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Typology, chronology, and phonetic mechanisms of Finnic secondary gemination in light of Soikkola Ingrian acoustic data

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ABSTRACT

Secondary gemination is a remarkable but little-known phonological process of singleton consonant lengthening into geminates in certain prosodic positions in Finnic languages. Its phonetic premises, typology, and chronology are still understudied. The aim of the paper is twofold. First, it summarises the main facts about secondary gemination and its place within general prosodic tendencies observed in Finnic languages. Second, it uses acoustic data from Soikkola Ingrian, which manifests one of the most developed Finnic systems of secondary gemination, to argue about the relative chronology and phonetic mechanisms of this gemination. The conclusion is that the phonetic duration of phonologised secondary geminates cannot be used as an argument for their age, because, as our acoustic data in [1] showed, their duration is regulated by compensatory stress-induced shortening as a function of the foot structure. On the other hand, the atypical prosodic positions of trisyllabic secondary gemination in Soikkola Ingrian can indeed suggest the younger age of this particular type of gemination.

Key words: consonant gemination, anticompensatory lengthening, relative chronology, Soikkola Ingrian, Finnic, timing, compensatory shortening, foot

1. Introduction

This paper is dedicated to a prosodic process attested in some Finnic varieties, especially in the dialects of the Finnish and the Ingrian language: lengthening of singleton consonants in certain prosodic positions to short or long geminates, e.g. ***kanā*** > ***kaⁿⁿnā*** [ˈkaⁿːaː] / ***kannā*** [ˈkaⁿːaː] ‘hen:PRT’. Such geminates are referred to throughout the paper as “secondary”, as opposed to “primary” (or original) geminates, as in ***linnā*** ‘city/fortress:PRT’. The latter correspond to Proto-Finnic geminates or consonant clusters (e.g. ****dn*** in ***linnā***). This terminology is further discussed in 2.2.

Although described and discussed in a series of studies, secondary gemination is little known to a wider audience, as most works are written in languages other than English. This prosodic process has barely been a subject of any general theoretical analysis in phonetics and phonology (but see [2], [3]).

The aim of the present paper is twofold. First, it summarises all relevant facts about the typology, the relative chronology, and the alleged phonetic origins of Finnic secondary gemination. Second, it uses our acoustic data from [1] on Soikkola Ingrian, a Finnic variety with one of the most developed systems of secondary gemination, as an argument in the debate about the relative chronology of this gemination and about its place within the prosodic trends observed in Finnic languages (the data will appear at: https://osf.io/rbw3m/).

In Soikkola Ingrian, secondary geminates have been phonologised into a separate degree of phonemic quantity, opposed both to singletons and to long (original) geminates. This has created a cross-linguistically rare ternary consonantal quantity contrast: ***kana*** [ˈkanaː] ‘hen’ — ***kaⁿⁿnā*** [ˈkaⁿːaː] ‘hen:PRT’ — ***linnā*** [ˈlinːaː] ‘city:PRT’ [4]. Our acoustic data has shown that the synchronic duration of phonologised secondary geminates is regulated by a general phonetic trend for compensatory shortening as a function of the structure of a given prosodic domain. Such shortening is observed also in other segments in Soikkola Ingrian, and attested for other Finnic languages, too [1]. On the basis of these findings, I argue below that the duration of secondary geminates in individual foot types cannot be used as an argument for their older or younger age, as proposed in some works [5]. On the other hand, I discuss that an atypical prosodic position of gemination in the trisyllabic foot in Soikkola Ingrian can indeed indicate its younger age.

I also argue that secondary gemination in Finnic languages is a particular phonologised manifestation of the phonetic trend referred to hereafter as “anticompensatory”, because its main principles contradict the compensatory shortening tendency. The compensatory trend shortens segmental durations in a context of increased quantity and/or number of other segments within a given prosodic domain. The anticompensatory trend, on the contrary, adds more duration in connection with more length and/or number of adjacent segments. Finnic compensatory shortening is a global stress-induced tendency observed at several levels of prosodic hierarchy: syllable, foot, phonological word. Anticompensatory lengthening, in turn, is a relatively local (mostly syllable-level) effect, partially governed by the higher-level compensatory mechanisms.

2. Finnic gemination: types, chronology, terminology

Some Finnic varieties manifest two historical types of geminates. PRIMARY (original) geminates date back to Proto-Finnic geminates or consonant clusters [6]. SECONDARY (late) geminates, recognised since Kettunen [7], [8], have emerged later out of singletons in certain prosodic positions, most notably before long vowels and diphthongs. Secondary gemination, being a late development, varies a lot across Finnic languages. It is very developed in some of them (e.g. in Ingrian), while completely absent from others (e.g. from Standard Finnish). Also the duration of secondary geminates is very variable. In particular, in the core Soikkola Ingrian varieties, in Eastern Votic, and in the Finnish dialects of North Karelia and Häme, secondary geminates remained shorter than primary geminates. This was a source of the ternary quantity contrast in these varieties [8]–[12]. Secondary (short) geminates have also been treated as lengthened phonetic instances of phonological singletons, cf. [5], followed by [11]–[13]. However, where words can be now opposed by a singleton vs. a secondary geminate, as in Soikkola Ingrian ***mātā*** [ˈmaːd̥aː] 'sleep:INF' vs. ***lō̆ttā*** [ˈloːtˑaː] 'broom:PRT', secondary geminates are independent phonemes. In other varieties, secondary geminates have eventually reached the length of primary geminates [11]. This happened e.g. in Hevaha and Lower Luga Ingrian, Western Votic, and in peripheral Soikkola Ingrian varieties [14], [4].

2.1. Typology of gemination

Finnic secondary gemination has allegedly emerged from phonetic physiologically motivated lengthening of consonants before long vowels and diphthongs [12], widely attested in Finnic languages and discussed in Section 4. Table 1 provides essential data on the five types of phonologised Finnic secondary gemination after the primarily stressed syllable of a disyllabic or a trisyllabic foot which have been distinguished in Finnic studies to date. Gemination also exists at the foot boundaries in multifoot words, but this is left out of discussion due to space limitations. The foot is understood here as a metrical stress domain delimited by rhythmically or lexically stressed syllables, whether primary or secondary, [15, p. 29]. The Finnic foot carries initial stress and can be mono-, di-, or trisyllabic.

Types 1-3 of gemination were outlined by Kettunen [16] for the Finnish dialects. Their labels reflect the spread of gemination across the Finnish dialects (across all, South-Western, or Eastern dialects, respectively). The three types occurred before long vowels and certain diphthongs (both marked as V: in Table 1) in both di- and trisyllabic foot[1], e.g. ****kanā*** 'hen:PRT' > ***kaⁿⁿnā*** [ˈkaⁿˑaː], ****kerkīmmä*** 'be.in.time:1PL' > ***kerk̆k̆īm̆m̆ä,*** now realised as [ˈkerkˑimæ] due to the 2nd syllable vowel and geminate shortening in trisyllables [1], [17].

In addition to the position before long vowels, these three types of secondary gemination have emerged also before the heavy diphthongs (also referred to as "bimoraic" in the literature) from the so-called "contracted" forms (which had lost certain elements), but not before the light ("monomoraic") diphthongs [18]–[20], [9, p. 22], [11]. For example, ***taloi*** 'house' < ****taloi*** (no segment loss in a diphthong and consequently no gemination), but ***talⁱⁱōi*** 'house:ILL' (<<Proto-Finnic ****taloihen***) or ***kot̆t̆īa*** 'home:PRT' (<< Proto-Finnic ****kotita***) with gemination.

Table 1: Types of Finnic gemination distinguished to date

N	Label of gemination	Consonantal types and prosodic positions	Ingrian example (Soikkola)	Finnic varieties in which attested
1	Common /General	all consonants before V: after a light (C)V syllable	****kanā*** > ***kaⁿⁿnā*** 'hen:PRT'	most Finnish dialects; all Ingrian dialects; Eastern Votic; (?South Estonian; ?Livonian)
2	South-Western dialectal special	only stops and *s* before V: after a light or heavy[2] syllable	****poikā*** > ***poik̆k̆ā*** 'boy:PRT'	South-Western and Eastern Finnish dialects; Soikkola, Hevaha, Oredež Ingrian
3	Eastern dialectal special (or broa-dened)	all consonants before V: after a light or heavy syllable	(Hevaha Ingrian) ****vīnā*** > ***vīⁿⁿnā*** 'vodka:PRT' [21, p. 25]	Eastern Finnish; Hevaha Ingrian
4	In trisyllabic words	all consonants after a light syllable before two light syllables -CV(i)CV(C)	****omena*** > ***om̆m̆ēna*** 'apple'	Soikkola, Hevaha, Oredež (inconsistently) Ingrian, (?Lower Luga Ingrian, ?Estonian dialects)
5	In trisyllabic words after a long syllable	only stops and *s* after a heavy syllable before two light syllables -CV(i)CV(C)	****murkina*** > ***murk̆k̆ina*** 'breakfast'	Soikkola and Hevaha Ingrian

Notes to Table 1: "N" — numbering of the gemination types (roughly in order of their wideness of spread, but see 3.2); "Label of gemination" — English translations of typical Finnish, Estonian, and Russian nominations of the gemination types (see also 2.2); "Consonantal types and prosodic positions" — consonantal types which undergo gemination and a prosodic context in which gemination occurs (see the detailed prosodic parameters of variability later in this section); "Ingrian example (Soikkola)" — by default, Soikkola Ingrian examples illustrate the gemination types, but for Type 3 absent in Soikkola Ingrian, a Hevaha Ingrian example is used; "Finnic varieties in which attested" — Finnic dialects where each gemination type has been attested. In cases where a similar phenomenon might actually represent a different prosodic process rather than gemination (cf. e.g. Section 5 on Type 4), a variety is placed in parentheses and is preceded by a question mark.

