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Abstract

This article provides conclusive first-hand evidence for the existence of a global musical culture that was already present in the Bronze Age. The studied prehistoric music connects Mediterranean with India, across thousands of miles of impenetrable mountains, highland plateaus, and deserts. The material that is discussed in detail in the article includes the Hymn to Nikkal and the Rig Veda. The Hymn to Nikkal is the oldest musical score that has yet been unearthed. It was found on the east coast of the Mediterranean. The Rig Veda is a collection of tens of thousands of verses dating from the same Bronze Age period as the Hymn to Nikkal. These verses have been passed down to us in an oral tradition in India, where they are considered a holy scripture by more than a billion Hindus today. The study of the musical connection between the Hymn to Nikkal and the Rig Veda, together with the ramifications that surround it, suggests that the Bronze Age saw the emergence of a global musical culture. Overall, the discovery of a global musical culture in the Bronze Age will strongly impact multiple fields of research including evolutionary linguistics and the study of cultural evolution and diversification, as well as the broader understanding of the human condition.

Keywords: music history; cultural history; cultural evolution; diversification

Introduction

News from the Bronze Age—about globalization!

One of the oldest scriptures to survive from ancient times is the Rig Veda. Today, it is still sung by more than a billion Hindus at their weddings and rituals. The text has been preserved with remarkable accuracy; only the accent has slightly changed.

The computer-aided analysis presented here is based on the study of cadences — harmonic or rhythmic elements marking the ends of verses. The hymn from Ugarit has two cadences, one in the middle and one at the end. The analysis presented here demonstrates that these cadences are identical to the two most common cadences of the Rig Veda. Furthermore, a close historical proximity is discovered. When focusing on the melody, it can be observed that the correspondence between the Mediterranean and India is strongest in the oldest hymns of the Rig Veda, those composed before the Vedic pronunciation changed.

The close historical but distant geographical connection that came to light in Bronze Age music is all the more stunning when one considers what happened later. The rhythms from Ugarit reappear in Greece, utilized by the Lesbian poet Sappho, then in Rome, and later more broadly in Europe and in music around the globe. Good rhythms and good music kept uniting people. At the same time, politics created borders. Ugarit burnt. The treatises between kings, pharaohs, or emperors never lasted.

Today, global ties are falling apart again. The new discovery about music in the Bronze Age that is presented in this article reopens the question: Do we need, once again, better music? We have long shared technologies, science, and art. Could a song like Bob Dylan's "Blowin' in the Wind" or a composition like those of the Rig Veda once again reunite us?

Results

India, Near East, and the Mediterranean in the Bronze Age

The kingdom of Mitanni was a Bronze Age society of the Near East that has left two immensely valuable gifts. The first gift is the earliest archaeological evidence for the existence of the Rig Vedic language and culture (Novák, 2007; Fournet, 2010).

This first gift is truly important because of both the of the Vedic culture, which has produced the scriptures of more than a billion Hindus today. Without the evidence from Mitanni, scholars would be at a loss, relying almost entirely on guesswork to determine when Old Indic and Vedic were originally spoken (Spinney, 2025).

In addition to helping scholars confirm their chronology of the Vedic language, the evidence from Mitanni also tells a story of its own. The archaeological evidence for the Vedic language that Mitanni has left is somewhat unconventional. It is not a full text written in Vedic. Instead, only individual words have remained, and these Vedic or Old Indic words fall in a narrow list of three categories: 1.) terms related to horsemanship, 2.) Vedic names of gods, and 3.) other Vedic names (Novák, 2007; Spinney, 2025; Gernot, 1989). Coincidentally, the country name "Mitanni" itself—or "Maitanni", as it appears in early sources—may be a testimony to ancient connections between the Hurrians who lived in Mitanni and the Indo-European ancestors of the Vedic Indians. "Mitanni" is derived from the Old Indic verb *mith-* "to unite". Specifically, the reconstructed accusative form **m[a]ithām̐* followed by the common Hurrian ending *-nni,* would give together *Maitanni* (Fournet, 2010). Similarly, the name of Mitanni's capital "Waššukanni" may be derived from the Vedic word root "vasu", signifying "wealth" Cotticelli-Kurras et. al, 2023. If these etymologies are correct, they suggests that this wealth-loving "United States" of the Bronze Age did indeed unite multiple cultures: the majority of the population was Hurrian, but there were also political, religious, and technological ties to Vedic-speaking peoples and their ancestors (Spinney, 2025).

Mitanni's second gift is more specifically linked to Hurrian culture, and it is all the more delightful. It is the oldest preserved musical composition. It was found in Ugarit, an independent city on the east coast of the Mediterranean (Laroche 1955, Krispijn, 1990; West, 1994; Thiel, 1977; Smith and Kilmer, 2000). The composition is a Hymn to Nikkal (Figure 1), part of a larger Hurrian musical library written on clay tablets, of which this hymn alone has been preserved in its entirety. Attempts to decipher the notation proved successful in the 20th century (Hagel, 2005). The composition is two-voiced, and, perhaps not unexpectedly, much shorter than the Hurrian lyrics (Krispijn, 1990; Hagel, 2005; Krispijn, 2002).

