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Phonological and morphological complexity in Uralic

1. Introduction

From 2016 through 2020 I shared in a project entitled “Grammatical characters in computational phylogeny: The causative alternation in Uralic”, directed by Riho Grünthal as PI. The project work amassed a sizable and well-organized body of data and important typological and historical findings (Grünthal et al. 2021; Grünthal et al. 2022; Nichols et al. 2022; Grünthal & Nichols 2016; 2018; and others nearing submission). The hours spent in discussion have sharpened my understanding of grammatical structure, the quirks and complexities and defining properties of individual Uralic languages, and how those reflect different contact events and geolinguistic situations. Analysis of the project material continues to occupy the bulk of my research time since then, but despite its salience I decided it would be unseemly to offer a festschrift paper in which the honoree himself figured as unacknowledged coauthor. Fortunately, the topic intersects with my ongoing work on language complexity, and this paper is intended to recognize Riho’s ability to base broader typological and historical conclusions on close structural analysis of Uralic languages.

The Uralic languages, with their mostly linear east-west distribution, generally well-understood histories, and increasingly good descriptive coverage, provide a natural laboratory for developing and testing typological features. Here I examine the distribution of phonological and morphological complexity across Uralic, using a representative sample of phonological and morphological complexity measures and a language sample designed to cover

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the primary branches and survey the easternmost and westernmost branches – Samoyedic and Saamic – more densely.

In typology, phonological and morphological complexity are usually measured by counting the same units used for description: the number of phonemes, inflectional categories, members of paradigms, markers per category, etc. Here, in contrast, I use a set of what can be called *configured* measures, metrics specially designed to capture complexity (and yielding better results, as noted below).[1] Instead of counting phonemes I reduce the phonological inventory to a small number of dimensions defined mainly on distributional and structural grounds. Instead of counting inflectional categories or markers, I reduce them to a small number of abstract category types or macrocategories and count the number of those that are actually implemented in the individual language. As a measure of morphological non-transparency I reduce inflectional and derivational paradigms to a sample of common morphological subparadigms and a sample of the ways in which each language does or does not conform to the ideal of one-form-one-function. Complexity is then a matter of dimensionality: the more dimensions implemented in a language, the more complex the system. Phonetics and the meanings and functions of morphological categories play almost no role, though of course these descriptive factors were important to the linguistic analysis involved in setting up the system in the first place. Dimensionality is not a phonetic or semantic matter. The measurement of phonological dimensionality is laid out in section 2 and that for morphological dimensionality in section 3.

Two kinds of complexity are surveyed here. The first type, *enumerative complexity* (also known as *taxonomic complexity*, *economy*, *inventory complexity*, and other terms) counts the number of elements in a system (e.g. phonemes, genders, possession classes) or values of a feature. This paper surveys phonological and morphological enumerative complexity, differing from most complexity surveys in using configured complexity. The second type, which I (Nichols 2020) call *canonical complexity*, measures the amount of non-transparency in a system, typically counting the number of mappings from function to form. (For examples and more discussion see Nichols 2019; 2020; in press; Audring 2017.) I measure it as the number of departures from the one-form-one-function ideal of canonicality theory (Corbett 2007 and later works) and some structuralist thinking. Examples of canonical complexity are

1. The notion of configured measures, and the system outlined below for measuring phonological complexity, are from work under revision with first author Frederik Hartmann.

syncretism (one form, two functions), allomorphy (two forms, one function), multiple exponence, discrepancies between singular and plural gender classes, non-transparent semantics of gender classification, number of declension or conjugation classes, etc., each within a strictly defined inflectional or derivational paradigm or subparadigm.

The survey is based on a sample of 20 Uralic languages that aims for adequate coverage of all branches and denser coverage of the easternmost and westernmost branches to make sure that any findings of east-west clinal distributions (which can be anticipated in any longitudinally broad sample of northern Eurasian languages) are on firm footing. Appendix 1 lists the languages, some metadata, and frequencies of the main complexity types surveyed.

