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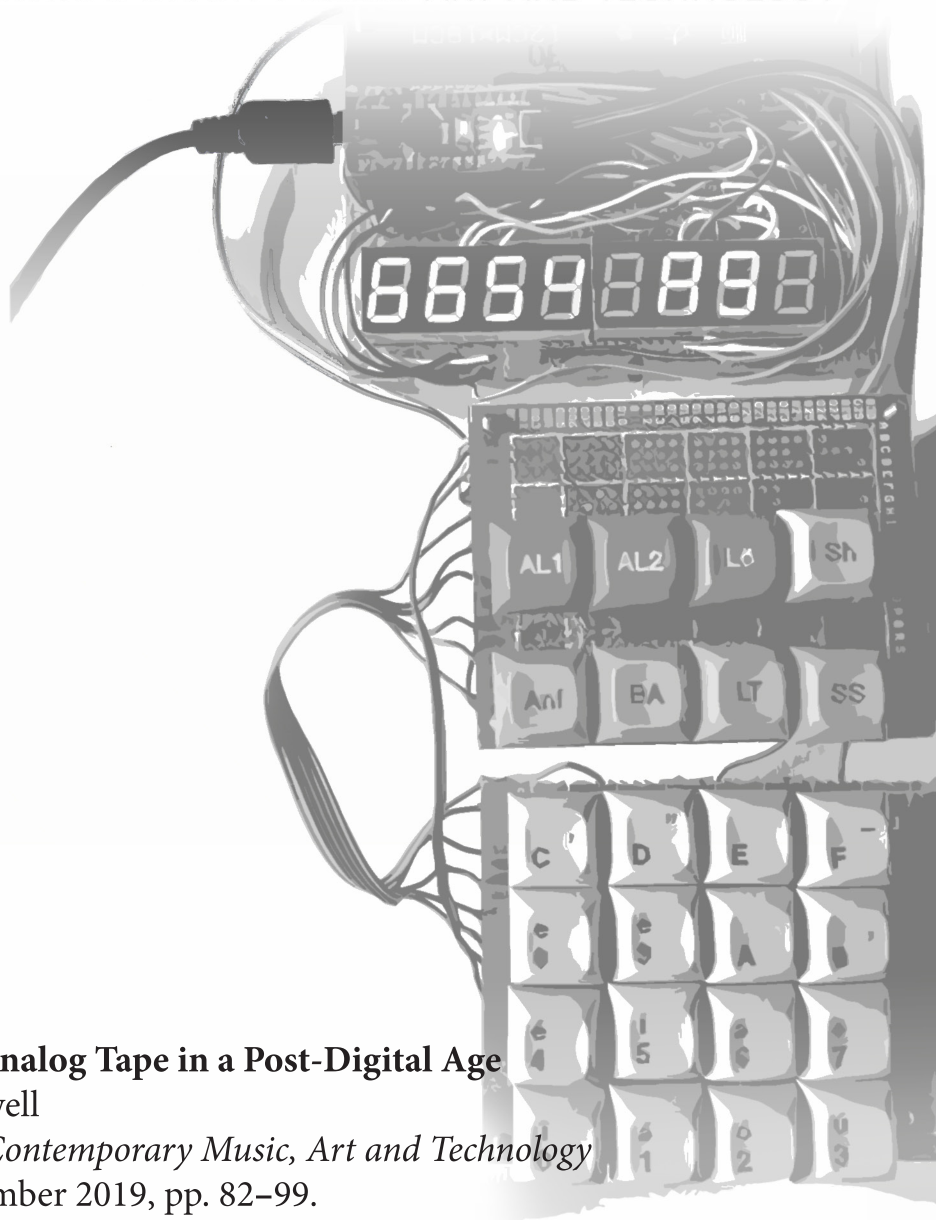

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COMPOSING WITH ANALOG TAPE IN A POST-DIGITAL AGE

Abstract: This essay explores the practical and theoretical dimensions of composing with analog tape in a post-digital age. Its point of departure is the belief that, instead of dismissing them as outmoded and impractical, we ought to embrace analog devices as invaluable tools for exploring the liminal realm in which encounters between concrete reality and abstract form take place. By working on sound as continuously varying electrical voltage as opposed to binary units of discrete value, a variety of compositional possibilities disclose themselves, particularly in relation to techniques of permutational variation. By reflecting on such techniques as implemented with analog rather than digital tools, crucial aesthetic insights emerge. The question of analog timbre is likewise explored, specifically in terms of aesthetic properties that testify to the unique physical origins of any given sound. Phenomenology as conceived and practiced by Husserl serves as a framework for these investigations. Its distinctive tools and methods enable exploration of the metaphysical dimensions of perceptual facts uncovered during encounters with analog and digital audio devices.

Keywords: analog and digital signal processing, permutational techniques of composition, timbre in electronic and electroacoustic music, the phenomenology of sound, musical temporality

Introduction

In the minds of musicians active in the middle of the last century, the phrase "composing with analog tape" would have resonated differently than it does today. At that moment, analog technologies for recording, playing back, and transforming

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sounds on tape had just laid the groundwork for new approaches to compositional technique and novel conceptualizations of musical form. Any invocation of tape would thus have struck a progressive note with such musicians, as to them it promised unprecedented control over sonic material in its "raw" form.

