THE RECURSION
THAT THOSE WHO STUDY LINGUISTICS SEEK
IS EVERYWHERE IF YOU KNOW WHERE TO LOOK FOR IT

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In this paper we build on previous claims that storytelling, music, and dance/performative gesture comprise intrinsic parts of human ritual, occurring ubiquitously across cultures and across time (Staal, 1979, 1980, 1984; Merker, 1999, 2009; Lewis, 2018). Ritual is unique in its emphasis on structural form and proper execution over semantic/functional content. Staal claimed that Vedic ritual in particular was recursive, based on its use of center-embedded symmetries. Here we trace the ubiquity of such structural principles throughout history at every level of analysis in literary (frame narrative, ring composition, chiasma) and musical composition (retrograde, sonata/minuet/rondo, arch form, twelve-tone) to argue that these persist as pervasive remnants of ritual culture. We then present the results of a corpus study showing that center embedding is more frequent in head-final languages, and raise the possibility that even in head-initial languages, center embedding may be more common than assumed. Taken together, the evidence we present suggests that center embedding is not only alive and well in human language and culture today, but that it has also likely been prevalent throughout the history of our species.

1. Introduction

Twenty years ago, Hauser, Chomsky & Fitch (2002) threw down the gauntlet for the study of language evolution with the strong claim that recursion (Fitch & Martins 2014:98, "the same hierarchical structure is repeated at multiple levels of the hierarchy") is the core property and *sine qua non* of the language faculty, and that it cannot have been an adaptive property that was selected for (2002:1572-3). Yet the concession is also made that recursion in language could have been exapted from other, non-communicative domains of animal cognition, such as navigation, number quantification, or social relationships (2002:1571,1578).

Here we take a slightly different tack in the quest for recursion by expanding on proposals by Staal (1979, 1980, 1984) highlighting the similarity of recursive properties in Vedic ritual and in language. Of particular note is Staal's claim that the center embedding evident in ritual may have served as a template for recursion

in human language—and not the other way around. In partial support of this idea, animals as cladistically diverse as Bengalese finches (Abe & Watanabe, 2011) and macaque monkeys (Jiang et al., 2018) have been trained to recognize recursive, center-embedded patterns; language therefore cannot be a necessary condition for this ability. Yet if the center embedding found in ritual played such a central role in the evolution of linguistic recursion, (1) **why would center embedding appear to be so infrequent today** (Karlsson, 2007; Levinson, 2013), and (2) **shouldn't there likewise be more traceable remnants of center embedding in human culture**? These are the questions we address in this paper. and we present what we find to be striking evidence along these lines.

With regard to (1), Staal (1980) proposed that the much more luxurious time scale on which ritual typically unfolds accommodates the complexity of center embedding without difficulty, whereas the speeded pace of spoken or signed language communication in real time gives rise to obvious problems of verbal working memory, as first pointed out by Chomsky & Miller (1963; see also Warren & Gibson, 2002, regarding reference form). However, given the apparent ease with which native speakers process head-final languages (e.g. Inoue & Fodor, 1995), we predicted that head-final languages should exhibit more center-embedding than head-initial or mixed-headedness languages, and conducted a corpus search to this end. We also assembled a collection of center-embedded examples from popular media in English. These results are found in section 4.

With regard to question (2) above, Lewis (2018) has described hunter-gatherer ritual as a communicative, transactional relationship between a society and the forces of nature, manifesting in institutionalized communal reenacts consisting of storytelling, music, and dance (with specified melodies, songs, and rhythms). This is remarkably consistent with traditional descriptions by Sanskrit scholars of the more formalized, heavily constrained, and institutionally codified ritual practice of Vedic culture. This in turn suggests that these may well be universal features of human ritual. Merker (1999, 2009) draws similar conclusions: "Presumably, the vocal, the gestural and the social aspects of group display were never separate, nor are they kept separate in the conceptual categories of a number of non-Western peoples even today. Their languages subsume rhythm, song, dance and ritual (celebration) under a unitary concept…." (Merker, 2009:53; see also Cassirer, 1946:40-41). More crucially for our purposes, Lewis (2018) emphasizes that the fundamental backbone and crucial focus of hunter-gatherer ritual is not its semantic content, but its specified acoustic properties, structural form, and manner of execution. This is precisely Staal's (1979, 1980, 1984) claim with regard to the structure of Vedic ritual as well.

We build on such cross-cultural similarities to show that center embedding persists and is well attested in the obvious descendants of early human ritual

culture today: structural features of (especially Western[1]) literary (section 2) and music composition (section 3). Taken together, the evidence we present suggests that not only is center embedding alive and well in human culture and cognition today, but that it has likely been prevalent throughout human history—and arguably in some prior hominin species as well. As such, the ubiquity of center embedding in human culture offers a tractable avenue for recursion to have gained a foothold in language via its common association with ritual and music.

