BALTO-FENNIC-SÁMI CONSONANT GRADATION AS FORTITION*

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A metrical account of consonant gradation in Balto-Fennic-Sámi which relies primarily on fortition as the driving mechanism is proposed as an alternative to the majority of accounts which treat gradation as primarily a lenition process. Gradation is argued to be a phonetically natural foot-balancing process triggered by lengthened foot-final vowels. In support of this analysis, foot-final vowel lengthening and foot-balancing are shown to be recurring diachronic and synchronic processes throughout the Balto-Fennic-Sámi family. Under the proposed account, Sámi, rather than Finnish, becomes the most conservative language with respect to synchronic manifestations of the original gradation process.

1. Introduction

Consonant gradation is an alternation affecting consonants in most Balto-Fennic languages and in the northern and eastern dialects of closely related Sámi (Lappish): e.g. Finnish *katto* 'roof' nom.sg. vs. *katon* 'roof' gen.sg. Gradation was a productive process during the proto-Balto-Fennic-Sámi period (henceforth: pBFS) over three thousand years ago, but has since been morphologized in the daughter languages.

In this paper, I attempt to offer a plausible account for gradation as a phonetically driven prosodic process which later became grammaticalized due to subsequent phonological developments. Drawing on data from contemporary Balto-Fennic and Sámi, I argue that gradation was merely a chronologically earlier instantiation of later better documented processes, some still fully productive synchronically, occurring in modern Finnish dialects, Southern Estonian dialects, Eastern Votic and Ingrian. By linking radical gradation to these better understood and more recent phenomena, radical gradation no longer remains a mysterious and synchronically unattested process; rather, it becomes a natural process with synchronic correlates in the daughter languages of proto-Balto-Fennic-Sámi, as well as in other languages outside of the Balto-Fennic-Sámi family.

2. Gradational alternations

2.1. The target of gradation

The paradigmatic alternations characteristic of radical consonant gradation (henceforth, "consonant gradation" or simply "gradation") are still apparent in all Balto-Fennic languages, except Veps and Livonian, and in both Northern and Eastern (but not Southern) Sámi. Below, I present examples from five languages/dialects which will serve as the basis for this paper: Sámi, Finnish, Estonian, Ingrian, and Karelian, the last two of which may be viewed as either eastern dialects of Finnish or languages very closely related to Finnish. Sámi, Estonian and Finnish will serve as the primary languages of comparison, because they display a representative cross-section of the various reflexes of the original gradation process: Sámi for the Sámi branch of Balto-Fennic-Sámi, Finnish for the northern branch of Balto-Fennic and Estonian for the southern branch of Balto-Fennic.

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Data for Karelian and Ingrian are presented where the reflexes of gradation differ markedly from Finnish. In other cases, the Karelian and Ingrian forms may be assumed to be identical to their Finnish counterparts in the *relevant* respects. The Sámi data is drawn primarily from Norwegian Sámi, described in great detail in Nielsen (1902, 1926) and Sammallahti (1977) and, in abbreviated form, in Bergsland (1976). The Estonian and Finnish forms generally represent the well-documented standard languages of Estonia and Finland, except where noted. I rely on Laanest (1966) for the Ingrian data and Holman (1975) and Turunen (1956) for Karelian forms. Other sources used are mentioned in the text at the relevant points.

The next four sections present the synchronic gradation alternations in Sámi, Finnish, Estonian, Ingrian and Karelian. For expository purposes, certain phonetic details have been omitted from the text, but are presented in footnotes. Following Finno-Ugric conventions, length is indicated by writing the lengthened segment twice; thus, /ee/ = IPA /eː/, /kk/ = IPA /kː/. Overlong segments are written triply, e.g. /kkk/ = IPA /kːː/. Since the syllable plays a large role in gradation, syllable boundaries are indicated by a period and may be assumed (since only single onsets were allowed in proto-Balto-Fennic-Sámi) to fall approximately in the middle of intervocalic geminate consonants and approximately two-thirds of the way into the articulation of overlong consonants. In support of this syllabification, Lehiste (1966) presents some spectrograms of Estonian speech containing small bursts, suggestive of minor rearticulations, at points during stop closures corresponding to the phonological syllable boundaries.

