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Mapping Music: Cluster Analysis Of Song-Type Frequencies Within And Between Cultures

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Abstract. Understanding cross-cultural patterns of musical diversity requires some method of visualizing these patterns using maps. The traditional methods of cross-cultural comparison have been criticized for ignoring the rich diversity of musical styles that exists within each culture. We present a compromise solution in which we map the relative frequencies of different "cantogroups" (stylistic song-types) both within and between cultures. Applying this method to 259 traditional group songs from twelve indigenous peoples of Taiwan, we identified five major cantogroups, the frequencies of which varied across the twelve groups. From this information, we were able to create musical maps of Taiwan. (This article refers to a supplementary speadsheet that can be found at http://neuroarts.org/pdf/Savage_Brown_2014_Supplement.xls)

Ethnomusicologists have an ambivalent relationship with maps. On the one hand, maps provide an essential tool for understanding the cross-cultural diversity of musical styles, which has been one of the primary goals of ethnomusicology since its beginnings in the comparative musicology of the late nineteenth and early twentieth centuries (Nettl 2005). On the other hand, ethnomusicologists have increasingly become aware of and interested in intra-cultural diversity, which is more difficult to visualize using maps.

Many ethnomusicologists have tried—either visually or verbally—to create maps of the major musical regions of the world following a model we will term here the "one culture = one music" model, in which the basic musical style of a culture is classified and mapped onto its geographical boundaries. This has often been inspired by similar attempts of anthropologists to create maps of culture areas or Kulturkreis (culture circles). Nettl (2005) offers a thorough review of major attempts at musical mapping and their various strengths and weakness, notably by Sachs (1929) for musical instruments of the world, Roberts (1936) and Nettl (1954) for Native America, Merriam (1959) for Africa, McLean (1976) for Oceania, and Lomax (1968) for world song style. Of these, Lomax's analysis of over 4000 songs from more than 200 cultures using his Cantometric classification scheme and its distillation into a map of ten major song-style regions (Lomax 1976) was certainly the most comprehensive and arguably the "least unsatisfactory" (Nettl 2005:330) attempt to create a musical map of the world.

Leaving aside numerous methodological and political issues involved in generating and interpreting such maps (e.g., Maranda 1970; Erickson 1978, Nettl and Bohlman 1991; Nettl 2005; Savage and Brown 2013), there remains the fundamental problem of how to represent musical diversity on a map. As stated above, most previous attempts at creating musical maps used a one culture=one music model where the basic musical style of a culture was mapped onto its geographical boundaries. Although Lomax (1976) sub-divided some geographic regions—notably Taiwan and Oceania—into several song-style regions, his map did not allow for multiple styles within a single song-style region. McLean's (1979) map came perhaps the closest to achieving this goal by using dashed and solid lines, and allowing these boundaries to overlap one another. While these maps provided some sense of intra-cultural musical diversity, they offered only a limited sense of the relative frequencies of the different musical styles within a given region.

In recent times, ethnomusicologists have come to focus more on intra-cultural diversity than on cross-cultural diversity, leading some to question the value of musical maps. While earlier scholars who created musical maps were aware of the reductionism inherent in assigning a single musical style to a culture, they also believed that minimal information was lost in the process, with Lomax (1968) in particular arguing that cultures' musical styles are relatively homogeneous. Others, using their own fieldwork experience however, argued that music was so heterogeneous as to make the mapping of a single "favored song style" (Lomax 1968:33) onto a geographic region all but impossible (Henry 1976; Feld 1984). Recently, an analysis of traditional group songs from Taiwan and the Philippines lent support to these claims, finding that 98 percent of the musical variability of a cross-cultural sample was accounted for by differences within cultures rather than differences between them, a profile strikingly similar to the partitioning of genetic diversity within and between cultures (Rzeszutek, Savage, and Brown 2012).[1] While this analysis succeeded in quantifying musical diversity, it did not attempt to provide a better means of mapping it.

Population geneticists, however, have long been aware of the issue of intra-cultural diversity and have developed phylogeographic methods for mapping genes onto geographic regions (Cavalli-Sforza, Menozzi, and Piazza 1994). The most influential method has been to measure and map the frequency of occurrence of various genetic types within and between populations. Unique DNA sequences are referred to as haplotypes, and groups of related haplotypes are referred to as haplogroups. Many cultures contain a diverse mix of individuals representing different genetic haplogroups, and mapping the relative frequencies of these different haplogroups has proven to be a powerful tool for visualizing genetic diversity and tracing prehistoric human migrations (Cavalli-Sforza et al. 1994).

To take a simple hypothetical example, a particular world region might contain three haplogroups: A, B, and C. Thirty percent of individuals from one area might possess haplogroup A, 30 percent haplogroup B, and 40 percent haplogroup C, whereas 50 percent of individuals from a second area might possess haplogroup A, 40 percent haplogroup B, 10 percent haplogroup C. Thus, while many genetic types might be shared between the groups in the region, the relative frequencies of these types might vary significantly among them, thus providing clues about their histories.

Applying these concepts to music, we introduce the new notion of a cantogroup or stylistic song-type.[2] By analogy with genetics, unique combinations of musical features will be referred to as cantotypes, and groups of similar cantotypes as cantogroups. Our method takes its lead from population genetics in that, instead of assigning a single musical style to each geographic region or ethnolinguistic grouping, we characterize a specific area as a mosaic with respect to the frequency of the cantogroups that make up the group of populations under consideration. So, just as a geneticist represents a population of people in terms of the relative frequencies of haplogroups contained within it, and just as different populations vary with respect to the relative proportions of haplogroups, so too can we represent a population in terms of the relative frequencies of cantogroups that make up its musical repertoire. Further, we can represent differences between groups in terms of the varying relative proportions of the cantogroups within each group. The basic idea of comparing relative frequencies of musical features across cultures is not new, being implicit in even the earliest comparative musicological descriptions and being subject to relatively sophisticated statistical analyses by the 1950's (Freeman and Merriam 1956). Some additional underlying concepts for this analysis have been developed to varying degrees in publications by Lomax (1968, 1976, 1980), Aarden and Huron (2001), Leroi and Swire (2006), and Grauer (2011), but we have synthesized them here for the first time into a comprehensive framework.