This is not to say that the *affordances* of tape were unprecedented, however. Phonograph cylinders anteceded tape by a half-century.[2] These devices, like their successors, gramophone discs, "captured" sound by inscribing traces of acoustic energy to a material medium via a stylus vibrated by a diaphragm. It was the advent of electron tube amplifiers in the 1910s that heralded the eclipse of such mechanical devices. Though initially adapted to stylus-based machines, electrical audio technology eventually became integrated with tape-based devices following the engineering of a reliable storage medium in the 1930s.[3]

Leaving aside the cultural significance of tape for society at large, its impact was epochal for music composition. It is consequent to experiments with tape by composers of the 1950s that electronic music as we now know it first came into its own.[4] The pivotal moment in this development entailed a shift from conceiving of audio technology as a way to fix sonic ephemera onto a durable medium to employing it as a compositional tool. Unprecedented, in other words, were not the technological affordances of tape per se, but the immediacy with which techniques leveraging their possibilities could be implemented.

Fast forward to today, however, and the once cutting-edge machinery of analog tape is the relic of a bygone era, typically resurrected only by musicians interested in its "retro" vibe. Meanwhile, for those to whom tape holds no particular appeal, digital audio devices promise the same affordances. Indeed, within a single digital audio workstation, compositional techniques first made possible by tape—or, rather, *digital analogues* thereof—are implementable with unparalleled immediacy.

We should pause at the seemingly self-evident appeal of such "immediacy", however. Even if a given compositional technique is more "immediately" implementable within a DAW than it is on tape, does that make the former inherently "better"? How should we value such immediacy? And what about techniques that may be implemented with comparable facility in the analog realm (e.g. retrograde, which can be achieved with the simple flip of a cassette on a four-track machine)?

Having raised such questions, conventional narratives of technological progress might seem to constrain the horizon of compositional possibilities afforded by tape. And yet, to composers of a phenomenological cast of mind, encounters with analog

2 For an overview of technological developments in audio recording antecedent to analog tape, cf. Clark 1999.

3 On the development of technology for embedding magnetizable particles in a plastic medium, cf. Fantel 1994.

4 The two most significant centers of tape composition in the mid-20th century were Paris, where worked Schaeffer's Groupe Recherches de Musique Concrète, and Cologne, where worked German composers at the studios of the Westdeutscher Rundfunk. On the GRMC, cf. Teruggi 2007, Schaeffer 2012. On the WDR, cf. Iverson 2019.

sound always promise the possibility of disclosing uncharted musical territory. The central question driving this essay, then, is this: What compositional possibilities are brought into existence by working with analog tape in our current musico-historical moment? More pointedly, given that tape-based audio technologies are scarce, the logistics of using them comparatively convoluted, and the effects they offer ostensibly achievable by more expedient means, why would one *choose* to?

Compositional Techniques

Before exploring the axiological dimensions of composing with analog tape, we must first consider more concrete issues: What compositional techniques are made possible by tape? Do they have predecessors in acoustic composition? What about their digital successors? How have they been applied historically? And how do such historical applications inform their current practitioners? In surveying the landscape opened up by these questions, certain properties and affordances of analog tape are salient. With heuristic intent, these are itemized and grouped into categories below:

I. Editing Techniques
   1. Looping
   2. Splicing

II. Configuration of Recording/Playback Mechanisms
   3. Multitracking
   4. Echo

III. Modulation of Recording/Playback Speed
   5. Diminution
   6. Augmentation
   7. Retrograde
   8. Perceptually Transformative Forms of [5], [6], & [7]

IV. The Timbre of Tape
   9. Analog Sound

I shall proceed through these sequentially.

[I] <u>Editing Techniques</u>

If by “editing” one means the arrangement of information in a temporally unconstrained—i.e. non-linear—way, then the ability to “edit” sound was effectively a new affordance of analog tape. “Effectively”, because editing techniques were rudimentary on mechanical audio devices. On the other hand, audio editing is founded on the ability to isolate sonic material in order to play it back *ad libitum*. Looping thus falls under its conceptual umbrella—a technique that, while practicable on tape-based media, by no means originated with them.

1. Looping

Indeed, at the moment tape became the tool of choice for composers of electronic music, looping was already achievable with other media. Its most immediate precedent application was on shellac records (i.e. Schaeffer's *sillon fermé* or "closed groove"). The looping mechanics of gramophone machines differ significantly from those of tape-based devices, however. The basis of the tape loop is a span of tape that may be recorded to and played back from continuously. Gramophone loops, by contrast, occur when a groove is locked into, resulting in a single revolution of pre-recorded sound being indefinitely repeated. With tape, therefore, looping is a much more flexible technique, as the constituent functions of "play", "record", and "erase" are more easily implemented.