Probably the prototypical complex consonant systems are those of sub-Saharan Africa, the Caucasus, and the North American Pacific Northwest. Complexity in these systems is achieved by increasing the places of articulation and features such as glottalization, implosion, prenasalization, pharyngealization, etc. Complexity in Uralic consonant systems is different from these prototypes; it chiefly involves palatalization and/or what is variously called gemination or length (called fortis below). Measuring Uralic consonant complexity for purposes of rigorous cross-linguistic comparison has required evaluating phonetic and phonological factors, positions in paradigms, and behavior in paradigmatic alternations that can usually be recovered from grammars and dictionaries but are not described consistently or brought together in the same way. Thus section 2 below devotes time to these factors, especially the status of underlying and derived consonants in Saamic and Finnic consonant gradation. Section 3 deals with morphological complexity in Uralic. Section 4 summarizes the findings and section 5 discusses some of the historical, geolinguistic, and typological implications.

2. Measuring consonant complexity

The measure used here counts the number of dimensions employed in the consonant system, specifically among stops and affricates only (since those are the sounds that usually display the greatest cross-linguistic variety of types and places of articulation). The dimensions take the form of consonant series, defined minimally in terms of articulatory closure or constriction and places of articulation. The series counted are those that are contrastive in the language. (1) lists the main series types that proved relevant to Uralic and its neighbors; Appendix 2 lists the full number found so far in a larger (but thinner) worldwide survey.

(1) Configured articulatory series for stops and affricates

- Major series types (modes of articulation), closure/constriction-related:
  - Voiceless
  - Voiced
  - Strength (fortis/lenis)
  - Aspiration (non-contrastive in Uralic, arguably contrastive in Germanic)
- Ancillary distinctions (acoustically, pitch-related)
  - Palatalization
  - Labialization
- Second closures (none found in Uralic)
  - Glottal (e.g. in ejectives)
  - Velar (in clicks)
- Place of articulation (primary closure)
  - labial
  - dental/alveolar
  - palatal
  - velar
  - uvular (rarely contrastive in Uralic)

The four types are listed for clarity, but the overall count per language just totals them up in a single figure for consonant dimensions (shown in Appendix 1).

Since this typology is a configured complexity measure and not a phonetic or phonological description, terms are fairly general and the transcription in examples below is not phonetic and does not use IPA characters or square brackets.

Note that articulatory modes, ancillary distinctions, and second closures can and do combine to define a single phonemic series such as voiced aspirates, voiceless prenasalized, long fortis (in several Saamic languages), and others.

Also counted are contrastive places of articulation for stops and affricates. For Uralic these are usually labial, dental/alveolar, palatal,[2] and velar. Again, terms are general and primarily mnemonic; the issue is the number of

2. Phonetically, usually palatoalveolar. There is no standard phonemic or morphophonemic transcription for stops in this series (largely because they are usually treated as though they were palatalized dentals; see just below). I use an acute accent mark with the stop letter (and similarly for sonorants *ń* and *ĺ*, not discussed here) and the established *č*, *š*, etc. for the affricates (and fricatives, not discussed here). In Uralic

series and not their phonetics. (2) shows some Uralic stop and affricate systems with their numbers of places:

(2)	North Saami	p	t	t́		k	(4 places)
			c		č		
	Finnish	p	t			k	(3)
	Estonian	p	t	t́		k	(4)
	Erzya	p	t	t́		k	(5)
			c	ć	č		
	North Mansi	p	t	t́		k	(4) (plus labialized k^w)
			c				
	North Selkup	p	t		k		(4)
				č			
	Tundra Nenets	p	t		k		(3) (plus palatalized p^j, t^j)

A few Uralic languages have only three place series, lacking palatals (Finnish and Tundra Nenets in (2)). The palatal series is recognized as a separate place of articulation in grammars of some Uralic languages, especially those with both a stop and affricate at that place, such as North Saami above (also Hungarian,[3] and Veps in the consonant chart of Grünthal (2015: 36)). In others it is treated as palatalization of a dental series. I judge them all to be independent place series and not ancillary palatalization; ancillary palatalization is found in Tundra Nenets, where it affects more than one place series. Cross-linguistically, a palatal series is often defective (as with palatals in English or Russian, which have palatal affricates but no stops). In (2), North Selkup is an example; there, the four series are paralleled by nasals at the same places, establishing the systematicity of the series. Erzya is another, complicated by the fact that there is a palatal stop with its corresponding affricate, distinct from the palatal affricate with no corresponding stop; a similar pattern is found in Veps (not in the sample here), see Grünthal (2022: 294) and especially (2015: 36).[4]

languages and those to the east, if there is no contrasting palatal stop the palatal affricate often has a stop as an allophone, often a major allophone.

