronous, a heterochrony both in an external and internal sense. It is externally heterochronous insofar as it constitutes a break with traditionally lived time, either in the mode of archival accumulation or festive precarity. It is internally heterochronous in the sense of containing multiple temporalities, shades of lived and "clocked" time, falling in and out of interference with one another.

Audio engineers are deeply familiar with the fact that clocks are material things and, for that reason, each clock marks time in its own unique way. This is captured neatly in what the "Audio Laws Committee" of the Audio Engineering Society terms "Golden's law": "A man with one watch knows what time it is. A man with two watches is never sure." Also known as Segall's law, the Audio Engineering Society attributes this saying to mastering engineer John Golden (Chinn, 2014). Golden's law playfully expresses the idea that, in the studio, there are as many "clock times" as there are clocks. This helps explain the studio practice[5] of limiting access to information about what time of day it is. As Studio A engineer Bob puts it, "The big thing about studios is you never put a clock in the studio 'cause then they don't know how long [it's been and] how much they owe you." In fact, Studio B does have a small digital clock on the console. Studio A, however, has no publicly visible clock at all. Most people in the studio carry timekeepers in their pockets in the form of smart phones, but this means that checking the time is largely a practice of individual investigation: You could not point to a clock, but you could glance at one in your hand. For an intern, at

[5] For an account of similar practices in casino management, see Schüll (2012, p. 203).

least, checking the time (especially in the form of glancing at your phone) is taken to be bad form, an indication of impatience and distractedness.

Gradually, studio occupants can learn to mark time in different, sometimes unusual ways. As Carl points out to me, even in his ostensibly clock-free studio, the rack-mounted Furman Power Center unit, which is tasked with compensating for fluctuations in the city's power grid, could be relied on to roughly mark the beginning and end of the normal workday with its voltage intake display. The number indicating available voltage falls or rises as nearby office buildings begin or end their business days, and the power supply compensates for these fluctuations. This carefully cultivated separation from conventional "banker's hours" gives studio time a sort of frictionless quality. As another Audio Engineering Society law, attributed to St. Louis-based engineer Joe Blasingame, puts it, "In the vacuum of the studio, time moves faster than anywhere else in the universe" (Chinn, 2014, para. 60). Electrical outlets, in this way, constitute small leaks in the temporal vacuum of the studio, nodes where the city's infrastructure pushes and pulls on the electroacoustic flows of a recording session. The shifting loads of a power grid can have more serious temporal effects than turning voltage read-outs into makeshift timekeepers, however. In a recent geopolitical example, political instabilities in the Balkan region led to a dip in the average frequency of AC electricity in continental Europe, causing many clocks to run six minutes slow (Nies & Camus, 2018). Engineers anticipate this sort of problem by employing crystal oscillators instead of using (as microwave ovens, clock radios, and other less-sensitive timekeepers do) the carrier frequency of AC electricity to drive their clocks. As we shall see, however, even crystal oscillators can cause problems in the world of digital audio recording, as small timing discrepancies tend to accumulate into audible forms of distortion.

Reconciling Human and Nonhuman Temporalities

Beyond the realm of analog-to-digital conversion jitter, similar forms of push and pull can arise around interactions between human and nonhuman timekeepers. Harold describes a case of this that took place during a session in Studio B:

> We had a drum machine going, and [the drummer] was playing [along] with the drum machine, so it was two tracks—drum machine and live drums. And his kicks were a little bit late, like, every once in a while. . . . And I was like "ok everybody just go on a lunch break, I'm gonna get everything kinda tightened up here kinda nice," and [the drummer] sat with me because he wanted to see what I was doing, and he's like "oh man that sucks, I'm off [time]." And you just try to make them feel comfortable. Like "dude that's a drum machine from the '80s those clocks are fucking out of control there's no way you'd ever play to it."

In this case, it fell to the engineer to negotiate hierarchies of timing, skill, and expressive authority among session participants (human and nonhuman alike) to make the process run smoothly. Harold's move to cast the drummer's playing in terms of temporal errors on the part of the drum machine offers an interesting counterexample to the "ideology of control" identified by David Noble (1978) in his account of the labor politics of numerically controlled machine tool development. Noble here refers to the tendency to conflate human activity with error, while defining correct functioning in entirely mechanical terms. By highlighting the drum

machine's material history (pointing it out as "a drum machine from the '80s") and describing its own clocks as "out of control," Harold plays with the ideology of control in the context of drum timing.

The role of the drummer in this particular recording session is also relevant to how time is kept. In this case, he is playing a supporting role to a well-known singer-songwriter, for whom the project is named. The songwriter, on previous releases, had performed most if not all of the instruments, often including the use of a drum machine. The drummer has been brought in to play along with the drum machine, a type of thing that, in the studio's temporal economy, usually has a stronger claim to mechanical objectivity than a human drummer would. The result of this arrangement is that the drummer is expected to both play well with the drum machine and, because he is not the featured artist in this project, to be modest in his own "human" contributions to the performance.