To reiterate: The effect most readily achievable with looping is isolating then repeating a sound or series of sounds. This may be done to provide a structural foundation on which to elaborate other sounds. Yet even in such a basic form, looping is a fundamentally transformative compositional technique. By virtue of the very act of repetition, sounds transform their perceptual nature: "Repeat the same sound fragment twice: there is no longer event, but music" (Schaeffer 2012, 13).[5]

In addition to rendering repeatable a chosen durational span, looping with tape affords a variety of effects if multiple machines play back the same material at different speeds. Flanging, for example, is a type of phasing produced by playing back the same audio on two machines simultaneously while varying the time interval separating them. In Western "art music", such techniques were pioneered in the 1960s by American "minimalists" Steve Reich and Terry Riley.[6]

Today, looping is a cornerstone of much digitally native electronic music. Cut-and-paste looping in a DAW environment provides a straightforward way of generating both small- and large-scale repetitive structures. Nor was looping on tape historically unprecedented—many sound-generating devices of the pre-electronic era were designed to provide automated repetition (Levaux 2017).

What is distinctive about tape-based looping, then? Consider the crucial difference between analog and digital loops. By default, all digital loops are precisely the same. This is decidedly not the case for tape (nor, significantly, for sonic repetitions in a natural acoustic environment). In other words, if anything recommends tape for looping, it is its inherently variable nature, thanks to which each audition of a sonic

5 And yet, "mirroring of material form and perceptual content is actually quite rare when it comes to using tape loops. Rather, the divergence of these two attributes is more common" (Kane 2017, 67).
6 Notable tape works in this vein include Riley's *Music for the Gift* (1963) and Reich's *It's Gonna Rain* (1965) and *Come Out* (1966); electroacoustic ones include Reich's *Violin Phase* (1967) and *Piano Phase* (1967).

phenomenon through its material filter offers something genuinely new to the ear.

2. Splicing

Along with looping, the technique of splicing was fundamental to tape-based music as it developed historically. The enthusiasm with which composers initially embraced splicing is understandable, given the unprecedented nature of its affordances. Splicing, as a method of non-linear editing, requires a static—i.e. temporally non-unfurling—objectification of an audio signal. Prior to the invention of technological devices for capturing sound, musicians, in the production of acoustic vibrations, were bound to the unidirectional flow of time. Splicing thus had no real predecessor.

Early works that explore splicing to notable effect include Schaeffer and Henry's *Orphée* (1953), Stockhausen's *Gesang der Jünglinge* (1956), and Varèse's *Poème électronique* (1958). And yet, so essential was splicing to tape music that to single out individual works as exemplary is an inexhaustible task. Moreover, to do so obscures the substantively divergent motivations composers had for embracing this technique. For example, to composers working in the tradition of *musique concrète*, splicing could serve as the first step towards transforming a sound "effect" into a sound "object". According to this logic, by decoupling a sound from its source—i.e. by forestalling its perception as referring to a physical object or event—an avenue is opened up to hear it in a "reduced" manner, or "in itself".

At the same time, the montage aesthetic achievable by splicing tape appealed equally to composers who adopted the polar opposite mindset of serialism. Thanks to its non-linear nature, tape splicing allows for the construction of complex durational (not to mention harmonic) musical relationships unactualizable by human performers. In the 1950s, it thus appeared tailor-made for musicians who subscribed to parametric approaches to composition then being developed from the logic of dodecaphony.[7] Messiaen's *Timbres Durées* (1952) is a notable example in this vein. Early tape works by Boulez (e.g. Études I & II, 1951) also fit this profile.

Splicing would remain of interest to composers through the 1980s.[8] Notable examples include the music of the band Negativland and the "plunderphonics" of Oswald (1985). Moreover, though no longer achieved with tape, montage continues to be a focus of electronic musicians. In its current guise it is practiced as a form of granular synthesis. Originally theorized by Xenakis (1971), granular synthesis was pioneered as a computer music technique by Roads (1988) and first explored as a real-time process by Truax (1990). It proceeds by partitioning a given sound according to an algorithmic scheme, then reassembling the resulting fragments

7 German composers of the WDR were indeed quick to assert a continuity between the practices of their electronic music studio and compositional techniques crystallized in the music of Webern, *inter alia* (Iverson 2019, 26-27).

8 An effect analogous to that of splicing tape produced by fragmenting vinyl records and gluing their pieces back together was explored by Marclay in the 1970s (Rebick 2016).

according to variably determined compositional parameters.

And yet, granular synthesis differs in many ways from tape montage. For instance, often absent from the former is the precision characteristic of the latter, insofar as the processes of granular synthesis are automated and "randomized" at the level of the grain. Of course, a composer could construct a "random" sequence of tape splices—Cage's *Williams Mix* (1951) does just this. This technique is far less laborious if implemented digitally, however. By the same token, the precise arrangement of sounds characteristic of tape montage is much easier in a digital environment that does not require a physical mechanism for isolating and resequencing (let alone measuring) its constituent elements.

In reflecting on musical montage with analog tape, then, we find ourselves in a situation similar to that of looping. Apart from unpredictable—and thus uncontrollable—variations in the mechanical operation of tape devices, not much distinguishes them for this application. The fact that such variations are typically taken as undesirable artefacts of analog media, coupled with the ease of implementation afforded by digital tools, makes these latter now widely preferred for the splicing of sounds together.

