Not By Art Alone:
Error, Bias, and Chaos in Musical Evolution

Robert Lopez-Hanshaw

[Chapter for: *Music in Human Experience: Interdisciplinary Perspectives on a Musical Species*]

Music changes over time. This is true of music in any culture, just as it is true that language changes over time in any community of speakers. Some patterns of change are more readily explained as responses to cultural values, and other patterns as the effect of underlying cognitive biases. In both cases, it is possible to use the framework of evolution to help describe and explain the changes. This chapter provides a brief introduction to evolutionary theory; overviews of both error-driven and value-driven patterns of change in music; and some of the intriguing effects encountered when these levels of analysis are combined. Together, these suggest approaching musical evolution as a chaotic system.

I. Musical Change as an Evolutionary Process

Evolutionary views of music are nearly as old as Darwin's idea of biological evolution. For example, nineteenth-century European musicologists Hugo Riemann and François-Joseph Fétis both believed that music evolved. Unfortunately, they both also participated in the “scientific racism” of the time. Fétis claimed that ancient Aryans had had superior hearing compared with surrounding cultures (Christensen 2019, 189), and for him, this explained the later development of complex European harmony. Riemann claimed that the German classical music of his time was the pinnacle of human musical achievement, and that all other cultures' music was a glimpse into a primitive “prehistory” of this apotheosis (Gelbart and Rehding 2011, 142). Of course, it is now plain that these interpretations are faulty, and that they contributed to a damaging trend of dehumanizing the out-group.

Music does not, as Fétis and Riemann supposed, innately strive toward artistic perfection. Margaret Kartomi put it very succinctly: “[M]usic has evolved in a measurable way, as long as ‘evolved’ is not defined as ‘improved.’” (Savage 2019, note 6) Nor does music *devolve*, or “degenerate,” as the early twentieth-century authoritarian governments of Germany and Russia each claimed (Snowball 2002; Mekanowitzky 1965). Rather, the position taken by this chapter is that artistic quality is a value judgement, not an objective absolute; and further, that this judgement is only relevant when it is made by the community of practitioners and listeners involved with the music in question. This position is now normative in musicology.

However, this still allows for an intriguing avenue of analysis. As a culture-specific value judgement, perceived artistic quality can have a strong effect on musical *change* within a given population. It can be analyzed as a selective pressure: music which satisfies this culture-specific requirement has a better chance of surviving and “reproducing” than music which does not. In fact, MacCallum, Mauch, Burt, and Leroi (2012) showed that random sound loops subjected to random mutation and replication could be selected for “musical appeal”¹ over many listener generations, and the resultant loops at the end of the process would resemble typical music from the listeners’ culture.

Music, then, seems to change in *response* to various forces. Some forces are culture-specific and more conscious, such as the preference for a certain set of features that make music “good.” Other forces are less conscious, such as the tendency to make some types of errors and not others when perceiving and producing sound. Tracing the cumulative effect of all such forces

¹ “Musical appeal” is necessarily a complex aggregate of different factors. MacCallum et al. were able to isolate “rhythmicity” and “chord clarity” as measurable components of musical appeal. However, together, these components only accounted for 4.2% of the observed selection effect, “leaving 95.8% [of musical appeal] unexplained” (MacCallum, Mauch, Burt, and Leroi 2012, 12085).

over generations, it may be possible to explain *why* music changes, and perhaps make limited predictions about how it may change in the future.

Evolution and Meaning

This evolutionary framework may appear unpleasantly deterministic, reducing the role of the creative process to a passive summation of abstract forces. Indeed, appeals to agency and meaning constitute a large part of contemporary criticism of cultural evolution in general (Savage 2019, 7). In lieu of a thorough defense, an extended analogy may be offered: First, few would claim that an analysis of the pigments in a master painting detracts from the appreciation of its image. Furthermore, few would claim that the greatest works of literary or oratory art are diminished by an analysis of the semantic and phonological changes that took place in the authors' languages over time. Painters and authors work with the set of materials available to them—whether pigments or words, or even higher-level conventions such as visual allegory and rhetorical form.