2. Center embedding in epic poetry

It turns out that not only is Vedic ritual center-embedded: the oral literature with which it is intertwined is as well. The so-called "frame story" structure of Indian epics like the *Mahābhārata*, in which stories are repeatedly embedded one within one the other, has been shown to reflect the structure of the rituals that serve as the narrative framework for the recounting of those tales (Minkowski, 1989). Alternatively, the epic embedding of one myth within another may be designed to elucidate and justify the particulars of ritual practice (Witzel, 1987). However, ABC…X…CBA narrative structure is not limited to Vedic culture, but ubiquitous across Indo-European epic poetry (Watkins, 1995). Classicists refer to it as ring composition (van Otterlo, 1944). This symmetrical structure has been identified in the *Iliad* and the *Odyssey* (van Otterlo, 1944; Whitman, 1958; Haig Glaser, 1969), the *Aeneid* (Duckworth, 1962), *La Chanson de Roland* (Niles, 1973), *Beowulf* (Niles, 1979), and in books of the Hebrew Bible (Fishbane, 1975; Alter, 1987; Rosenberg 1987; Douglas 2007). The same structuring device has been claimed for literary works as diverse as *1001/The Arabian Nights* (whose core tales are recognized to be of Indian and Persian origins; Irwin, 1994), Boccaccio's *Decameron*, Chaucer's *The Canterbury Tales*, Shakespeare's plays (Rose, 1972), Mary Shelley's *Frankenstein*, and Sterne's *Tristram Shandy* (Douglas, 2007).[2]

Importantly, however, the literary technique of center embedding applies not only at the level of entire works, but also to the more fine-grained structure of individual hymns, poems, or verses. It is instantiated and signaled by a number of both narrative and linguistic bracketing devices, including case, tense/aspect, person, mood, connectives, and specific lexical forms (Minkowski, 1989). For just one such example, so-called riddle hymns of the *Ṛg Veda* have a recognizable structure in which the enigma itself is embedded in a verse in the middle of the hymn, with parallel and symmetric stylistic and lexical bracketing devices on

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[1] For literature at least, Douglas (2007:5,8) cites further examples from Madagascar, China, Burma (Myanmar), Thailand, Vietnam, Malaysia, Indonesia, Trans-New Guinea, and Hawai'i.

[2] See Dane (1993) for a general critique of analyses of classical and medieval literature that rely on ring composition as an organizing principle.

either side (Brereton, 1999; Jamison, 2004); Douglas 2007:36-37 includes both of these conventions in her criteria for ring composition). Likewise, at the level of individual verses or lines, chiasmus, the symmetrical (ABBA) structuring of phrases or clauses via lexical and/or syntactic means, is a common poetic device.

3. Center embedding in musical composition

The same structural principle is prevalent in the composition of Western music. Palindromic or mirror patterns in music are called retrograde, meaning that the music is identical on some parameter when performed both forward or backward.[3] Such early forms do exist, for example a 14th century rondeau by Machaut and a 16th century canon by Byrd. However, these are exceedingly rare, especially from the Baroque through the Romantic eras, due to the homophony that dominated from the 17th through 19th centuries: chordal structure supporting an independent melody, based on a series of harmonic progressions going from dissonance to consonance. That said, as might be expected, eminent formalists like Bach and Haydn both toyed with strictly palindromic composition in individual works.

However, musicologists have since expanded the definition of hierarchical structure in music to include composition at every level of analysis, from multi-movement works, individual movements, and passages within movements to musical gestures such as themes, motifs, rhythm, texture, and color. Recursive structure provides the architectural basis for the sonata (ABA), so-called ternary forms (ABA) like the minuet, and the rondo (ABACABA). Recursiveness also manifests in the arch form, in which passages or movements are mirrored on the basis of key, tonal center, or contour. A variety of well-known composers from Beethoven and Schumann through Mahler and Bartok composed in arch form in some of their works. Rohrmeier (2011) has analyzed tonal harmonic progressions as compatible with a context-free grammar. Palindromic permutations were also fundamental to the 2nd (twelve-tone) Viennese school, the later return of tonality in minimalism (Porter 1971), and 21st century eclecticism. Symmetry has thus played a central role in the history of Western music as well as in its literature.

4. How frequent is center embedding?

The received wisdom in linguistics and psycholinguistics is that center embedding is uncommon because of the burden it imposes on working memory resources

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[3] Interestingly, this is one (and the most difficult) of the techniques—called *ghana-pāṭha* recitation—employed by Vedic pandits to learn by oral means the vast repertoire of hymns they are required to commit to memory. Individual words of the hymn in various combinations are repeated forward and backward, with total disregard for syntactic or semantic well-formedness (Egenes 1989:48).