2.1.1 Stops

Stop consonants appear in three grades in total, but only two in any one paradigm. There are thus two paradigms involving plosives[1]. In Sámi and Estonian, the first alternation is between overlong and geminate stops. The corresponding Finnish and Karelian alternation involves geminates and single voiceless stops[2].

(1) Plosives-- Alternation 1

Sámi	Finnish	Estonian	Karelian	
bapp.pɑ 'priest'	pap.pi 'priest'	pappp 'pope'	lepp 'alder'	nom.sg
bap.pɑst	papis.sa	pap.pist	lepæstæ	elat.sg.

The second paradigmatic alternation has different reflexes in Balto-Fennic and Sámi. In Sámi, geminate voiceless stops are in alternation with single voiced stops, fricatives or approximants, depending on the dialect and the place of articulation. In Finnish, single stops are in alternation with either zero or /v/ in the case of velars, a fricative /v/ in the bilabial series, or a voiced stop, tap, lateral or fricative in the dental series, depending on the dialect and to some extent on the individual (see Kettunen 1959, map 65). Although the weak grade forms show much variation depending on the place of articulation in Finnish, the relevant generalization is that the weak grade is a lenited version of the single voiceless stop. Estonian basically mirrors Finnish with respect to the lenited series of stops with some minor exceptions not discussed here (see Tauli 1973). An important difference between Karelian and Finnish exists in the bilabial series, where a voiced bilabial stop and a voiced fricative are in paradigmatic alternation in Karelian, in contrast to the Finnish alternation between a voiceless single stop and a voiced fricative. In (2) below, the bilabial series is presented.

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[1] In Sámi, and in certain dialects of Finnish, affricates undergo similar alternations to the stops. In Estonian and in standard Finnish, sequences which behave like affricates in Sámi and Finnish dialects, pattern with consonant clusters consisting of two obstruents with respect to gradation. In Estonian but not standard Finnish, such clusters undergo gradation.

[2] Geminate and overlong plosives in many Sámi dialects are preaspirated.

(2) Plosives-- Alternation 2

Sámi	Finnish	Estonian	Karelian	
lop.pe 'permission'	lapa 'flat(of sword)'	tapa 'way'	laba 'flat'	nom.sg
lobest	lavasta	tavast	lavasta	elat.sg.

2.1.2. Non-plosive consonants

Gradation as it affects consonants other than plosives is more straightforward with less interlanguage variation. In Sámi, overlong non-plosives are in alternation with geminates, while geminates are in alternation with singletons. In Finnish (and Karelian), sonorants and fricatives within the same paradigm are identical at the level of phonemic transcription, although they are phonetically longer before open syllables than before closed syllables in many dialects (Laurosela 1922, Lehtonen 1970). In Estonian, single sonorants and fricatives are invariant throughout a paradigm, but geminates do alternate with overlong consonants.

(3) Non-Plosive Consonants

Sámi	Finnish	Estonian	
nam.mɑ	ni.mi	ni.mi 'name'	nom.sg.
na.mɑst	ni.mes.tæ	ni.mest	elat.sg.
gomm.me 'ghost'	kum.ma 'wonder'	nɤmmm 'heath'	nom.sg.
gom.mest	kum.mas.ta	nɤm.mest	elat.sg.

2.1.3. Consonant clusters

Two types of consonant clusters must be considered separately. First, there are consonant clusters in which the first consonant is a sonorant and the second consonant is a plosive.

(4) Sonorant + Stop Clusters

Sámi	Finnish/Karelian	Estonian	
ball.ke	palk.ka	palkkk 'wage'	nom.sg.
bal.kest	pal.kasta	pal.kast	elat.sg.
juoll.ge	jal.ka	jallk[3] 'leg'	nom.sg.
juol.gest	ja.las.ta	ja.last	elat.sg.