In order to illustrate this novel method of comparative analysis for music, we used music from twelve groups of indigenous peoples living in Taiwan[3]—the most diverse region in Lomax's map—as a test case. We classified 259 songs using the CantoCore classification system (Savage, Merritt, Rzeszutek, and Brown 2012), applied cluster analysis to identify major cantogroups across the twelve populations, and then created maps of relative cantogroup frequencies for each population. Compared to the standard one culture=one music approach, our method permits a quantification and mapping of cross-cultural differences, while at the same time respecting the diversity of musical styles within each group.

Indigenous Music In Contemporary Taiwan

Taiwan provides an excellent example for a case study in mapping musical diversity. Although it is a small island, it has some of the highest levels of diversity in the world, not only musically but also in other domains, such as linguistics and genetics. While these populations, like indigenous peoples in most parts of the world, have been greatly affected by colonialism and globalization, most have managed to preserve substantial amounts of their musical, linguistic, and genetic heritages even as they have adapted to changing lifestyles. Importantly, Taiwan's musical diversity has led it to be well-documented by ethnomusicologists from both inside and outside of Taiwan.

There are currently fourteen officially recognized groups of indigenous peoples in Taiwan, numbering about 500,000 in total, or about 2 percent of Taiwan's modern-day population. All of the indigenous peoples originally spoke Austronesian languages and are thought to share descent from a proto-Austronesian culture that first occupied Taiwan at least 5,000 years ago (Blust 1999; Bellwood and Dizon 2008; Gray et al. 2009). Taiwan's high degree of linguistic diversity is one of the strongest pieces of evidence that has led to it being widely regarded as the primary homeland of the more than 1,000 Austronesian-speaking peoples that are spread throughout the Pacific and Indian Oceans, as far west as Madagascar, as far east as Rapanui (Easter Island), and as far south as New Zealand.[4] Nine of the populations (Amis, Atayal, Bunun, Paiwan, Puyuma, Rukai, Saisiyat, Tao, and Tsou) have long been recognized as distinct from one another. Between 2000–2008, five populations that were previously lumped together with nearby groups (Thao, Kavalan, Truku, Sakizaya, and Sediq) were officially recognized as distinct by the government. Many groups, most notably the various Siraya populations in the western plains, still remain unrecognized.

Beginning in the seventeenth century, successive colonizations by the Netherlands, China, Japan, and the Republic of China (Taiwan), resulted in the introduction of new musical styles and contexts, such as Christian hymns, folk and classical music from China, and *enka* and karaoke from Japan. Colonialism also resulted in the suppression of many indigenous musical traditions—particularly those involving headhunting, which was formerly widespread but is no longer practiced today (Kurosawa 1973; Loh 1982; Hsu 2002; Tan 2008). Due to these influences, as well as more general economic, demographic, and cultural trends accompanying globalization, contemporary indigenous Taiwanese music spans a vast variety of forms, including traditional music, with minimal cross-cultural influence; contemporary Chinese, Japanese, and Western music performed and enjoyed by indigenous Taiwanese; and much music with traditional roots that has been substantially influenced by cross-cultural contact. This last category includes not only obvious hybrids, such as Siraya songs sung in Chinese or Christian hymns sung in Bunun style, but also newly-composed urban songs with traditional roots or songs influenced by inter-tribal contact, such as the pan-aboriginal style often marketed to tourists. Tan (2008) described some of the complexities and politics of these interactions, focusing on the famous example of the unauthorized remix of a recording of a traditional Amis weeding song (Enigma's "Return to Innocence") that became famous worldwide when it was used to promote the 1996 Atlanta Olympics.

The Song Sample

The choice of a data sample depends greatly on the research question in mind. For example, a project from our group focusing on the relationship between musical diversity, genetic diversity, and ancient migrations among Austronesian-speaking peoples used a sample of hundreds of traditional group songs from a variety of genres in and around Taiwan (Rzeszutek, Savage and Brown 2012; Brown et al. 2014), whereas Tan (2008) emphasized the evolution of a single song as it came to symbolize interactions between indigenous Taiwanese music and forces of globalization. One could easily imagine research questions that might require a sample of hundreds or thousands of songs from a single culture or village, or on the other hand, questions that might require only a handful of examples from a specific genre sparsely sampled from around the world.

To demonstrate our new mapping methodology, we chose to use the sample of 259 traditional group songs from twelve indigenous Taiwanese populations analyzed by Brown et al. (2014) because it provided a useful balance of cross-cultural and intra-cultural diversity from a relatively well-sampled but geographically-restricted area.[5] These songs come from ethnomusicological field recordings by Kurosawa Takatomo, Lü Bing-Chuan, Hsu Tsang-Houei, and Wu Rung-Shun, and have mostly been made available for free by the Taiwan Music Institute at *http://music.ncfta.gov.tw*. Full information for these songs, including discographic information, classifications, and cross-references to online recordings are listed in the supplementary online material.[6] This sample also allowed us to demonstrate some potential applications of the resulting maps, specifically regarding migrations of Austronesian-speaking cultures, and to highlight some of the strengths and weaknesses of the methodology. Some of these weaknesses (of which there are many) are described in detail in the Limitations section of the discussion below. Meanwhile, it is crucial to bear in mind that the resulting maps cannot simply be seen as representative of indigenous Taiwanese music in general without careful consideration of sampling limitations and other issues, such as using discrete boundaries to map the populations.

Methods

Here, we introduce a three-step framework for classifying, clustering, and mapping cantogroup (stylistic song-type) frequencies within and between cultures. An overview of these three steps is shown in Table 1.

