

Which melodic universals emerge from repeated signaling games?

A Note on: Lumaca & Baggio (2017) Cultural Transmission and Evolution of Melodic Structures in Multi-generational Signaling Games

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Main Text (Word count: 1197)

Language and music are peculiar human behaviors. We spend a large portion of our lives speaking, reading, processing speech, performing music and listening to tunes. At the same time, we still know very little as to why and how these structured behaviors emerged in our species. For the particular case of music, the mystery is even greater than language. Music is a widespread human behavior which does not seem to confer any evolutionary advantage. A possible approach to study the origins of music is to hypothesize and empirically test the mechanisms behind this structured behavior [1, 2]. For language, potential mechanisms were first tested in-silico [3, 4], showing how random pairs of signal-meanings become more structured and systematic when artificial agents play a ‘game of telephone’ with them. These results were replicated with human participants evolving a language-like system [5], confirming the importance of computer simulations in testing hypotheses on the cultural evolution of human behavior. Finally, recent work applied this approach to musical rhythm [6], showing that musical structures can indeed emerge via cultural transmission .

A recent paper in Artificial Life adopted this methodological approach, testing the emergence of a sound system at the boundary between music and language [7]. Similar to communication systems found in humans, other animals and in-silico experiments, a meaning space was paired with a signal space. The meaning space coincided with a set of pictures showing different facial emotional expressions. The signal space was a set of 5-note patterns. Crucially, the experimenters randomly paired meanings to signals, which were in turn randomly structured. These random pairings of emotional expressions and random note sequences were then used in signaling games, where pairs of participants used note sequences to communicate emotional states. The resulting signal-meaning pairs, with all their human-introduced variations, were then used in new signaling games with new participants. Over time, the small biases introduced in each artificial transmission step accumulated, displaying quantitative trends. In particular, the authors found the emergence, over the course of artificial human generations, of features resembling some properties of language and music.

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50 A number of methodological solutions make this paper quite valuable. For instance, an obvious potential
51 confound when mapping proto-musical structures to emotional states is that some of these mappings are
52 already ingrained and universal in human cognition [8]. The authors circumvent this potential confound
53 by using the Bohlen-Pierce (BP) scale [9], to which the average human being is never exposed, rather
54 than the common 12 tone equal temperament scale (the black and white piano keys).

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56 For centuries, the study of music has been the sole prerogative of the humanities. Lately, however, music
57 research is being increasingly investigated by psychologists, neuroscientists, biologists, and computer
58 scientists [10-21]. Scientists need rigorous and operational definitions. One solution to define music is
59 looking at the most recurrent properties of musical cultures around the world [22, 23]. The resulting
60 properties, called (statistical) *musical universals* are features of music which appear above chance in all
61 world cultures. Recently, comparative musicologists compiled a list of 32 potential universals. Then, 304
62 music recordings from all over the world were coded and compared for presence or absence of each of
63 these features. Across human cultures, 21 features qualified as global universals, spanning melody,
64 rhythm, social context, performance style, etc [23].

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66 How do these universals arise? Some hypothesized that the process of cultural transmission might slowly
67 shape random signals into proto-musical systems [24]. Indeed, research tracing how rhythmic patterns are
68 learnt and transmitted in the lab showed convergence towards all 6 universals previously found for
69 rhythm [6]. Random sequences of durations are shaped into music-like rhythmic sequences [20]. Is this
70 also the case for melodic properties? The recent paper in Artificial Life did not tackle this question
71 directly [7], but might still provide insights on the emergence of melodic universals in human minds.
72 Although the original focus of the article was not on musical universals, it did investigate the
73 intergenerational transmission of melodic structures. By applying the musical universals framework to the
74 results of Lumaca and Baggio's signaling games, signals change, seemingly approaching some of the

melodic universals (see Table 1). In particular, the data provides indirect evidence for the emergence of melodic-like patterns which: (a) exhibit arched contours, (b) span small frequency intervals, and (c) possibly repeat within the system.