3. The Hungarian palatal stops (orthographic *ty*, *gy*) are distinctive in the unusually large extent of tongue-palate contact. In contrast, the palatal stops of other languages are more similar to the palatalized dentals of Russian, perhaps influencing the analyses.

4. The descriptions make the important observation that members of the palatal series are more frequent than palatalized counterparts of labials and velars, supporting my analysis of the palatals as a separate series.

Languages of the two westernmost branches, Finnic and Saamic, have additional modes of articulation created by consonant gradation, which was initially phonologically conditioned (more fortis onsets of open syllables, more lenis in closed syllables). By now the grade variants are fully phonologized, and the defining environments are partly morphological in Finnic and fully so in Saamic. (The alternations are still synchronically productive in Saamic, apart from South Saami, which lacks them entirely; and in Finnish, but mostly frozen elsewhere in Finnic.) Some grammars include these series in the phoneme chart (e.g. Feist 2015 for Skolt Saami, Wilbur 2014 for Pite Saami), but most list them separately, usually in connection with morphophonemic alternations.

The question of concern here is whether the fortis series is to be considered a separate series or a CC sequence. Gradation affects only medial consonants: the (historical) conditioning environment is the closed or open nature of the following syllable, so final consonants cannot undergo gradation; and it does not affect initial consonants (though CVC words do occur, the initial consonant does not alternate). Now, cross-linguistically, intervocalic fortis consonants are most often heard as geminate (in the East Caucasian languages where they occur, they are usually geminate when intervocalic but unaspirated, and no longer or minimally longer than their non-fortis counterparts, when initial). The intervocalic allophone differs phonetically from a sequence of identical consonants. In these circumstances it is not difficult to argue that the fortis series is a mode of single consonants. For languages where matters are less clear I use three criteria for status as single consonants. First, they must occur independently in roots, in the same kind of environment as their non-fortis counterparts. Second, they should display all or most of the same places of articulation as their non-fortis counterparts. Third, and most important, it is a single consonant if it alternates with a single consonant in an environment which is clearly not the result of cluster simplification. All three criteria are met in the following examples.

Finnish (examples selected from Fromm 1982: 49–50; Karlsson 2018: 50–53; Pöchtrager 2008: 359) has two grades: strong and weak. In (3) the strong grade is underlying and the weak grade occurs in onsets of closed syllables. Note that “strong” and “weak” label grades and not modes of articulation; /t/ e.g. strong in *katu* but weak in *hatu-n*, though the two are phonetically identical. When geminates are strong grade, their weak grade is a single consonant, meeting the third criterion.[5]

5. Here and below I align Finnish and Saami examples vertically by strong and weak grade, mixing consonant modes in the same column.

(3)

Strong Nom.	Weak Gen.	Gloss	Alternation
hattu	hatu-n	hat	-tt- ~ -t-
katu	kadu-n	street	-t- ~ -d-
seppä	sepä-n	smith	-pp- ~ -p-
leipä	leivä-n	bread	-p- ~ -v-

However, a fortis consonant closes the syllable and triggers gradation in the previous syllable, thereby behaving like a geminate (the adessive case of *matto* in (4) begins with fortis *-ll=*, which is audibly syllabified as *-l.l-*).

(4)

Strong Nom.	Weak Gen.	Weak Adessive / Ablative	Gloss
matto	mato-n	mato-lla	'on the mat'
katu	kadu-n	kadu-lla	'on the street'
katto	kato-n	kato-lta	'from the roof, off the roof'

Thus the status of the fortis series is split: partly sequence-like, partly singleton-like. The general operative principle for coding fortis consonants in this project is that if there is one piece of solid evidence in favor of singleton status, the fortis is coded as a singleton.