Step 1: Classification of Songs

Patrick Savage coded all of the songs using CantoCore (Savage et al. 2012), a song-classification scheme modeled after Cantometrics (Lomax and Grauer 1968; Lomax 1976). This scheme codes twenty-six characters related to song structure, including rhythm, pitch, text, texture, and form. The complete coding scheme is presented and explained in Savage et al. (2012), which also describes the complexities of the classification process, including the presence of both

Table 1. Overview of the 3-step analysis framework.

Step	Level Of Analysis	Methods	Description
1. Classification of songs	Individual songs	CantoCore (Savage et al. 2012)	Classify each song according to 26 features of song structure (See Supplementary Spread sheet)
2. Clustering of songs into "cantogroups" (stylistic song-types) (Fig. 2)	All songs of a corpus	k-means cluster analysis (Hartigan & Wong, 1979)	Assign songs to song-type clusters based on their stylistic similarities, *irrespective of geography*
3. Mapping of cantogroup frequencies (Fig. 4)	Geographic regions		Map cantogroup frequencies onto geographic regions, emphasizing:
		a) Pie charts	a) All cantogroups in each culture's repertoire
		b) Modal profiles	b) The most common cantogroup in each culture's repertoire
		c) Contour maps	c) Cross-cultural patterns in the frequencies of each cantogroup

ordinal characters (e.g., melodic interval size varying from small to large) and nominal characters (e.g., different discrete meter-types, such as a-metric, hetero-metric, and iso-metric), as well as the occasional need for multi-coding, in other words, the need to select multiple character-states for the same song when that song has diverse features (e.g., both descending and arched melodic contours).

Step 2: Clustering of Songs into Cantogroups (Stylistic Song-Types)

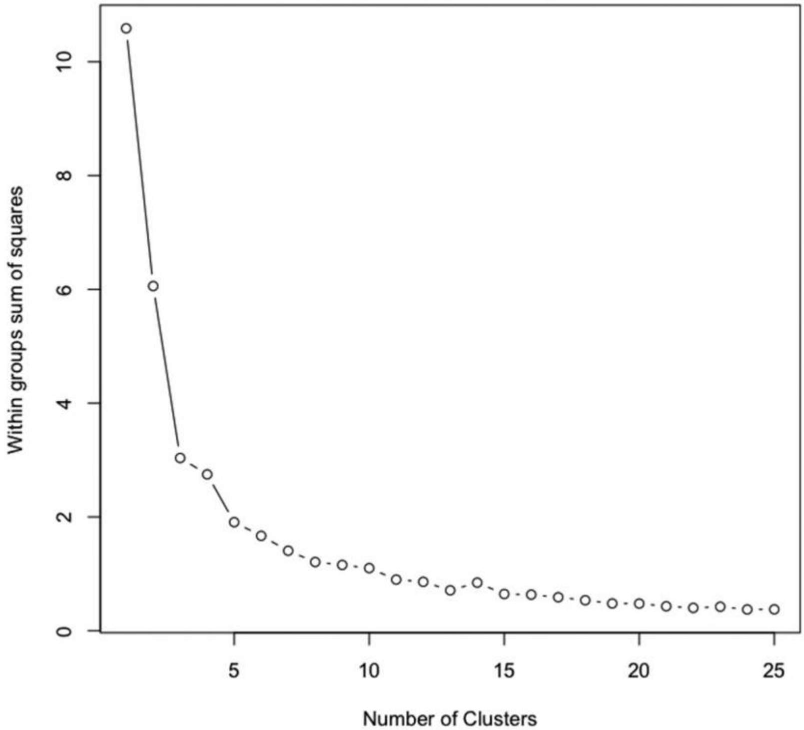
Step 2 examines musical similarities among the songs. For technical reasons, this is typically referred to as a distance (difference) rather than a similarity. Hence, the end result is a distance matrix representing the distances between all 33,411 pairs of songs in the sample of 259 songs as a number between zero and one, where zero represents two songs with identical CantoCore codings (i.e., zero distance between them) and one represents two songs with maximally different codings on all of the twenty-six CantoCore features coded. Such a distance matrix can be visualized in two dimensions using the multivariate statistical method of multidimensional scaling (MDS), as described by Rzeszutek et al. (2012).

Next, we looked at the clustering of songs into cantogroups (stylistic song-types). In order to do this, we analyzed the musical distance matrix using k-means cluster analysis (Hartigan and Wong 1979), using the statistical program, R V2.11.0 (R Development Core Team 2011). K-means cluster analysis is a standard method of looking for clusters in a dataset that allows one to identify the number of clusters that gives the most parsimonious balance between minimizing the number of clusters and minimizing variance within each cluster. In the case of our analysis, identification of the elbow of the scree plot (Figure 1), as recommended by Everitt and Hothorn (2010), suggested that five clusters/cantogroups was the most parsimonious grouping for our corpus of 259 songs. This result was then used in the next step of the analysis, which attempted to visualize cantogroup frequencies for each of the twelve populations whose music contributed to the dataset.

Step 3: Mapping Cantogroup Frequencies

For each of the twelve populations, cantogroup frequencies were calculated as the percentage of a group's songs belonging to each of the five cantogroups. The multidimensional scaling plot in Figure 2, below, shows how each of the 259 songs was assigned to one of the five cantogroup clusters generated using the k-means cluster analysis. It was then a simple matter of looking at each population, one at a time, and calculating the percentage of its songs that were members of each of the five cantogroups. Cantogroup frequencies were mapped in three different ways:

Figure 1. Scree plot for the k-means cluster analysis of the 259-song corpus. As the number of clusters increases, the variance (within-group sum of squares) decreases. The elbow at five clusters represents the most parsimonious balance between minimizing the number of clusters and minimizing the variance within each cluster.