Figure 1. Marble head fragment of goddess Ningal with inlaid lapis lazuli eyes that made her look lively in Ur, during the 3rd millennium BCE. Chin, mouth, and nose are not preserved. By the time the Hurrians adopted the cult of Nikkal, "Ningal" had been part of Near Eastern culture for more than a millennium, serving as goddess of fertility. Penn Museum, B16228, height 10cm, on display in Near Eastern Galleries. Akkadian, from Ur, Irak.

To confidently study this music, and what it reveals about the people who sang it and their united Hurrian, Vedic, and Near Eastern context, we must begin by mapping the lyrics onto the musical notation. Once this is done, we can perform and listen to this composition written down by a scribe with a Semitic name on the Mediterranean in a barely understood Bronze Age language of the Caucasus (Figure 2). The composition's rhythmic patterns will yet reveal something quite remarkable that will require us to provide a conclusive proof and a nuanced discussion.

Figure 2. Ruins of the palace gate at Ugarit, located on the East Coast of the Mediterranean. It is here that the clay tablet with the Hymn to Nikkal was found. The performers of the music would have walked through this gate.

Demonstrating a Musical Connection in the Bronze Age

The analysis of the Hymn to Nikkal given in the present article begins by mapping the lyrics onto the music. The problem faced by earlier scholars who attempted to perform this mapping was that the music was shorter than the lyrics. However, this is not uncommon. Many musical compositions have less music than lyrics. Mostly, this apparent inequality emerges when the music is repeated over multiple strophes (Duckworth, 2012).

As a matter of fact, "strophic" musical arrangements are common. Repeating the music makes it easier to memorize it, while performing it with multiple, different strophes satisfies the human need for novelty and variation. Perhaps for this reason, strophic musical arrangements have been found in most cultures from Antiquity to the present day.

In the case of the Hymn to Nikkal, it is very likely that a strophic arrangement was chosen; it can make for an exact mapping of the lyrics onto the music. Each syllable in the lyrics is thus mapped exactly onto one musical symbol (Figure 3). The resulting music-with-lyrics arrangement is performed in the attached audio file (Supplemental Material).

Admittedly, there are many instances in which the mapping of the Hurrian lyrics onto the music is still uncertain. However, these uncertainties arise entirely due to illegible syllables in the lyrics, or due to linguistic uncertainty. Hurrian remains a little-known language, belonging perhaps to its own linguistic group.

Figure 3. Hymn to Nikkal, mapping of syllables onto the music. Each syllable is mapped exactly onto one dyad (chord comprised of two tones). To visualize the cyclic nature of the harmonic progression that makes the main body of the hymn, the music is visualized here on a circle. The following arrangement has been chosen: 1.) each black symbol is a tone, 2.) the relative wavelength of the tone is the distance to the center of the circle, and 3) the music progresses counterclockwise. Easy to recognize are the descending melodic lines, seen as sequence of tones that spiral out of the circle.

Ugarit, the city where the clay tablet with the Hymn to Nikkal was found, was a melting pot of cultures, boasting its own alphabet as far back as the 14th century BCE (National Museum of Damascus, 2025). This alphabet may have emerged to help scribes manage linguistic differences. Unfortunately, our scribe—Ammurabi by name—did not use this first cuneiform alphabet, but the standard syllabary, developed much earlier, and not for Hurrian (Krispijn, 2002). The problem is how spoken syllables are translated into written syllables. For example the Hurrian text "we-ša-al ta-ti-ib ti-ši-ja" [perhaps "she loves them with her heart" (a recurring phrase in Hurrian)] and "ka-li-ta-ni-il Ni-ka-la" [perhaps "hear this, Nikkal"], are likely seven true syllables, although nine and eight are written. A more difficult problem is posed by sequences of two or even three vowels as in "zi-u-e" [meaning unknown], which may or may not have been spoken as one, two, or three syllables in Hurrian. As a rule of thumb, we expect to see slightly more syllables written than pronounced. The problem with this type of orthography is that normally, it would be best interpreted by fluent speakers of the language, because every falsely accepted syllable offsets all that follow in the same verse. Luckily, contracting vowel clusters into one syllable always yields the expected text length. In this way, the lyrics can be mapped onto the music. In principle, it is not necessary to perform this mapping only to study the melodic lines and the rhythm. The mapping is provided here only for the sake of completeness.

Now that we have mapped the lyrics onto the music, we can continue without hesitation to focus on the melodic lines and the rhythm. The music is written down in two voices, as a sequence of dyads (Hagel, 2005). Technically, "dyads" are chords composed of two tones, as opposed to "triads" which consist of three tones. Dyads could have been played, for example, on double pipes commonly known under the later Greek name "auloi" (Figure 4) or on lyres or harps, where two strings were frequently played simultaneously, one with each hand (Figure 5).

