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Statistical universals reveal the structures and functions of human music

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Music has been called "the universal language of mankind." Although contemporary theories of music evolution often invoke various musical universals, the existence of such universals has been disputed for decades and has never been empirically demonstrated. Here we combine a music-classification scheme with statistical analyses, including phylogenetic comparative methods, to examine a well-sampled global set of 304 music recordings. Our analyses reveal no absolute universals but strong support for many statistical universals that are consistent across all nine geographic regions sampled. These universals include 18 musical features that are common individually as well as a network of 10 features that are commonly associated with one another. They span not only features related to pitch and rhythm that are often cited as putative universals but also rarely cited domains including performance style and social context. These cross-cultural structural regularities of human music may relate to roles in facilitating group coordination and cohesion, as exemplified by the universal tendency to sing, play percussion instruments, and dance to simple, repetitive music in groups. Our findings highlight the need for scientists studying music evolution to expand the range of musical cultures and musical features under consideration. The statistical universals we identified represent important candidates for future investigation.

ethnomusicology | cross-cultural universals | group coordination | evolution | cultural phylogenetics

Humans are relatively homogenous genetically but are spectacularly diverse culturally (1). Nevertheless, a few key cross-cultural universals, including music, are present in all or nearly all cultures and are often considered to be candidates for being uniquely human biological adaptations (2–4). Although music has been called "the universal language of mankind" (5), there is considerable debate as to whether any specific musical features are actually universal, and even whether there is a universally valid definition of music itself (6, 7). Supporters have proposed lists of up to 70 candidate musical universals (e.g., refs. 8–12), but skeptics (e.g., refs. 13–15) have gone so far as to claim that "the only universal aspect of music is that most people make it" (14). These debates are important because the demonstration of musical universals could point to constraints that limit cross-cultural variability, as well as provide insights into the evolutionary origins and functions of music (16). However, despite decades of theoretical debate, there has been little attempt to empirically verify the actual global distribution of supposedly universal aspects of music.

It is important to note that the concept of a cross-cultural universal does not necessarily imply an all-or-none phenomenon without exceptions. Classic typologies from anthropology and linguistics distinguish between absolute universals that occur without exception and statistical universals that occur with exceptions but significantly above chance (2, 17, 18). They also distinguish between universal features that concern the presence or absence of particular individual features and universal relationships that concern the conditional associations between multiple features (*SI Discussion*). In language, for instance, the use of verbs is a feature of most languages (i.e., a universal feature), and languages in which verbs appear before objects also tend to have prepositions (i.e., a universal relationship; ref. 17). Analogous proposals have been made for music, such as the use of an isochronous (equally timed) beat as a universal feature, and the association between the use of an isochronous beat and group performance as a universal relationship, such that music without an isochronous beat is thought to be more likely to be performed solo (12).

A number of empirical studies (e.g., refs. 19–25) have revealed cross-cultural musical similarities between particular Western cultures and particular non-Western ones, but none of them has quantitatively tested any candidate musical universals on a global scale. Alan Lomax's pioneering Cantometrics Project (26) presented a global analysis of music centered on a taxonomy of song style, but unfortunately these data could not be used to systematically test most candidate universals because the Cantometric classification scheme ignored many musical features of interest (e.g., scales) precisely because they were assumed to be too common to be useful. Furthermore, Lomax did not include nonvocal instrumental music in his analyses, and his dataset has not been made publicly available. In the decades since Cantometrics, musicologists, anthropologists, and psychologists have all tended to avoid global comparative studies of music, focusing instead on finer-grained studies of one or several specific societies. Obstacles to a global study of music, beyond sociological factors such as the rise of postmodernism, include the absence of global samples, cross-culturally applicable classification schemes, and appropriate statistical techniques (27).