Lumaca and Baggio's work is an important and innovative piece of science on many levels. Notably, it provides some indirect, preliminary evidence for how the process of cultural transmission can make some acoustic features converge towards *melodic* universals. At the same time, a few experimental decisions make this work difficult to interpret robustly in light of all musical universals. First of all, the introduction of meaning in a work on musical structure is likely to divide readers. In fact, the field of music cognition is split between those arguing that music has no referential meaning attached, and others who believe music and meaning are indissoluble [25-27]. Moreover, even those who assume a large role for meaning in music would likely not think of that role as functioning in the way it is presented in this paper, where melodic signals are negotiated to refer to, and help a partner guess, a set of very specific referents [26]. Second, the experimental design puts strong constraints on the types of pattern seen by first generation participants. Musical tones are already discretized, and limited in duration and number of elements (exactly five tones per pattern). These a priori experimental constraints limit the dimensions along which the sound system could evolve, precluding in turn the possibility to test the emergence of most universals because these universals are already built-in into the system [6, 28]. These remarks might be useful to inform future research on the evolution of melodic universals. In particular, we suggest that an experimental design closer to Verhoef's work might be more appropriate to study the evolution of melodic universals [29-31]. If signal-meaning associations are removed and universals still emerge, the presence of meaning will be shown unnecessary for music to appear [6]; in fact, previous work by Lumaca and Baggio suggests that meaning should not play a role [32]. Similarly, if first-generation participants are exposed to patterns free to vary in duration and not already discretized, emergence of all melodic universals - including the transition from continuous to discrete pitches, organization of scales and constraints on phrase length - will be empirically testable [29, 30]. Finally, future experiments could

replace system learning for immediate recall. In other words, instead of having participants learn a whole system and then transmit it to the next participant, participants could learn and transmit individual patterns [6, 33]. Transmitting individual patterns (immediate recall) makes it harder for self-consistent systems of signals to emerge. Hence, if a system emerges nonetheless when employing the more conservative immediate recall method, a stronger pressure for systematicity must exist.

To conclude, a number of recent experiments has found direct or suggestive evidence for the emergence of proto-musical features in the lab [6, 7, 20, 28-30]. Given this amount of experimental human work, closed-form mathematical modeling and computer simulations are now needed to both test the internal consistency of experimentally generated hypotheses and make new predictions.

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119 Table 1. How musical universals related to melodies in [23] compare to evolved melodies in [7].

Melodic universal adapted from [23]	Evidence from [7]
(1) Sound systems show discrete pitches.	The emergence of this universal cannot be shown from data in [7], as the pitches were discrete to start with.
(2) Sound elements are organized in scales of few (≤ 7) elements per octave.	This universal cannot be shown from data in [7], as the unique elements were 5 or less to start with.
(3) Sound elements are distributed over non-equidistant frequencies.	This universal cannot be shown from data in [7], as the frequency distance between sound elements was experimentally fixed.
(4) Evolved melodies show descending or arched contours.	There is an increase of mirror patterns over generations, suggesting the emergence of arched contours (pg.416, paragraph 3.5, [7]). No evidence for descending contours is provided.
(5) Melody contours span small frequency intervals (≤ 750 cents, i.e. a musical fifth).	The mean interval size decreases over generations (pg.415, paragraph 3.3, [7])
(6) Sound sequences show presence of motivic patterns.	This universal cannot be shown from data in [7], as the duration of tones was fixed.
(7) Sound sequences consist of short phrases (≤ 9 seconds).	This universal cannot be shown from data in [7], as length of phrases was experimentally constrained.
(8) Phrases are repeated.	The tone system becomes increasingly compressible. Increased compressibility could be achieved by having sequences which are either probabilistically or deterministically more predictable. The latter case would correspond to repeating phrases, hence indirectly suggesting that some motifs might repeat across patterns (pg.416, paragraph 3.8, [7]). Notice, however, that the universal refers to patterns repeating <i>within</i> one unit of the system, not <i>across</i> units of the system.

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