[1] If not explicitly stated otherwise, all language examples hereafter are from Soikkola Ingrian and all reconstructions refer to the diachronic level immediately preceding the modern forms (this can be a level later than Proto-Finnic).

[2] Heavy syllables in Finnic languages can have any structure apart from (C)V. In Soikkola Ingrian, the specific types of heavy syllables after which gemination occurred were *(C)V:, *(C)VR, *(C)V:R (V: — long vowel or diphthong, R — sonorant *l, m, r, n*).

Types 4 and 5 have been distinguished specifically on the basis of three Ingrian dialects: Soikkola, Hevaha, and partially Oredež Ingrian [9], [21]. Soikkola and especially Hevaha Ingrian represent the most advanced Finnic systems of secondary gemination.

Types 4 and 5 show gemination in the trisyllabic foot before a sequence of two unstressed light syllables *-CV(i)CV(C), i.e. before a short vowel (or a light diphthong) rather than before a long vowel or a heavy diphthong.

Type 4 is the gemination of any consonantal type after a light stressed syllable (C)V. In Finnic languages, the post-tonic unstressed vowel after a light stressed syllable undergoes phonetic lengthening. This stress-induced lengthening is known as "half-long vowel" [22]–[24] and is cross-linguistically atypical. Vowel lengthening had likely developed earlier than secondary gemination [25, pp. 128–129], and it was phonologised into a long vowel in Type 4: ***omena*** [ˈomeːna] > ***om̆mēna*** [ˈo**m**ˑ**e**ːna] 'apple'. The second light syllable could also contain an original (i.e. light) diphthong, the first component of which was phonetically lengthened [9, p. 25], [26, p. 38]: ***hepoisen*** [ˈhebo̯ˑi̯ẓe̯n] > [ˈhe**p**ˑ**o**ˑi̯ẓe̯n] > ***hep̆poisen*** [ˈhe**p**ˑoi̯ẓe̯n] 'horse:GEN'. This type of Ingrian gemination finds the only and very imperfect parallel in Estonian dialects [27, p. 183]; see Section 5. The foot with the light stressed syllable (both trisylabic and disyllabic) is referred to hereafter as "light foot", and any other type of foot as "heavy foot".

Type 5 is gemination of stops and *s* after the first heavy syllable (other than (C)V)): ***murkina*** > ***mur**k̆**k**ina* [ˈmur**k**ˑina] 'breakfast', i.e. this is gemination in the heavy trisyllabic foot. This type does not find any parallels in other Finnic varieties [26, p. 39], [27, p. 186], [9, pp. 14–15, 25–26, 82–84], [21, p. 30], [20, p. 32].

Types 4 and 5, where secondary geminates have emerged in the trisyllabic feet before a *short* vowel, indicate that the general prosodic mechanisms of Finnic gemination are more intricate than has been commonly thought, which is further addressed in Section 5.

Based on the overview of gemination in one-foot words above, we can now give a general summary of the parameters of its dialectal variability. The following five parameters can be distinguished.

1. Phonological status of consonant lengthening: phonetic (see Section 4) — phonologised (i.e. secondary gemination).
2. Synchronic duration of secondary geminates: shorter than primary (original) geminates — of same duration.
3. Types of consonants involved: only stops *p*, *t*, *k*, and a fricative *s* — all consonantal types.
4. Left prosodic context: after a light stressed syllable (C)V — also after a heavy stressed syllable (C)V:, (C)VR, (C)V:R.
5. Right prosodic context:
   a. in a di- and a trisyllabic foot: before long vowels and heavy diphthongs;
   b. in a trisyllabic foot only: before two light syllables *-CV(i)CV(C), and:
   — in the light foot, the 2nd syllable vowel, which was phonetically "half-long", phonologised as long;
   — in the heavy foot, the 2nd syllable vowel remained as phonetically and phonologically short.

In Soikkola Ingrian, the five types of gemination have also occurred in the secondary stressed disylabic or/and trisyllabic feet, although not always consistently (this is partially conditioned by variable footing in certain multifoot words). Examples of gemination in the secondary stressed disyllabic foot: ***vīkattehē*** > ***vīkattehē*** ~ ***vīkatte**h̆**h**ē* [ˈviːgåtːe̯ˌheː ~ ˈviːgåtˌte**h**ˑeː] 'scythe:ILL' (Type 1), ***haravoikā*** > ***haravoi**k̆**k**ā* [ˈharaːˌvoi̯kˑaː] 'rake:IMP:2PL' (Type 2); in the secondary stressed trisyllabic foot: ***opastajoja*** > ***opastaj̆**j**oja*** [ˈobo̯aːʃˌtaj̆ˑoːja] 'teacher:PL:PRT' (Type 4), ***pilahuisivat*** > ***pilahuiš**š**ivat*** ~ ***pilahuisivat*** [ˈpiłaːˌhui**ʃ**ˑivat ~ ˈpiłaːˌhuiʒivat] 'rotten:CND:3PL' (Type 5, with vacillation).

On the contrary, gemination did not occur in certain structures which would satisfy its required structural conditions synchronically but did not fit them in that earlier period when gemination was under formation. Two main types of synchronic exceptions exist.

1. In the trisyllabic foot, the 2nd syllable was originally heavy. This was the case when there was a geminate at the 2nd and 3rd syllable boundary, cf. a development from reconstructed Proto-Finnic to modern Soikkola Ingrian: ***makat̆tak*** >> ***mātā*** [ˈmaːd̥aː] 'sleep:INF', ***lak̆kat̆tak*** >> ***lakata*** [ˈłaǧaːd̥a] 'sweep:INF', ***harak̆kan*** > ***harakan*** [ˈharaːǧan] 'magpie:GEN'.
2. Non-initial long vowels in some positions have emerged after the formation of phonological gemination. For example, there was no gemination in Soikkola Ingrian before the late compensatory lengthening of short V_2 due to the late loss of the 3rd syllable: ***aitassa*** > ***aitās*** [ˈai̯d̥aːʃ] 'barn:IN' (although gemination in this position has been attested in Oredež Ingrian [16, p. 184]).

Synchronic exceptions like these show that secondary geminates cannot be considered as phonetic instances of phonological singletons in Soikkola Ingrian (contrary to [13], [11], [12], [5]). They should be seen as independent phonemes contrasted to singletons, cf. synchronic pairs like ***lōt̆tā*** [ˈloːtˑaː] 'broom:PRT' vs. ***mātā*** [ˈmaːd̥aː] 'sleep:INF'.

On the other hand, secondary gemination is still active as a morphophonological mechanism. For example, it occurs in recent Russian loanwords like ***saraj (capaŭ)*** > ***sar̆rāja*** [ʃarˑaːja] 'woodshed'. There are also cases of late reanalysis of the synchronic exceptions to gemination listed above, by analogy to the regular types, e.g. ***harak̆kan*** > regular ***harakan***, but also late analogical ***har̆rākan*** [harˑaːkan] 'magpie:GEN' [9, pp. 91–92], [26, p. 71].

2.2. Issues in the absolute and relative chronology of gemination and in the related terminology

Among Finnish and Estonian scholars, there has been a hot debate on the relative and absolute chronology of different types of secondary gemination in Finnic varieties [26], [28], [27], [9], [21], [29], [20], [12], [30]. Proposed chronologies have been based on the following four types of criteria:

1) known migrations of Finnic groups;
2) relative chronology of gemination with respect to other sound changes;
3) wideness of geographic spread: the more widespread the type of gemination is, the older it is supposed to be;
4) phonetic duration of geminates: the longer the secondary geminates phonetically are, the older they are.

Given that this paper is focused on Ingrian and that the Ingrian dialects have the most complex systems of gemination, the discussion below primarily concerns the chronology of the gemination types in the Ingrian dialects.