Another limitation of previous cross-cultural studies is that they have sometimes assumed that the music of a given culture

Significance

Which features of music are universal and which are culture-specific? Why? These questions are important for understanding why humans make music but have rarely been scientifically tested. We used musical classification techniques and statistical tools to analyze a global set of 304 music recordings, finding no absolute universals but dozens of statistical universals. These include not only commonly cited features related to pitch and rhythm but also domains such as social context and interrelationships between musical features. We speculate that group coordination is the common aspect unifying the cross-cultural structural regularities of human music, with implications for the study of music evolution.

can be represented by a single style. However, our previous work has demonstrated that musical variation within a culture can be even greater than variation between cultures (28). Empirically evaluating candidate musical universals thus requires a sample of real musical examples, rather than generalizations about dominant musical styles. For example, although much South Asian and Western music uses an isochronous beat, there are many examples within these cultures that do not (e.g., North Indian *alap* and opera *recitative*). Here we synthesize existing schemes to develop a methodology for classifying specific musical features and apply it to a global sample of music recordings. This enables us to provide empirical support for a number of statistical universals that have been proposed in the literature, as well as to identify a number of previously unidentified universals. We are also able to reject some proposals that do not in fact seem to be universal.

The Global Music Dataset

To enable a global statistical analysis of candidate musical universals, we recently developed a manual, acoustic classification scheme called CantoCore that is modeled after Cantometrics but that allows us to code the presence or absence of many candidate universals not codable in the original scheme (29). Based on the most comprehensive existing list of proposed musical universals by Brown and Jordania (12), we were able to combine CantoCore, Cantometrics, and the Hornbostel–Sachs instrument classification scheme (30) to operationalize the presence or absence of 32 musical features (*SI Materials*).

These features include a number of candidates that are rarely discussed in the music evolution literature. Thus, in addition to features from the domains of pitch (e.g., discrete pitches) and rhythm (e.g., isochronous beats) that are commonly cited as putative universals by scientists studying music evolution, our scheme also includes features from the domains of form (e.g., phrase repetition), instrumentation (e.g., percussion), performance style (e.g., syllabic singing), and social context (e.g., performer sex). Some of these features are nested within others by definition. For example, the contrast between syllabic vs. melismatic (nonsyllabic) singing is only relevant for vocal music and must be coded as NA (not applicable) for purely instrumental music.

We systematically coded these features for each of the 304 recordings contained in the *Garland Encyclopedia of World Music* (ref. 31; Fig. 1). These recordings represent the most authoritative and diverse global music collection available, emphasizing on-site field recordings of traditional, indigenous genres (both vocal and instrumental), but also including a variety of examples of contemporary, nonindigenous, and/or studio recordings, chosen with the aim of emphasizing the diversity of the world's music.

Fig. 1. The 304 recordings from the *Garland Encyclopedia of World Music* show a widespread geographic distribution. They are grouped into nine regions specified a priori by the *Encyclopedia*'s editors, as color-coded in the legend at bottom: North America (*n* = 33 recordings), Central/South America (39), Europe (40), Africa (21), the Middle East (35), South Asia (34), East Asia (34), Southeast Asia (14), and Oceania (54).

Although the size of the sample is relatively small compared with the vast array of music that humans have produced, it has a broad geographic coverage and is more stylistically diverse than larger samples that have focused only on Western classical and popular music (e.g., refs. 32 and 33) or only on traditional folk songs in the case of cross-cultural samples (e.g., refs. 22 and 26). The geographic and stylistic diversity of this sample make it ideal for testing candidate musical universals. In particular, the encyclopedic nature of this collection, with its intention of capturing the great diversity of musical forms worldwide, should tend to make this sample overrepresent the real level of global diversity, and thus make it a particularly stringent sample for testing cross-cultural statistical regularities.

Here we use phylogenetic comparative methods used by evolutionary biologists (34) that have been increasingly applied to cultural systems (e.g., refs. 1 and 35–41; *SI Methods*). These methods enable us to control for the fact that different cultures have different degrees of historical relatedness and thus cannot be treated as independent (a phenomenon known in anthropology as "Galton's problem"; ref. 35). We followed the practice of other studies of cultural evolution by using language phylogenies (ref. 42; Figs. S1 and S2) to control for historical relationships in nonlinguistic domains (e.g., refs. 1 and 35–40). Our aim is not to attempt to reconstruct the evolutionary history and ancestral states of global music making, but simply to control for an important potential source of nonindependence in our sample using well-established techniques.