Figure 4. Greek performance on double pipes, later referred to as "auloi". White marble sculpture, Cycladic islands, 2800-2300 BCE. Next to the Egyptian harp player in the next figure, this sculpture illustrates that double-

voiced instruments were widespread across the Mediterranean and Near East. Auloi have been present there for four millennia, well into the Roman period. Of course, two voices are louder than one, and with early strings and pipes being perhaps less advanced than modern-day instruments, it makes sense to favor a louder, fuller double-voiced sound.

Figure 5. Instruments to perform two-voiced compositions were widespread around the Mediterranean and in the Near East around the time the Hymn to Nikkal was written. This includes harps and double pipes, which were common throughout antiquity. Here is the image of a harper playing with both hands, created during the reign of Pharaoh Ramses III. Egypt from around 1186 to 1155 BCE (20th Dynasty, New Kingdom). It is evident that playing such an instrument busied both hands, letting the performer unable to turn a tablet with musical notation. This is at once confirmed with the Hymn to Nikkal, which has the musical notation only on one side of the tablet. Only the lyrics run over the narrow edge and onto the verso of the tablet, which was preferred by the vocalists who had both hands free. This reconfirms that the hymn was indeed performed with instrumental accompaniment, that the instrumentalists and vocalists were distinct individuals, and that it was sufficient for the latter to read the lyrics, not needing to read the score in parallel to the lyrics while performing.

In the Hurrian musical notation, following the dyads are numeric values. Initially, historians interpreted these numbers as some kind of repetition. They imagined that the dyads were repeated as many times as indicated by the numbers. The aim of this rather unnatural interpretation was to lengthen the music and make it equal the length of the lyrics, but this attempt proved unsuccessful mostly because the music then became too long (Krispijn, 2002). In parallel, the suspicion arose that the numeric values after each dyad encoded its duration, rather than repetition (Hagel, 2005). A fact that speaks for this interpretation is that the ratio of long and short tones would be 1.4, which is also found in the contemporary Rig Veda (Supplementary material).[1] Additionally, the interpretation of the numbers as tonal duration allows mapping the lyrics precisely onto the music, as has already been established earlier in this article. Last but not least, now that we have durations, there is a rhythm—and not only there is one, which is essential to most music, but this rhythm is stunningly beautiful when performed… The rhythmical patterns don't seem at all random, but strike a deep chord with many audiences.

Listening to this music, one can only wonder: Where does this beauty come from? The rhythm seems strangely familiar. How does this sense of familiarity arise, in a musical composition that is more than 3,000 years old? The repeated cadence-like rhythmic patterns seem particularly appealing (Figure 6).

Figure 6. Hymn to Nikkal, rhythmic patterns. As in Figure 3, the main body of the music is once again drawn on a circle, with the distance between the black symbols and the center of the circle representing the wavelength. Here, in addition to the arrangement chosen in Figure 3, the angles counterclockwise from the vertical line represent the time each tone is played. This visualizes the rhythm. Whereas in Figure 3, the harmonic progression was shown to be very coherent, the rhythm shown here adds a unique signature to the piece, grouping dyads and setting accents. Perhaps the image is reminiscent of herding behavior among animals that form groups when they stand and files when they move. In particular, the composition starts and ends slow (seen in the lower left of the circle), while the main body of the strophic progression has most of the active movement with descending melodic lines—the sequences of tones seen spiraling out, of the circle.

Cadences in music mostly refer to harmonic sequences that mark the end of a compositional entity (Randel, 1999). A simple example is the sequence Sol—La—Si—Do / G-A-B-C in European

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[1] An overlooked fact that also speaks for this interpretation is that the values 2 and 4 are more frequent than expected, while 3 and 5 are more rare (Hagel, 2005, has a figure that visualizes this, but doesn't discuss it). Translated to modern-day notation, this means that half and full tones are more frequent than extended half and extended full tones. This still holds true today, and it appears to have been the case in Hurrian music as well.

classical music. People easily recognize this sequence as a so-called "authentic cadence" for a composition in Do major / C major. In addition to harmonic cadences, there are also rhythmic cadences. These are rhythmic patterns that mark the end of a rhythmic unit—the end of a verse, for example (Van Nooten and Holland, 1995). Rhythmic cadences can be studied across both the Hymn to Nikkal and the Rig Veda because the rhythms are known in both cases. Before we do that, let us briefly review what cadences are, in a broader sense. It is helpful to have a broad understanding of the matter before addressing 3000-year-old compositions.

Cadences are not unique in music. Closely related to music, they are also found in poetry. The Rig Veda, for example, employs many formulas to mark the end of a verse or a hymn (Bloomfield, 1916). Similarly, European poetry frequently utilizes rhymes, which mark the ends of verses (Zhirmunsky and Hoffmann, 2013). In a way, harmonic cadences are "harmonic rhymes", and rhythmic cadences are "rhythmic rhymes".

Both, rhymes and cadences, give audiences a sense of familiarity and comprehension. Indeed, even in daily life, when people say that something "doesn't rhyme" or "has no rhyme or reason", they often use these words as an idiom to indicate that something isn't right (Merriam-Webster Dictionary, 2025). Perhaps rhymes and cadences thus reflect a deeper human need for harmony and comprehension. It is OK to have complex thoughts that aren't always easy to follow, but people feel reassured when these thoughts always lead to the same conclusion. They rhyme.