1. Pie charts: The relative frequency of each cantogroup was plotted separately for each population as a pie chart. Importantly, any given pie chart provides information about musical diversity *within* a culture, whereas a comparison of pie charts among groups provides information about diversity *between* cultures.
2. Modal (most common) profiles: The modal cantogroup for each population was mapped in a manner akin to Lomax's modal profile. This representation only provides information about between-culture musical diversity since each culture is represented exclusively by a single cantogroup.
3. Contour maps: Relative frequencies were plotted separately for each cantogroup as contour maps using the Kriging algorithm in Surfer V8.0 with default settings. This representation is similar to that of the modal profile in that it emphasizes cross-cultural patterns by focusing on only a single cantogroup at a time, but it is similar to the pie-chart method in that it allows the representation of more than one cantogroup for each culture. This method makes no reference to cultural groups but simply demonstrates the geography of the region. Not surprisingly,

the hot spots on the map correspond to cultures showing high frequencies of that musical type.

Song-Level Analysis and Clustering

In order to demonstrate the musical relationships among the 259 songs used in our sample, we used a multidimensional scaling plot, as shown in Figure 2 below. Songs that are closer together in the plot have greater musical similarity—as based on their CantoCore codings—than songs that are further stylistic song-types apart. Songs are colored in grayscale according to their membership in one of the five cantogroups identified using k-means cluster analysis.

For ease of interpretation, we have given each cantogroup a label according to its predominant geographic distribution (see Figure 2, below), but the cluster analysis does not incorporate any *a priori* information about cultural or geographic affiliations. The five cantogroups correspond well with our qualitative

Figure 2. Multidimensional-scaling visualization of the cluster analysis of 259 traditional group songs from twelve indigenous peoples of Taiwan. Each circle represents a single song, color-coded in grayscale according to its membership in one of five cantogroups (stylistic song-types), as identified through k-means cluster analysis and shown in the legend to the right of the figure. Key musical features of each cantogroup are presented in Table 2 and are described in the text.

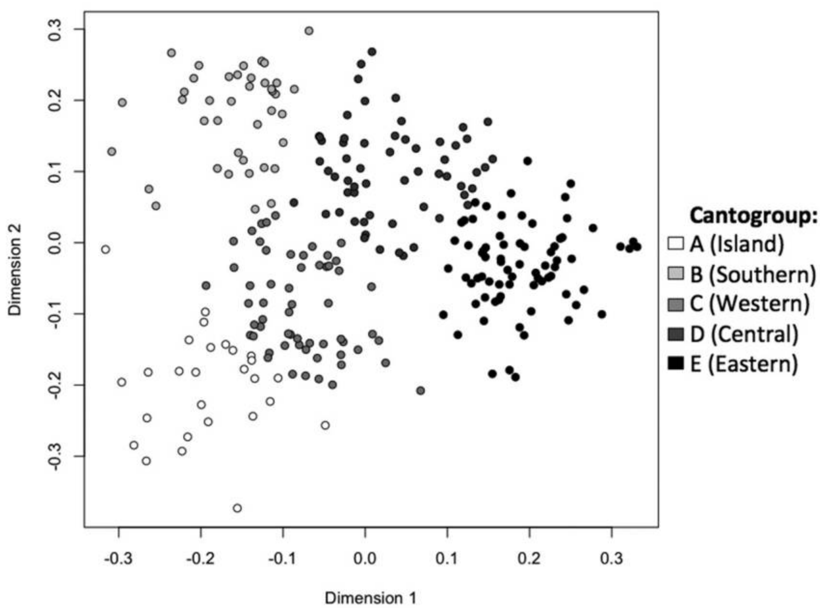


Table 2. Simplified description of notable musical features of each of the five cantogroups, color-coded in grayscale as in Figures 2 and 3. Precise definitions of terms can be found in Savage et al. 2012). Not all songs in each cantogroup necessarily contain all of these features, since cantogroups are defined based on overall similarity rather than any particular feature.

Cantogroup	Notable Musical Features
A ("Island")	Irregular—a-metric, small melodic range, sparse scales (<4 notes), long phrases, loosely coordinated unison and/or hetero-rhythmic, and heterophonic
B ("Southern")	Irregular—iso-rhythmic ("homophonic"), hetero-contour ("drone"), hemitonic, hetero-metric, small melodic range, low durational variability
C ("Western")	Semi-regular–largely one-part ("monophonic"), hetero-metric, sparse scales (<4 notes), long phrases
D ("Central")	Semi-regular—iso-rhythmic ('homophonic"), consonant, short phrases, descending/arched contours
E ("Eastern")	Regular—iso-metric, moderately dense (4–5 note) scales, large melodic range, some responsorial and/or polyphonic (Amis only)

musical intuitions about the stylistic song-types for these populations and with previous work by Kurosawa (1973), Loh (1982), and Hsu (2002).

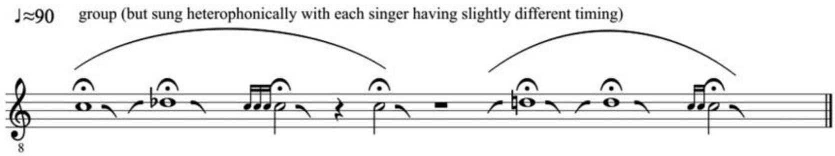
Table 2 presents a summary of some of the salient musical features of each cantogroup, color-coded as in Table 2, above. The progression from cantogroup A to cantogroup E could be thought of as an approximate progression along a spectrum of musical regularity (Savage et al. 2012): songs of types A and B tend to be irregular, i.e., non-metric, non-motivic, hetero-rhythmic or drone-based, hemitonic (chromatic), and have a small melodic range, compared to the more regular songs of type E that tend to be metric, motivic, mono- or polyphonic, anhemitonic, and have a large melodic range. Cantogroups C and D represent intermediate states between these stylistic extremes. For example, cantogroups C and D tend to have moderate ranges and hetero-metric meters, but cantogroup C tends to be monophonic while cantogroup D tends to be homophonic. This description is not meant to be comprehensive or apply to each song in each cantogroup, but is simply designed to show some of the key features that broadly distinguish each of the five major cantogroups identified in the k-means clustering analysis for the twelve populations. To provide concrete examples of these abstract descriptions, we have transcribed brief excerpts from prototypical songs from each cantogroup in Figure 3.