We also performed a large number of additional analyses to assess the effects of different modeling and sampling assumptions. These included analyzing groupings based on musical/geographic regions (rather than language affiliations), comparing the full sample of all recordings against a subsample containing only indigenous music, and altering the branch lengths of the phylogenetic trees (*Materials and Methods* and *SI Methods*).

Results and Discussion

Universal Features. Fig. 2 and Fig. S3 shows the frequencies of the 32 candidate features. Twenty-one features had phylogenetically controlled global frequencies significantly greater than 0.5 (Fig. 2, gray box). Eight features that were specifically predicted to be universal failed to meet this threshold: vocal embellishment, syllabic singing, vocables, membranophones, idiophones, aerophones, dissonant homophony, and pentatonic scales. Many of these features do display widespread distributions and surprising cross-cultural similarities when they do occur [e.g., pentatonic scales throughout the world tend to show surprisingly similar interval structures (43, 44)], but they are not universal in the sense of characterizing the bulk of the world's music. Three features—high register, loud volume, and dance—were specifically predicted only as being universally related to other features and not as universal features themselves (12), and thus their failure to meet this criterion is less surprising.

Three features were predominant on a global scale but were not consistently in the majority within each region. Sex segregation and phrase repetition still displayed consistent trends across all but one region, whereas percussion use was more variable, with the majority of recordings in North America, Europe, and East Asia all lacking percussion instruments. The remaining 18 universal features that passed both criteria are shown using a black box in Fig. 2 and summarized below:

Pitch: Music tends to use discrete pitches (**1**) to form nonequidistant scales (**2**) containing seven or fewer scale degrees per octave (**3**). Music also tends to use descending or arched melodic contours (**4**) composed of small intervals (**5**) of less than 750 cents (i.e., a perfect fifth or smaller).

Rhythm: Music tends to use an isochronous beat (**6**) organized according to metrical hierarchies (**7**) based on multiples of two

or three beats (**8**)—especially multiples of two beats (**9**). This beat tends to be used to construct motivic patterns (**10**) based on fewer than five durational values (**11**).

Form: Music tends to consist of short phrases (**12**) less than 9 s long.

Instrumentation: Music tends to use both the voice (**13**) and (nonvocal) instruments (**14**), often together in the form of accompanied vocal song.

Performance style: Music tends to use the chest voice (i.e., modal register) (**15**) to sing words (**16**), rather than vocables (nonlexical syllables).

Social context: Music tends to be performed predominantly in groups (**17**) and by males (**18**). The bias toward male performance is true of singing, but even more so of instrumental performance.

All of these features have possible parallels in nonhuman animals. In particular, the learned songs of birds are often compared with human music. Like human music, birdsong tends to use discrete pitches (although there is debate about how analogous they are to human scales), descending or arched melodic contours, small intervals, short phrases, modal register, and to be performed predominantly by males (refs. 16, 22, and 45; *SI Discussion*). Although synchronized rhythms based on isochronous beats were long thought to be uniquely human, recent research has discovered that innate neural mechanisms underlying rhythmic entrainment (the ability to synchronize to a beat) seem to have evolved convergently in humans and several vocal-learning lineages of birds and mammals, but not in nonhuman primates (16, 46). However, communicative signaling using instruments (e.g., African great ape drumming) and semantically meaningful vocalizations (e.g., vervet monkey alarm calls) are found in nonhuman primates but are rare or absent in birds (9, 47). Thus, although multiple features of human music have parallels in other species, it is the combination of these features as a package that seems unique to humans.

Universal Relationships. Table S1 and Fig. S4 show the likelihood ratio (LR) values from the phylogenetic analyses of all pairwise relationships between the 32 features. Twenty-seven features were significantly associated with at least one other feature after controlling for phylogenetic relationships (LR > 9.49; *SI Methods*). The five features not significantly related to any others all involved pitch or rhythm. All of these features—nonequidistant scales, ≤7 scale degrees, descending/arched contours, two-/three-beat subdivision, and two-beat subdivision—were among the most common of the universal features identified above.

Ten features (shown with bold boxes in Fig. 3) maintained at least one relationship that was consistent across all nine regions (shown with black lines in Fig. 3). All 10 features formed a single interconnected network centered on group performance and dance (Fig. 3 and Table S2).