In Finnish, plosives following a sonorant show the same alternations affecting plosives in intervocalic position: geminates alternate with single stops and single stops have various reflexes in the weak grade depending on the consonants involved; sometimes the stop is deleted, sometimes it completely assimilates to the preceding sonorant (see Hakulinen 1961 for discussion). In keeping with the pattern observed in intervocalic stops, single voiceless stops following a sonorant consonant in Ostrobothnian Finnish are phonetically longer in the onset of an open syllable than in the onset of a closed syllable (Laurosela 1922). In Estonian, post-consonantal single stops are in paradigmatic variation with overlong stops, as in intervocalic position. Estonian sonorant + single stop clusters display an alternation similar to the corresponding Sámi alternation. In Estonian,

[3] The transcription of the /l/ as a geminate (rather than an overlong) is somewhat arbitrary, since phonetically it typically displays durations intermediate between geminates and intervocalic overlongs (see Lehiste 1966 and Ojamaa 1976 for phonetic measurements).

however, the stop is often deleted in the weak grade, depending, as in Finnish, on the place of articulation and the nature of the preceding consonant.

In contrast to the Finnish and Estonian examples, in which gradation primarily affects the second member of the cluster, it is typically the first member of the sonorant + stop cluster which varies in Sámi. The first member of the cluster is long in the strong grade, but single in the weak grade. The contrast in length of the stop has been reduced to a voiced vs. voiceless distinction[4]. It should be emphasized that in all languages for which measurements are available, both members of many clusters undergo some lengthening in the strong grade; the principal target of lengthening, however, is the segment which is written as longer in the table.

Other consonant clusters which do not consist of a sonorant followed by a stop (including sonorant + fricative clusters) vary less between languages. In Finnish, there are no paradigmatic alternations. In Estonian and Sámi, it is the first member of the cluster which receives the bulk of the additional length in the strong grade.

(5) Other Consonant Clusters

Sámi	Finnish	Estonian	
guojj.kɑ[5]	kos.ki	kossk[6]	'waterfall' nom.sg.
guoj.kɑst	kos.kes.ta	kos.kest	'waterfall' elat.sg.
muoðð.ke	mat.ka	mattk	'journey' nom.sg.
muoð.kest	mat.kas.ta	mat.kast	'journey' elat.sg.
bɑll.vɑ	pil.vi	pillv	'cloud' nom.sg.
bɑl.vɑst	pil.ves.tæ	pil.vest	'cloud' elat.sg.

To summarize the gradation alternations affecting consonant clusters, the general pattern seems to be that relatively short clusters are in alternation with relatively long clusters. The segment which is the principal target of lengthening in the strong grade appears to vary from language to language, depending also on the type of cluster.

2.1.4. The origin of the gradational alternations

In summary, gradation is for the most part a quantitative alternation in Sámi, and also to a lesser extent in Finnish, Estonian, Ingrian and Karelian. In this paper, I argue that gradation originated during the pBFS period as a strictly quantitative process of lengthening, and that differences between the modern languages are the result of readjusting the locus of lengthening. I also argue that the qualitative alternations in the modern languages are the result of later lenition processes resulting from natural articulatory and aerodynamic considerations.

3. The environment of gradation

To understand the environment of gradation, it is useful to invoke the notion of foot (Lehiste 1965a, Liberman and Prince 1977), a rhythmic constituent smaller than the word, consisting of a single

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[4] Note that the liquid + stop clusters have several different phonetic realizations depending on the dialect and the individual speaker. The reader is referred to the works listed in section 2.1., as well as Engstrand (1987a) for the phonetic details of Lule Sami liquid + stop clusters. Nasals have completely assimilated to the following stop in most Northern Sami dialects, but not in Eastern Sami.

[5] The glide before the /k/ in the Sami form is due to a lenition rule which applied after the pBFS period.

[6] See footnote 3 regarding the transcription of the /ss/ as a geminate.

stressed, or strong, syllable and a neighboring unstressed, or weak, syllable. The Sámi (Korhonen 1981,1988; Bergsland 1976; Nielsen 1926) and Balto-Fennic languages[7] (Lehiste 1965a, Laanest 1975) employ trochaic feet, which consist of a stressed syllable followed by an unstressed syllable; since the first foot is strongest, the result is primary stress on the first syllable and secondary stress on subsequent odd-numbered syllables, with the exception of word-final odd-numbered syllables which are generally unstressed. Crucially, word-final odd-numbered syllables do not belong to the foot consisting of the previous two syllables; hence they are not weak syllables in the relevant sense: e.g. the final syllable in Sámi lúkk.ka.rɑ 'sexton' nom.sg. is not a weak syllable. The following examples from Sámi illustrate stress assignment: púr.re.vuò.tas, súp.pe.jit, bíb.bmabèt.tet, víl.ljai.dà.sa.det, rákk.ka.sĩi.da.sæ̀d.det (examples from Collinder 1938, Nielsen 1926, and Bergsland 1976).