An equivalent of cadences and rhymes also exists in scientific thinking. In particular, any validation process requires that the same result is obtained a second time through an independent path. Formally speaking, the result then works like a rhyme, reappearing at the end of a new, independent statement. For example, training an Artificial Intelligence algorithm often includes not only a first step in which the algorithm is fitted to training data but also a testing step in which the performance of the fitted algorithm is tested against an independent set of testing data. The testing is often done repeatedly, to check whether the performance actually improves. The training thus goes through multiple epochs where the algorithm is first trained, yielding a training accuracy, and then tested, yielding a testing accuracy (Hastie et al. 2009). For each epoch, one can state:

$$\text{Algorithm}(data\_train) = Acc \,,$$
$$\text{Algorithm}(data\_test) = Acc \,.$$

Here, an algorithm is first trained on a training dataset *data_train*, after which it is tested on an independent testing dataset *data_test*. For the training to be successful, the accuracy *Acc* obtained during training and testing must gradually converge over multiple training epochs. Thus, the accuracy in the mathematical statement above performs roughly the same formal role that a rhyme performs in verses. It reconfirms an idea. Most validation techniques require this type of testing where a result is obtained a second time, through an independent path.[2]

The recurring theme in all of these cadences, rhymes, and validation techniques is that the person exploring them takes different, sometimes surprising, and even opposed paths, while always returning to the same, reassuring final conclusion. In this sense, cadences are formally, and even literally, "conclusions". It is good to follow complex chains of thought, but, at the end of the day, one would like to see the reassuring presence of a foreseeable, unchanging conclusion.

What then, do these considerations have to say about cadences? Good cadences have to be reassuring, clearly recognizable endings, and not chance encounters. Otherwise, someone could say, "True, the two independent paths you have taken yield the same result, but just by chance!" In

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[2] Similarly, approximation can work like a rhyme. Archimedes, for example, calculated π by proceeding with two independent constructions which both lead up to π, estimating the lower and upper bounds of this number (Archimedes, 2010). His approach can be summarized as follows for a circle with diameter = 1 and with inscribed and circumscribed *n*-edged polygons:

$$(\text{for } n \gg 1) \quad (\text{perimeter of inscribed } n\text{-gon}) = \pi \,,$$
$$(\text{for } n \gg 1) \quad (\text{perimeter of circumscribed } n\text{-gon}) = \pi \,.$$

mathematics, the concept of statistical significance was developed to settle exactly that question: is a result obtained by chance? Technically, low statistical α values stand for low probability that one deals with a chance encounter, and, therefore, high "statistical significance" (Moore et al. 2016). We will utilize statistical significance to identify just how unique the Hymn to Nikkal and Vedic poetry are in their use of cadences. It turns out, the cadences utilized in the Hymn to Nikkal and in Vedic poetry are not mistakable for chance encounters, as will be shown. Instead, they are good, recognizable, and reassuring verse conclusions.

To summarize, it is good if a cadence is clearly recognizable, creating a sense of familiarity. This is not to say that poetry or music cannot explore new and exotic ideas. Most people like setting sail and expanding their horizons. However, in the end, no port is as beautiful as that of one's own motherland (Hatzidakis, 1960). Even Ulysses, coming home after twenty years of absence, eventually recognized his dear Ithaka, although he felt lost, at first (Homer, 1995). Sindbad the Mariner—a figure similar to Ulysses but drawn from Arabian Nights—solved the problem differently. He returned home repeatedly, once after each adventure. His returns home work like rhymes and cadences in an exuberant story full of metal islands, flying bird-ladies, and submerged rivers, none of which was quite as desirable as Sindbad's own home town. In the end, one has to "drive the point home," as English speakers sometimes say (Sinclair, 2004). Rhymes and cadences are an artistic form that satisfies this human desire for familiarity and recognizable order.

Many musical cultures have discovered cadences, beginning with the Indian culture that brought forth the Vedas. Notably, verses in the Vedas can have many different openings, but the number of different cadences is much smaller. For example, the most popular verse form of the Rig Veda—the Triṣṭubh—has at least five common opening patterns but virtually only one typical ending. This cadence marks the ends of more than 95% of a total of 16,450 Triṣṭubh verses (padas) in the Rig Veda, and it is a rhythmic pattern that, although only three syllables are fixed in it, makes for a clear and reassuring finale for each verse that it crowns (Van Nooten and Holland, 1995). Stunningly, this cadence returns in the poetry of the ancient Greeks and Romans (in Aeolic verse forms; West, 1982). Perhaps both Vedic and Greek speakers inherited it from their Proto-Indo-European ancestors, who passed it down onto them together with their language (White, 1909). If so, did the cadence remain unchanged over the millennia? The same shared ancestors would also have passed down the melodic accent in their language, due to which melodies go down in pitch after word accents (West, 1992; Edgerton, 1952). Or were cadences and falling melodic lines simply beautiful, and people across language borders passed them back and forth between them, again and again, simply because of the delight they experienced?