Of course, artists need not *only* use these extant materials: William Shakespeare and James Joyce, for example, both invented new words and new variations on conventional literary forms (Bevington 2011; Binelli 2017). It was a powerful artistic statement in each case, and each had considerable influence on subsequent authors. Yet this does not invalidate the analogy. Each of these cases can *also* be analyzed as a particularly successful “mutation” in the evolution of English-language literature; its success enabled by (among other things) a culture-specific selection bias towards novelty. Analyzing cultural values themselves as evolutionary forces need not rob them of their experiential validity, and analyzing artistic innovations as “mutations” need not rob them of their meaning as art.

The study of musical change as evolution, then, only engages with the *materials* used by the musician: melodies, rhythmic patterns, pitch systems, and other conventions. These musical *materials* need not say anything about *meaning*. And in the particular case of music, it is far from settled as to precisely how (or what) meaning is conveyed in the first place. Though it clearly involves the evocation of emotion, there are a variety of approaches to understanding this phenomenon (cf. Patel 2008, section 6; Huron 2006).

Therefore, this chapter takes the position that questions of meaning are orthogonal to the study of musical evolution.

A Basic Evolutionary Framework

Three basic phenomena are required in order for evolution, in the common Darwinian sense, to take place: heritability, mutation, and selection (Claidière, Scott-Phillips, and Sperber 2014, 2). A given trait must be transmitted to subsequent generations: the trait must be “heritable.” There must also be some mechanism that introduces variation in each trait, so each subsequent generation is not a perfect copy of the last: each trait must be capable of “mutation.” (A related source of variation for a given trait is “gene flow,” where a new variant might be introduced into one population after originating by mutation within a different population.)

Finally, different variants must be transmitted to subsequent generations at different rates. Selection is the classic rate determiner. This is typically divided into “positive selection,” whereby individuals with one variant reproduce more frequently than the rest; and “negative selection,”² where individuals with another variant reproduce *less* frequently than the rest, or

² Also known as “purifying selection,” which is a good term to avoid when talking about characteristics of human culture.

cannot reproduce at all. The first variant is “selected for,” and the second is “selected against.” Selection thus involves the *fitness* of a variant characteristic.

Another important pathway of change is “drift.” Independent of fitness, a variant’s mere *frequency* in one generation influences its frequency in the next. Common variants in one generation are most likely to remain common in subsequent generations, and very uncommon variants are at risk of loss, all due to chance. Drift is more prominent in smaller populations, where individual chance events have a proportionally larger impact.

These basic phenomena can also explain patterns of change over time in cultural domains, such as language and economics (Mesoudi 2011; Richerson and Boyd 2005). The analogy is seemingly straightforward in music. Melodies, rhythmic patterns, tuning systems, and other musical elements are transmitted from one generation of listeners and performers to the next (heritability); these musical elements may change during the process of transmission (mutation), or new variants may be introduced from outside (gene flow); some variants become more common than others (selection and drift).³

The major point of difference is that, in genetic evolution, mutation is random. Broadly speaking, any nucleotide might be deleted, inserted, or replaced, at any location.⁴ But in music—and cultural evolution in general—mutation can also occur by “guided variation” (Mesoudi 2011, 56), where the nature of a mutation is influenced by the individual who is transmitting it. For example, a teacher might slightly change a learned melody by adding ornamentation, and then teach this new version to their students.

³ See Savage (2019, 2–5) for a historical summary of the development of this analogy.

⁴ This is not strictly true. For example, in humans, mutations are much more likely to occur at recombination sites than elsewhere (Halldorsson, Palsson, Stefansson, Jonsson et al. 2019). However, genetic mutation is still “random” in the sense most relevant to this discussion.

In addition to guided variation, another important mutation mechanism in cultural evolution might be called “constrained mutation.” Constrained mutation in cultural evolution describes *which random mutations are likely to occur* and which are not. If a particular error is more likely to occur during transmission, then, over many generations, the frequency of mutations containing that error is likely to increase, even though there is nothing about the mutation itself which makes it more likely to reproduce—in other words, is not positively selected. Constrained mutation, then, can *cause* drift.

The differences are important. In guided variation, mutations are *not* random, but rather chosen by the agent who transmits them. In constrained mutation, the mutations themselves *are* random, but some variants are more likely than others to arise. Both of these processes influence the set of possible mutations *a priori* (for which there is not a simple parallel in genetics). In contrast, selection only influences the reproduction rate of those mutations which are already extant.