Lauri Kettunen devoted special attention to Ingrian secondary gemination in his famous atlas of Finnish dialects [16, pp. 182–188]. He considered both "common" gemination (Type 1 in Table 1) and different types of "special" gemination (Types 2 and 3) in Ingrian to originate from a common Karelian-Ingrian proto-dialect (*inkeroiskannakselainen alkumurre)* [16, p. 187], cf. also [31]. Antti Sovijärvi, who left the fullest early description of synchronic and historical phonetics of Soikkola Ingrian, noted that "common" and "special" gemination in Ingrian have the same prosodic conditions, so it is impossible to say which one of the two, if any, is earlier [9, p. 85]. He attributed both to as early as the XIth century [9, p. 89].

On the contrary, according to Rapola [20, p. 28], Finnish dialects could be still lacking any kind of gemination even until the XVI-XVIIth century, because the dialect of Scandinavian Forest Finns (*metsäsuomalaiset)*, who migrated away from other groups of Savo Finns in that period, lacks even the "common" gemination (Type 1).

Arvo Laanest, a prominent researcher of Ingrian dialects, also suggested that "common" gemination (Type 1) might have developed in Ingrian earlier that all other types of gemination [21, pp. 23–29], [29, p. 154], because adjacent Finnic varieties (first of all, Finnish and Votic dialects) also have "common" gemination but lack the gemination of Types 2-5.

Kettunen [16, p. 187], Sovijärvi [9, pp. 24, 89], Laanest [32] Rapola [20, p. 30], and Nahkola [12, p. 2] all noted the parallels between the Finnish South-Western dialectal special gemination and the "special" gemination in Ingrian (both of Type 2). For Finnish, Type 2 is considered to be the oldest among the gemination types. Some signs of it could be traced in written texts already in the XVIth century [30, p. 10], although nowadays it is not as widespread across dialects as "common" gemination (Type 1). Kettunen speculated either on an indirect influence of these Finnish dialects on Ingrian (through Savo Finnish dialects), or on a possible Estonian influence in the development of both [16, p. 183], [27, p. 10]. However, all Ingrian gemination, as said, might in general be older than the Finnish one, and there used to be no direct geographic connection between the Ingrian dialects and the South-Western Finnish dialects.

On the other hand, Finnish Eastern dialectal special gemination (Type 3), described by Hakulinen [28] and Palander [30] and considered to be the youngest type of Finnish gemination, finds a parallel only in Hevaha Ingrian, but not in other Ingrian dialects, including Soikkola Ingrian. Gordon [5] compared Soikkola Ingrian "special" gemination of Type 2 to the Eastern Finnish one (Type 3) instead of the South-Western one (Type 2; cf. above), probably by mistake. On this ground, however, he drew a conclusion that Ingrian "special" geminates, which he observed as phonetically shorter than "common" geminates, are shorter because they are younger in the language. This conclusion is put under doubt in Section 3 on the basis of our Soikkola Ingrian acoustic data.

At the same time, Ingrian gemination in trisyllabic feet (Types 4-5) was considered younger than other Ingrian gemination types by Sovijärvi (dated by him not before the XIIth c., when Proto-Ingrian was formed as an independent variety; [9, p. 90]). The reason for this was exactly because this gemination does not find any robust parallels in cognate varieties.

However, this chronology is also not without problems. Sovijärvi proposed a detailed relative chronology of the Soikkola Ingrian trisyllabic gemination with respect to preceding and following sound changes [9, pp. 85–88]. He chronologically placed this gemination before a loss of vowels in certain word-final suffixes (e.g. the suffix of active past participle *-nut/-nüt* or a nominal word-formation suffix *-nen/-sen*). For example, the word 'horse' in the genitive singular still contains a vowel in the formative *-nen/-sen* (cf. ***heppoisen*** in 2.1) but has lost the vowel in the nominative plural: ****hepoiset*** > ***heppoist***. Sovijärvi argued that the loss of vowel in such cases should chronologically follow the formation of trisyllabic gemination, otherwise there would have been no conditions for gemination in words like ***heppoist*** (cf. a synchronic exception nr. 2 to gemination discussed in 2.1). Laanest [21, pp. 133–135], [29, pp. 154–155], however, noted that such relative chronologisation of these two sound changes comes into conflict with the fact that the aforementioned vowel loss is systematically found also in the Oredež Ingrian dialect and in the neighbouring Finnish dialects, while trisyllabic gemination is inconsistent in Oredež and completely absent from Finnish dialects. Based on synchronic Finnish data in Ruoppila [33, pp. 137–138], Laanest suggested that the vowel loss was a long-lasting process which could have started before the formation of trisyllabic gemination and could have finished after it. In our Soikkola Ingrian field data collected since 2006, actually both ***heppoist***-type and ***heppoiset***-type forms are still attested [34].

As already said, Laanest [21, pp. 23–29], [29, p. 154] thought "special" Ingrian gemination (Types 2-3) to be as late as trisyllabic gemination, i.e. that both emerged in the Proto-Ingrian period.

Finally, researchers have also suggested that similar gemination types might have emerged independently in different Finnic varieties rather than under a mutual contact influence. This might be the case with Type 2 gemination in the Finnish dialects vs. in the Ingrian dialects, or with "common gemination" (Type 1) across Finnish dialects. Both types might have emerged in several centres simultaneously under similar phonetic pressures [9, p. 27], [20, pp. 29–30], [27, p. 10], [30, pp. 10–11].

To summarise, the chronologisation debate touches upon the following points. First, it is unclear whether the gemination has developed in one centre (and in which one, precisely) and then spread across Finnic varieties under a contact influence, or whether it has emerged independently (and even in different periods) in several centres. Second, while gemination in trisyllabic words (Types 4-5) is usually considered the youngest, it is unclear whether "common" gemination (Type 1) and "special" gemination (Types 2-3) have the same age or not — and whether the relative and absolute chronology of the gemination types differs across Finnic varieties.

The chronologisation issues have even brought about a certain terminological confusion in English. As said, for Finnish dialects, South-Western "special" gemination (Type 2) is usually considered older than "common" gemination (Type 1), but Eastern "special" gemination (Type 3) is considered younger than the latter.

It happened, therefore, that in a number of works [11], [12], and in the English resumes of [30], [35, p. 69], Type 2 (*lounaismurteiden erikoisgeminaatio*) was translated as "South-Western gemination", but Type 1 (*yleisgeminaatio)* as "primary gemination" (see, however, a correct English term "general gemination" in [36]). Type 3 (*itämurteiden erikoisgeminaatio*) was rendered as "secondary gemination". This terminology was continued by O'Dell [37, p. 16], Gordon [5], and Spahr [3]. This is, however, misleading because all these types of gemination are late and, therefore, secondary in comparison with original (primary, or early) geminates. In fact, in the Finnish, Estonian, and Russian terminological tradition, original

geminates are often referred to as "primary" (Fin. *alkuperäiset;* Est. *algupärased, varajased* or *primaarsed;* Rus. *pervičnyje / первичные* or pervonačal'nyje / *первоначальные*), while all late geminates are usually called "secondary" (Fin. *myöhäsyntyiset* or *sekundääriset*; Est. *hilisgeminaadid* or *sekundaarsed*; Rus. *vtoričnyje / вторичные*). Therefore, I propose to call the original geminates "primary" and all the types of late geminates (cf. Table 1) "secondary" (cf. the same nomination in [38]). This is especially relevant for Ingrian dialects, where, as said, it is not at all clear whether "common" (Type 1) and "special" (Types 2-3) secondary gemination is of the same age or not.

2.3. Research questions of this study

In what follows, I seek to provide additional phonetic evidence to the discussion of the relative chronology of gemination. I evaluate the criteria of chronologisation listed in 2.2 in light of the acoustic data obtained for secondary geminates and other connected timing phenomena in Soikkola Ingrian.

The phonetic data indicate, as I argue, that the most (if not all) previously used criteria of the chronologisation of gemination might be too weak. On the other hand, one new phonologically based criterion can be proposed.

3. Soikkola Ingrian acoustic data

3.1. Summary of the data and findings from [1]

For the chronological discussion, I use our acoustic data on segmental durations in 22 structural types of trisyllables in Soikkola Ingrian reported in [1]. Phrase-final tokens were recorded in 2014-2016 in the field from five female speakers born in 1929-1936. The speakers were given an oral phrase in Russian and asked to translate it into Soikkola Ingrian. In this paper, I specifically focus on the duration of secondary/short geminates and the other two quantity types (singletons and primary/long geminates) as a function of the foot structure.

Figure 1 presents raw mean durations of the three consonantal quantities in the C_2 position (following either the first syllable stressed vowel V_1, as in ***vīkate*** 'scythe', or a sonorant R after V_1, as in ***murǩkina*** 'breakfast') in the 22 trisyllabic types. Raw means (in ms) are reported within the boxes, and the number of tokens is given below each box at the bottom. In Figure 1, some of our original 22 types are conflated because certain structural factors have turned out to be irrelevant for the synchronic duration of C_2. First of all, in our original set, short V_1 was systematically opposed to two types of long V_1, either a monophthong or a diphthong (e.g. ***vīkate*** 'scythe' vs. ***leikata*** 'cut:INF'). However, long monophthongs and diphthongs resulted similar both in their own duration and in their influence on the durations of other segments, so they are grouped together in Figure 1 under long V_1. Second, our acoustic study found that the length contrast in V_2 is lost from trisyllables, so the boxes in Figure 1 are grouped only by the possible combinations of three structural factors in the first syllable: V_1 length (V vs. V: — short vowel vs. long vowel or diphthong), C_2 length (C vs. C· vs. C: — singleton vs. short/secondary geminate vs. long/primary geminate), and the presence of a sonorant R (*r*, *l*, *m*, *n*) between them (yes or no).