The same cadence together with falling melodic lines is also found in the Hymn to Nikkal. To expand on this point, the present article comes with a computational evaluation. The cadences extracted from the Hymn to Nikkal in their full length of seven syllables were searched amid verse endings in the Rig Veda, and this search returned several thousand exact matches. To demonstrate that these numbers are statistically significant, the present computational evaluation contains a comparative study against a set of 1,000 altered Rig Veda versions, in which word order was randomly changed. A computer code thus generated 1,000 permutations of the Rig Veda. These permutations created without care for the rhythm reveal that the rhythmic patterns of the Hymn to Nikkal and the Rig Veda are not a chance encounter. Indeed, the cadences of the Hymn to Nikkal are frequent in the real Rig Veda, while being significantly more rare among the random textual permutations, none of which repeats the hymn's cadences with equal frequency as the real Rig Veda. Thus, the cadences that have been found in the Hymn to Nikkal connect it with the Rig Veda, interlinking the two musical cultures (Supplemental Data).

Statistically speaking, the link is by no means a randomly generated chance encounter. The α value, which denotes the probability that the cadences of the Hymn to Nikkal are also found in the Rig Veda simply by chance, is always extremely low in our analysis, below statistically detectable levels. With 1,000 permutations created for the Rig Veda, α is calculated for each of the analyzed cadences to be below 1/1000.

As a rule of thumb, the α values of multiple independent tests can be combined by multiplying the individual values. This gives $1/1000^2$ in our case. Thus, the likelihood that the cadences of the Hymn to Nikkal are found in the Rig Veda with the same frequency as we found them, but as a chance encounter, has a likelihood of less than one in a million times. The following can be concluded: If the authors of the Rig Veda had not favored the rhythms they actually favored, they would have had to create more than a million modified Rig Vedas, and they would still not have created the cadences of the Hymn to Nikkal with equal frequency in any of these copies. In reality, they favored these cadences, and they repeated them frequently in the one and only Rig Veda they created.

Perhaps real numbers help further elucidate the statistical result. The Hymn to Nikkal contains two clearly recognizable cadences that mark the middle and the end of the composition. For these two cadences, the numbers are:

+ **3673** Rig Vedic verses end with the first cadence of the Hymn to Nikkal;
+ **3803** Rig Vedic verses end with the final cadence of the Hymn to Nikkal;
= A total of **7476** Rig Vedic verses end with one of two cadences of the Hymn to Nikkal. This number corresponds to **19%** correspondence in a total of total 39,688 verses in the Rig Veda. Thus, approximately every fifth verse in the Rig Veda ends with one of two cadences of the Hymn to Nikkal.

By comparison, the permuted Rig Vedas do not at all yield such frequencies. In the 1,000 permuted Rig Vedas, the previous numbers fall to:

+ **627** verses end with the first cadence of the Hymn to Nikkal in the one text among a thousand permuted Rig Vedas that has the highest number of matches with this particular cadence;
+ **444** verses end with the final cadence of the Hymn to Nikkal in the one text among a thousand permuted Rig Vedas that has the highest number of matches with this particular cadence;
= A total of **1071** verses end with one of the two cadences of the Hymn to Nikkal in the two permuted Rig Vedas that combined have the highest number of matches. This number corresponds to **3%** in a one-in-a-million-times-best combination of two most fittingly permuted Rig Vedas. Evidently, this percentage is still much lower than the one previously obtained, in spite of the 1,000,000 unsuccessful attempts to piece things together by chance.

The close match that we received between a single hymn and an entire collection of verses is a rare find. The Rig Veda, as a concrete case, is a collection that is quite diverse (Thomson, Slocum, 2025). There are more than a hundred different cadences that are utilized (if the last seven syllables of a verse are taken into account). Therefore, no two cadences can possibly receive a 100% match simply because there are more than two different cadences in the entire collection. How good then, is a correspondence of 19%?

This question can be answered with a test. Imagine picking a duplet of two consecutive cadences from the Rig Veda. Once this authentic Rig Vedic duplet is selected, one can perform with it the same experiment as with the Hymn to Nikkal. One can extract two cadences of the same length as those extracted from the Hymn to Nikkal, and one can search all exact matches for these two authentic Rig Vedic cadences across the entire Rig Veda, utilizing the method already applied to the cadences of the Hymn to Nikkal. A simple question emerges: If one does this, would the authentic Rig Vedic cadences or the ones of the Hymn to Nikkal receive a higher number of matches?

This testing method can be expanded to generate robust results. We utilized a sliding window that picked all possible verse duplets from the Rig Veda. For each duplet, we performed the search previously performed for the Hymn to Nikkal. The final question was, how does the Hymn to Nikkal compare to all the possible authentic duplets that we found in the Rig Veda? Can the Hymn to Nikkal beat the Rig Veda at its own rhythmic game? (It would be something like Tennis, which was certainly standardized in England, but the best international payers end up outcompeting unprofessional and perhaps even average Englishmen at their own game.)