In Sámi, gradation is only observed foot-medially between the nuclei of strong and weak syllables: eg. papp.pɑ vs. pap.pist. Between weak and strong syllables in Sámi, there are no alternations: e.g. lukk.ka**r**ɑ 'sexton' nom.sg vs. lukk.ka.**r**ist elat.sg. (cf. foot-medial /r/: vɑ**r.r**ɑ 'blood' nom.sg. vs. vɑ.**r**ɑst elat.sg.)

In Finnish, gradational alternations occur intervocalically between all syllables: man.si**k.k**a ‘strawberry’ nom.sg. vs. man.si.**k**an gen.sg., joh.de**t.t**u ‘lead’ past passive participle nom.sg. vs. joh.de.**t**un past passive participle gen.sg. (Collinder 157). Following Hakulinen (1961), I assume that the expanded environment of gradation in Finnish is due to later analogical extension of the process.

In Estonian, gradation is in general only directly observable between the first two syllables, i.e. foot-internal to the first foot, although there are still dialectal vestiges of what would appear to have been earlier productive alternations in syllables spanning a foot boundary, as in Finnish (see Collinder 157 for evidence) .

4. Earlier Analyses: Gradation as Lenition and Analogy

Gradation is generally assumed to have originated as a productive process during the proto-Balto-Fennic-Sámi period[8](Wiklund 1896, 1915; Itkonen 1969; Décsy 1969a,b, 1965; Korhonen 1981, 1988; Tauli 1954; Pikamäe 1957; Steinitz 1952, Bergsland 1945; Ravila 1960, etc.). Virtually all authors assume that gradation affected only the stops, both intervocalically and after sonorant consonants, during the pBFS period. Later during the proto-Sámi period, gradation spread to other consonants and consonant clusters by what has been called “analogy”. Setälä (1896) and Tauli are in the minority in their view (the one I will espouse) that gradation applied to consonants other than plosives and to clusters already during pBFS and, hence, that Sámi is the most conservative language with respect to gradation.

Gradation is generally assumed to have originated as a phonetic shortening and lenition process applying foot-internally before *closed* weak syllables, which became phonologized over time (Korhonen 1981, 1988, Ravila 1960, Wiklund 1896, Posti 1953, etc.). Scholars assume that there

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[7] There are complications in some languages, but the basic trochaic pattern appears to hold for all of the languages. For example, in Finnish pentasyllabic words, the fourth syllable may attract stress away from the third syllable, if the fourth syllable is heavy (CVV(C) or CVC) and the third syllable is light (Sadeniemi 1949). Itkonen (1946) discusses certain morphologically related conditions under which stress may migrate past a light third syllable onto the fourth syllable in Inari and Skolt Sámi.

[8] A small minority of scholars at the end of the nineteenth and the beginning of the twentieth century, notably Setälä (1896, 1912) and Szinnyei (1922), argued that gradation was a productive process as far back as the proto-Uralic period. Subsequent work has, however, shown that the consonant alternations of Samoyed which led scholars to this conclusion are independent developments which occurred later.

was an original opposition between single and geminate voiceless stops during the early pBFS period. The single voiceless stops and geminates were shortened before a closed weak syllable, then gradually the shortened single stops became voiced stops (Ravila 1960, etc.) or spirants (Décsy 1965; Hakulinen 1961; Pikamäe 1957, etc.) in most languages; thus early pBFS *p,*t, *k > late pBFS *p̆,*t̆,*k̆ > (pre)-modern *b (*β), *d (ð), *g (ɣ), and early pBFS *pp, *tt, *kk > late pBFS *pˈ, tˈ, *kˈ > (pre)-modern *p, *t, *k (ˈ indicates half-length, ˘ indicates shorter duration)[9] In contrast, the stops remained unlenited before *open* weak syllables. Under this scenario, gradation is a lenition rule involving shortening and/or voicing, as depicted in (6).