We can observe a strong structural impact of the preceding segments on the duration of C_2 in all the three quantity classes. A statistical investigation with mixed effects linear regression models, reported in [1], has shown that the impact of V_1 length is significant in both types of C_2 geminates but not in C_2 singletons. The impact of the presence of R is significant in all the three length classes of C_2. The overall structural impact has a generally compensatory nature. The duration of C_2 (and of other foot segments, as well) shortens as a function of an increase in the quantity and number of adjacent segments (cf. a recent overview on "poly-subconstituent" shortening in [15, pp. 135–143]). Compensatory effects are widespread in Finnic languages and have often been linked to isochrony (especially to foot isochrony). However, as discussed in [1], they might also simply be a superficial effect of stress, in line with a proposal by White and Turk [39].

Our acoustic study additionally explored the influence of the number of syllables in the foot on segmental durations. The study compared the four shortest types of trisyllables (VC, VC·, and VC: with either a short or a long original V_2) with four disyllables of the same structure of the first two syllables. This part of the study discovered, among other things, that both types of C_2 geminates (but not C_2 singletons) are significantly shorter in the trisyllabic structures than in the comparable disyllables.

In Figure 1, the duration of all the three types of C_2 forms a ladder-like pattern. Duration grows in an inverse relation to the decrease in structural complexity and segmental quantity in the first syllable. The only exception is a singleton C_2 in the foot "VC", i.e. in the light foot, which is prosodically exceptional in Finnic languages also for many other parameters [40]. Because of this pattern, C_2 duration can superficially look like a "continuum of lengthening", cf. [5], rather than a distinct phonological contrast. However, as Figure 1 shows, in the maximally comparable structural contexts (i.e. differing only in the length of C_2) the three phonological quantities of C_2 are always clearly distinguished. All structural influences on C_2 duration — both an impact of the first syllable structure, and the impact of the number of syllables in the foot — are purely phonetic.

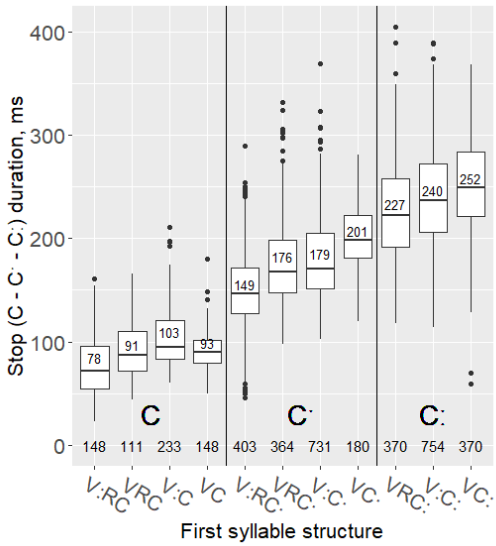

Figure 1. *Raw mean duration (in ms) of the three length classes of C_2 stops in Soikkola Ingrian trisyllables grouped by the first syllable structure*

Earlier researchers of Soikkola Ingrian had already noticed some aspects of this compensatory shortening, both impressionistically and, in some cases, experimentally. For example, Sovijärvi [9], Laanest [21], and Gordon [5] described secondary geminates following the heavy stressed syllable (which can be (C)V:, (C)VR,

(C)V:R) in Soikkola Ingrian as being shorter than those after the light stressed syllable (C)V (e.g. in ***lōt̆tā*** [ˈloːtˑaː] 'broom:PRT' shorter than in ***tap̆pā*** [ˈtap̆ˑaː] 'catch:3SG'). Our acoustic study has shown that this is just one piece of a larger puzzle where all quantity types of C_2 are affected, to varying degrees, in a compensatory way by the foot structure. The relevant foot structure factors include the parameters at the syllabic level (the impact of the 1st syllable structure on C_2, as shown in Figure 1) and at the foot level (the impact of the number of syllables in the foot, cf. Figures 2-3 in 4.1).

A comparison of our results on the trisyllabic foot to the results obtained by Markus on some bifoot trisyllabic words [38, pp. 48–49] indirectly suggests a possibility of an additional compensatory impact also at the whole word level. As said, in our data on trisyllabic feet all the three length classes of C_2 were always clearly distinguished in comparable contexts. In the data by Markus, the duration of long and short geminates in the bifoot trisyllabic structures like ***kattāmā*** [ˈkat:aːˌmaː] 'cover:SUP' vs. ***mak̆kāmā*** [ˈmak̆ˑaːˌmaː] 'sleep:SUP' was nearly the same (165 ms and 162 ms, which is close to the typical duration of a short geminate). That study, however, contained data from only one speaker, and that speaker was not represented in our study in [1]. Therefore, it is not entirely clear whether the result by Markus represents an individual idiosyncrasy or, indeed, a stronger compensatory impact in a bifoot than in a one-foot trisyllabic word.

3.2. Phonetic duration of geminates and the chronologisation criteria (3) and (4)

Phonetic findings reported above allow us to question the validity at least of the chronological arguments (3) and (4) from the list in 2.2. Especially weak in light of these data appears the aforementioned hypothesis, supported by Laanest and Gordon, that "common" secondary gemination after the light (C)V syllable (Type 1 in Table 1) might be older than "special" gemination after the heavy syllable (Types 2-3) in Ingrian dialects. Both Laanest [21, pp. 23–29], [29, p. 154] and Gordon [5, p. 82] have used the argument (3) about the wideness of geographic spread: "common" gemination is older because it is more widely spread across Finnic varieties. Gordon [5, pp. 93–94] has additionally used the argument (4): that geminates which emerged through "common" gemination (Type 1) are phonetically longer (as his study showed) because they are older than those which have emerged through the "special" gemination of South-Western type (Type 2) in Soikkola Ingrian.

However, the longer duration and even the wider geographic spread of "common" gemination can be accounted for by purely phonetic factors, namely, by the compensatory stress-induced shortening of segments in longer structures, discussed in 3.1. Geminates in C_2 after the heavy stressed syllable are shorter than after the light stressed syllable simply because the preceding segmental matter is longer. This durational difference is just a particular manifestation of compensatory shortening, and it does not need to be explained through a different age of gemination after the light vs. heavy syllable. Therefore, the argument (4) is extremely weak in the discussion of the relative chronology of gemination.[3]

Turning to the argument (3), we can now compare the wideness of geographic spread of the five types of gemination in Table 1 (in a decreasing order from top to bottom) with the prosodic conditions on each type of gemination in the third column. We observe the following inverse correlations between the wideness of spread and the structural conditions on phonologised gemination:

1) each consequent type is generally less spread across Finnic varieties;
2) each consequent type has generally more structural restrictions on gemination (in terms of both the consonantal types involved and the prosodic conditions).

The correlations are not entirely strict if we consider all the five types separately. However, they become strict if we ignore the condition 3 from the list on p. 73 on the quality of consonants and group some of the gemination types together: Type 1 (before V: after a light syllable) as opposed to Types 2-3 (before V: after a heavy syllable) as opposed to Types 4-5 (in the trisyllabic foot).

The fact that the decreasing wideness of geographic spread inversely correlates with the increasing structural complexity and length of the foot could also be linked to the poly-subconstituent shortening at different levels of prosodic hierarchy: syllable, foot, and word. Phonetic duration of secondary gemination decreases from Type 1 to Types 2-3 because of an increase in the structural complexity of the first syllable. Duration further decreases from Types 1-3 to Types 4-5 because of an increase in the overall length of the foot (2 vs. 3 syllables). With a further increase in prosodic complexity from a one-foot trisyllable to a bifoot trisyllable, phonologised gemination becomes impossible, cf. the one-foot ****murkina*** > ***murk̆kina*** [ˈmurkˑina] 'breakfast' with gemination but two-foot ***murkinā*** [ˈmurgʲˌnaː] 'breakfast:PRT' without gemination.

We can, therefore, hypothesise that, due to poly-subconstituent shortening, the longer and the more complex the syllable, the foot, and the word structure has been, the weaker the originally phonetic effect of consonantal lengthening (cf. Section 4) was likely manifest. Due to the progressively shorter duration, also the perceptual salience of consonantal lengthening used to be progressively weaker throughout the Types 1-5. Therefore, the chances for its phonologisation into secondary gemination were progressively smaller. As a result, "common" gemination (Type 1) is now the most widely spread, "special" gemination (Types 2-3) is less common, and trisyllabic gemination (Types 4-5) is attested only in the dialects of Ingrian (with some imperfect parallels to a less complex Type 4 in South Estonian dialects, cf. Section 5).