The result speaks for itself. The two authentic Rig Vedic cadences that fetched the smallest number of matches received only 19 total matches, or 0.05% correspondence. This is a very low number. The median number of matches was much higher, reaching 1001 matches or 2.5%

correspondence. Evidently, this number is still much lower than the 7476 matches or 19% fetched by the cadences of the Hymn to Nikkal. Therefore, the Hymn to Nikkal matches up with the Rig Veda at least as well as if it was taken from within the Rig Veda itself—and even if picked from within, it would be one of the more characteristic duplets. Indeed, the statistics demonstrate that if the Hymn to Nikkal were part of the Rig Veda itself, its two cadences would be positioned among the topmost 1% most characteristic ones in the Rig Veda—that is on the top 100th percentile (Supplemental material).

Perhaps this excellent result seems stunning and requires an explanation—but the explanation is easy. The Hymn to Nikkal samples two typical Rig Vedic cadences. In this way, it receives excellent matches—it works like a sampler. Similarly, the collection "Best of Chopin" may be more representative for all of Chopin's work than each separate collection of Valses, Nocturnes, Mazurkas, posthumous works, and other types of composition. In this sense, the Hymn to Nikkal appears to sample best Rig Vedic cadences.

As a matter of fact, the final cadence of the Hymn to Nikkal is also the most widespread cadence across all verses in the Rig Veda. Similarly, the first cadence of the Hymn to Nikkal is the second most widespread Rig Vedic cadence, and the most widespread in the Triṣṭubh meter, specifically. The composers of the Hymn to Nikkal could not have chosen better. The two cadences they chose not only rank on the 100th percentile in our test, they are exactly the cadences of *the one* best-performing authentic Rig Vedic duplet that cannot possibly be outperformed!

Thus, the choice of the two cadences is excellent. Both Vedic Indians and Hurrians would have agreed. One can confidently say that Vedic Indians would have loved this hymn. They would have recognized its rhythm as their own. One can also say that the Hurrians liked it because the Hurrian musical library from Ugarit likely held not one but two or perhaps even more copies of the Hymn to Nikkal; there exist fragments of a second clay tablet that appears to have held the same composition. The Hymn to Nikkal was something that was performed and copied, perhaps many times. One could almost say that archaeologists unearthed here the top song of the Bronze Age hit parade.

With these considerations in mind, it can be concluded that the cadences of the Hymn to Nikkal are signature Rig Vedic cadences. The occurrence of these cadences on a clay tablet on the Mediterranean is remarkable, establishing a global musical connection in the Bronze Age. Beyond any doubt, it can be said that the Hymn to Nikkal "rhymes", rhythmically speaking, with the Rig Veda—and not just rhythmically speaking. In principle, we can also test the music.

Studying melodic lines has one main limitation. The music is known only in the case of the Hymn to Nikkal, but it is somewhat uncertain in the case of the the Rig Veda. However, "uncertain" does not mean "entirely unknown". Ancient commentators of the Rig Veda said that the melodic lines in the Rig Veda were determined by word accents. The melody went up in pitch with the word accent and went down after it. While this basic information alone cannot facilitate a complete reconstruction of the music, the basic melodic structure can nevertheless be determined. If this is done, the statistical test performed initially only with the rhythm can be performed once again, this time taking both rhythm and melodic structure into account. The picture then becomes even clearer.

Our two cadences of the Hymn to Nikkal—this time taking into account both rhythm and melody[3]—find more than a thousand total matches across the Rig Veda. We have the following numbers:

+ **461** Rig Vedic verses end with the first cadence of the Hymn to Nikkal, taking both rhythm and melody into account.

+ **724** Rig Vedic verses end with the final cadence of the Hymn to Nikkal, taking both rhythm and melody into account.

= A total of **1185** Rig Vedic verses end with one of the three cadences of the Hymn to Nikkal, taking both rhythm and melody into account. This number corresponds to **3%** of the Rig Veda that can be sung with these cadences.

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[3] Both upper and lower voice of the Hymn to Nikkal yield the same word accent pattern.

Approximately every thirtieth verse of the Rig Veda has the same rhythm and melodic structure as the two cadences of the Hymn to Nikkal. By comparison, measured against the corpus of randomly permuted Rig Vedas, these numbers fall to:

+ **81** rhythmic and melodic matches for the first cadence in the best permutation.
+ **81** rhythmic and melodic matches for the third cadence in the best permutation.
= A total of **162** matches, corresponding to **0.4%** in the one-in-a-million-times-best combination of two most fittingly permuted Rig Vedas. Evidently this number is still much lower than the one obtained before, in spite of the 1,000,000 attempts to piece things together by chance.

These results strengthen the ones previously obtained. When only the rhythm was considered, the Hymn to Nikkal received six times more matches with the authentic Rig Veda than with the one-in-a-million-times best combination of two most fittingly permuted Rig Vedas. This result was already quite remarkable. Now, when the music is also considered, this number rises still further from six to eight. The new result demonstrates that the music as a whole—including rhythm and melody—is even more typically Rig Vedic than the rhythm alone.

Here again, the excellent correspondence between the Hymn to Nikkal and the Rig Veda is no chance encounter. Considering that the rhythms of our two cadences are already defined, the melodies added by the Hymn to Nikkal on top of these rhythms are compatible with the two most frequent accent patterns present in the Rig Veda in association with these specific rhythms. In addition, a closer look at some of the oldest hymns of the Rig Veda demonstrates that, here, the correspondence is the greatest.