(6) Gradation as Lenition

early pBFS *lapasta > late pBFS *lap̆asta > (pre)- modern (*)labasta (>lavasta)
but early pBFS *lapa > late pBFS *lapa > (pre)-modern (*)lapa

early pBFS *pappista > late pBFS *papˈista > (pre)-modern (*)papista
but early pBFS *pappi > late pBFS *pappi > (pre)-modern (*)pappi

early pBFS *palkkasta > late pBFS *palkˈasta > (pre)-modern (*)palkasta
but early pBFS *palkka > late pBFS *palkka > (pre)-modern (*) palkka

early pBFS *jalkasta > late pBFS *jalk̆asta > (pre)-modern (*) jalgasta
but early pBFS *jalka > late pBFS *jalka > (pre)-modern (*) jalka

Analyses often associate gradation with Verner's law in Germanic, by which voiceless fricatives became voiced except when the immediately preceding syllable bore primary stress (Wiklund 1896, Posti 1953, Korhonen 1981, 1988 etc.). According to Korhonen (1988: 275), "radical gradation has always been caused by the need for greater articulatory energy in the closed syllable after the syllable with the main stress than in the open syllable. This brought about a corresponding drop in intensity at the preceding syllable juncture and a weakening of the [onset] consonant." Thus, the argument goes, the stress at the middle and end of the closed weak syllable triggered a drop in intensity at the onset of the syllable and the coda of the preceding syllable. This drop in intensity was manifested in the lenition of the onset/coda preceding the closed syllable nucleus. The naturalness of this lenition process will be considered in more detail in section 7.

Accounts which assume a single voiceless consonant, *papista, as the weak grade of geminate stops must either posit a later lengthening process to derive the short geminates which surface after a short vowel in modern Estonian: pappist, or alternatively, they must say that the Estonian broke off from Finnish before the phonetically shortened geminates reduced to true singletons.

To capture the Sámi facts, traditional accounts must assume a uniform lengthening of *all* foot-internal consonants and clusters before open syllables. Under this approach, geminates became longer geminates, single consonants became geminates, and short consonant clusters became long clusters before *open* syllables. Most accounts attribute this extension of gradation to all clusters and non-plosive consonants in Sámi to analogy (e.g. Korhonen 1981, 1988), since it takes an existing quantitative alternation and applies it to a larger set of consonants.

[9] In Lule Sami (Collinder 1938), the weak grade reflex of voiceless stops are still voiceless.

(7)

pre-Sámi	*kumma	>	proto-Sámi	*kummma
pre-Sámi	*nime	>	proto-Sámi	*nimme
pre-Sámi	*matka	>	proto-Sámi	*mattka
pre-Sámi	*gaska	>	proto-Sámi	*gasska

In summary, the traditional view treats gradation as a process of lenition followed by analogical fortition. The merits of this approach will be considered in section 7.

In the next section, drawing on proposals advanced by earlier scholars, I present an alternative to the traditional approach to gradation; I will assume *fortition* of *all* consonants and consonant clusters triggered by metrical factors, an account which I will argue to be more explanatory and plausible than the majority view.

5. Gradation as fortition

I will draw here on a few earlier proposals. First, following Setälä and Tauli, I will argue that all consonants and consonant clusters, not just plosives, were originally targeted by gradation. Second, in keeping with the accounts of Setälä, Steinitz and Tauli, I will argue that fortition played a central role in the early stages of the gradation process. Finally, following Korhonen and others, I will argue that the gradation was originally strictly quantitative in nature, before later natural lenition processes acted to produce the attested synchronic forms. Unlike earlier accounts of radical gradation, however, I argue that gradation was the Balto-Fennic-Sámi manifestation of a metrical rule of foot-balancing like those seen in many modern languages. The proposed analysis crucially hinges on three assumptions related to segmental quantity in pBFS. First, as will be discussed in this section and in 6.1.2., coda consonants in pBFS blocked vowel lengthening in weak syllables but not consonant lengthening in strong syllables. Furthermore, I follow the consensus (Ravila 1960; Korhonen 1981, 1988; Itkonen 1946, 1969) and start with a series of single and geminate voiceless stops in pBFS chronologically prior to gradation. Lastly, I adopt the (not completely uncontroversial, see Itkonen 1969) position that there were either no phonemic long vowels (or long diphthongs) in pBFS at the time foot-final vowel lengthening applied, or that long vowels were sufficiently outnumbered by short vowels to allow gradation to become entrenched as a productive process. This final assumption is necessary in the proposed metrical account of gradation, because a strong syllable containing a long vowel would be heavy enough to block the foot-balancing process described in the following paragraphs.