North Saami has a more complex system. The phonological conditioning, historically conditioned by open vs. closed syllables as in Finnish, has been completely morphologized, so the split behavior of Finnish does not apply in North Saami (or other Saamic). In North Saami there are two non-fortis modes (voiceless and voiced) and three fortis modes: plain fortis, strong fortis (i.e. fortis fortis; usual term "overlong"), and preaspirated. (Aikio & Ylikoski call the fortis mode clusters, but they meet all three criteria for simple consonants). Examples (see Aikio & Ylikoski 2022: 153–155 for a full list):

(5)

Strong Nom.	Weak Gen.	Gloss	Alternation
áhčči	áhči	father	fortis preaspirate ~ single preaspirate
geahči	geaži	end, tip	single preaspirate ~ single (voiced)
guos'si	guossi	guest	strong fortis/overlong ~ fortis
geassi	geasi	summer	fortis ~ single
Gen.	**Nom.**		
gohččo	gožu	soot	fortis preaspirate ~ single (voiced)

Skolt Saami is still more complex, with some consonants having three contrastive grades in the same paradigm.[6] (6) shows a two-grade lexeme and a three-grade one, where the weak grade is the same for both lexemes but the alternation sets are different.

(6) Skolt Saami (Feist 2015: 96, 97)

Weak	Strong	Overlong		
ǩiiđ	ǩiđđ	(ǩi′đđe)	'spring'	(sg.acc; sg.nom; sg.ill)
ǩiõđ	ǩiõtt	ǩiõt'te	'hand'	(pl.nom; sg.nom; sg.ill)

This set shows why many grammars do not include the fortis series in the phoneme chart: if the concern is to display a headword or citation form followed by its grades in their conditioning contexts, it is difficult to align the phonology with the morphology, so gradation and grades are treated under morphophonemic alternations. Here the display is designed only to capture the structure of series, whatever the morphological positions.

The total number of articulatory modes, ancillary distinctions, second closures, and places of articulation implemented in a language is the count of dimensions for that language. The dimensions are configured in that they measure complexity rather than describing phones, and the complexity is enumerative because it counts the number of items (in this case, dimensions) in a system. Appendix 1 gives the total consonant dimensions for the Uralic languages surveyed here.

3. Measuring morphological complexity

Types of morphological complexity, and the measures used here, are laid out in Nichols (2009), (2019), and (2020).

3.1. Enumerative morphological complexity

This measure is calculated here using the features from Nichols (2009) with some additions and updates. The main change is that the 2009 count used as one component the index of inflectional synthesis of the verb as defined in Bickel & Nichols (2013): the number of separately marked categories possible on finite verbs, where both the inventory of elements and the number of

6. A reviewer notes that there is a marginal case in North Saami as well, with overlong grade in certain imperative forms as well as the present participle.

them are counted. That approach lays the emphasis not on dimensionality but the open-ended number of categories and their markers (a major question in doing that survey was deciding whether a newly encountered inflectional category is one of those already listed, i.e. comparing functions of categories). For this paper, instead, I used the Autotyp measure of macrocategories per inflected verb form: the known inventory of possible inflectional categories was reduced to the nine broad or generic ones given in (7), and all were counted just as present/absent. The effect is that these define a possible inflectional space with emphasis on the number of dimensions and not on the semantics or functions of categories in that dimension, i.e. it makes the count configured.

(7) Macrocategories of the verb, from the Autotyp database (Bickel et al. 2022)

- TAM and similar
- Evidential
- Inter-clausal (marking of clause connection, etc.)
- Number (pluractional, multiple argument, etc.; not agreement with arguments)
- Operators (e.g. negation)
- Valence (voice oppositions, inflectional causatives, etc.)
- Pragmatic (definiteness, etc.)
- Classification (classifiers, when marked on the verb)
- Event specifications (local, spatial, etc. categories)

In addition to macrocategories, counted here are the number of argument roles indexed; the number of different alignments marked on nouns, pronouns, and verbs; and present/absent values for noun plural, noun dual, numeral classifiers, agreement gender, and inclusive/exclusive opposition in independent pronouns. The goal is to provide a schematic map of some of the major dimensions of the inflectional space, and evaluate complexity by determining which dimensions a given language implements.