The combination of rhythm and melody of the final cadence of the Hymn to Nikkal is compatible with the overall most frequent combined rhythm and accent cadence in Book 5 of the Rig Veda—the book of the Atri family. At the same time, the first cadence of the Hymn to Nikkal, taking rhythm and melody into account, matches up exactly with the overall most frequent cadence found in Books 4 and 6 of the Rig Veda—the books of the Vamadeva and Bharadvaja families (Supplemental material). Together, these three books—4, 5, and 6—are among the oldest Rig Vedic material and most likely contemporary to the Hymn to Nikkal. Later Rig Vedic material may have experienced changes in accent pronunciation, with the melodic accents gradually shifting from their original positions to the positions where they are still pronounced today.

Despite the gradual shift in accent pronunciation over time, the first cadence of the Hymn to Nikkal remains the second most frequent melodic and rhythmic cadence across the entire Rig Veda, including the newer Rig Vedic hymns (Supplemental material). While there is one combination of rhythm and melody that is more common across all of the Rig Veda than the first cadence, this particular most frequent pattern resembles the positions between the two cadences of the Hymn to Nikkal. It features the same rhythm and only one difference in accent. Thus, the choice of the melody is once again excellent.[4]

It can be concluded that the Hymn to Nikkal "rhymes" both rhythmically and melodically with the Rig Veda. Furthermore, it does not rhyme with random permutations of the Rig Veda, and it

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[4] The statistics demonstrates not only that there is an excellence correspondence between the Hymn to Nikkal and the Rig Veda, but also within the Rig Veda, the same accent patters often occur repeatedly in the same hymns. For example, book 5 and 6 contained the accent patterns mentioned before frequently in the same hymns, with statistical significance. So for example the result in Book 5 is as follows. The the ratio of lines with the top most frequent cadence to hymns that have that cadence is 2.5, whereas in a thousand permutations this ratio falls to min. 1.0, median 1.1, mean 1.14, and max. 1.5. For book 6, the result is: 1.6 ratio in the real Rig Veda, and min. 1.0, median 1.3, average 1.3, and max 1.7647 among in a thousand permutations where the same number of same cadences is distributed among the same number of hymns each with the same number of lines as in the authentic Rig Veda.

rhymes with the Rig Veda across thousands of miles of mountains and deserts, yet precisely as if it were the most beautiful signature part of it.

Given that the two cadences studied here make for such a unique line-up, it may be valuable to briefly go beyond statistics and ask: How do they sound?

The final cadence of the Hymn to Nikkal—which is also the one most widespread rhythmic cadence in the Rig Veda—resembles an iambic meter that alternates between long and short positions. This makes the cadence a very regular rhythm, reminiscent of a heartbeat. This rhythmic pattern is combined with a melody that alternates between up and down in a similar, repeated way. The experience is truly spellbinding because the short positions in the rhythm coincide with lower tones in the music, while the long positions coincide with higher tones (Figure 7).

Figure 7. Hymn to Nikkal, rhythmic patterns. Here, the prelude is also included, and the music is therefore arranged on a spiral to make place for it. The 'iambic' final cadence is easily recognized here at the outside end of the spiral.

Scholars have argued that this type of meter is typical for Indo-European poetry, but it is indeed more widespread, recurring in music across the globe from Africa to America. While this other music does not come quite as close to the Rig Veda as the Hymn to Nikkal, it must nevertheless be acknowledged that the broader category of this iambic rhythm has permeated global musical culture for millennia.

The other cadence of the Hymn to Nikkal—which is also the second most frequent rhythmic and melodic cadence of the Rig Veda—is less regular in appearance. It does not have the straightforward linearity of the iambic meter. Instead, there are clusters of short and an long positions. This feature makes the cadence less linear or more "nonlinear" in appearance. As such, this cadence is more specifically Rig Vedic and more clearly recognizable as something culturally inherited. To expand on this point, we have performed a study of cadence occurrences across older and newer Hymns in the Rig Veda. This study reveals that this cadence was initially the most frequent one. Only gradually, it was outcompeted by the iambic cadence, which is more frequent in the Atri family book, where it may have originated, spreading to dominate in the newer books of the Rig Veda. It may have been liked for its simplicity and efficiency.

Perhaps this brief discussion of our two cadences opens a new perspective. The idea of combining them in one joint hymn makes for a beautiful juxtaposition of linearity and nonlinearity. One cadence is linear in appearance, the other, nonlinear.

There exist many variant cadences that are linear and many that are nonlinear in appearance. However, we ended up with a linear and a nonlinear one—not two linear or two nonlinear ones. Why?

The juxtaposition of a linear and a nonlinear cadence reflects awareness and appreciation of the the two basic modes of human perception. When observing the world, people can perceive both linearity and nonlinearity. Linearity is all about lines, directional movement, and simplicity. Nonlinearity is about curves, rotation, and sophistication. These two types of perception often complement each other. For this reason, featuring both linearity and nonlinearity in an artwork often makes it richer.