In an extreme scenario, the age might not be a relevant factor in the wideness of geographic spread of various types of gemination at all, so the argument (3) is also very weak. As mentioned in 2.2, Rapola [20, pp. 29–30] noted that no clear centre of the spread of secondary gemination across Finnish dialects could be established; there might have been up to three independent centres. It is, therefore, plausible that phonologised gemination spontaneously emerged out of phonetic lengthening (discussed in the next section) in different Finnic varieties independently and in different time periods. This would further undermine the validity not only of the criterion (3) about the wideness of spread, but also of the criterion (1) about the known migrations of Finnic groups, because both criteria rather imply a single centre of the emergence of gemination.

[3] Different duration of segments can still be sometimes used as an argument about their age. For example, in Soikkola Ingrian, the "new" non-initial long vowels which occasionally emerge in spoken speech as a reduction of the ***VhV*** sequence (e.g. ***kastehet*** [ˈkaʃteɣet > ˈkaʃteːt] 'dew:PL:NOM') are about 1/3 longer than "old" long vowels (e.g. ***kastūt*** [ˈkaʃtuːt] 'get_wet:3PL') [41]. However, the prosodic context in which the compared segments occur must be the same, which is not the case of secondary geminates after the light vs. heavy syllable.

4. Phonetic premises of gemination

4.1. "Anticompensatory" lengthening

Many Finnic varieties synchronically manifest phonetic lengthening of consonants before long vowels and diphthongs in various prosodic positions. It has been argued that phonologised secondary gemination, most cases of which occur exactly in this context, has emerged out of such lengthening. At initial stages, the lengthening was a local phonetic effect between two adjacent sounds ([11, pp. 149–150], [12, pp. 18–20] on Finnish dialects, cf. [42, p. 231]). In some Finnic varieties, this lengthening then gained more prominence in certain prosodic positions and was phonologised as secondary gemination, sometimes eventually reaching the duration of primary (original) geminates in the course of phonologisation (see Section 2). A similar lengthening phonologised into secondary gemination is observed also in cognate Saami languages [2], [43].

As a purely phonetic effect, the lengthening of consonants before long vowels and diphthongs synchronically exists in a subtler version also outside the positions of gemination or in Finnic varieties without any phonological secondary gemination at all. Experimental results on different variants of Finnish, both standard and dialectal, have systematically shown that both a single consonant and an original geminate are longer before a long vowel than before a short vowel in the otherwise comparable context. This was observed in both initial and non-initial syllables [44, pp. 19–20], [42, p. 231], [23, pp. 123–124], [45, p. 90], [41].

Those who have studied phonological secondary gemination in eastern Finnish dialects [10, p. 247], [46, p. 51], [47, p. 27], [30, pp. 231–232], [12, pp. 57–59] note that also primary (long) geminates are often lengthened before long vowels and diphthongs, e.g. *kala* 'fish' → dial. [ka**l**:oa] (PRT; secondary gemination of a singleton), *kallo* 'skull' → [ka**l**:ˑoa] (PRT; phonetic lengthening of a primary geminate) discussed by Marjatta Palander [30, p. 232]. In turn, weaker secondary gemination correlates with weaker lengthening of primary geminates [30, pp. 231–232]. More generally, a "functional unity" of secondary gemination in the original light foot and the phonetic lengthening of any coda type in the heavy foot in Finnic languages has been outlined by Holman [48]. He essentially speaks about a common articulatory basis of the two features (see 4.2).

In line with Holman's idea, in Soikkola Ingrian, along with secondary gemination after the original light syllable, also consonantal clusters in the C_2 position of the heavy foot are phonetically lengthened before long vowels and diphthongs [9, pp. 15–16]. Additionally, a long geminate in C_2 has longer duration before a long vowel in the disyllabic foot both in case of sonorants in pairs like *li**nn**ā* 'city:PRT' – *li**n**na* 'city' [49], and in case of stops in pairs like *ta**pp**ā* 'kill:3SG' – *na**tt**a* 'slime' [1]. Conversely, in the pairs of trisyllabic feet like **kat**t**ī(m̆)ma* > *kat**t**ima* 'cover:1PL' – *kat**t**ila* 'cauldron' in [1], there was no difference in the duration of C_2, because the original long 2nd syllable vowel phonologically shortened. Raw duration of C_2 in the four pairs of disyllables vs. trisyllables from [1] is illustrated in Figure 2. Raw means are reported within boxes, and the number of tokens is given below each box at the bottom. A coding such as "2.VCV", "3.VCV" refers to the number of syllables in the foot and the type of structure (labelled "foot nucleus structure"). The pairs of disyllables and trisyllables were of the following type (C_2 is marked in bold):

*ta**p**a* ['taba:] 'kill:IMP' (2.VCV) — *la**k**ata* ['ɬaga:da] 'sweep.INF' (3.VCV);

*ta**pp**ā* ['tapˑa:] 'catch:3SG' (2.VCˑV:) — *ma**tt**āla* ['matˑa:ɬa] (3.VCˑV:);

*ta**pp**ā* ['tap:a:] 'kill:3SG' (2.VC:V:) — **kat**t**ī(m̆)ma* > *kat**t**ima* ['kat:ima] 'cover:1PL' (3.VC:V:);

*na**tt**a* ['nat:a] 'slime' (2.VC:V) – *kat**t**ila* ['kat:iɬa] 'cauldron' (3.VC:V).

Statistical modelling of C_2 durations in these pairs is illustrated in Figure 3. It was conducted according to the following formula:

> C_2 duration ~ Type of structure ("Foot nucleus structure") * Number of syllables in the foot + (1 | speaker) + (1 | wordform), data = 812 tokens (1)

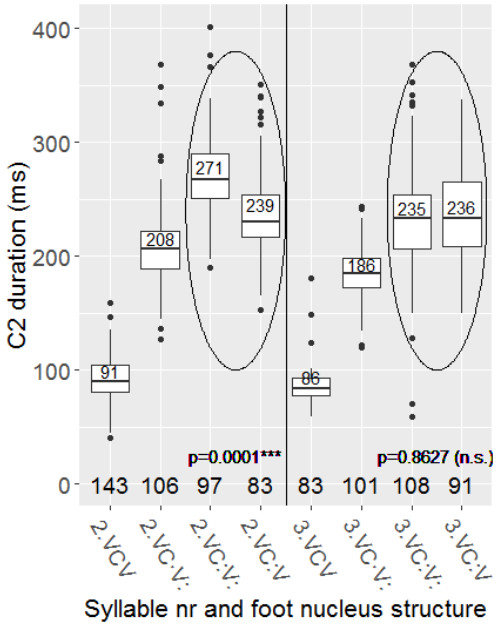

Figure 2. *Raw mean duration (in ms) of C_2 stops in four pairs of disyllables and trisyllables with the same foot nucleus structure*

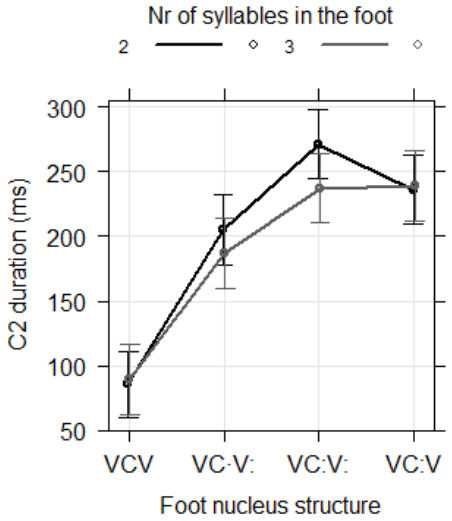

Figure 3. *Modelled influence of the number of syllables in the foot and the type of the foot nucleus on C_2 duration*

Anticompensatory lengthening in the C_2 long geminate before a long vowel, as compared to the position before a short vowel, in the pairs of disyllables like ***tappā*** 'kill:3SG' – ***natta*** 'slime' was statistically significant (modelled 35 ms, SE = 8.2, df = 52, p = 0.0001***). This difference is highlighted for raw means by a circle in the left part of Figure 2. Conversely, C_2 duration did not differ in the pairs of comparable trisyllables like ****kattī(m̆)ma*** > ***kattima*** 'cover:1PL' – ***kattila*** 'cauldron' due to the shortening of long V_2 in ****kattī(m̆)ma*** (modelled -1.5 ms, SE = 8.8, df = 46.2, n.s.). The lack of difference is highlighted for raw means by a circle in the right part of Figure 2.