[II] Configuration of Recording/Playback Mechanisms

Whereas the techniques of looping and splicing involve arranging sounds in a discrete, linear way, the following techniques involve combining sounds in a simultaneous, additive manner.

3. Multitrack Recording

Multitrack sound recording and playback is a basic affordance of every DAW. It has also been an affordance of tape since the 1960s. In principle, this affordance, whether recording multiple tracks simultaneously or mixing a newly recorded track with previously recorded ones, is identical in the digital and analog realms.[9] When considered apart from other affordances, then, multitracking on analog tape does not distinguish itself sufficiently from its digital counterpart to justify widespread preference for it.

9 That said, on tape machines a version of "sound-on-sound" recording—i.e. a technique pioneered by Les Paul who recorded sounds additively onto a single track with acetate discs—may be achieved by disengaging the erase head and pressing moving tape to which sounds have already been recorded into contact with a magnetizing head to which a different signal is being fed.

4. **Echo**

On tape, "echo" is produced by multiple electromagnetic heads positioned in linear succession—e.g. record, play, play. Such configurations mimic the "natural" echo caused by reverberations in a physical space. Delay time is determined by how far apart the heads are positioned and how fast the tape moves on the transport. By varying the delay time, one can produce a variety of effects, from close reverberation to distant reflections of longer intervals.

And yet, more is possible. Early in the history of audiotape, machines were designed to feed the delayed signal back into the recording path in order to produce various other effects. Consider the morphophone, first developed in 1953 by the Groupe de Recherches Musicales. This machine had 12 electromagnetic heads—one record, one erase, and ten playback. Discrete signals from each of the playback heads could be fed back into the system as well as individually filtered to provide spectral variations.

It is possible to implement echo effects by digital means. However, the distinctive flavor of analog tape echo—still very much in demand—is not digitally replicable. Once again, we run up against the fact that the precise "copies" of sounds afforded by digital means lack the unpredictable variations caused by the mechanical "imperfections" constitutive of analog technologies. While undesirable if one listens with an expectation of "absolute fidelity", this aspect of tape machines helps impart, among other things, analog "character". A chief example of such an "imperfection" is the variable operational speed of analog devices. Beyond the minute, "unintentional" variations characteristic of tape-based machines known collectively as "wow and flutter", such variability, when explored systematically, affords the ability to alter operational speeds to aesthetic effect.

[III] Modulation of Recording/Playback Speed

Modulating the recording and/or playback speed of a tape machine alters not only the duration of the sounds it transduces but also their frequencies. This is because, although it presents itself to consciousness as an atemporal perceptual unity, what musicians call "pitch" is in fact dependent on durational cycles. Consequently, as is the case with all analog devices operating with linear transport velocity and equipped with stationary mechanisms for transducing signals, any change in transport speed will proportionally alter both the tempo *and* the pitch of the sounds transduced. This affordance of tape has myriad musical applications. Collectively, they may be grouped under the umbrella of permutational techniques of composition.

Permutational techniques of composition seek to preserve some or all of the ratios and proportions inherent in the durations and frequencies (or, relationally, the rhythms and harmonies) of musical sounds. They have been of intense albeit sporadic interest to composers of a certain cast of mind throughout the history of Western music. Composers of the 14th and 15th centuries, for instance, often dissociate the musico-perceptual phenomena of pitch and duration in order to subject them to parallel processes of periodic repetition—a technique known as "isorhythm". Composers of the late 15th and early 16th centuries took this logic one step further, subjecting a motive or melody to more elaborate techniques of transformation—specifically, augmentation, diminution, retrograde, and inversion.[10] Northern European composers of keyboard music of the 17th and 18th centuries (e.g. Sweelinck, Froberger, and Bach) upheld this compositional tradition in such genres as the ricercar, fantasia, and fugue. Finally, 20th-century twelve-tone musicians resurrected these techniques with much enthusiasm though variable awareness of the work of their forebears.[11]

5. **Diminution**
6. **Augmentation**

To recap: Augmentation and diminution can be construed as transformations effectuated on ratios and proportions obtaining between frequencies and durations inherent in sounds. Construed in this way, these terms encompass not only their historically salient namesake techniques that expand or compress durational relationships by a discrete factor while preserving pitch, but also those that continuously transform durational relationships independently of pitch (known as *accelerandi* and *decelerandi*), as well as those that transform pitch while preserving durational relationships (known as transpositions). Transposition, in other words, is simply augmentation or diminution effectuated in the frequency domain, whereas *accelerandi* and *decelerandi* are augmentations and diminutions effectuated in the time domain.