Within this network of universal relationships, group performance (**1**), isochronous beat (**2**), motivic patterns (**3**), and few durational values (**4**) were also identified individually above as universal features, with phrase repetition (**5**) narrowly failing this designation. This suggests that simple, repetitive rhythms play a fundamental role in coordinating group performance in almost all of the world's music. The remaining five—percussion instruments [**6**; including both membranophones (**7**) and idiophones (**8**)], dance accompaniment (**9**), and syllabic singing (**10**; i.e., one or two syllables per note without melismatic embellishment)—were not necessarily common individually but tended to appear with these other features when they did appear.

Interestingly, despite both being positively related to the other features that comprise this network, syllabic singing and percussion instruments were negatively related to one another (Table
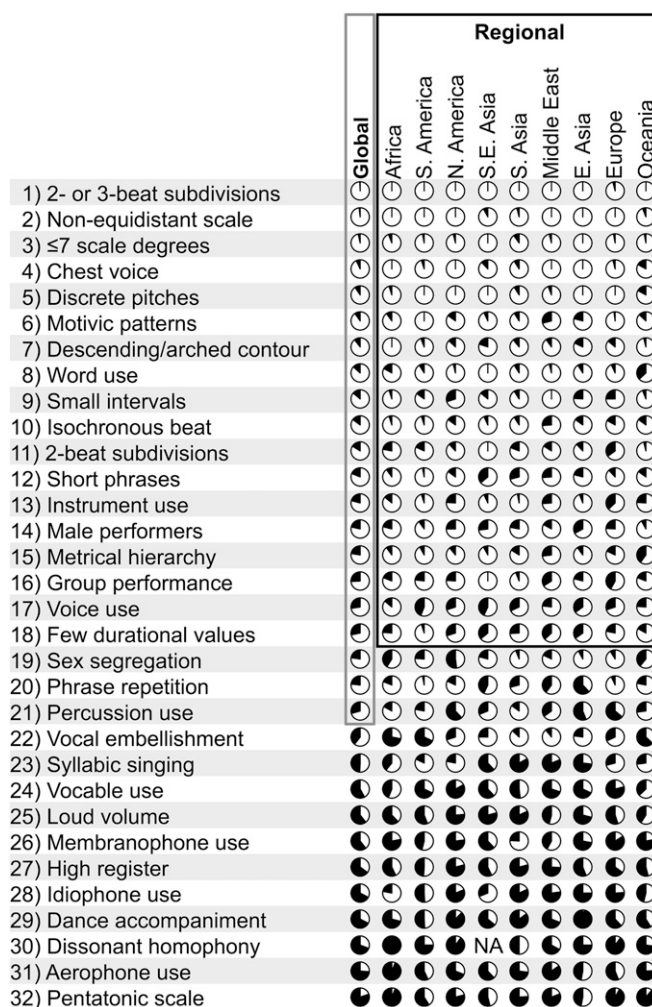
Fig. 2. Pie charts for the 32 musical features organized according to their frequencies. White slices indicate presence, and black slices indicate absence. [NA (not applicable) codings do not contribute to these analyses; see Fig. S3 for an alternate visualization that includes NAs.] Features whose phylogenetically controlled global frequencies were significantly greater than 0.5 are highlighted using a gray box, and features with frequencies greater than 0.5 in each of the nine regions are highlighted using a black box. Note that vocal embellishment and syllabic singing have global frequencies whose values are slightly greater than 0.5, but not significantly so (*SI Methods*). The pie chart for dissonant homophony in Southeast Asia is not included because all 14 recordings from this region were coded as NA.

S1), presumably because percussion tends to drown out singing, making clearly enunciated syllables superfluous. This suggests that syllabic singing and percussion instrumentation represent optional and opposing pathways that can be chosen to achieve similar goals of coordinated group performance in different contexts.