In many cultural domains, we see similar patterns of change occur in disparate societies. But we also see that the *rates* of change can be drastically different in different societies, or even in the same society at different times (Savage 2017, 96; Greenhill, Heggarty, and Gray 2020, 227). There are also many instances where similar societies took opposing paths from a similar starting point. Striking examples can be found in language: in English, for example, some communities pronounce the sound written “th” as “f,” though others distinguish between the two. This merger is common across the world’s languages, because of the two sounds’ acoustic similarity (Blevins 2006, 134); but there is no obvious reason why one speech community would merge the sounds and another within the same language would not.

Earlier frameworks struggle to account for such inconsistent change, either modeling it as random noise, or removing it from the domain that the model attempts to explain (cf. Bresnan and Aissen 2002, 82). But, by taking an evolutionary perspective, the mutual feedback between all of these forces—guided variation, constrained mutation, and the many negative and positive selection pressures that “filter” this variation—helps explain why we see both broadly similar patterns of change in many cultural domains, and drastic differences in the *realization* of those patterns. These resemble the hallmarks of chaotic systems, as we will discuss later.

II. Case Studies

We will next outline some specific cases of evolutionary change in melody, rhythm, and pitch system, all relatively separate musical domains. Each was chosen because it presents contradictory or ambiguous evidence about the nature of musical change.

Melody

Patrick Savage (2017) finds that melodies tend to transform over time in broadly systematic ways. Three trends are especially notable: a) more rhythmically prominent notes are more resistant to change than those less prominent; b) insertions and deletions are more common than substitutions; and c) substitutions typically take place over adjacent scale steps rather than larger intervals. Savage suggests that insertions and deletions tend to be artistic choices (analogous to guided variation), and that substitutions tend to be errors, since it is more likely to misperceive a note as an adjacent scale step than one far away (analogous to constrained mutation).

However, he also highlights an interesting case of ambiguity, in a change that took place in the melody “Scarborough Fair” between a 1965 commercial recording and the famous 1966

Simon and Garfunkel version (figure from Savage 2019, 6, part b only; used under Creative Commons 4.0 International license):

The image displays a musical score for the song "Scarborough Fair" by Simon and Garfunkel. It consists of two staves, both in G major (one sharp) and 3/4 time. The lyrics are written below the notes. Red circles highlight specific notes on both staves, and red arrows point from these circles to a legend box on the right. The legend box contains two entries: "Substitution" with a red arrow pointing down and "Deletion" with a blue arrow pointing down. The lyrics are: "Are you go-ing to Scar - bo-rough Fair? Pars - ley, sage, rose - ma - ry and thyme".

In this case, two of the observed trends are in conflict: the substitutions took place by adjacent scale steps, but occurred in a rhythmically prominent position. Savage notes, “Paul Simon has yet to respond to my query” regarding the source of this change, so it must remain speculative (Savage 2017, 21).⁵ If Savage’s generalizations are taken at face value, they suggest that the change is most likely due to error. But if that is true, why—in such a skilled musician—did it occur in a location that is usually *less* error-prone than others? On the other hand, if Simon’s motivation was artistic, why did the change still adhere to a pattern shared by changes that do stem from error? Finally, what if the variant melody had substituted F-Eb for the original Eb-F, rather than D-Eb? Savage’s predictions seem to treat this as equally likely, because both substitutions involve adjacent tones. Yet, this alternate substitution would change the melody’s contour, a feature which is among the first to be perceived and easiest to remember (Patel 2008, 194ff).

Savage describes melodic change as mediated by “the dynamic, largely unpredictable actions of many individual musicians,” and models it as a process of random mutations with broad statistical tendencies, strongly resembling biological evolution. Yet, modeling this

⁵ One wonders if he might have better luck asking Art Garfunkel.

“Scarborough Fair” change (and any others like it) as essentially random events, leaves many questions unanswered. Possible patterns are subsumed under noise.