To achieve something of these effects with tape, Schaeffer developed two mechanical devices that enabled the systematic alteration of playback speed: the chromatic and sliding phonogènes (1953). Again, the caveat with analog devices is that any change in either the time or frequency domain necessarily entails a change in the other. Because the chromatic and sliding phonogènes worked by means of linear transport mechanisms and stationary playback heads, they could not produce true *accelerandi* and *decelerandi*, nor transpositions in the traditional manner. To comprehend this aspect of analog devices, compare the equivalent methods of augmentation and diminution in the digital domain, known as "time-stretching" and "pitch-scaling". To be able to operate within the time and frequency domains independently, one must separate pitch from duration. Digitally, this typically involves "decomposing" a sound waveform by means of Fourier transformation. Digital signal processing is in this respect aligned with traditional compositional practice. Just as digital techniques of speed-based transformation may be applied within the time and frequency domains

10 On the fundamentality of such techniques to Medieval compositional tradition, cf. Hallowell 2013.
11 On this congruence of Modernist and Medieval compositional approaches, cf. Hallowell 2015.

independently, so too can a melody be transposed, or its elemental durations altered independently of pitch, when conceived of as an eidetic entity in the mind of the composer. This is because such operations, whether mental or digital, occur *outside* of "real time"—i.e. they are mathematical operations. They thus run contrary to the physical reality of sound.

7. Retrograde

Speaking of, another technique of permutational transformation afforded by analog tape is playing a sound "backwards"—i.e. in retrograde. Also achievable with digital tools, retrograde gives an acoustically impossible result. That is to say, in physical reality, one cannot reverse the passage of time, unidirectionally as it flows. And yet, although time's arrow is not preserved in a retrograde transformation, what is preserved are sequential relationships of sonic events. This is important, especially to musicians who cultivate form as emergent from eidetic variations of motivic entities.

It is instructive to compare retrograde with another permutational technique of transformation—inversion. While not easily implemented on tape (nor, for that matter, by digital means), inversion preserves the frequency ratios obtaining between successive pitched sounds while altering their directionality in a metaphorical "pitch space". In this way, inversion is similar to retrograde. To implement the former, however, discrete frequencies must be transformed independently of their durations. To do this, they must first be modeled mathematically.

Or must they? Inversion, like all permutational techniques requiring independent control over the time and frequency domains, is in fact achievable with analog tape. Overcoming the obstacle of the physical bond of pitch and duration, however, requires a tape machine equipped with rotating electromagnetic heads. Rotating head mechanisms—the foundation of, among other devices, the video cassette recorder—operate as follows: As the tape is moved in linear fashion by a transport mechanism, an electromagnetic head or series of heads mounted to a rotating cylinder (known as a "drum") scans the signal at a single point periodically. If its rotation is contrary to the motion of the tape, then the pitch will be shifted "up", as the relative playback speed that obtains between the moving components is increased. If it rotates *in* the direction of the tape, then relative speed is decreased, and the sounds are pitch-shifted "down". Finally, if the rate at which the capstan moves is precisely coordinated with that of the rotating heads, "time-stretching"—an effect in which pitch is preserved while duration is altered—may be achieved.[12]

However similar in effect, it is important to distinguish the manner in which

12 In 1963, Schaeffer's Groupe de Recherches Musicales constructed a machine called the universal phonogène that was capable of producing such transformations. For accounts of the engineering behind such technology as it pertains to audiotape, cf. Carlos 2008 and Marlens 1966. On its applications in the realm of videotape, cf. Remley 1999.

such analog machines operate from the logic of digital methods for pitch-shifting and time-stretching. Whereas the latter accomplish their task algorithmically, operating on 1s and 0s that only *represent* sound, the former operate *directly* on physical traces of acoustic energy. This means tape-based systems elaborate a *new* signal in parallel to the original, one constructed from infinitesimal durational spans of the latter played back in rapid succession so as to give the aural impression of a unitary sound.[13]

Technical issues such as these get at the heart of why one might choose to use analog tape when digital tools are readily available. To foreshadow the direction in which we are heading: Analog tape serves the composer as a sort of *memento temporis* or continuous reminder of the true nature of sound as it discloses itself to us perceptually. In so doing, it also reminds us of the fact that our perceptual categories for sound are not isomorphic with its ontological properties.

8. **Perceptually Transformative Forms of [5], [6], & [7]**

This category distinguishes itself from the preceding ones in that, at their extremes, speed-based transformations alter not only the material properties of sonic phenomena but also their perceptual character. Consider a speed change so extreme that discrete, periodically repeating pulses morph into a unitary frequency (in other words, that a steady pulse becomes a pitch). Such an effect has been put to great compositional use by many electronic musicians—a notable example occurs in Schaeffer's *Strette* (1978).[14] Beyond such usefulness, this kind of transformation serves as an object lesson in how phenomenological questions are never just materialist ones but always also, and *a priori*, idealist in nature. More pointedly, it reveals how the perceptual dimension of a phenomenon encompasses and constitutes its material one *transcendentally*.

[IV] The Timbre of Tape

What is meant by this phrase? It depends on what one understands by "timbre". At this point, let us observe that if there is a "timbre" characteristic of analog tape—which is traditionally construed as a *medium* for the transmission of sound and not a sound-making device *per se*—then it resides in the particular sound that tape transmits "through itself".