Cross-Cultural Distribution of Cantogroups

Our analysis allows us to move beyond the one culture=one music approach and think about each population as a mosaic of stylistic features, as represented

Figure 3. Transcriptions of short excerpts from representative songs from each of the five cantogroups described in Table 2. Lyrics are taken from published liner notes and are not included for songs that use vocables (non-lexical syllables). All songs have been transposed to end on C for consistency. See table in supplementary online material for additional song meta-data and access to recordings.

(a) 30-second excerpt (1:22–1:52) from song no. 195 (*Millet Harvest Song* from the Tao [Yami]), representing Cantogroup A (Island). Notated a minor 3rd above actual pitch.



(b) 27-second excerpt (0:27–0:54) from song no. 142 ("A Welcoming Song from the Rukai"), representing Cantogroup B (Southern). Notated a minor 2nd below actual pitch.

(c) 28-second excerpt (0:06–0:34) from song no. 183 ("Song to Welcome Gods from the Saisiyat"), representing Cantogroup C (Western). Notated a major 3rd above actual pitch.

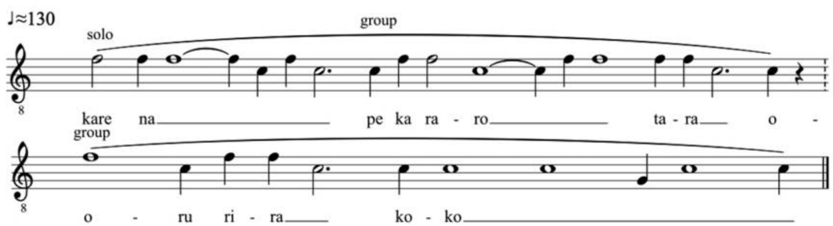
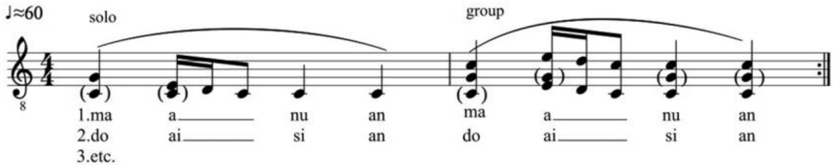


Figure 3. (cont.)

(d) 16-second excerpt (0:22–0:38) from song no. 43 (*A Song for Healing and Expelling Evil* from the Bunun), representing Cantogroup D (Central). Notated a minor 2nd below actual pitch.



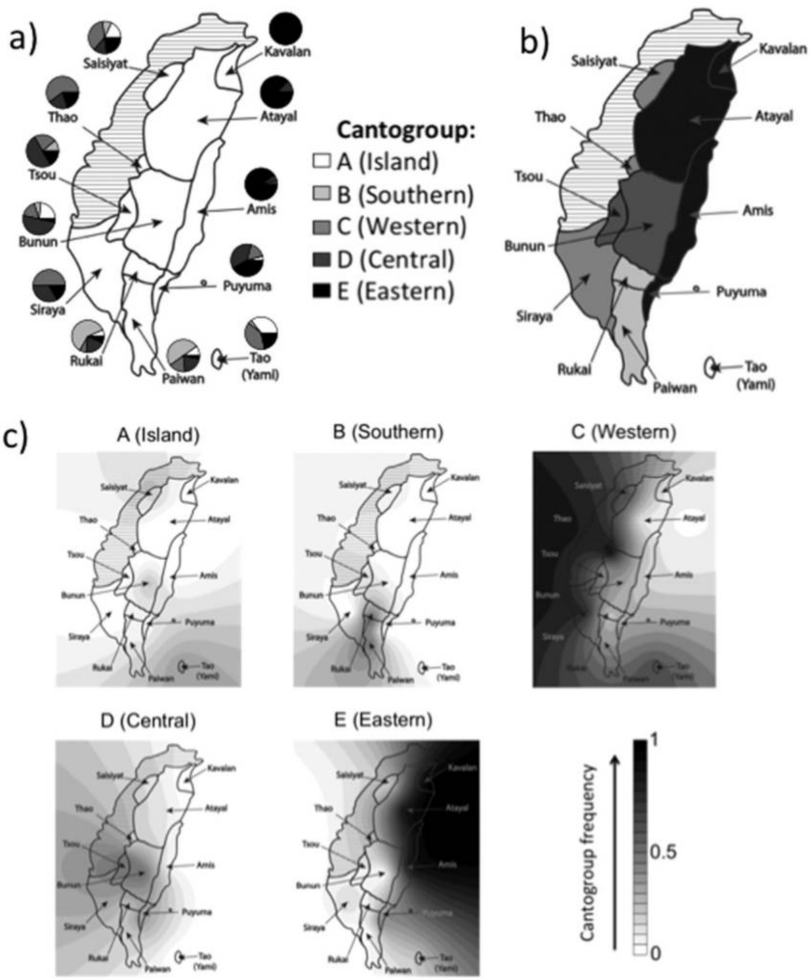
(e) 20-second excerpt (1:00–1:20) from song no. 2 (*The Elders' Gathering Song* from the Amis), representing Cantogroup E (Eastern). Notated a minor 3rd lower than sounds.

in our analysis by the diversity of cantogroups. Figure 4 shows maps of Taiwan with the cross-cultural distribution of cantogroup frequencies visualized in three ways. In Figure 4a, each group is associated with a pie chart that shows the relative frequencies of the five cantogroups in each group's repertoire. In Figure 4b, each population's area is colored according to its modal cantogroup. The one exception is the Tao, who are assigned to the Island cantogroup A although they have a slightly higher frequency of the Western cantogroup C.