Rhythm

Savage also notes that written music is more resistant to change than aurally transmitted music (Savage 2017, 61). One might then generalize that a strong music notation tradition would strongly affect the music of its host culture, such that music which easily fits the notation system would be selected for, and music which is difficult to notate would be selected against. Literacy would be a strong conservative influence.

A case of evolution in Ottoman rhythmic patterns seems to support this. Mehmet Ekinci (2018) points out that a group of metrical patterns (*usuls*) called *semai* seems to have diverged into two branches in the late eighteenth century. One form of *semai* divides each beat into 5 parts (grouped either 3+2 or 2+3), and another divides each beat into 3 parts (grouped either 2+1 or 1+2). Yet, there are many older melodies of which versions have been preserved in *both* forms; and descriptions of *semai* from this earlier period are highly inconsistent. Ekinci presents evidence that *semai* may have originally been an “ovoid rhythm” which did not feature a strict subdivision of the beat into equal parts, but rather a shifting and subtle sense of inequality. Such rhythms are indeed still found in nearby folk musical traditions (Ekinci 2018, 56-58). At some point leading up to the late eighteenth century, this inconsistent rhythm then crystallized into two variants, each one possible to represent unambiguously in notation, unlike the pre-eighteenth-century original.⁶

⁶ Even if the original *semai* was not in fact an ovoid rhythm, Ekinci persuasively argues that it was, at minimum, subject to a level of stylistic and performance diversity that impeded accurate notation. Thus, the contradiction regarding notation’s influence would still apply—though not as directly.

However, an example from French music seemingly shows the opposite effect. In the sixteenth through eighteenth centuries, melodic passages *notated* as several notes of equal duration in succession would, instead, be *performed* with subtle, shifting inequality. This performance technique was known as *notes inégales*, and was “subject to definite... rules,” even though the “rate of such inequality varied...and was more or less arbitrary.” This mode of performance was so ubiquitous in France that “[w]hen a composer intended the written value of notes to be preserved, he marked them ‘equal’” (Kochevitsky 1973, 27). However, elsewhere in Europe, “where performers could not be counted on to alter the rhythm in given situations, a composer who particularly wanted inequality had to indicate it” (Fuller 2001, section 1).

If a notation system tends to induce the regularization of ambiguous rhythms, why did *notes inégales* thrive for so long? On the other hand, if it *is* possible to perceive and produce such ambiguities despite a theory and notation that do not accommodate them, why did *semai* regularize and split?

Pitch System

Patel (2008) notes several major trends among musical pitch systems (19). Two stand out: first, pitch systems usually use only up to 5-7 pitches at one time, corresponding to the number of discrete categories that humans can reliably keep track of (Clough, Douthett, Ramanathan, and Rowell 1993); and second, the intervals among pitches in a system tend to differ in size by at least 80¢, in order to be perceived as different types of interval (Burns and Ward 1978). In addition, consonance—i.e., simultaneous pitches whose frequencies are related by simple integer ratios⁷—is known to play a role in early auditory development for all humans

⁷ Due to the limited scope of this chapter, I cannot rigorously define the concept(s) of consonance. I use it here and elsewhere only in the sense of small-integer frequency ratios. This

(Trainor and Unrau 2011, 235), so it is widely assumed to affect pitch systems. Combining these and related observations, some researchers conclude that tuning systems evolve toward one of a small set of cognitively optimum configurations. This has been used to explain, for instance, the current European 12-tone equal temperament system (Hajdu 1999), or Javanese and Balinese gamelan tunings (Sethares 2005, Chapter 10).

By itself, the European case seems to support this view. The most common European pitch system has been broadly stable for well over a millennium: the diatonic scale and its modes, with their pattern of alternating whole tones and semitones, are attested from the earliest examples of European music theory and notation. During those thousand years, this system underwent at least three major theoretical reinterpretations,⁸ in which the nominal tuning of each interval in the system changed—for example, a “semitone” has historically ranged between roughly 60¢ and 120¢ in size⁹—but the underlying structure remained consistent. Because it satisfies all of the above cognitive universals, and has remained stable for so long, the diatonic scale is a possible example of a cognitively optimum pitch system. Were that the case, one would expect that deviations from trends with a cognitive basis would be rare in other pitch systems, perhaps due to a greater difficulty of transmission.