Below I provide another example showing anticompensatory lengthening in the word-initial consonant (C_1) before long vowels and diphthongs in Soikkola Ingrian. It is explored in the data on trisyllables from [1]. Figure 4 shows the results of mixed effects linear regression modelling of C_1 duration as a function of the length of the following vowel V_1 (short vs. long/diphthong) according to the formula in (2), which includes random intercepts for speakers, wordforms, C_1 quality, and V_1 quality, as well as random slopes for speakers.

$$C_1 \text{ duration} \sim V_1 \text{ length} + (1 + V_1 \text{ length} \mid \text{speaker}) + (1 \mid \text{wordform}) + (1 \mid V_1 \text{ quality}) + (1 \mid C_1 \text{ quality}), \quad \text{data=3600 tokens} \qquad (2)$$

Modelled C_1 is expectedly lengthened before long vowels and diphthongs, as compared to the position before short vowels. The lengthening is slight but still statistically significant (by modelled 9 ms, SE = 2.5, df = 22.6, t = -3.4, p = 0.002512**).

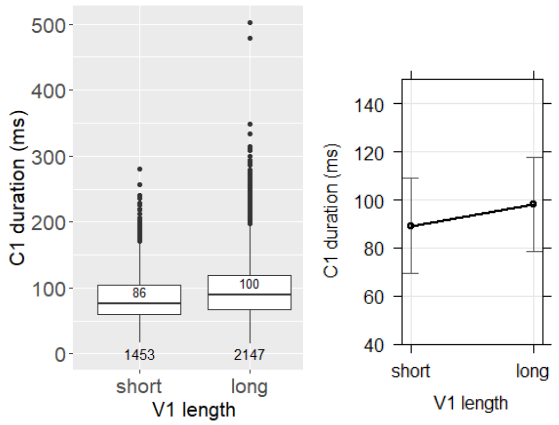

Figure 4. *Raw (left) and modelled (right) duration of C_1 as a function of V_1 length in Soikkola Ingrian trisyllables (in ms)*

The lengthening of consonants before long vowels and diphthongs, which is a phonetic basis for secondary gemination, creates an effect opposite to the compensatory effects, as it adds more duration in connection with more length. Compensatory effects are based on an inverse relation of the duration of a given prosodic subconstituent (e.g., segment, syllable, foot) to the increasing quantity and number of other sub-constituents within a constituent of a higher level (syllable, foot, word, respectively). Compensatory effects create an impression of isochrony (which may be stronger or weaker), where the general duration of a prosodic constituent is preserved notwithstanding the length and quantity of its sub-constituents.

On the contrary, the acoustic effect achieved by the anticompensatory lengthening is that the durational ratio between the adjacent segments (the consonant and the following vowel) remains constant notwithstanding the phonological quantity of both [41]. This, in turn, implies a direct relationship between the duration of a given subconstituent and the length/quantity and number of other subconstituents within a prosodic constituent of a higher level. An anticompensatory/anti-isochronic nature of the Finnic lengthening of consonants before long vowels has been explicitly pointed out in several works [50, p. 148], [12, pp. 24, 32], [37, p. 15], [24, p. 58], [41].

The process of maintenance of the durational ratio between the consonant and the following vowel can also work in the opposite direction. As mentioned above, in our data on trisyllables, the duration of C_2 long geminates has apparently become shorter before the originally long but now phonologically shortened V_2. A similar process has been observed in Finnish dialects by Marjatta Palander. When dialectal Finnish speakers de-geminated secondary geminates (of Type 1, i.e. "common" gemination), trying to get rid of a distinct dialectal feature, the following long vowel shortened, i.e. ***kallā*** 'fish:PRT' became ***kala*** not ****kalā*** [30, p. 230]. Here, too, the ratio between the vowel and the preceding consonant was maintained. Importantly, this ratio differed from the ratio between the same segments in the true light foot (as in ***kala*** 'fish', where V_2 is phonetically a "half-long" vowel, mentioned in 2.1).

On the basis of these observations, Wiik [51], Palander [30, p. 233], and Nahkola [12, pp. 88–89] argued that phonological "common" secondary gemination has developed as a "push chain" effect after the emergence of the "half-long" vowel, under a paradigmatic threat of a merger between two types of structures: ****kala*** 'fish' and ****kalā*** 'fish:PRT'.

In other Finnic varieties, where secondary gemination is attested only as an extremely late phenomenon and in very few positions (Estonian, Votic — in the latter gemination has developed only in the varieties in contact with Ingrian [52]), such a merger between the two structures has indeed happened [40]. Crucially, Estonian acoustic data do not provide any clear evidence for the phonetic anticompensatry lengthening tendency either. Estonian has an innovative quantity system with no contrast of long and short vowels in the unstressed syllables. Therefore, anticompensatory lengthening could be potentially observed only in the word-initial consonants (C_1) before long vs. before short vowels. Estonian data on C_1 are controversial: C_1 duration shows an anticompensatory effect in some studies [53], but a compensatory one in others [54]–[56].

It seems, therefore, that the "push chain" hypothesis might not be that strong, and that the most important factor in the development of phonologised secondary gemination is the existence of consistent phonetic lengthening of all types of consonants before long vowels and diphthongs, as attested in Finnish and in Ingrian.

The degree of the phonetic lengthening itself and of its phonologisation varies both across and within the respective Finnic varieties. Nahkola [12, pp. 196, 212–214] noted that, in those Finnish dialects where the phonetic lengthening is in process of phonologisation into gemination, consonants in more frequent words undergo lengthening more often. According to Nahkola [12, pp. 41–43, 229], who refers to the lexical diffusion and frequency actuation hypotheses in the studies of sound change, this supports the view of the phonological secondary gemination as originally physiologically motivated. Such argumentation is in line also with recent usage-based approaches, which hypothesise that lexical frequency prompts sound change. It has been argued that sound

change starts from frequent words and morphemes due to a higher level of automatisation in their production [57, pp. 11–12], [58], [59].

Conversely, the aforementioned reverse process of de-gemination, observed in the XXth century, is seen by Nahkola as sociologically rather than phonetically motivated [12, pp. 89–92, 131–132, 145, 165, 276]. Its spread, on the contrary, starts from the least frequent words and in formal speech.

The physiologically motivated process of consonantal lengthening before long vowels and diphthongs should likely have an underlying articulatory basis. Its articulatory mechanisms have not yet been instrumentally studied, but some impressionistic hypotheses have been proposed in earlier studies. They are explicated below and put in light of modern articulatory models, in a hope to create a starting point for future articulatory research on Finnic languages in this field.

4.2. Proposed reasons and mechanisms of anticompensatory effects

Certain compensatory effects (most notably, the reduction or lengthening of V_2 as a function of the weight of the first syllable — heavy or light, respectively) and anticompensatory secondary gemination show a correlation across Finnic varieties both in the degree of their prominence and in their geographical distribution. The areas of the "half-long" vowel (lengthened short V_2 in the light foot, as in ***kana*** ['kana:] 'hen') and of "common" secondary gemination (Type 1, i.e. in the original light foot with a long V_2, as in ****kanā*** > ***kaňňā*** ['kaˑn:a:] / ***kannā*** ['kan:a:] 'hen:PRT') coincide in Finnish dialects [36], [51]. Both the oldest type of Finnish gemination (Type 3, "South-Western special") and the strongest V_2 reduction in the heavy foot are attested in South-Western Finnish dialects [60, pp. 13, 44–45]. Secondary gemination, the "half-long" vowel in the light foot, and the reduced V_2 in the heavy foot are also prominently manifest in the Ingrian language and in the Finnish dialects of Karelia and Ingria [40], [61].

The development of Finnic secondary gemination has been seen by many authors as a metrical strengthening of the foot-initial stressed syllable through an increase in its quantity and, therefore, as a metrical "centralisation" of the foot. This strengthening has often been impressionistically linked to the "striving" of these languages to restore the intensity/quantity balance between the stressed and the unstressed part of the word. Such a balance had been disrupted when long vowels and diphthongs emerged in the non-initial unstressed syllables giving "too much" quantity to the latter [2], [8], [9, pp. 22–27], [12, pp. 18–32], [16, p. 183], [20, p. 25], [26, p. 47], [30, pp. 9–10], [60, pp. 97–99], [62, p. 326], [63, pp. 228–230], [64, pp. 68–70], [65, pp. 303–305].

The aforementioned geographic correlation between secondary gemination and the "half-long" vowel has been accounted for in early research by the common articulatory mechanisms of both. Both phenomena, which are cross-linguistically atypical, have been linked to the "articulatory over-exertion" [66, p. 147], i.e. an intense articulation of the consonant in anticipation of the following long vowel [26, pp. 40–47], [66, pp. 145–148], [67, p. 25], [68, p. 148]. Some authors have proposed that the strengthening of the first syllable happened through the lengthening of the consonant (rather than of the preceding stressed short vowel) due to a phonetically "close contact" (*luja liittymä*) between these two sounds ([12, pp. 12, 20–21], [46, p. 188], [50, pp. 148–149], cf. Trubetzkoy's original notion of the correlation of close contact, or syllable break in [69]). This close contact has been related to the tense articulation of the initial stressed syllable [22], [70, p. 78]. In Finnish, the tenseness of articulation has also been perceived as drastically decreasing throughout the word after the first light syllable or within the first heavy syllable [60, pp. 41–42].