This highlights the weakness of the modal-profile method in cases where two song-types are almost equally common. In this case, we have chosen here to represent the Tao by the more distinctive cantogroup (A) rather than the slightly more frequent cantogroup (C). The color-coding in Figures 4a and 4b is the same as in Figure 2 and Table 2. The same information is visualized in a different way in Figure 4c, where the frequency of each of the five cantogroups is plotted on five separate maps to better visualize geographic trends.

This cluster analysis demonstrates some important findings about Taiwanese indigenous music.

Figure 4. a) Musical maps of twelve indigenous peoples of Taiwan. a) A map based on relative cantogroup frequencies. Relative frequencies of all five cantogroups are shown separately for each of the 12 Taiwanese populations using pie charts. See Figure 2 for each population. This map is similar to that in Figure 4a except that only the dominant cantogroup is shown, and this is placed onto the geographic region for each population. The color-coding of cantogroups in a) and b) is the same as in Figure 2 and Table 2. c)Frequencies of each of the five cantogroups are visualized on five separate contour maps. Note that the color-coding in c) is different from a) and b)—now, darker colors represent regions of higher frequencies of that cantogroup, as shown in the legend on the bottom right. Population locations are based on maps from Trejaut et al. (2005) and Li (2008), and are merely approximate, highly simplified representations of the complex populations demography.



1. Geographic trends. Geography is an important factor in Taiwan's musical diversity, particularly its high mountains running down the center of the island and the ocean separating Lanyu (Orchid) Island from the mainland. Populations on the western side of the mountains tend to be dominated by the Western cantogroup C (medium grey color), whereas those on the eastern side of the island have a much larger representation of the Eastern cantogroup E (black color). In other words, populations on the eastern side of the island have songs that seem to have more musical regularity (e.g., metric rhythms, motivic melodic patterns) than do those on the western side of the island.
2. Repertoire diversity. Some groups, such as the Atayal and Kavalan, are dominated by a single style, whereas others, such as the Saisiyat, have complex mixtures of all five styles, hence having more diverse repertoires (relatively speaking).[7] Importantly, our analysis allows us to move beyond the mere existence of musical diversity and attempt to quantify it.
3. Long-distance similarity. In addition to observing expected trends of musical similarity between neighboring groups (e.g., Paiwan and Rukai in the south), we also found some evidence for similarities between populations that are quite distant geographically, as seen between the presence of the Island cantogroup A (white color) among a subset of the repertoires of the Tao, Bunun and Saisiyat, who are all geographically and culturally isolated from each other by a combination of mountains, oceans, and neighboring populations.
4. Nearby dissimilarity. We also see situations in which neighboring groups have dissimilar musical styles, as in the case of the Bunun and Amis.

We can reduce the findings of the above analysis in the manner that others have done before us and present a map of the single dominant style of each culture, which Lomax (1968) referred to as the modal profile. A comparison of Figures 4a and 4b, for example, shows the power of our cluster analysis. While we can indeed reduce the intra-cultural musical diversity to a single dominant style, as in Figure 4b, we can also visualize information about intra-cultural diversity, as shown in Figure 4a. Hence, the focus can be on inter-cultural differences, intra-cultural diversity, or a combination.

Maps and their Meanings

We have presented a new type of analysis for comparative musicological studies that permits inter-cultural analysis without ignoring intra-cultural diversity. In fact, the analysis can be employed equally well for either purpose, or better yet, in combination. For someone interested in regional cross-cultural trends, the map of dominant cantogroups in Figure 4b might best represent the preferred analysis, whereas for someone interested in stylistic diversity within a single culture, the pie-chart analysis of cantogroup frequency in Figure 4a might best represent the preferred analysis. To us, this approach represents a happy medium between the need for cross-cultural analysis and the need for taking intra-cultural musical diversity into account in comparative studies. As mentioned above, our analysis allows us to move beyond simply stating that intra-cultural musical diversity exists and allows us also to quantify this diversity. It is not the case that such diversity is the same in all cultures. Some cultures have relatively more homogeneous repertoires while others have more diverse repertoires. Our approach provides a method for measuring this diversity for the first time.

Although the use of group singing as a vehicle for, among other things, Christian missionization might have been expected to have had a homogenizing effect by removing regional patterns of musical difference, the appearance of clear regional patterns throughout Taiwan, and the existence of distinctive polyphonic traditions in many populations since before Christian influence (Loh 1982), suggests that the patterns may indeed be helpful in exploring older patterns of migration and contact.[8] In order to think about the migrational implications of our cluster analysis, we can now revisit the musical trends that this analysis revealed:

Geographic Trends

The analysis found an approximate division of the island into a western half (dominated by cantogroup C) and an eastern half (dominated by cantogroup E). This appears consistent with the linguistic models of Sagart (2008) and Li (2008), which propose that the initial colonization of Taiwan occurred on the west coast and circled the mountains to reach the east. Because the number of groups considered here is relatively small (twelve) and the mechanisms of musical evolution largely unknown, we do not feel that this musical sample provides enough evidence to distinguish between the specific details on which the two theories differ, such as whether the initial colonization began in the northwest (Sagart 2008) or the southwest (Li 2008).

Repertoire Diversity

Diversity is often used by scholars who study human migrations as an indicator of antiquity, with greater diversity (of genes, languages, etc.) being indicative of a longer period of residence in a given homeland (Sapir 1916; Cavalli-Sforza, et al. 1994). While we observed differences in cantogroup diversity among the twelve Taiwanese populations, we saw no obvious geographical or cultural trends in this parameter. Hence, musical diversity—at least for the corpus of songs used in our analysis—might not be a useful parameter for the study of the Austronesian migration.