However, those broad trends—a relatively small number of pitches per octave, a minimum interval size contrast of roughly 80¢, and use of harmonic consonance—are regularly

corresponds roughly with the sensory aspect of the common Western notion of consonance. However, see Tenney (1988) for a detailed and thoughtful analysis.

⁸ Namely, it began as a so-called Pythagorean system, and proceeded through Just Intonation, meantone, and well temperament/equal temperament phases. See Gann (2019) for a thorough but friendly discussion.

⁹ Both extremes are found in the late Renaissance/early Baroque “1/3-comma meantone” tuning. Semitones in other historical European tunings typically stayed in the 90¢-110¢ range. Barbour (1951) exhaustively treats the minutiae of this subject.

violated, with no obvious consequence for the systems that do so. In fact, a group of Middle Eastern pitch systems seem to be *increasingly* violating these trends over time.

Turkish music theory recognizes a rich variety of intervals, many of which vary from each other in total size by as little as 23¢ (Bozkurt, Yarman, Karaosmanoğlu, and Akkoç 2009). Arabic classical music, a loose group of related traditions, also utilizes intonational flexibility. Arabic traditions not only recognize subtle variants of a pitch used in different contexts, but also the fact that the normative intonation of a single pitch can be different in neighboring geographical areas—which can provide salient information about the background of a particular player (Farraj and Shumays 2019, 164). This flouts the trend of a minimum effective interval size difference.

Acoustic consonance is also difficult to pinpoint as a selective force. First, in the Middle Eastern systems mentioned above, many “dissonant” intervals are used frequently and structurally; so they are clearly not systematically selected against. Second, particularly in Turkish music, many intervals are *more* consonant than the nearest European equivalents—despite the relative absence of harmony as a strong artistic motivator.¹⁰

Finally, although Turkish and Arabic pitch systems do tend to use 7 or fewer pitches at a time (absent any modulations), the pitch complexity required of performers has arguably increased in recent times. Changes in fretted instruments provide a tangible clue.¹¹ In Turkey,

¹⁰ Turkish and Arabic music were historically melodic, to the near exclusion of harmony; and although both have incorporated some harmony during the last century or two, melody is still of primary structural importance.

¹¹ Whether or not this reflects any change to the underlying pitch system, the trend toward adding frets clearly *does* show an increased expectation of pitch specificity and accuracy in performance. This suggests that, at minimum, the more complex elements of the pitch system have become more culturally important in recent times, and that approximations and inaccuracy are less tolerated. This alternate interpretation still argues against the hypothesis that pitch complexity should be negatively selected.

between the eighteenth and twentieth centuries, the *tanbur* went from using 21 frets (de Zorzi 2018, 95) to as many as 35 frets per octave (Gedik, Bozkurt, and Çirak 2012, 97). The *saz*, much more of a folk instrument than the *tanbur*, also saw an abrupt increase in frets during the mid-twentieth century (de Zeeuw 2020, Chapter 4). The Arabic *buzuq* follows this trend as well (Farraj and Shumays 2019, 28-29).¹² Even in neighboring Greece, some microtonally fretted instruments have been adopted in recent decades. The *lâvta/politiko laouto* is one such. Previously associated with ethnic Greeks in Istanbul, it was (re-)introduced to Greece in 1985 (Elias 2008, 59), part of a broader “reappropriation” of Ottoman musical heritage (57). Since then, several luthiers have added microtonal frets to emphatically Greek instruments, such as the *bouzouki*, which are normally fretted in 12-tone temperament (Lopez-Hanshaw, in preparation). This last case intriguingly suggests a pitch system *adding* complexity.

If complexity in pitch systems is negatively selected, why would a broad group of musical cultures apparently evolve *toward* it? And what accounts for the contradictory relationship with consonance? It should either apply universally, or only to cultures that use musical harmony. Instead, it appears that neither scenario is accurate.