At the same time, in the Finnish varieties with the phonetic consonant lengthening still in process of phonologisation, in cases where the lengthening is absent, the first syllable strengthening can sometimes happen through the stressed short vowel lengthening, e.g. ****puhū*** > ***puhhū*** ['puh:u:], but also ***pùhū*** ['pu·hu:] 'speak:3SG' [12, pp. 257–258], [22]. Such vowel lengthening is phonologised in some Finnish dialects, but less often than secondary gemination, and is described as conditioned by an "open contact" (*höllä liittymä*) between the first and the second syllable. Lehtonen (1970: 91-93) gives an overview of the concept of "syllable contact" in application to Finnic languages and its alleged acoustic and perceived correlates.

The results of a similar process of stressed syllable strengthening through lengthening before an originally long vowel or diphthong are observed in Standard Estonian. This is how the development of the third quantity degree in Estonian is usually accounted for [71], [72, p. 181], [73, pp. 346–348]. The difference here is that the phonologised lengthening has generally occurred in Estonian through the mechanisms other than secondary gemination.

4.3. Earlier proposals in light of modern articulatory models

Arvo Eek, who conducted a series of articulatory (palatographic and cineradiographic), acoustic, and perceptual studies on Estonian in the 1960-1990s, later on proposed a sketch of an articulatory model of the foot which includes a possible abrupt shift in motor control between its two parts [74], [75]. The stressed syllable is tense and pronounced with a greater muscular effort and is also well-controlled for (it shows higher velocity of articulators, less articulatory target undershoot, and less coarticulation). This control and the tenseness of articulators are then abruptly released in the second, relaxation, phase. In his model, Eek drew upon the models of speech articulation and motor control system contemporary of the 1960-1980s and made inferences about muscular activity from acoustic and articulatory data.

By now, the most elaborate model of this kind has been developed under the Articulatory Phonology / Task Dynamics (AP/TD) framework. It represents speech activity as a sequence of coordinated (coupled) articulatory gestures which gradually activate and deactivate. Each gesture passes through several articulatory phases, and initial phases of some gestures can overlap with the final phases of the previous gestures. Articulators performing the gestures are modelled as critically damped mass-springs (oscillators) moving to and from gestural targets.

At present, coupled oscillators model speech activity mostly up to the level of syllables [76]. Prosodic patterns of higher levels are not yet integrated into AP/TD at the same level of detail, which triggers constant further development of this framework cf. [77], [15], [78]. Some prosodic patterns are modelled in AP/TD through π-gestures (prosodic gestures [79]), which account for lengthening at the initial and final prosodic boundaries at different levels of prosodic hierarchy, and μ-gestures (modulation gestures [80]) accounting for the lengthening related to lexical stress. These gestures are gradually activated and deactivated at prosodic boundaries over a timespan of several single articulatory gestures.

Later versions of AP/TD have also introduced theoretical sketches of coupling oscillators for the prosodic levels over the syllable, i.e. for the foot and the phrase, to account for poly-subconstituent shortening at these levels [80], [81]. Eek's articulatory model of the foot is conceptually similar to these foot-level oscillators. It might be possibly represented in the AP/TD framework as a π-gesture regulating the level of muscular contraction throughout the foot, but this is still an open field for future research.

While there is no space for a full-fledged discussion on the articulatory basis of observed acoustic compensatory and anticompensatory effects (including gemination) in the Finnic timing patterns, some potential challenges posed by Soikkola Ingrian data to both Eek's model and AP/TD are outlined below.

Eek's early model, which was largely based on Estonian and Finnish acoustic data, conceptually differed from the current AP/TD on one important point. AP/TD presumes phonological representations to be spatiotemporal, i.e. timing-intrinsic (this point has recently been defended again [76]). Eek, on the other hand, followed those earlier variants of Articulatory Phonology which presumed timing-extrinsic, symbolic phonological representations (e.g. [82] et seq.). However, some recent proposals within AP/TD which try to re-introduce "an approach to speech-motor control based on ...phonology-extrinsic timing mechanisms, and symbolic phonological representations" [15, p. 313]. Importantly, these proposals use the data on Finnic duration and quantity as a crucial argument. For example, some studies have shown that Finnish strongly regulates phrase-final lengthening in short vowels but not in long vowels, because if a short vowel lengthens it could be confounded with a phonologically long vowel [83], [84].

In our study on Soikkola Ingrian [1], vowels and consonants of progressively higher quantity degrees manifested progressively stronger compensatory effects. In general, the durational variability of sounds progressively grows in higher quantity degrees (cf. Figure 1). Given that the variability of both speech and non-speech movements proportionally grows with an interval duration in accordance with Weber's law (viz. [15, pp. 90–95]), this fact suggests that long vowels and consonants rather correspond to single longer gestures of articulators rather than to the sequences of two gestures predicted by AP/TD.

As for the anticompensatory effects discussed in this paper, one can compare the modelled 9 ms of difference in the singleton C_1 consonants before the long vs. short vowels in trisyllables (Figure 4) with the modelled 35 ms (raw 32 ms, see Figures 2-3) of difference between the C_2 long geminates before the long vs. short vowels in disyllables. The difference is much bigger for C_2 than for C_1 in terms of absolute duration (increase by 9 vs. 35 ms, i.e., four times) than in percentage (increase by 10% vs. 15% of the duration of a segment, i.e. 1.5 times, cf. Table 2). Note that this comparison is limited by the facts that the prosodic positions are not entirely comparable (C_1 in trisyllables vs. C_2 in disyllables) and that C_1 contains different types of consonants (*p*, *t*, *k*, *r*, *n*, *l*, *m*, *v*, *j*, *h*, *s*) while C_2 contains only the stops *p*, *t*, *k*.

Still, the general trend here is the same as for the compensatory effects: longer phonemes seem to manifest stronger phonetic anticompensatory lengthening in terms of absolute and proportional duration than shorter phonemes. Such fact also rather speaks in favour of a long segment as a single articulatory gesture targeting a long phoneme rather than as two sequential gestures targeting two consequent identical segments.

Table 2: Anticompensatory lengthening in the C_1 singletons of trisyllables and the C_2 long geminates of disyllables

	Modelled duration before V	Modelled duration before V:	Increase in ms before V:	Increase in % before V:
C_1 singletons of trisyllables	89 ms	98 ms	+9 ms	+10%
C_2 long geminates of disyllables	236 ms	271 ms	+35 ms	+15%

It also remains unclear how the effect of the anticompensatory lengthening of consonants before long vowels and diphthongs should itself be accounted for in AP/TD. A π-gesture in this model is a local clock-slowing mechanism accounting for initial and final boundary lengthening. However, this gesture refers only to prosodic boundaries, while anticompensatory lengthening seems to be stronger in the middle of the foot (in C_2) than at the beginning of the foot (in C_1). As discussed above, foot-internal lengthening of singleton consonants had been so prominent that it has been phonologised as secondary gemination in many Finnic varieties. AP/TD could account for this effect as prosodic boundary lengthening only if one could hypothesise that non-initial long vowels (as in ***kanā*** 'hen:PRT') originally carried secondary stress. In the bifoot trisyllables (as ****murkinā*** 'breakfast:PRT'), however, where the third syllable clearly carries secondary stress, secondary gemination did not happen (see 3.2). On the other hand, gemination happened before two light and clearly unstressed syllables in the trisyllabic foot (as in ****murkina*** > ***murk̆kina*** ['mur**k**ːina] 'breakfast').

Some studies have touched upon anticompensatory effects in light of AP/TD models, though. O'Dell [37, pp. 105–106] notes that the anticompensatory relation observed between the durations of a consonant and the following vowel in Japanese [85] could be accounted for by a compensatory mechanism at a higher prosodic level (the word). At the disyllabic word level, when the whole second syllable shortens, the whole first syllable, including both C1 and V1, lengthens. A relation of this kind, however, has not been observed for the anticompensatory lengthening in Finnic varieties.

Also the Finnic compensatory stress-induced V_2 lengthening in the light foot with the 2nd syllable short vowel (as in ***kana*** 'hen'), which, as said in 4.2, is a compensatory effect geographically correlated to secondary gemination, presents some challenges for AP/TD and the related models. At present, μ-gestures accounting for prosodic lengthening and compensatory shortening effects related to lexical stress predict these effects in stressed vowels but not in the unstressed ones [80]. For example, Tilsen [86, pp. 49–50] explicitly states that "accent" (in his terms, the articulatory control over acoustic prominence through a variation in pitch, duration, spectral tilt, and the related articulatory kinematics) can occur only on the syllables which are stressed in the structural sense. However, in the case of Finnic "half-long" V_2, we observe stress-related lengthening in a structurally unstressed syllable.