In the account proposed herein, gradation was a two stage process. First, short vowels were lengthened in weak open syllables, i.e. in absolute foot-final position. Then, in order to compensate for the additional length in the weak open syllable, speakers lengthened the stressed syllable of the foot. As part of this process of "prominence preservation" of the strong syllable, all consonants, both single and geminate (following the traditonal reconstruction of single consonants and geminates) were lengthened in a chain shift, and short consonant clusters became longer clusters. The output of this process of "foot balancing" or "foot optimization" were feet which were maximally balanced, yet still preserved the duration contrast between the original singletons and geminates. Gradation may be viewed as one instantiation of foot balancing[10].

The process of foot-final vowel lengthening and foot balancing is schematized below in (8) for the early pBFS forms *lapa, *pappi, *jalka, and *matka. (ˈ indicates a segment intermediate in duration between a short segment and a long one, which is indicated by a colon.)

[10] A slightly different type of foot balancing is found in Fijian (Schütz 1985, Hayes 1995), where a heavy (=CVV) strong syllable of a foot is *shortened* before a light (=CV) weak syllable belonging to the same trochaic foot. The result is a foot consisting of two light syllables.

(8) Gradation as a two stage process

	Stage 1 Foot final lengthening	Stage 2 Foot balancing	Late pBFS
early pBFS *la**pa**	*la**pa**ˈ	*la**pˈa**ˈ	*la**pˈa**ˈ
early pBFS *pa**ppi**	*pa**ppi**ˈ	*pa**ppˈi**ˈ	*pa**ppˈi**ˈ
early pBFS *ja**lka**	*ja**lka**ˈ	*ja**lˈkˈa**ˈ	*ja**lˈkˈa**ˈ
early pBFS *ma**tka**	*ma**tka**ˈ	*ma**tˈkˈa**ˈ	*ma**tˈkˈa**ˈ

Under the scenario proposed here, the degree of strength of the foot-medial consonant or cluster is not directly a function of the openness or closedness of the unstressed syllable, as has been assumed in traditional analyses of gradation. Rather, an *indirect* relation holds. The strength of the foot-medial consonant or cluster is a function of the length of the unstressed vowel, which in turn is a function of the openness or closedness of the unstressed syllable. In sections 6.1 and 6.2, synchronic evidence for the two postulated historical processes driving gradation: foot-final vowel lengthening and foot balancing, will be presented.

Vowels in closed weak syllables did not lengthen, since they were not in foot-final position. Hence, there was no need for foot-balancing to apply before closed weak syllables (9).

(9) Gradation blocked before closed weak syllables

	Stage 1 Foot final lengthening	Stage 2 Foot balancing	Late pBFS
early pBFS *la**p**an	n.a.	n.a.	*la**p**an
early pBFS *pa**pp**in	n.a.	n.a.	*pa**pp**in
early pBFS *ja**lk**an	n.a.	n.a.	*ja**lk**an
early pBFS *ma**tk**an	n.a.	n.a.	*ma**tk**an

After the additional consonant length before foot-final lengthened vowels had been added in the proto-language, the amount of lengthening was later subject to readjustment and redistribution in the daughter languages. Two of the more pervasive processes to alter the original output of gradation were lenition of the weakest grade of stops and rearrangement of phonetic duration in consonant clusters. These chronologically later processes as well as others are discussed in some detail in appendix 1.

6. Evidence for gradation as fortition: chronologically later instantiations of gradation

In this section, I discuss a number of processes in the daughter languages of proto-Balto-Fennic-Saami which display the same mechanisms argued in this paper to have driven the original gradation process. In section 6.1., I provide synchronic evidence for foot-final vowel lengthening. In section 6.2., I present synchronic processes of consonant lengthening triggered by long vowels in weak syllables, processes which mirror pBFS gradation.

6.1. Lengthening at prosodic boundaries

Cross-linguistically, segments at prosodic boundaries are often subject to lengthening. A number of studies (e.g. Wightman et al. 1992; Beckman and Edwards 1992 for English, etc.) have shown that lengthening may occur at utterance, phrase and word boundaries, depending on the language. In general, it seems that the magnitude of the lengthening effect at prosodic boundaries is related to the size of the prosodic constituent at whose boundary the segment appears: the larger the prosodic grouping, the greater the lengthening effect (Wightman et al. 1992).