III. Chaotic Interaction

It is reasonable to conclude that no single factor influences musical evolution equally across all cultures. To cope with this, a model could attempt to measure only a handful of variables in an idealized system, relegate any between-culture contradictions to culture-specific factors, and leave it at that. Yet, as a result of such over-idealizations (see Claidière, Scott-Phillips, and Sperber 2014, 4), “we have no theory to explain just how” the transmission of

¹² This is mirrored by the development and proliferation of microtonal *mandal* tuning levers for the large zither-type *kanun*, in both Turkey and the Arab sphere, during the twentieth century.

music affects its form (Nettl 2015, 300). Given the amount of study that has been undertaken on cultural values themselves, outside the field of music, this feels like an abdication!

Citing diverse research, Creanza, Kolodny, and Feldman (2017, 7784) observe that many cultural trends, such as baby names and fashion styles, can change abruptly and thoroughly in an “S-shaped” curve. Much like the weather, these changes can be forecast, but not predicted. This is because culture, like weather, is the product of a large number of variables that mutually influence each other. Such systems can exhibit exquisite sensitivity to very small perturbations, but can *also* exhibit resilience against perturbations (Rego-Costa, Débarre, and Chevin 2018). This is the stereotypical “butterfly effect” of chaos and complexity theory: it is possible, in a weather model, to trace the origin of a hurricane back to an event as tiny as a butterfly’s flapping wing—but on the other hand, most butterflies do not seem to cause hurricanes.

In order to make sense of this in musical evolution, it is useful to consider the types of variables that interact, and the ways in which they interact. This may assist in creating more informative, holistic models, and this chapter will conclude with one such possible approach. So we will first examine in more detail the types of change that originate in cognitive biases, and then the types that originate in culture.

Cognitive Biases Cause Drift

Patel (2008, 21) suggests viewing musical pitch systems as *phonological*, based on “how pitch categories are created and maintained in the context of an organized system of pitch contrasts.” *Evolutionary Phonology* is a model that distinguishes the possible pathways for sound change in language, assuming a statistical learning paradigm, and it has broad empirical support (Blevins 2006). The extension of these pathways to musical change could be highly instructive.

Under statistical learning, a person subconsciously extracts statistical regularities from their environment, and uses those to form mental categories of various experiential phenomena. The phenomenon is robust, and not limited to language (Endress, Slone, and Johnson 2020; Kóbor, Janacsek, Takács, and Nemeth 2017). In phonology, this means each individual constructs an internal representation of their language's sound system based on regularities among the sounds they hear; and this representation is constantly updated during the process of communication (Pierrehumbert 2003).

Careful experimentation has demonstrated that individual speakers of the same language do not all attend to the details of a speech signal in the same way. For example, some may subconsciously attend to a slight nasal quality on a vowel, and thus interpret it as the sequence “vowel+N,” but others may interpret the same signal as a vowel alone, ignoring the nasal quality (see Beddor 2015). Articulation, too, varies between speakers (*ibid.*), and even within the same speaker between formal speech and everyday conversation (Ernestus and Warner 2011). Thus, two speakers of a language are unlikely to share the same mental representation of their language's sounds; and even if they did, both their perception and their production would *still* show inter- and intra-speaker variation.

Using this line of research, Blevins formalized three pathways of linguistic sound change:¹³

- 1) A listener hears a single unambiguous sound, but misinterprets it as an instance of a different sound (e.g., speaker produces “th” and listener interprets it as “f”). Blevins names this “CHANGE.”

¹³ The below is summarized from Blevins 2006. Examples are changed and simplified for illustrative purposes.

- 2) A listener hears an *ambiguous* sound sequence, but interprets it differently from the speaker who produced it (e.g., speaker's representation is "an," speaker produces nasalized "ã," but listener could interpret it as "an," nasalized "ã," or non-nasal "a"). Blevins names this "CHANCE."
- 3) A listener hears a *range* of variants of the same sound, but assigns it a category different from the category used by the speaker (e.g., speaker's category is "zh," speaker produces a range of sounds between "zh" and "j," but listener interprets the whole range as being instances of "j" category instead).¹⁴ Blevins names this "CHOICE," although there is no conscious choice involved.

As a consequence of the listener's internal category differing from that of the speaker, the range of variants that is then *produced* by the original listener may have a different distribution than that of the original speaker. This, in turn, could cause a new listener to interpret the underlying category still more differently. Over generations, the accumulation of these mismatches can cause a sound within a language to shift, split, merge, disappear, or alternate in different contexts. However, it *need not*. At every iterative step of this process, there is also the chance that a sound change will not result.