13 This raises an interesting question concerning the relationship between the ontological and perceptual dimensions of a given sound, and how these play into determining its essence phenomenologically. For now, it must suffice simply to acknowledge this tangent in passing.

14 Schaeffer elsewhere acknowledged the aesthetic potential of such "phase transitions": "I have obtained some quite remarkable transformations by playing a fragment recorded at 78 RPM at 33 RPM. […] With this apparently quantitative change there is also a qualitative phenomenon" (Schaeffer 2012, 14-5).

9. Analog Sound

Unlike digital sound, with analog tape, input is not the same as output. In more technical terms, tape exhibits a non-linear frequency response. Tape signals thus require appropriate equalization on outward transduction in order to be heard as "aesthetically acceptable" when played back over loudspeakers. The challenge is that, along with its characteristically non-linear frequency response, tape generates and accumulates noise. Such noise was widely considered in the heyday of analog tape to be a disadvantage of the medium, and much engineering energy was devoted to improving its signal-to-noise ratio. Unavoidable, however, is the degradation of analog signals recorded to tape, especially through iterative copying.

And yet, in a post-digital world, noise and non-linear frequency response may be construed as the "timbral signatures" of tape. Take, for example, the case of distortion. Signal distortion on analog tape takes the form of saturation, which, according to the logic sketched out above, leads to genuine timbral transformations by introducing new frequencies not predictably contained in the original signal. This is distinct from digital forms of distortion such as bit-crushing, which turn continuous waveforms into sawtooth ones by reducing the sample rate. Accordingly, distortion achieved via tape saturation gives a characteristically "fuzzy" sound, which is subjectively less "harsh" than its digital counterpart (this is also related to what is often called analog "warmth").

Apart from this subjectivist reasoning, it is worth noting that noise in the physical world is of the same quality as it is on magnetic tape—that is, it is inherently random. Unlike digital noise, which, since it is trackable in a mathematically precise manner, can be reverse engineered and eliminated, analog noise cannot be removed—again, because it is random. Another way to conceptualize this point is that analog signals are indices of "real world" sounds and, by that virtue, preserve traces of "real" acoustic energy. Digital signals, by contrast, merely represent such sounds according to pre-determined mathematical schemata. This leads us to the question: Why might a composer seek to preserve randomness and indexicality?

Aesthetic Insights

Before addressing this question, we must clarify its terms. "Randomness" may be construed as an irreducibly complex state that cannot be predictively modeled mathematically. "Indexicality", meanwhile, denotes the phenomenal quality of possessing a determinate link to physical reality.[15]

To formulate a provisional answer to our question, then: Analog devices convey the authenticity of sounds *qua* temporally constituted phenomena by preserving

15 Thanks to its indexicality, tape, along with other forms of analog media, holds "the potential to suggest a physical, non-symbolic layer of meaning" (Kramer 2017, 57).

their irreducible complexity and maintaining an indexical link to physical reality. This raises a further question, however: What do authenticity and reality mean in this context? We will explore this question from complementary perspectives correlating to the themes of sections [III] and [IV].

Timbre

Timbre is traditionally defined as tone "color" or "quality". It has been identified with the harmonic spectra of sounds (i.e. the frequencies of their partials) and/or their "attack, decay, sustain, release" (ADSR) envelopes.

And yet, timbre is inherently unquantifiable. Or is it? Consider the enterprise of additive synthesis, according to which timbre (or what is postulated as such) is engineered "from the ground up" with a finite number of sine waves. The logic underlying this approach rests on Fourier theory, which holds that a sound consists ultimately of a fundamental frequency accompanied by an exhaustively specifiable set of overtones. As those who practice additive synthesis would have it, by adjusting the partials of such frequencies and sculpting their ADSR envelopes, a "complex sound" is brought into being.

Or is it? To reiterate: According to this way of thinking, all sounds are "made up of" pure sine waves exhaustively specifiable via mathematical analysis. However, analysis is limited, quite literally, to yielding analytic truths. In other words, while one might set out to "decompose" a waveform into "elemental" components, the act of decomposing *essentially alters* the signal decomposed.

To illustrate this fact, let us consider digital signal processing in greater detail. DSP is a two-step process—discretization and quantization.[16] Quantization involves assigning whole number values to a continuously varying (i.e. analog) input. DSP quantization is therefore a specific application of the general mathematical technique of quantization, which entails mapping a potentially infinite set of continuously varying values to a set that is necessarily finite. The process by which these values are then converted to binary code is called "pulse code modulation". Once an audio signal, formerly analog, is converted via PCM, it can be operated on like any other kind of digital data. It can also be copied without a loss in quality through successive generations.

To render this type of signal back into the physical world, a digital-to-analog converter is needed. In theory, it is possible to "exactly" reconstruct an analog signal in this way. In practice, however, it is not possible. Specifically, it is not possible because it is impossible to sample (i.e. discretize and quantize) at an infinite sample rate. What is more, the slower the sample rate, the more "digital distortion" is introduced. This fact underlies the Nyquist theorem, which states that to "faithfully" render an audio signal, a sample rate of at least double its highest (i.e. fastest) component

16 For a summary of these principles, cf. Watkinson 1999.

frequency is needed (sampling at rates slower than this leads to "aliasing", or the *predictable* production of frequencies not present in the original signal).