3.2. Canonical morphological complexity

Counts for canonical complexity are taken from the database used for Nichols (2020). Briefly, they count the number of departures from one-form-one-function in specific paradigms of noun, verb, and pronoun inflection. Examples of such departures include instances of syncretism, multiple marking, allophony, and zero marking; declension and conjugation classes; gender switches between singular and plural; semantic non-transparency of gender assignment; and others. The survey is labor-intensive and has been completed for fewer languages than the enumerative phonology and morphology surveys, but Uralic is well enough covered to permit some conclusions to be drawn.

4. Findings

4.1. Phonological complexity

Appendix 1 shows the consonant complexity totals for the sample languages; Appendix 3 shows the statistical significance levels. There is a significant east-west cline of consonant complexity, with greater complexity in the west. The cline – both its directionality and the absolute levels – fits into the more general north Eurasian cline. That is, Uralic consonantal complexity is as expected given its position in Eurasia. However, the phonetics and phonology of the complexity is distinctive in Uralic. The complexity in the western part of the cline involves fortis-nonfortis oppositions and is due chiefly to consonant gradation in Saamic and Finnic. Gradation is now phonologized or morphologized, so all grades of all affected consonants are phonemically independent. As argued in section 2, the fortis consonants are not sequences but single phonemes, and this means that consonant inventories in Saamic languages can be very large.

The less complex systems in the eastern part of Uralic resemble those of their neighbors (mostly Turkic), and a similar two-mode, four-place type is reconstructed for Proto-Uralic (Aikio 2022).[7] The same applies to syllable structure, which is generally quite simple not only in the eastern branches of Uralic but also in the neighboring languages. In the west, the Germanic and especially Slavic neighbors have distinctly more complex syllable structure, and their long contact with the westernmost Uralic branches may have favored the development of more complex syllables there.

Appendix 3 shows that configured complexity (the rows for Consonant dimensions) reaches distinctly higher levels than descriptive, non-configured complexity (the rows for Consonant phonemes).

Vowel inventories have no significant asymmetries of complexity and have not been discussed here.

7. Aikio's display (2022: 5) is phonetically based and sets up separate alveopalatal, postalveolar, and palatal columns, but their contents are in complementary distribution (except for the possible *š, whose status is uncertain).

4.2. Morphological complexity

With enumerative morphological complexity, there is again a significant east-west cline, but in the opposite direction: complexity is greater in the east, chiefly due to the indexation of more roles and marking of more inflectional categories on the verb.

Canonical complexity shows a similar cline with greater complexity in the east. The cline for canonical complexity is probably more reliable, as its range of possibly complexity points is greater. It does not reach statistical significance (Appendix 3), however, probably because sociolinguistic factors (chiefly, the decomplexification expected of a language with large numbers of L2 learners) and not just geolinguistic factors are involved in its emergence. In addition, there is a non-clinal distribution of interest: the total canonical complexity is highest in Samoyedic and Saamic, i.e. in the most peripheral branches.

The last column in Appendix 1 shows the proportion of canonical complexity points carried by the verb. Verb canonical complexity is higher than noun canonical complexity in all languages except for Kildin Saami and South Saami, and the difference between the verb and noun levels is greater in the eastern part of the family. Branch by branch, the difference is less in Finnic and Saamic than elsewhere. These frequencies echo the larger areal tendencies in Eurasia (and worldwide): the two are nearly level in Europe and in Indo-European languages, but verb canonical complexity is appreciably greater in Siberia (and North America; it is greater for nouns only in Africa). This must be a reflex of the amount of inflectional morphology on verbs vs. nouns. It forms a bumpy worldwide cline, with verb percentages lowest in the west and highest in the east. (Verb percentages are lowest where gender agreement with nouns is most elaborated, led by Africa. Second highest is western Eurasia, where Indo-European, East Caucasian, and Semitic languages mostly have gender systems.) The overall frequency in Uralic echoes the longitudinal position of the family in Eurasia and the world, and within Uralic there is a slight cline conforming to that larger tendency.