A critical aspect of this model is that it is recursive. Ambiguity is a function of the perceptual distance between existing, language-specific sound categories—without reference to any external, "natural" sound categories. So, as categories shift around, this causes their relative perceptual distance to increase or decrease, which in turn affects the likelihood of their

¹⁴ Depending on your speech community, you may experience such a range with the ending sound in the word "garage."

involvement in a future sound change. “Natural” categories are not privileged with extra stability.

Pitch system drift is a very suggestive piece of evidence for applying this framework to music. When a musical pitch system is not subject to strict top-down standardization, neighboring communities of practice diverge: intervals are tuned differently from region to region, or even village to village, within the same musical tradition. This is true across much of the Arab sphere, as mentioned above, and in locales as far separated as the Svaneti region of Georgia (Gelzer 2002, 194) and the island of Java (Surjodiningrat, Sudarjana, and Susanto 1993), to name just a few examples. Indeed, this is likely the norm, and standardization the exception, much as language naturally diverges into a continuum of dialects.

On the other hand, among many differences between language and music at the phonological level, one in particular stands out: competence. While language competence can be expected of the vast majority of members of a society, musical competence cannot. Some societies may enjoy widespread musical competence, if music is an everyday social act expected of everyone. But where this is *not* true, incompetence appears to be the norm. Musical novices seem to have only a rudimentary set of abstract pitch categories, if any. Rather, they remember familiar tunes holistically, and can identify features like melodic contour and a very general size difference for intervals (Smith 1997). This is neatly captured by a statistical learning model with the categorical abstraction phase left incomplete. Such a condition could easily be caused by the lack of feedback that musical novices would otherwise gain from a community of practice, in stark contrast to their experience with language sound categories.

Cultural Biases Are Recursive

Cultural values regarding cultural products often operate at a high level of abstraction. Thus, the output of gradual, sound-level evolution by error—a very low level of abstraction—can be “invisible” to cultural values as selective forces. But this is not always true. For example, contemporary Icelandic speakers are highly conservative when it comes to their language, and so they both *notice* certain nascent language changes, and police themselves when they produce them (Friðriksson 2008).

Even very deeply-held cultural values, such as romantic partner preferences, can change in a society over time (Buss 2001). It is quite plain that musical values do so as well. When this happens, it changes the fitness environment for music, altering both the choices made by musicians (guided variation) and the response by the community of practice (selection). Such rapid environmental change can induce chaotic behavior in an evolutionary system, although it can also *suppress* chaotic behavior in some circumstances (Rego-Costa, Débarre, and Chevin 2018).¹⁵

Values also affect each other—and themselves. One simple example of a feedback loop can be constructed using a small set of very generic cultural values, namely a success bias, a conformity bias, and a nonconformity bias (from Creanza, Kolodny, and Feldman 2017). These biases are respectively defined as: to value and imitate successful individuals; to value and imitate that which is popular; and to value the flouting of convention. If an individual with a strong nonconformity bias acted unpredictably and was then socially rewarded for the act, then a reaction could occur on two levels. On a straightforward level, individuals with a success bias might imitate the unpredictable action, and then individuals with a conformity bias might also

¹⁵ Such suppression may have contributed to the success of earlier, more static theories of evolution in the first place (see Doebeli and Ispolatov 1994), as researchers did not need to interpret evolutionary systems as chaotic in order to produce results.

imitate the action at a lag, once it has become sufficiently popular. So the initially unpredictable action itself would enjoy a moment of high selective fitness. But on a more recursive level, those with a success bias might conclude that nonconformity was the root cause of the action's success, and might thus begin to value nonconformity itself. This would cause an increase in the frequency of unpredictable actions over the whole society, which would in turn increase the likelihood that one such action might be socially rewarded, and the cycle could begin again.