The drum machine from the '80s (more than likely an aforementioned TR-808) was itself chosen for this session not because newer drum machines with better clocks were not available, but because it brought a distinct sound, energy, or feel to the recording. The artist in this case had been using drum machines of this sort for many years, and although it might well have been a practical necessity at the start, it was now a part of his signature nostalgic and eccentric sound. The drummer was stuck, meanwhile, in an uncertain domain between human and mechanical repertoires of performative evaluation. Where conventional studio stage management practice called for Harold to send people off to lunch and fine-tune the drum timing behind the scenes or during "off time," the drummer's perplexing position in the ensemble compelled him to stay behind and attend to the editing of his own performance. With the drum tracks in front of him and the drummer anxiously looking over his shoulder, Harold had to finesse the prerecorded track as well as the drummer's self-presentation. Reading this episode as a case of jitter, we can say that the internal clocks of the drummer and the drum machine fell into disagreement, requiring the engineer to manage what was in effect a dispute as to how exactly the clocking relationship ought to be properly understood. It is the ambiguity of the clock hierarchy in this case that makes visible the otherwise invisible work of preserving temporal order between humans and instruments in the recording process.

Conclusion

Writing about the relation between time and control, Barbara Adam (2006) observes that time-reckoning and habituation to particular temporalities engender

> a sense of ownership and control. As such, time tracking produces not only knowledge that locates humans in the wider scheme of things but also results in useful know-how, that is, in-order-to knowledge for the maintenance and enhancement of power. (p. 121)

Jitter and clocking, as developed in this article, provide a way of specifying what is going on when temporalities fall out of agreement, what sorts of resistance temporal control may encounter, and what sorts of practices the "maintenance" of temporal control may entail. By using these two concepts to explicate the broader sociotechnical practices of recording and signal processing engineers, I have tried to explore how the concrete practices of signal production, storage, and circulation may help us imagine the temporality and audibility of media in new ways. The ways that engineers are required to deal with the processual

character of artifacts such as clock circuits, which seem to present themselves as technical black boxes, can illuminate the "when" of media infrastructures in terms of particular social practices. Attending to jitter as a sociotechnical relation, and clocking as a specific form of maintenance, makes emerging forms of power and value more intelligible to media theorists.

In the domain of surveillance, for example, we can consider the ways forensic science is turning to electrical network frequency fluctuations as a way to precisely locate digital audio recordings in space and time (Garg, Hajj-Ahmad, & Wu, 2013). In terms of value production, meanwhile, we can consider how the identification of new forms of noise (either as unintended signals or, revising Mary Douglas's definition of dirt, as "energy out of time"), suggests more efficient production processes and more specific forms of skilled labor to cultivate and exploit. In the studio, at least, the proliferation of increasingly precise clocks and instrumentally rationalized clocking practices seems, paradoxically, to have occasioned increasingly esoteric and aestheticized ways of actually hearing what sort of time is being kept. This is accountable, in part, in terms of the political economy of audio production. The effect of time-saving technologies, particularly those afforded by digital recording, has been to displace many of the standard skills of the audio engineer. New perceptual skills of the sort to which Bob Katz refers—hearing clock jitter, evoking eras with equipment, or bringing humans and nonhumans into sync—emerge largely in attempts to reconcile more traditional practices with new technologies, and to demonstrate the value of one's skilled labor in the face of increasing amateurization and automation. In this way, looking at jitter and clocking can contribute to a more nuanced understanding of how the relation "clock time" and embodied duration are refashioned as a domain of work is subject to the pressures of capital accumulation.

Zooming out from the specific temporal practices of the studio and focusing on broader industrial trends make this clearer still. On the one hand is a steadily contracting recording industry, which approaches the engineer as a source of productive labor that needs to be disciplined and rendered increasingly efficient (Beer, 2014; Olivarez-Giles, 2009). On the other hand is a growing recording technology industry, for which the engineer is a customer who needs to be enrolled in ever-accelerating cycles of consumption (Théberge, 1997). The engineer is required, in the meantime, to work ever faster, and to do so with an ever-diversifying ensemble of clocks. Focusing on speed or slowness alone, as Wajcman (2008) argues, fails to capture the variety of clocks that are caught up in processes of acceleration or deceleration. Clocking, then, has taken on an involutionary character, turning elaborately inward and cultivating, in miniature, new beautiful superstitions.

References

Adam, B. (1998). *Timescapes of modernity: The environment and invisible hazards*. London, UK: Routledge.

Adam, B. (2006). Time. *Theory, Culture & Society*, *23*(2–3), 119–126.