To review: Although timbre *qua* sonic parameter is often invoked to analyze music of purely digital origins, it is not obvious how we ought to construe it in such a context. More to the point, unless the phenomenon of timbre is to be identified entirely with any of those quantifiable parameters cited above, what gives rise to its perception can only be those aspects of a sound that convey its characteristically singular origins in an irreducibly complex manner. Another way of construing this point is that it is the physical irregularities collectively conveyed through the aforementioned parameters that make a particular sound *sound* like itself.

Let us rephrase this point from the perspective of the distinction between genuine randomness and "pseudo-randomness". Strictly speaking, true randomness could only ever be a *naturally occurring* phenomenon.[17] Digital "random number generators", by contrast, give seemingly "random" values that are in fact determined in advance by an algorithm governing the mathematical processes that produce them. Granted, *subjectively* one may find no distinction. More specifically, one might not be able to tell the difference between digitally generated noise and noise in the real world, discerning equally in both cases an absence of periodicity, structure, or intentionality. However, this does not resolve the phenomenological question of how the ability to discern such a distinction maps onto one's knowledge that it exists.

Based on the preceding investigations, we can categorically assert that analog audio devices materially preserve, and thus authentically transmit, timbre.[18] This is bound to ring paradoxical, given how digital devices are held to be superior according to conventional logics of audio "fidelity". And yet, it is not a question of fidelity construed as quantifiable according to some metric but rather of authentically preserving the material substrate of sound *per se*. DSP devices, by contrast, can only ever operate *around* the phenomenon of timbre. To put a finer point on it, there is no such thing as digital timbre. In fact, when applied in the extreme, DSP transformations obscure timbre through their iterative operations on audio signals *qua* quantized representations, which inevitably move the sounds thus encoded away from the realm of timbre *stricto sensu*.

All this may seem fine in theory. Translated to the practical realm of music, however, things get murkier. One might counter that a sound source is not always—indeed routinely is not—securely identifiable as such, whether in a musical context or not. Moreover, one could forestall the entire debate by questioning whether preservation of the source material in such a manner is an aesthetic desideratum in the first place.

17 "Hidden variable theories" deny that reality on the quantum scale is inherently random. There are also those who claim randomness is not an ontological trait of reality but rather one we thinking beings impose upon it. Whether such arguments hold water depends on one's conception of the mind-world relationship.

18 Schaeffer formulates this point in a different way: "It is incredible how much a metronome can lack a sense of rhythm!" (Schaeffer 2012, 6).

That the sources of sounds be unrecognizable is, of course, a stated goal of Schaeffer's earliest conception of musique concrète (Schaeffer 2012, 6-7; cf. Teruggi 2007, 214). This conception served in turn as the basis for a critique of musique concrète mounted by early composers of *elektronische Musik* interested in distinguishing their own enterprise. Their critique centers on the question of whether a sound can ever be truly decoupled perceptually from its source. Coming from the world of radio drama, Schaeffer's first sonic materials were sound effects comprising an institutional audio library. By contrast, German composers were of a "high Modernist" mindset. This meant they considered the audio technologies at their studios as a means to fulfill the serialist ideals forged by Schoenberg and Webern—as far more, in other words, than mere tools for the arrangement of "sound effects".

We have wandered far from our discussion of analytic versus synthetic conceptions of timbre. And yet, perhaps we have not. For one could interpret the divergent approaches of mid-century French and German practitioners of electronic music in terms of opposing philosophies of composition—one proceeding from sonic reality by working on "concrete" sounds adapted from the "real world", the other from preconceived notions of sonic phenomena as represented in a symbolic system (i.e. serialism).[19] However theoretical, such distinctions between mediums of and operations on sound that hew to its authentic origins, and those proceeding from representations of sound through non-sonic logics, are at the core of our experience of analog timbre in a post-digital landscape, and thus merit the most serious reflection.

Time

To recall a takeaway from earlier: In operating on *representations* of sonic phenomena rather than on the phenomena themselves, digital technologies, like traditional compositional techniques, can perpetuate a misguided notion that the time and frequency domains are ontologically independent. Though they present themselves *epistemologically* as distinct, this is, ontologically speaking, not so. The most efficient way to reveal this fact musically involves the employment of permutational techniques of composition. Such techniques are crucial—indeed indispensable—to extracting this aesthetic insight from within the materiality of analog tape.

As a framework to evaluate such techniques as implemented with analog tape, phenomenology as conceived and practiced by Husserl is apt for two reasons. First, as Husserl was interested in time and its role in the constitution of objects of perception, phenomenology allows one to explore the metaphysical consequences of the

19 Schaeffer intentionally avoided such preconceived notions of musical form and compositional technique, opting for an "inverse path to reach music […] from sound data instead of notation" (quoted in Gayou 2007, 203).

affordances of analog and digital audio devices. Second, insofar as phenomenology is founded on the imaginative exploration of phenomenal essence—a process that Husserl terms "eidetic variation"—it offers an opportunity to synthesize insights drawn from analog and digital technologies as they pertain to musical phenomena.