Long-Distance Similarity

Long-distance similarities were observed between songs of the Tao population of Lanyu Island and those of the Bunun and Saisiyat in the north, as well as with the Ifugao to the south in the Luzon region of the northern Philippines (Rzeszutek et al. 2012). The Tao-Ifugao connection is consistent with the evidence from oral traditions, archaeology, linguistics, and genetics that suggests that the Batanes Islands were a waypoint for the expansion of Austronesian-speaking cultures from Taiwan into the Philippines, and that the ancestors of the Tao migrated north from the Batanes back to Lanyu Island within the last 1,000 years (Blust 1999; Bellwood and Dizon 2008; Li 2008; Gray et al. 2009; Loo et al. 2011).

However, the presence of some songs from Island cantogroup A within the repertoires of the Tao, Saisiyat, and Bunun does not seem to match any known extra-musical relationships between these peoples. Upon closer inspection, the broad similarities in their CantoCore classifications seem to conceal important differences in features regarding interval structure and performance style. For example, although most songs from this cantogroup contain sparse scales falling within a small melodic range, the Tao songs tend to be sung with a raspy voice and pitches seem to alternate with microtonal variation between the tonic and a whole tone above or below the tonic; the Saisiyat songs tend to be sung with a wide, open vocal style and pitches alternate between the tonic and a fourth above the tonic; further, the Bunun songs (mostly variants of the millet harvest song known as *pasibutbut*)[9] tend to have a few long held notes that gradually rise microtonally in pitch. Thus, it seems that these songs are less similar than they might appear on the surface, according to their CantoCore classifications, and it is probable that the existing similarities represent convergent evolution (i.e., independent invention) of similar musical styles rather than shared descent from the same proto-musical roots. Or, as John Blacking (1971) might put it, while these songs' surface structures have superficial similarities, they probably do not originate from the same deep structure.

Nearby Dissimilarity

Oftentimes, areas that look proximate on a map are actually separated by large geographic and/or cultural barriers. Hence, the observation of musical dissimilarity among what appear to be neighboring populations on a flat map may reflect geographical barriers to migration and exchange, as in the separation between the Bunun in the Eastern mountains and the Amis on the Eastern coast. In the case of Taiwan, the high degree of linguistic diversity (Blust 1999) serves as a further obstacle to cultural exchange.

Limitations of the Cantogroup Method of Mapping Music

Discreteness of Cultural Boundaries

In addition to the sampling limitations mentioned in the song sample section, a major limitation of the current study is its use of discrete boundaries to map the populations. Even if they had lived in neatly circumscribed boundaries (which is unlikely), the effects of intermarriage, urbanization, and globalization have certainly changed the population today. In fact, mapping people is at least as difficult as mapping music, and trying to simultaneously map both musical and demographic diversity becomes vastly more complex. Brown et al. 2014 have attempted a first step towards doing so by exploring correlations between musical and genetic diversity using restricted samples of both music and individuals that are relatively free from cross-cultural contact. To apply these types of methods to a less-restricted sample of contemporary Taiwan as a whole would presumably require more sophisticated mapping techniques, not to mention larger samples.

Choice of Classification Features

An important limitation of our analysis is related to the choice of musical features for classification. The logic of comparative musicological analysis has been discussed in great detail elsewhere (Savage et al. 2012; Savage and Brown 2013). In creating the CantoCore classification scheme, we intentionally excluded features related to performance style that are prominent in Lomax's Cantometrics scheme but that we found to be less reliable for classification. However, they are certainly important features of music. As the example of the Tao, Bunun and Saisiyat shows, these features can be a very useful supplement to CantoCore's structural approach. Whatever the preferences for features, we believe that classification must be a centerpiece of comparative musicological analyses, not only for questions, such as migration, cultural evolution, or musical universals (Brown and Jordania 2013), but also for questions regarding non-acoustic dimensions of musical classification, such as some aspects of social meaning (Feld 1984, Savage and Brown 2013).

Modeling Musical Evolution

A second limitation highlighted by the Tao-Saisiyat-Bunun example is the difficulty of distinguishing similarity based on phenetic (surface similarity) versus phylogenetic (common evolutionary history) considerations. While genetic haplogroups are explicitly defined by shared phylogenetic descent, we do not currently have good methods for distinguishing between surface similarity and shared history for music, and the degree to which concepts developed from evolutionary biology can be appropriately applied to cultural evolution is itself debated (Rahaim 2006, Tëmkin and Eldredge 2007; Savage and Brown 2013). This makes interdisciplinary comparisons with ethnographic, linguistic, genetic, archaeological, historical, and other sources of evidence all the more important.

Discreteness of Clusters

Another important limitation inherent in our analysis is that each song can only be assigned to a single cluster based on overall similarity across all twenty-six CantoCore features. While this is a useful method for exploring complex musical data, it is not ideal for representing songs that lie at the boundaries between different clusters or for modeling musical *admixture* (i.e., songs whose musical features are derived from multiple musical sources). In the future, more complex model-based k-means clustering methods such as STRUCTURE (Pritchard, Stevens, and Donnelly 2000) may be more useful for modeling such admixture than the current distance-based method. However, care will be needed in determining whether such evolutionary models are appropriate for modeling musical evolution.

Sampling

A crucial limitation that is inherent in any comparative project is sampling. One of the major criticisms of Lomax's Cantometrics project was that his samples of approximately ten songs per culture were too small (Maranda 1970). To avoid this, we aimed at assembling thirty songs per culture (a common sample size in population genetics), but to do this we relied on multiple recording sources stemming from different recording projects undertaken during various time periods from the 1940's to the 2000's. The sampling of songs for each of these recordings was in turn influenced by various factors and dynamics involving the performers, fieldworkers, recording labels, etc. For example, the number of variants of the pasibutbut millet harvest ritual song in the Bunun sample that fall into the Island cantogroup A seems to be out of proportion to its representation in the overall Bunun repertoire (although it is still less than half as common as the Central cantogroup D). This sampling bias most likely resulted from the extremely distinctive sound of this style, which is said to have originated from the sound of frogs croaking in a field (Tan 2008), leading it to become famous among ethnomusicologists around the world, being featured, for example, in collections such as *Les Voix du Monde* (Leothaud, Lortat-Jacob, and Zemp 1996).