Agger, B. (2011). iTime: Labor and life in a smartphone era. *Time & Society*, *20*(1), 119–136.

Ash, J. (2012). Technology, technicity, and emerging practices of temporal sensitivity in videogames. *Environment and Planning A*, *44*, 187–203.

Baccigaluppi, J., & Crane, L. (2004). Alan Parsons: Life after Abbey Road and Pink Floyd. *Tape Op*. Retrieved from https://tapeop.com/interviews/btg/42/alan-parsons/

Beer, D. (2014). The precarious double life of the recording engineer. *Journal for Cultural Research*, *18*(3), 189–202.

Bull, M. (2007). *Sound moves: iPod culture and urban experience*. New York, NY: Routledge.

Chakrabarty, D. (2000). *Provincializing Europe: Postcolonial thought and historical difference*. Princeton, NJ: Princeton University Press.

Chinn, R. (2014). *Laws for audio engineers*. Retrieved from http://www.aes.org/sections/pnw/laws.htm

Crane, L. (2016, March). Gavin Lurssen: Mastering with a master. *Tape Op*, 94. Retrieved from http://tapeop.com/interviews/112/gavin-lurssen/

Elias, N. (1992). *Time: An essay*. Oxford, UK: Blackwell.

Farmelo, A. (2012). *The problem with A-B'ing and why Neil Young is right about sound quality.* Retrieved from http://tapeop.com/blog/2012/04/11/problem-bing-and-why-neil-young-right-about-sound-/

Feld, S. (2015). Acoustemology. In D. Novak & M. Sakakeeny (Eds.), *Keywords in sound* (pp. 12–21). Durham, NC: Duke University Press.

Foucault, M. (1984). Of other spaces: Utopias and heterotopias. *Architecture/Mouvement/Continuité*, (5), 46–49.

Galison, P. (2003). *Einstein's clocks, Poincaré's maps*. New York, NY: Norton.

Garg, R., Hajj-Ahmad, A., & Wu, M. (2013). *Geo-location estimation from electrical network frequency signals.* Retrieved from https://ece.umd.edu/~minwu/public_paper/Conf13/1305_ENFLocalize_icassp13.pdf

Greene, P. D., & Porcello, T. (Eds.). (2010). *Wired for sound: Engineering and technologies in sonic cultures*. Middletown, CT: Wesleyan University Press.

Harvey, D. (1980). Between space and time: Reflections on the geographical imagination. *Annals of the Association of American Geographers*, *80*(3), 418–434.

Hassan, R. (2003). Network time and the new knowledge epoch. *Time & Society*, *12*(2/3), 225–241.

Helmreich, S. (2011). Listening against soundscapes. *Anthropology News*, *51*(9), 10.

Hennion, A. (2013). An intermediary between production and consumption: The producer of popular music. *Science, Technology & Human Values*, *14*(4), 400–424.

Hong, A., & Jasper, M. (2006). Apogee Electronics: Big Ben master clock, DMS-1 M-clock, DMS-2 D-clock. *Tape Op*. Retrieved from https://tapeop.com/reviews/gear/51/big-ben-master-clock/

Horning, S. S. (2004). Engineering the performance: Recording engineers, tacit knowledge, and the art of controlling sound. *Social Studies of Science, 34*(5), 703–731.

Horning, S. S. (2013). *Chasing sound*. Baltimore, MD: Johns Hopkins University Press.

Hughes, S. A. (2003, November). What I wish I'd learned in school. *Mix*. Retrieved from https://www.mixonline.com/recording/what-i-wish-id-learned-school-366969

Illich, I. (2000). *The loudspeaker on the tower*. Bremen, Germany: Silja Samerski.

Ingold, T. (2011). *Being alive*. London, UK: Routledge.

Jackson, S. J. (2016). Speed, time, infrastructure: Temporalities of breakdown, maintenance, and repair. In J. Wajcman & N. Dodd (Eds.), *Sociology of speed* (pp. 169–186). Oxford, UK: Oxford University Press.

Kassabian, A. (2015). Sound and immersion in timekiller games. *Journal of Sonic Studies*, *10*, 1–7.

Katz, B. (2007). *Mastering audio: The art and the science* (2nd ed.). Waltham, MA: Focal Press.

Kostelnik, A. (2016, July). Randall Dunn: Supporting superstitions. *Tape Op*. Retrieved from http://tapeop.com/interviews/114/bonus-randall-dunn/

Kromhout, M. J. (2017). *Noise resonance*. Amsterdam, Netherlands: Amsterdam School for Cultural Analysis.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago, IL: University of Chicago Press.

Landes, D. S. (1983). *Revolution in time: Clocks and the making of the modern world*. Cambridge, MA: Harvard University Press.

Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Cambridge, MA: Harvard University Press.