Also the compensatory shortening is stronger in our Soikkola Ingrian data in the unstressed syllable of the heavy foot (up to the phonological shortening of long V_2 in the trisyllabic heavy foot) than in the segments of the stressed syllable [1]. Maybe in Finnic

languages, a foot-level stress-related μ-gesture should include not only the stressed syllable but also the following unstressed one(s). In other words, it is something like Hirsch's "interval" [87] rather than the syllable which is the domain of a μ-gesture.

These examples of V_2 lengthening and shortening also show that the degree of compensatory effects is not the same within the Finnic foot. Eek, who had built his model primarily on Finnic data, explicitly claimed that "the temporal compression ...need not be the same for every constituent part of the frame" [75, p. 253]. Current AP/TD models can in principle allow unequal compression within the foot, given gradual activation and deactivation of gestures and overlapping of their different phases, but this question has not been explicitly elaborated yet. A different degree of poly-subconstituent shortening in different positions within a prosodic domain (a lot of evidence for which comes specifically from the Finnic languages) is seen as a general challenge for the alleged periodicity of articulatory control structures in AP/TD [15, p. 144].

In general, even the most recent AP/TD models might not be yet sufficiently specified to make concrete predictions in case of complex durational patterns characteristic of Finnic languages. Moreover, speech motor control models are usually restricted to articulatory trajectories and rarely account for muscle contractions and the tenseness of articulation (cf. [15, p. 13]). The latter, however, has been perceived as crucial for the distinction between stressed and unstressed syllables in the Finnic languages, as well as potentially responsible for the cross-linguistically atypical prosodic phenomena like secondary gemination and the "half-long" vowel.

5. Changing prosodic properties of phonologised gemination and a new criterion (5) for chronologisation

As said, phonetic anticompensatory lengthening is a local process acting only at the syllabic level between two adjacent sounds, a vowel and a preceding consonant. Compensatory effects are, in turn, more global, as they are observed at several levels of prosodic hierarchy: syllable, foot, word. The compensatory trend seems to control over the anticompensatory one in the sense that the former regulates the degree of the phonetic manifestation of the latter. Following the compensatory mechanisms, the degree of the phonetic prominence of anticompensatory lengthening is inversely proportional to the length and complexity of the prosodic domains at various hierarchic levels (at least the syllable and the foot), as discussed in Section 3.

Our data from [1] has shown that phonological secondary geminates undergo structure-induced compensatory shortening in the same way as long geminates and, to a lesser extent, singletons (cf. Figure 1). Conversely, phonological secondary geminates also influence other neighbouring sounds in a compensatory way, as various Soikkola Ingrian data has also demonstrated [9], [5], [17].

The same kind of compensatory impact of secondary geminates on other sounds has been observed also in earlier studies. Phonologised secondary gemination in Soikkola Ingrian and in Finnish dialects has often brought about the shortening of the following long vowels and diphthongs, especially in long words [9, p. 27], [30, pp. 222–227]. The longer duration the lengthened consonants obtained in Finnish dialects and the more they were phonologised, the stronger the shortening of the following and the preceding vowels became, especially of the long vowels in non-initial syllables [23, pp. 126–129], [30, pp. 222–229], [12, pp. 257–260].

The duration both of the phonetic anticompensatory lengthening and of the phonological secondary geminates, therefore, seems to be regulated by compensatory mechanisms. However, in some Finnic varieties, phonologised secondary geminates have also acquired entirely new prosodic properties, as compared to the original phonetic lengthening of singletons.

Most importantly, phonologised secondary gemination in some varieties is conditioned by very general rhythmic factors rather than just by the length of the following vowel. For example, in Finnish dialects, the presence or absence of phonologised secondary gemination can be regulated by word stress placement rules and by the degree of lexical and phrasal stress [12, pp. 184–187, 238–239].

One of the most illustrative examples showing that secondary gemination at late phonological stages of its development can be conditioned by general rhythmic factors rather than by the length of the following vowel, is the idiosyncratic Soikkola Ingrian gemination in the trisyllabic foot before two light syllables (of Type 4, i.e. ***omena** > **om̆mēna*** 'apple', and of Type 5, i.e. ***murkina** > **murk̆kina*** 'breakfast', cf. Table 1). Sovijärvi [9, pp. 24–25] argued that gemination, which strengthens the stressed syllable, happened here in order to rhythmically "counter-balance" the following two short unstressed syllables. This type of gemination occurred only in Ingrian and even not in all of its dialects. In Soikkola and Hevaha, it is observed consistently, in Oredež inconsistently, in Lower Luga dialect — sporadically, only after the light stress syllable (i.e. of Type 4), and in very few words [88].

In Lower Luga Ingrian (LL), what looks like trisyllabic gemination might actually be an extremely recent development. It might have emerged through a process of paradigmatic levelling or through a contact influence. One of the indicators is that the "half-long" V_2 in the original trisyllabic light foot has not phonologised here into a long vowel (as it has happened in Soikkola ***omena** > **om̆mēna***). For example, the following forms are attested in my field data [88, pp. 230–231]: ***olisi*** 'be:CND:3SG' > ***oliz*** ['oli:z] (North LL) ~ ***olliz*** ['ol**l**:**i**z] (East, West, South LL), ***olisid*** 'be:CND:3PL' > ***olisid*** ['oli:sid] (North, East, South LL) ~ ***ollisid*** ['ol**l**:**i**sid] (West LL). Maybe the development of gemination here is linked to the loss of the final vowel, as in South and West Estonian dialects, where a similar process occurs: ****jumala** > **jum̆mal*** ['jum·a:l] 'God'. The Estonian process is sometimes compared to the trisyllabic Ingrian gemination [16, p. 188], [21, p. 29], but more often is considered as a separate mechanism of compensatory lengthening in the 1st syllable due to the loss of the final vowel [66, pp. 148–149].

On the other hand, such gemination before a short vowel in Lower Luga Ingrian is sporadically documented also in words which have not been originally trisyllabic, e.g. in a tetrasyllabic word ****mänisimmä*** 'go:CND:1PL' > regular ***mänisim̄*** ['mæ**n**i:sim:] (East LL), but also irregular ***männ**isim̄(')* ['mæ**n**:i:sim(ʲ):] (West, South LL). This more directly indicates a late analogical development.

Coming back to the trisyllabic gemination in general, we can see that this gemination is no longer a consequence of the original phonetic condition on anticompensatory lengthening (the length of the following vowel). This fact clearly indicates that Types 4 and 5 have indeed developed chronologically later than Types 1-3. In order for the Types 4-5 to emerge, phonological gemination must have first emerged before long vowels and diphthongs. The factor of the prosodic context of gemination, therefore, can be taken as an additional criterion (5) helping us to establish the relative chronology of the types of secondary gemination discussed in 2.2 and 3.2.

6. Conclusion

This paper has considered the development and relative chronology of the Finnic secondary gemination of singleton consonants after the stressed syllable in one-foot words, attested especially in the dialects of Finnish and Ingrian. Phonological gemination has apparently emerged out of purely phonetic lengthening, observed in experimental studies on various Finnic languages also as a living phonetic tendency.

This lengthening is characterised as "anticompensatory" in this study, as it is in a way contrary to the stress-induced compensatory effects in Finnic languages, which are more numerous and better known outside Finnic studies. In connection with more quantity in some segments (or their higher number), the compensatory shortening reduces duration in other segments, while the anticompensatory lengthening adds duration in other segments.

The anticompensatory lengthening is far more local in its scope than the compensatory trend and is partially regulated by the latter. The dominance of the global compensatory trend over the local anticompensatory one accounts for the observed progressively shorter durations of secondary geminates in progressively more complex syllable, foot, and word structures.

Moreover, an interaction between compensatory and anti-compensatory effects can also account for the progressive increase in both structural and geographic restrictions on Finnic gemination as a function of an increase in foot length and complexity (from Type 1 to Types 2-3 to Types 4-5). I argue that, because of this interaction, earlier proposed criteria of phonetic duration, structural and geographic restrictions on various types of Finnic gemination can hardly be used for the relative chronologisation of these types (especially Type 1 as being older than Types 3-4).

In turn, Types 4-5 ("trisyllabic gemination"), which manifest gemination outside of its original phonetically motivated context before long vowels, can be more safely considered as younger than the other types. The trisyllabic gemination could have likely developed only after the phonologisation of gemination in its original context.

Additionally, I have considered the challenges posed to modern articulatory models (Articulatory Phonology and Task Dynamics) by some Finnic timing effects. These are the two cross-linguistically atypical Finnic prosodic phenomena in the light foot — secondary gemination and stress-induced lengthening of short unstressed vowels — and the unequal degree of compression and lengthening throughout the Finnic foot. Accounting for these three challenges in AP/TD remains a task for future research.

7. Abbreviations

1, 2, 3 — 1, 2, 3 person, CND — conditional, GEN — genitive, ILL — illative, IMP — imperative, IN — inessive, INF — infinitive, NOM — nominative, PL — plural, PRT — partitive, SG — singular, SUP — supine.

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