There are many other sampling problems here that are both similar to and different from genetic sampling. Should very similar songs be excluded? If so, how should the cutoff be defined? How should one deal with the fact that many recordings are performed by the same singer or by musicians from the same generation, region, or pedagogical lineage? These problems are not unique to music, but they are also not identical to related problems in genetics or linguistics, or other disciplines. As in any sampling project, including those in hard sciences, such as population genetics, the sample is inevitably an incomplete snapshot of the true population.

Perhaps more worryingly, our decision to focus only on group songs, while providing the benefit of a more controlled sample, carries with it the drawback of ignoring the importance of solo songs in cultures' repertoires and perhaps exaggerating the importance of group songs. In future projects, we plan to include both solo and group songs. The drawback of using only group songs is most severe in the case of cultures such as the Atayal who sing solo songs almost exclusively.

Thus, although we wanted to include the Atayal for completeness because they are one of the largest groups in Taiwan in terms of both population and geographic area, this inclusion should be seen with caution. Not only were we forced to use a small sample (eight songs), but we were unable to include songs from the neighboring Sediq and Truku populations who were classified as Atayal sub-groups until very recently, songs that share many geographic, linguistic, and musical connections with the Atayal. There are no available recordings of traditional Truku group songs. For the Sediq, there are a number of recordings available of their unique canonic singing style, but unlike the Atayal there is no genetic sample available to allow for comparison with music to better understand Taiwan's migrational history. Ultimately, we decided to include the Atayal sample, problematic as it was, with the understanding that the goal of the present article is more to highlight our new methodology for mapping music than to provide a definitive musical map of Taiwan.

At various points, we had to refine and reanalyze the sample after realizing that we had accidentally failed to exclude certain non-traditional songs, duplicate songs, or children's songs.[10] Overall, the conclusions remained largely unchanged, suggesting that the current analysis is generally robust to small changes in the sample. However, the gold standard for scientific validity is independent replication, and we have included our song classifications and meta-data in the supplementary online material to aid researchers interested in exploring the replicability of our results (see http://neuroarts.org/pdf/Savage_Brown_2014_Supplement.xls).

Implications for Future Research

To ethnomusicologists with an interest in comparison but who think that comparative methods ignore the musical diversity found within cultures, our method might be able to offer something of value as its analysis rests on the balance between intra- and inter-cultural variation in musical styles. This applies not only to research on historical questions about prehistoric migrations such as we have touched on here, but also to questions that may be more useful to others interested in contemporary phenomena.

For example, one intriguing potential application of this method might be to provide additional documentation of the musical/cultural heritage of unrecognized peoples, such as the Siraya, to petition for governmental recognition, or for groups both within and outside of Taiwan to aid in their petitions for inclusion in UNESCO's Intangible Cultural Heritage lists (c.f. Hemetek 2006 for a discussion of such applied ethnomusicology in the case of Romani petitioning the Austrian government for recognition as a *Volksgruppe*).

The method, as we have shown, begins with a classification of songs using classification schemes like Cantometrics and CantoCore, followed by the clustering of songs into groupings that we refer to as cantogroups, by analogy to haplogroups in genetics. Using the cantogroup concept, we were able to show that cultures' musical repertoires represent mosaics of song-types and that each culture varies in the relative frequency of the cantogroups that make up its musical repertoire. Using this information, we were able to generate a variety of musical maps based on relative cantogroup frequencies. We believe that this analytical approach could provide rich opportunities for mapping the world's musical diversity.

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Notes

1. Importantly, differences between cultures were still highly statistically significant despite the high degree of intra-cultural diversity, indicating that—as in population genetics—the between-culture component of diversity is not meaningless (Edwards 2003). It should be noted, however, that this analysis was restricted to a specific set of structural features for a specific set of traditional group songs from Taiwan and the Philippines, and thus this number could well be different for different musical samples or analysis methods.

2. The current article deals specifically with stylistic song-types. However in principle, the cantogroup method could be applied to any kind of song-type, whether defined by stylistic features or otherwise.

3. These populations are commonly referred to as the "aboriginal tribes" of Taiwan, but "indigenous peoples" is the preferred name used by insiders and by the Council of Indigenous Peoples, the official governmental branch of the Executive Yuan in charge of indigenous affairs.

4. This debate carries political significance, particularly due to the sensitive political relationship between the Republic of China (Taiwan) and the People's Republic of China (Stainton 1999).

5. Note that this sample includes 39 songs from three populations (Thao, Kavalan, and Siraya) ultimately not published by Brown et al. (2014) becuase of difficulties in obtaining matching genetic data with which to make a direct comparison.

6. The majority of the songs have also been published commercially (Lü 1977; Cheng 1989; Gründ 1989; Wu 1992–1995, 1998; Wang 2008). See Lin (2013) for further information about this website.

7. Diversity in this case refers specifically to the different combinations of structural features and does not imply any value judgments about whether more diversity is a good or bad thing. Note that the relative amounts of diversity could also be affected by sampling issues, such as unequal sample sizes or the specific exclusion criteria used for the study.

8. Of course, there are many songs with explicit Christian influence in these peoples' repertoires, but these songs were not included in this particular sample.

9. Brown et al. (2014) excluded duplicate recordings of the same song from their analysis, but in the case of *pasibutbut* it is debatable whether the different pasibutbut variant recordings should qualify as duplicate recordings of the same song. Removing these samples would not affect any of the overall conclusions of this analysis, but this does highlight further difficulties in sampling restrictions.

10. These were excluded not because they are any more or less valuable, but because of the specific exclusion criteria developed with the aim of comparing musical and genetic diversity. Thus, children's songs were excluded because they had been predicted to show fewer cross-cultural differences due to developmental constraints resulting in a near-universal tendency towards simplicity and regularity.

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