Previously, Brown and Jordania (12) had predicted six of the features examined here as being universally related to one another. The predicted relationship between two of these—high register and loud volume—was significant globally but failed our regional consistency criterion due to an inconsistency in South Asia, where high-pitched chordophone instruments are often played in a quiet, introspective manner. The remaining four predicted features— isochronous beat, dance, group performance, and percussion instruments—were found to be part of our universal network of 10 features. This is consistent with the use of a regular isochronous beat as a key entrainment mechanism that allows multiple individuals to synchronize their playing, singing, and dancing (16).
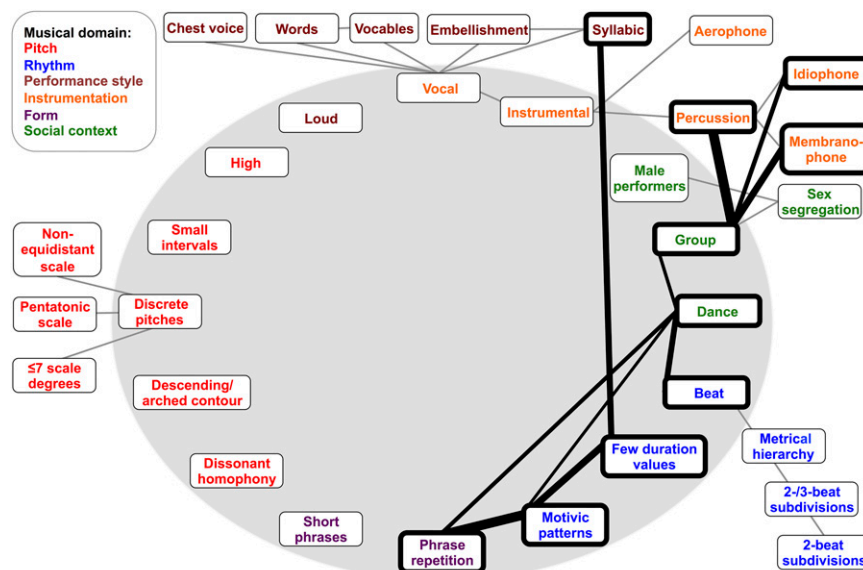
Fig. 3. Universal relationships between the 32 musical features. Features are color-coded by musical domain (see legend at top left). The 16 nonnested features are distributed around the shaded oval, and the remaining 16 nested features outside the oval require one of the former features by definition. Dependent relationships implied by definition are highlighted using gray lines and were excluded from the analyses. Black lines indicate universal relationships that were significant after controlling for phylogenetic relationships and whose directions were consistent across all nine regions, with the width of each line proportional to the strength of the LR statistic from the phylogenetic coevolutionary analysis (see Table S1 for all pairwise LR values). Ten features (highlighted using bold boxes) formed a single interconnected network joined by one or more universal relationships.

Of the six previously unidentified features identified as part of this network, all but one are natural extensions of the original predictions. Membranophones and idiophones are the two specific classes that make up percussion instruments. Phrase repetition, motivic patterns, and few durational values are types of structural regularity that help to create simple, predictable rhythms that can be easily danced to.

The most surprising member of this network is syllabic singing, an aspect of performance style whose connection with rhythm may not be immediately obvious. However, syllabic singing (i.e., enunciating a new syllable for each note) makes it easier to coordinate groups of singers but limits those singers' ability to rapidly change notes compared with nonsyllabic singing, where extending a syllable's final vowel over a number of notes allows for greater rhythmic freedom and virtuosic embellishment. The inclusion of syllabic singing in a network of relationships centered on group performance and dance is also consistent with Lomax's proposal of a central role for singing style in distinguishing between two contrasting styles that he labels as "individualized" and "groupy," where individualized styles are characterized by embellished solo singing in free rhythm whereas groupy styles are characterized by syllabic communal singing and dancing to simple, regular rhythms (26).

The network of universal relationships we identified covers most of the domains under investigation, with the domain of pitch notably absent. This is all of the more striking because, individually, features of pitch are the most common of all of the domains. Their absence in the network of universal relationships may therefore be related to their lack of variance in the sample. This lack of variance reflects the fact that discrete pitches organized into simple scales are the most fundamental building blocks of almost all human music, providing a deep structure that varies little despite the huge surface diversity in the ways in which such scales can be realized.