5. Discussion and conclusions

To summarize, the complexity levels and family-internal complexity clines of Uralic position the family as expected in the typological context of northern Eurasia. The processes that have created that profile postdate the dispersal of Uralic across Eurasia, so the consonant gradation of Saamic and Finnic is not a peripheral inherited archaism but a later and local development (as the comparative method shows). It is intriguing that in their higher phonological complexity the westernmost branches resemble their Germanic neighbors – yet the phonetics and phonology of gradation is specifically Uralic. That is the case at first glance, but Schrijver (2014) argues that a Paleo-Laplandic substratum contributed to early Saamic a tendency to develop consonant gemination.

For the other large-scale geolinguistic distribution in Uralic, the higher canonical complexity of morphology in the peripheral branches Saamic and Samoyedic, I have no ready explanation. It could be due to external contact effects at the edge of the family, where exotic contacts brought in additional features. However, if the contact effects were profound – as they are known to have been in Saamic, which absorbed what is considered a Paleo-Laplandic population to the north (Aikio 2012) – one expects decomplexification in the absorbing language (Trudgill 2011 and much other work). In Samoyedic as well, there seems to have been strong substratal influence resulting in some vocabulary replacement, but no obvious decomplexification at least in the arena of canonical complexity – which is where decomplexification is expected. Another possible explanation is decomplexifying innovations spreading from the better-connected and probably more influential languages in the central part of the family, along the Volga. Only comparative-historical work by Uralicists can explain this distribution.

Typologizing Uralic consonant complexity has forced an explicit reckoning of the status of fortis consonants (results of gradation) in the inventory, and how the products of alternations like gradation are to be described generally in phonological typology.

Finally, it can be observed that the configured measures of consonantal complexity structure the consonant system independently of just how the consonant series are implemented phonetically. In that regard they make up a sound pattern in what I think is close to Sapir's sense (1925): abstract dimensionality which is stable as a system though diachronically it can drift over different phonetic implementations. That abstract system is stable across not only Uralic but much of interior northern Eurasia, suggesting that the phonological type has been brewing and diffusing in the region for a long time and Uralic has been part of its evolution.[8]

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Appendix 1: Complexity data on languages and branches

			Coordinates:		Consonants:			Morphology:		Canonical:
	Branch	Glottocode	Lat. N	Long. E	Dimensions	Phonemes	Syllable	Enumerative	Canonical	% verb
Languages										
South Saami	Saamic	sout2674	62.35	13.70	7	20	5	5	12	0.42
Pite Saami	Saamic	pite1240	66.03	17.43	9	43	4	5	43	0.60
North Saami	Saamic	nort2671	69.00	22.11	12	35	4	5	25	0.56
Skolt Saami	Saamic	skol1241	69.38	29.72	10	93	3	5		
Kildin Saami	Saamic	kild1236	67.00	35.83	11	110	3	5	31	0.48
Finnish	Finnic	finn1318	62.00	25.00	7	21	2	5	10	0.60
Estonian	Finnic	esto1258	59.00	24.73	8	17	3	6		
Mordvin (Erzya)	Mordvin	erzy1239	53.00	45.39	7	27	9	6	12	0.75
Mari (Hill)	Mari	mari1278	56.60	46.57	5	23	4	5	11	0.64
Komi	Permic	komi1268	62.00	54.95	7	26	3	6		
Udmurt	Permic	udmu1245	57.50	52.50	7	26	2	5		
Hungarian	Hungarian/Ugric	hung1274	47.00	19.66	7	50	3	6	14	0.79
Mansi (North)	Mansi/Ugric	mans1258	62.00	63.15	6	19	3	9	11	0.73
Khanty (East)	Khanty/Ugric	east2774	64.00	73.35	5	17	3	7	13	0.77
Khanty (North)	Khanty/Ugric	nort3264	66.10	67.09	5	16	3	6	9	0.67
Kamas	Samoyedic	kama1351	55.07	94.83	7		3	6		
Selkup (North)	Samoyedic	selk1253	65.00	82.30	6	16	2	7		
Enets (Forest)	Samoyedic	fore1274	63.72	86.50	6	21	3	8		
Nenets (Tundra)	Samoyedic	nene1249	69.00	71.02	7	26	2	9	19	0.63
Nganasan	Samoyedic	ngan1291	71.00	86.21	6	19	2	9	20	0.75
Branches *										
Saamic				25.4	9.8	58.6	14.4	5.0	19.5	0.69
Finnic				27.6	7.0	19.0	12.5	5.5	11.8	0.74
Mordvin				44.0	7.0	27.0	5.0	6.0		
Mari				46.9	5.0	23.0	10.0	5.0	11.0	0.64
Permic				53.7	7.0	26.0	7.0	5.5	12.0	0.75
Ugric **				61.6	5.8	25.5	11.3	7.0	10.0	0.60
Samoyedic				86.2	6.2	20.5	13.0	7.8	27.8	0.52