The examples of artworks that blend linearity and nonlinearity are countless. The most famous one may be Leonardo da Vinci's "Vitruvian Man". It is a human figure placed in the center of both a square and a circle. The square can be taken to represent linearity, while the circle represents nonlinearity. Thus, the juxtaposition of linearity and nonlinearity appears as a recurrent theme in art history, both in the visual arts and music. The Hymn to Nikkal is a musical example. It featured two cadences. One is linear in appearance, the another, nonlinear. Around the same time, exactly these two cadences were also the most frequent ones in the Rig Veda.

Discussion

Global Ramifications

The Hymn to Nikkal bears a distant influence, linking distant Bronze Age societies. These societies were also connected through politics, religion, and technology. Which connection, then, was the first? Is it possible that music and Art connected the world before speech, money, religion, or politics? Perhaps the role of music is underestimated because archeologists never get to hear musical compositions performed by prehistoric people…

The Hymn to Nikkal reveals that music both spreads and blends in easily, linking distant motives and themes. As a matter of fact, the hymn reflects an intricate web of connections. The clay tablet on which the hymn was inscribed was found in Ugarit. The musical notation is Hurrian, although not originally. Adding to the global connections, the Hurrian musical notation is derived from Near Eastern musical notation. Also, Nikkal is a Near Eastern goddess, venerated by the Akkadians already a millennium earlier, then as Ningal (Figure 1). Thus, the Hymn to Nikkal reveals connections across a broad range of cultures, including India, the Caucasus, the Near East, and the Mediterranean. This is something common for music. In music, everything seems interconnected. We can certainly say this for the present day, when songs literally go viral. Was there—just perhaps—a global musical culture already in the Bronze Age? (Figure 4).

To answer this question, the Hymn to Nikkal provides direct evidence. However, more evidence will be needed, and additional direct evidence is unlikely to be found, considering the fleeting nature of music. Besides, when the Hymn to Nikkal was unearthed, it was initially classified as a mathematical text. Music is not only hard to find, but even if found, it is hard to recognize, interpret, and contextualize. Nevertheless, even in absence of new evidence, it may be important to remember a simple rule of cultural evolution: Competing cultures experience competitive exclusion. Good ideas spread easily and conquer the world. They have wings. A global musical culture in which some musical ideas were disseminated and came to dominate could have easily established itself. Assuming that there are basic means of communication, and assuming that some musical ideas have more appeal than others, competitive exclusion immediately emerges, and with it, a cohesive musical culture that covers the globe. On the other hand, avoiding competitive exclusion requires nonlinear mechanisms of diversification which—by being nonlinear—are unstable, giving rise to periods of diversification alternated with periods of unification (Baciu, 2018, 2020, 2023). Perhaps then, it is fair to say that, in the beginning, the world was united by Art.

Good ideas, useful words, easily memorized songs, and well-recognizable cadences can make sense to many audiences, and they often spread by themselves. Perhaps the greatest gift of the Hymn to Nikkal is its musical echo of descending melodic lines (Figure 3 and 6) and cadences also found in India, Greece, and later Rome. As a last example, compare the first 14 positions of the main part of the Hymn to Nikkal ¯ ˇ ¯ ¯ ˇ ¯ ¯ ˇ ˇ ¯ ˇ ¯ ¯ ||, with the Sapphic verse ¯ ˇ ¯ ¯ ¯ | ˇ ˇ ¯ ˇ ¯ ¯ ||, named after Sappho, but widely utilized in Greece, Rome, and, as recently as 1801, by Hölderlin in Germany. Sappho's verse is almost identical to the Hymn to Nikkal. Only the three middle positions in the Hymn to Nikkal are replaced with the caesura in the Sapphic verse, nothing else is removed or added. Also, some of the most beautiful verses by Sappho fit the music of the Hymn to Nikkal. On the other hand, comparing Sappho's verse and the Hymn to Nikkal with the Rig Veda, the Hymn to Nikkal is closer. The reason is that the last 10 out of the above 14 positions of the Hymn to Nikkal ¯ ˇ ¯ ¯ ˇ ˇ ¯ ˇ ¯ ¯ || are the number one most frequent verse ending of this length in the Rig Veda. If one adds another short or long opening syllable as a starting position, one receives the most common Triṣṭubh verse, in its full length.

If the Triṣṭubh meter is beautiful through its irregularity that makes its echoes easily recognizable even in distant lands, the regular iambic-type of rhythm is doubtlessly a heartbeat that seems to unite the whole world. It returns in endless poems, march music, and countless compositions in two quarter beat. Were such musical patterns simply something so good that people liked them—and over millennia and globally?

In the course of history, countries often tried to conquer each other. Many times, they applied force in the hope of succeeding. They did not succeed because war hardens people, making them

hate, fight, and only desire to beat each other. In the meantime, music conquered the globe effortlessly. It united people, making their hearts beat *for* each other.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. Studied cadences with matching Rig Veda samples as well as commentary and statistical analyses.

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Data Availability Statement: Full analyses in Supplemental Material.

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