Latour, B. (1992). Where are the missing masses? In W. E. Bijker & J. Law (Eds.), *Shaping technology* (pp. 225–258). Cambridge, MA: MIT Press.

Lynch, M. (1985). *Art and artifact in laboratory science: A study of shop work and shop talk in a research laboratory*. London, UK: Routledge & Kegan Paul.

Mackenzie, A. (2001). The technicity of time. *Time & Society*, *10*(2/3), 235–257.

McGowan, P. (2014). *Why jitter matters: Interview with Ted Smith.* Retrieved from https://www.youtube.com/watch?v=7FyKVZ9D3E0

Meintjes, L. (2003). *Sound of Africa!: Making music Zulu in a South African studio*. Durham, NC: Duke University Press.

Munson, W. A., & Gardner, M. B. (1950). Standardizing auditory tests. *The Journal of the Acoustical Society of America*, *22*(5). https://doi:10.1121/1.1917190

Nies, S., & Camus, C. (2018). *Continuing frequency deviation in the continental European power system originating in Serbia/Kosovo: Political solution urgently needed in addition to technical.* Retrieved from https://www.entsoe.eu/news/2018/03/06/press-release-continuing-frequency-deviation-in-the-continental-european-power-system-originating-in-serbia-kosovo-political-solution-urgently-needed-in-addition-to-technical/

Noble, D. F. (1978). Social choice in machine design: The case of automatically controlled machine tools, and a challenge for labor. *Politics & Society*, *8*(3–4), 313–347.

Olivarez-Giles, N. (2009, October 13). Recording studios are being left out of the mix. *Los Angeles Times*. Retrieved from http://articles.latimes.com/2009/oct/13/business/fi-smallbiz-studios13

Pagani, C. (2001). *Eastern magnificence and European ingenuity: Clocks of late imperial China*. Ann Arbor, MI: University of Michigan Press.

Pensado, D. (2013). *Mix engineer Mick Guzauski—Pensado's place #115*. Retrieved from https://www.youtube.com/watch?v=aKmvfgCILHg

Peters, J. D. (2015). *The marvelous clouds: Toward a philosophy of elemental media*. Chicago, IL: University of Chicago Press.

Pickering, A. (1993). The mangle of practice: Agency and emergence in the sociology of science. *The American Journal of Sociology*, *99*(3), 559–589.

Pöppel, E. (1988). Time perception. In J. A. Hobson (Ed.), *States of brain and mind: Readings from the* Encyclopedia of Neuroscience (pp. 124–125). New York, NY: Springer Science+Business Media.

Porcello, T. (1998). "Tails out": Social phenomenology and the ethnographic representation of technology in music-making. *Ethnomusicology*, *42*(3), 485–510.

Porcello, T. (2004). Speaking of sound: Language and the professionalization of sound-recording engineers. *Social Studies of Science*, *34*(5), 733–758.

Prentice, R. (2013). *Bodies in formation: An ethnography of anatomy and surgery education*. Durham, NC: Duke University Press.

Revill, G. (2016). How is space made in sound? Spatial mediation, critical phenomenology and the political agency of sound. *Progress in Human Geography*, *40*(2), 240–256.

Schüll, N. D. (2012). *Addiction by design: Machine gambling in Las Vegas*. Princeton, NJ: Princeton University Press.

Schütz, A. (1951). Making music together: A study in social relationship. *Social Research, 18*(1), 76–97.

Shapin, S. (1996). *The scientific revolution*. Chicago, IL: University of Chicago Press.

Silverstein, R. (2006). Lucas van der Mee: Behind the gear with Apogee Electronics. *Tape Op*. Retrieved from https://tapeop.com/interviews/btg/51/lucas-van-der-mee/

Star, S. L. (1999). The ethnography of infrastructure. *American Behavioral Scientist*, *43*(3), 377–391.

Sterne, J. (2012). *MP3: The meaning of a format*. Durham, NC: Duke University Press.

Théberge, P. (1997). *Any sound you can imagine: Making music/consuming technology*. Hanover, NH: University Press of New England.

Thompson, E. (2002). *The soundscape of modernity: Architectural acoustics and the culture of listening in America 1900–1933*. Cambridge, MA: MIT Press.

Traweek, S. (1992). *Beamtimes and lifetimes: The world of high energy physicists*. Cambridge, MA: Harvard University Press.

Wajcman, J. (2008). Life in the fast lane? Towards a sociology of technology and time. *The British Journal of Sociology*, *59*(1), 59–77.

Weeks, P. (2002). Performative error-correction in music: A problem for ethnomethodological description. *Human Studies*, *25*, 359–385.

Winer, E. (2014, June). Artifact audibility. *Mix*. Retrieved from http://www.mixonline.com/news/profiles/artifact-audibility/366521