IV. Foregrounding Complexity: A Path to Resolve Ambiguities?

Returning to the case studies for a moment, it can be seen that an analysis using mutually-influencing trends can provide some insight. In general, melodic substitution errors could be reframed as instances of Blevins' CHANGE pathway: a sound neatly mistaken for an adjacent sound. This is less likely in "Scarborough Fair," for the reasons originally stated. But an alternate error pathway is plausible. Because music is *constructed* by each musician (Claidière, Scott-Phillips, and Sperber 2014, 4; Strachan, Curioni, Constable, et al. 2020) and not simply imitated, then any information gaps in a melody would be filled constructively rather than randomly. In addition to likely maintaining the original melodic contour, it is plausible that such reconstructions would most often resemble common melodic cells, rather than uncommon ones (cf. Savin 1963). This, in turn, might affect the types of non-ornamental innovations that musicians are likely to make. A rational first step is to determine whether or is a more common cell in pre-tonic contexts; and this is readily accomplished using existing melodic corpora.

As Ekinçi points out, a single performance of the *usul samai* rhythm might have been *perceived and notated* interchangeably in either form (Ekinçi 2018, 53). This echoes Blevins' CHANCE pathway, where an ambiguous sound is assigned a category by a listener, but the

listener's actual articulation of the sound need not change at all. Perhaps it was only later, after the notated versions of *samai* had a chance to affect the chain of transmission, that they began to be taken at face value. As for *notes inégales*, there is no particular evidence that notational incompatibility led to the practice's extinction; it could easily have been simple fashion.

In the two pitch systems, it appears that the main arbiter of change versus stability—in these centralized, rationalized, classicized systems—has been musicians, composers and theorists consciously wrestling with the *idea* of naturalness. Conscious engagement with the low-level materials of music meant that expected lower-level evolutionary processes, like drift, were simply not allowed to occur. This makes naturalness itself (whatever that means!) nearly irrelevant for analysis. A more interesting line of inquiry might be, to what degree do the theoretical priorities of each pitch system align with most listeners' actual experience? How well can Turkish *novices* attend to the microtunings?

V. Conclusion: Toward A More Informed Model

Evolution—particularly cultural evolution—has traits characteristic of chaotic systems. How can musicologists meaningfully engage with that idea? Luckily (and perhaps surprisingly), the field of archaeology provides a way forward. Archaeologists have made increasing use of a tool called *Agent-Based Modeling*, or ABM, and it is poised to reach great prominence in the field (Cegielski and Rogers 2016). This tool readily simulates chaotic systems, and is in fact a crucial tool in Complexity Science itself (Manson, Sun and Bonsal 2011).

An ABM is a computer program in which individual “agents” and their decisions (“if X, then Y...”) are simulated. Researchers look for patterns that emerge when a population of agents is allowed to interact. Because musical evolution emerges from many interactions among individuals over time, this approach is intuitively useful. Musical evolution might be modeled as

a community of listeners and performers, each creating and responding to a set of melodies generated and transformed by conditional rules. Indeed, such work already has direct precedent (Miranda 2002), though it is more often seen in the analysis of whale vocalizations (Filatova and Miller 2015; McLoughlin, Lamoni, Garland, Ingram, et al. 2018) or used as an artistic tool for generating music (Beyls 2007; Tricaud 2018).

The conceptual separation of constrained mutation, guided variation, and selection may seem difficult to reflect in a model, since they all ultimately affect the frequency of a particular variant in a population. An ABM, on the other hand, can separate mutation from selection by using two steps for each generation: first, agents generate melodies (with any new mutations); and then agents respond, perhaps by learning them, or choosing not to.

Furthermore, each agent's choices can be assigned a particular probability reflecting the likelihood that a particular selection or mutation will occur; and these probabilities themselves can change in response to the agent-created environment. In this way, conscious versus unconscious processes can be effectively separated, not by their *nature*, but by their *effect*. Social biases are more susceptible to change in response to the environment than are the more stable cognitive biases; so, cognitive error biases in an ABM can contribute a steady (and small) amount to the "choice" of mutation in each generation, and social biases can contribute a variable and conditional amount. Overparametrization is a risk in a model such as described above (see Burnham and Anderson 2004), but it is quite possible to envision one with fewer parameters to investigate a narrow phenomenon. The salient point is that the number of parameters doesn't matter as much as their interdependence.

If this chapter communicates nothing else, let it be this: interdependence is critical to understanding musical evolution. Any conceptual model that seeks to describe it must engage with that fact, not idealize it away.

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