General Discussion

Despite decades of skepticism about the presence of cross-culturally universal aspects of music, we have provided strong empirical evidence for the existence of a number of statistical universals

across a diverse sample of the world's music. Although there is a long history of armchair speculation regarding musical universals, our analyses provide, to our knowledge, the first quantitative evidence in support of a series of proposed candidate universals using a global musical sample. We used strict criteria across a diverse sample to qualify as "universal," and our analyses were restricted primarily to surface features that could be analyzed from audio recordings alone using existing classification schemes. Therefore, there may well be more statistical universals that we were unable to verify here. Future research might be able to adapt our methods to test candidates involving more-complex cognitive processes, such as perception of octave equivalence or associations between music and emotion (8, 12), or even to test candidate universals in nonmusical domains.

Although we found many statistical universals, absolute musical universals did not exist among the candidates we were able to test. The closest thing to an absolute universal was Lomax and Grauer's (26) definition of a song as a vocalization using "discrete pitches or regular rhythmic patterns or both," which applied to almost the entire sample, including instrumental music. However, three musical examples from Papua New Guinea containing combinations of friction blocks, swung slats, ribbon reeds, and moaning voices contained neither discrete pitches nor an isochronous beat. It should be noted that the editors of the *Encyclopedia* did not adopt a formal definition of music in choosing their selections. We thus assume that they followed the common practice in ethnomusicology of defining music as "humanly organized sound" (48) other than speech, with the distinction between speech and music being left to each culture's emic (insider, subjective) conceptions, rather than being defined objectively by outsiders. Thus, our analyses suggest that there is no absolutely universal and objective definition of music, but that Lomax and Grauer's definition may offer a useful working definition to distinguish music from speech.

Whereas some of the universals we identified—such as discrete pitches and isochronous beats—have long been speculated to be universal, many of the features we identified came from rarely discussed domains, including performance style and social

context. In particular, the network that we identified of 10 features linked by universal relationships crossed all of the domains except pitch, linking repetitive formal structures, regular rhythms, simple syllabic singing style, and use of percussion instruments centered on a communal, participatory social context involving group performance and dancing—a combination that is also reminiscent of religious rituals and altered states of consciousness (49, 50). This network includes all four "core components of human musicality"—song, drumming, social synchronization, and dance—identified recently by Fitch (47) as promising candidates for future cross-species comparative study. We suggest that the statistical universals we identified represent additional candidates for expanding the scope of research on music cognition and music evolution, which has traditionally focused primarily on pitch and rhythm processing of Western music (16, 51).

Our current analyses only allow us to speculate on the reasons for the existence of these statistical universals, which are likely to be quite diverse. For example, at a proximate level, descending/arched contours and small intervals are consistent with the idea that there are basic motor constraints on vocalization, something that is shared with speech and animal song (22). Meanwhile, at the functional level, the predominance of male performances in our sample is also shared with animal song, consistent with Darwin's hypothesis that music evolved through sexual selection for individual display (52, 53). However, the network of universal relationships we identified centered on synchronized group performance and dancing is largely unique to human music and goes against the idea of soloists signaling their quality, as envisaged under the sexual selection hypothesis. Instead, this network is consistent with the notion that a primary function of musical performance cross-culturally is to bind groups together and to coordinate their actions (25, 54, 55), whereas the predominance of male performers in our sample may perhaps be more reasonably explained by widespread patriarchal restrictions on female performance (11, 54, 56). Importantly, however, these explanations need not be mutually exclusive, and the reasons that music evolved in the past might not necessarily correspond with its current functions (ref. 11 and *SI Discussion*).

Human music can indeed take on a wonderful variety of different forms, yet the presence of many statistical universals supports the idea that there are factors that constrain the diversity of culturally learned behaviors such as music. We have speculated that many of the aspects we have identified as being common to most music can be linked to the coordination and cohesion of human groups. Now that these regularities have been established, more-nuanced ideas about the reasons behind their existence can be explored through further cross-cultural and cross-species comparative research. More generally, this study highlights the benefits of a systematic, cross-cultural, and multidisciplinary approach to studying music (27). Whereas scientific research on music has largely been limited to Western classical and popular music, our global music dataset fills a crucial void in our understanding of human music and will hopefully serve to complement existing research and encourage larger-scale cross-cultural projects in the future. By combining traditional ethnomusicological approaches with state-of-the-art scientific tools, the cross-cultural study of music may offer far-ranging insights into human biological and cultural evolution.