(Chomsky & Miller, 1963), as also noted by Staal (1980).[4] Yet given the apparent ubiquity of center embedding in other cultural domains derived from ritual, we hypothesized that center embedding may actually be more common in language than is generally assumed. For instance, center embedding is both more tolerable and more common in writing than in speech, thanks to the use of externalized cognitive representations that are stable over time (Karlsson, 2007). This impression is buttressed by the number of naturally occurring examples we encounter in our casual reading and in corpora. Here is just one such example:

…the idea [that only the people
[who heard the tale straight from Homer's lips]
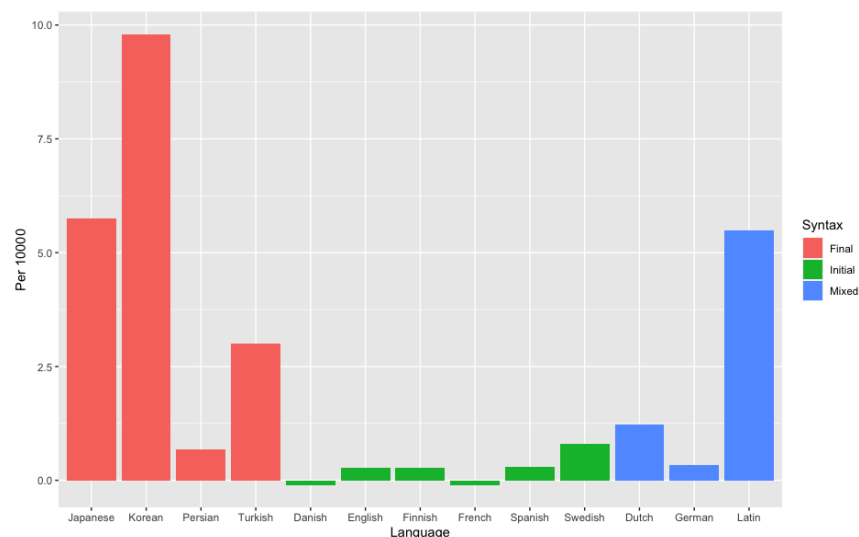had the authentic experience of the epics] is facially absurd.

Figure 1. The occurrence per 10,000 sentences of center embedded structures in corpus searches of head-final and head-initial languages, and of languages with mixed headedness.

However, the bulk of the linguistic literature on center embedding focuses on English and other European languages (e.g. Karlsson, 2007). We predicted that center embedding should be more common in head-final languages, given that clausal complementation with SOV word order favors center-embedded structure, and subjects are therefore more frequently separated from their verbs anyway. We

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[4] Levinson (2013) has claimed that center embedding is more common in conversational discourse, but see Legate et al. (2014) for a critique of Levinson's claims regarding syntactic recursion.

searched the UD database (Nivre et al., 2018) for center-embedded structures in a variety of head-final and head-initial languages, as well as in languages with mixed headedness. With the help of native speaker linguists, we eliminated sentences with incorrect syntactic tagging and parenthetical clauses. Fisher's exact tests confirmed a significant 3-way difference: head-final languages > mixed headedness languages > head-initial languages (Figure 1; all $p < .0001$).

5. Conclusion

Starting from the rather uncontroversial notion that storytelling, music, song and dance are inextricably bound up in human ritual as a unified whole (Lewis, 2018; Merker, 2009), we have attempted to show that the purported center-embedded structure of ritual itself (Staal, 1979, 1980) is likewise an intrinsic part of (at least Western) epic poetry and classical music. Our suggestion is that these remnants of ancient ritual reflect a human preoccupation with symmetric structure (Douglas, 2007). Merker (2009:56) goes so far as to characterize language as a meta-ritual: "Language shares with the ritual mode out of which it grew an insistence on proper form, yet differs from it by its emancipation from the finite particularity of rituals." It has been claimed that center embedding is more prominent both in conversational discourse (Levinson 2013) and in writing (Karlsson 2007). We have shown that it is in fact more common in (the writing of) head-final than in head-initial languages, and we suspect that it is also more common than corpus studies would suggest, even in head-initial languages.

Taken as a whole, our proposal meshes well with others that seek the source of recursion in human language across levels of linguistic analysis, cognitive domains, and spheres of human (and animal) cultural activity. Our findings simultaneously broaden the body of available evidence for such proposals, help to contextualize them in a larger cultural framework, and sharpen the empirical linguistic facts relevant to the use of center embedding in human language.

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