* Entries for all branches are means calculated from coordinates for all languages in the project database (not just those surveyed here).

** Ugric is not a proven branch, but contact connections within the group are so close that they can be lumped together to balance the sample.

Appendix 2: Configured articulatory types based on closure or constriction

To count as a series, a set of consonants must have at least two members (or, if there is only one primary stop/affricate series, there must be a fricative or nasal series making most of the same distinctions). If a series is found only in loans that have not been nativized, it is not counted here. Examples are North Saami voiceless aspirated stops or South Saami retroflex fricatives and affricates, both found only in loans from Swedish.

(a) Modes of articulation. These define the major consonant series. There seems to be no cover term for them, but they include what Ladefoged & Maddieson (1996) call airstream mechanisms and laryngeal settings. *Strength* and *fortis* are cover terms for what may be realized in one or another language as voicing, length (gemination), or other properties. The consonant gradation of Finnic and Saamic involves strength oppositions.

- Voiceless
- Voicing
- Strength (fortis/lenis)
- Aspiration
- Creaky voice
- Preaspiration
- Prenasalization
- Ejective (glottalization)
- Implosive
- Click

(b) Ancillary distinctions of pitch and similar. These can be difficult to pin down phonetically as to whether they are properties of the consonant or of the adjacent vowels. They crosscut more than one series rather than defining a single one of their own, and where present they generally apply to sonorants.

- Palatalization
- Labialization
- Labiovelarization
- Velarization
- Uvularization
- Pharyngealization
- Breathy voice

(c) Secondary closures. Some modes of articulation involve two closures, and the second articulation counts as a separate dimension here (so a mode such as ejective or implosive gets two points, one for the mode and one for the second articulation). None of these secondary closures apply to Uralic languages.

- Glottal (in ejectives and implosives; found primarily in Africa and the Americas, but also in the Chukotka-Kamchatkan family in northeastern Siberia and in the East Caucasian family)
- Velar or uvular (in clicks, found only in Africa)
- Labial or velar (in labial-velars, found primarily in Africa)

Appendix 3: Significance levels for east-west correlations (Spearman's rank correlation test)

	n	r_s	*t*	*df*	*p*	
Languages:						
Consonant dimensions	20	-0.6432	-3.56	18	0.0011	*
Consonant phonemes	19	-0.5011	-2.39	17	0.0144	**
Vowel dimensions	19	-0.1827	-0.77	17	0.2259	
Vowel phonemes	19	-0.3433	-1.51	17	0.0747	
Consonants/syllable	20	-0.4944	-2.41	18	0.0134	**
Synthesis	20	0.3221	1.44	18	0.0835	
Morphological EC	20	0.7169	4.36	18	0.0002	*
CC	13	-0.1901	-0.64	11	0.2676	
Branches:						
Consonant dimensions	7	-0.6671			n.s.	**
Consonant phonemes	7	-0.3571			n.s.	
Vowel dimensions	7	-0.0714			n.s.	
Vowel phonemes	7	-0.1429			n.s.	
Consonants/syllable	7	-0.4865			n.s.	
Synthesis	7	0.4183			n.s.	
Morphological EC	7	0.7274			0.05	**
CC total	6	-0.0286			n.s.	

* $p < 0.001$
** Minimally significant or close to significant.