To put ourselves in a phenomenological situation, consider what happens when we hear a steady beat. We might feel compelled to count such beats. Consider, however, what might happen if the steady beat morphed into a unitary pitch. We typically feel compelled to count nothing in particular when we hear a pitch, though, if our perceptual apparatus were attuned to its scale, we could count the regular oscillations of the soundwave producing it, just as we would count a metronome click. Of course, we *could* count along to the passage of time *ad libitum* while listening to a pitch, or any other sound for that matter. Regardless, the point is that time does not appear as immanent to the phenomenon itself. Pitch thus discloses itself as a *durationless* phenomenon.

Following Husserl, we can say that just because we "know" that pitch is dependent on duration, it does not follow that our perception of it as durationless is "wrong". Rather, the fact that pitch and pulse, or frequency and duration, appear to us as distinct entities ought to be taken as the point of departure for reflection on how they are constituted in and by sound *qua* temporal phenomenon. In other words, such self-evident distinctness to our perceptual apparatus ought not to be dismissed as mere error brought about by the inadequacy of our senses but rather embraced as a foothold to be leveraged for critical reflection. To quote Husserl (1991):

> What we accept […] is not the existence of a world time, the existence of a physical duration, and the like, but appearing time, appearing duration, as appearing. These are absolute data that it would be meaningless to doubt. […] That the consciousness of a tonal process, of a melody I am now hearing, exhibits a succession is something for which I have evidence that renders meaningless every doubt and denial (5).

Similarly: "Every consciousness of continuity is the consciousness of a unity" (249). Or also:

> The object [of consciousness] is not the extension but what is extended. […] [W]e can then always make the extension itself into an object, divide it, and distinguish its parts. The continuity of […] moments, as continuity, is penetrated throughout by the unity of something identical (249).

To work with analog tape devices thus debunks the myth that the time and frequency domains are ontologically independent. In fact, both are fundamentally bound up with the unidirectional flow of time, despite routine operation within these categories on perceptually distinct phenomena by present-day musicians equipped with digital tools. By transforming sounds through recording- and playback-speed modulation on analog devices, then, one discloses the temporal essence of musical phenomena through the authentic preservation of "real time" as *lived duration*.[20]

Conclusion

Let us return to the conventional wisdom that sparked the generative question of this essay. It may be summed up as follows: Any compositional technique that one might wish to achieve with analog tape can be approximately accomplished digitally, and more readily at that. Next, the question: In light of this fact, how should we value tape-based audio devices? That is to say, why compose now with analog tape?

As should be clear, it is the position of this essay that the compositional affordances of analog tape ought not to be evaluated simply in terms of how expedient it is to work with. Rather, they should be considered in light of the *values* one puts into practice as a musician and composer. That value exists in composing with analog tape is clear if and only if, prior to embarking on the compositional process, one embraces the perceptual ramifications of sound as a temporally bound phenomenon, and commits to preserving the irreducible complexity of timbre as a unitary aesthetic phenomenon.

In these ways, analog tape serves as a reminder of an authentic ontology of sound, one capable of inspiring analogous compositional techniques and musical ideas in turn. Composing with analog tape invites—if not compels—the musician to *think through* the materiality of sound, and to take the implications of such materiality into consideration throughout the compositional process. This, to me, is what it means to compose with analog tape—not simply to "use" it, but to work with it by following its indexical logic and immersing oneself in its all-encompassing flow.

20 Cf. Bergson 1961.

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COMPOSING WITH ANALOG TAPE IN A POST-DIGITAL AGE
(summary)

Scholars have extensively investigated analog tape as a cultural artefact. Many have interpreted the symbolic significance of tape from a critico-theoretical perspective. Others have explored it as a lens of inquiry for socio-political and historical phenomena. Finally, many studies have examined the role still played by tape in cultural politics outside North America and Europe. Largely absent, however, are reflections on the value of engaging with analog tape as a compositional tool in our post-digital age.

Granted, composing with tape might seem too impractical, as digital technologies can efficiently achieve operations that are of great difficulty for analog devices—e.g. independent transformations within the time and frequency domains. As I show in this essay, however, the tradeoffs for such efficiency are twofold: first, removal from the inherently unidirectional flow of time; and second, from "groundedness" in sound as a physical phenomenon. Within such a framework, it is claimed that analog technologies preserve the "authenticity" of sound. If one composes first and foremost from a perspective that values mindfulness of such authenticity, however remote it might be from conscious sensory perception, then analog technologies are to be taken seriously as compositional tools, despite the logistical challenges of working with them.

All this ought not to be taken as a form of deliberate anachronism, however. Rather than evaluate analog audio devices in isolation from the assemblage of materials and techniques that comprise contemporary compositional practice, I show how analog and digital technologies, in dialectical counterpoint with each other, offer composers unique insights into the nature of sound as the material substrate of music, and invaluable guidance in implementing compositional techniques proceeding conscientiously from qualities immanent thereto.

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