Materials and Methods

This section is a summary of methods used. See *SI Materials* and *SI Methods* for full details.

Data. The presence or absence of 32 candidate features was operationalized using a musical classification scheme created by combining preexisting musical classification schemes (refs. 26, 29, and 30 and *SI Materials*). When features could be coded as neither present nor absent, this was coded as NA (not applicable) and excluded from the analyses (alternative analyses

including NA codings are shown in Fig. S3). P.E.S classified the 304 recordings from the *Garland Encyclopedia of World Music* (31) manually and supplemented and corrected these classifications with metadata from the *Encyclopedia* and by contacting recording fieldworkers. Full codings and metadata for the 304 recordings analyzed are available in Dataset S1. E.S. independently coded a randomly selected subset of 30 recordings while being blind to the study's hypotheses to assess interrater reliability, which averaged 81% (Table S3).

Primary Analyses. Universal features and relationships were assessed across the subsample of indigenous music ($n = 201$) using a phylogeny based on language classification (ref. 42 and Fig. S1) to control for nonindependence (57, 58). To assess whether the patterns seen in these global scale analyses were consistent at a regional level, we examined the direction of the trend for a given candidate universal across all nine geographic regions defined a priori by the *Encyclopedia*'s editors ($n = 14$–54 recordings per region, Fig. 1). Because language phylogenies are not perfect proxies for historical relationships between cultures, these regional analyses enable us to capture the potential bias introduced by regional musical influences that cross linguistic boundaries, such as the Middle Eastern classical *maqam* and related systems that include Afro-Asiatic, Indo-European, and Turkic-speaking cultures, and that might not be fully accounted for in the phylogenetic comparative analysis. To assess trends in the regional analyses, we used both indigenous and nonindigenous recordings to calculate frequencies for the universal features, and Pearson's Φ coefficients for the universal relationships (*SI Methods*).

Confirmatory Analyses. A number of confirmatory analyses were performed to check the robustness of the phylogenetic comparative analyses. Previous simulation work has shown that phylogenetic comparative analyses can be fairly robust to horizontal transmission (59), but we have further tried to mitigate this source of error in the present analyses by confining our phylogenetic analyses to indigenous music. Furthermore, to specifically examine the robustness of our results to horizontal transmission, the results using the indigenous subsample ($n = 201$) were compared with phylogenetic comparative analyses run on the full sample of recordings ($n = 304$; i.e., including the 103 nonindigenous recordings with evidence of horizontal transmission).

Second, the topology of the phylogenetic tree used in these analyses is based on established classification schemes (42) in which neither the branch lengths within each language family nor the relationships between language families are known (i.e., the tree was constructed "by hand" and is not based on an analysis that produces branch lengths in units of time or linguistic change). Our results could therefore be contingent on our decision to make all branch lengths, including the branches joining the language families, equal (by taking a value of 1; see *SI Methods* for further discussion of complications involving comparison across language families). To check how sensitive our results were to this assumption, we performed three different transformations of the branch lengths to produce three new highly contrasting ultrametric phylogenetic trees that were used in confirmatory analyses (Fig. S2).

These confirmatory analyses produced results that were highly consistent with our main findings, with very high correlations between parameter estimates (mean $r = 0.98$, minimum $r = 0.92$; see *SI Methods* and Tables S4 and S5). Except for one minor discrepancy involving idiophone-group relationships—which does not affect our conclusion that percussion instruments in general are part of a network of universal relationships—the final lists of statistical universals were identical under all of the alternative analyses (*SI Methods*). Thus, our analyses were highly robust to altering the assumptions that underlie the phylogenetic comparative analyses. Furthermore, our regional-consistency analyses, based on geographic/musical regions defined by the *Encyclopedia*'s editors rather than linguistic affiliations, help to ensure that the statistical universals we identified are not simply artifacts of our use of phylogenies based on language. Finally, because the recordings for each of the nine regions were selected by a different team of leading ethnomusicologists without any formal selection criteria, our regional-consistency analyses also help to control for differences in the implicit selection criteria that they may have used, including how they may have defined "music."

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