Although foot-final lengthening has not been widely investigated, Teranishi (1980) reports that, in Japanese verse recitation, CVCV sequences, analyzed by Poser (1990) as a foot, tend to be recited as one isochronous unit, and the second vowel is often lengthened relative to the first one in order to demarcate the foot: For example, the phrase *komo rona ru kozyo ono hoto ri* "Nearby an old castle in Komoro" may be recited in disyllabic groups with the second vowel in each group lengthened: *[komoː] [ronaː] [ru koː] [zyo oː] [no hoː] [to riː].* This process of vowel lengthening applying to the second vowel of disyllabic units bears close resemblance to the process of foot-final lengthening argued to have triggered gradation in Balto-Fennic-Sámi: in both cases, the vowel at the right edge of a prosodic grouping of two syllables is lengthened.

6.1.1 Foot-final vowel lengthening in Balto-Fennic-Sámi

Lehiste (1965, 1968) found that vowels in weak syllables in Estonian are up to 50% longer than their stressed counterparts in foot-initial syllables, *when the preceding stressed syllable is short*. Wiik and Lehiste (1968) found a similar effect in certain Finnish dialects. For example, Lehiste's (1968) measurements show that in Estonian words of the type /sɛkamini/, the second and fourth vowels, which are unstressed, are on average 105ms and 96ms. By contrast, the first and third vowels, the stressed ones, are only 79ms and 59ms. In trisyllabic words of the type /lipisɛp/ and /sadada/, the second vowel is 106ms in comparison to the first vowel which measures on average only 83ms. Unlike their counterparts in open syllables, unstressed vowels in *closed* syllables are not lengthened word-internally; thus, the second vowel in words of the /ulatta/ type measured 82ms, identical in duration to the first vowel. It is also important to note that Lehiste's study reveals that the duration of a vowel is determined primarily by its position in the foot and not by its position in the word. In other words, any possible word-final lengthening or shortening effects in Estonian are of a much smaller magnitude than the foot-final lengthening effect. Must (1959), Ojamaa (1976), and Krull (1992) report similar results in their studies of Estonian. Wiklund (1915) reports the same tendency for unstressed vowels to be longer than the preceding stressed vowel in CV syllables in several Finnish dialects. Unfortunately however, the aforementioned studies on Estonian either focussed on disyllabic words, for which the data could be confounded by word-final effects on vowel duration, or they did not control for surrounding consonants or vowel quality .

6.1.2. Estonian foot-final vowel lengthening: An experiment

In order to test whether the lengthening effect found by earlier studies occurs after CVC and CVV strong syllables, or only after CV strong syllables, a controlled study of vowel duration in tri- and tetrasyllabic words in standard Estonian was conducted. Results are reported in detail in Gordon (to appear). The corpus consisted of words with non-controversial stress patterns, i.e. stress on odd-numbered syllables, with the exception of short word-final syllables which were unstressed. Most words in the corpus were nonsense words modeled after actual Estonian words; all words began with the syllable /sa/ and appeared in a carrier sentence. Syllables of the form /ta/ and /tat/ were added to this base in all possible combinations yielding a large corpus of tri- and tetrasyllabic words. Vowels in the first two syllables, i.e. those belonging to the first foot, were measured to abstract away from potential word-final duration effects. The results from two speakers show that short vowels in open weak syllables following CV, CVV and CVC strong syllables are longer than short vowels in both open and closed strong syllables. (Long vowels do not occur in syllables after the first in the native vocabulary, due to historical shortening processes.[11]) Table 1 shows mean vowel durations in milliseconds for the *second* vowel (unstressed /**a**/) in word-initial feet of the CVCV, CVCVC, CVCCV, CVCCVC, CVVCV, and CVVCVC types averaged over two speakers.

[11] Dipthongs whose second member is /i/ do occur , however.

Table 1: Duration of vowel of Second Syllable(Unstressed) in Estonian (two speakers)

CVC*V*	CVC*V*C
134ms	117ms
CVCC*V*	CVCC*V*C
116ms	85ms
CVVC*V*	CVVC*V*C
129ms	104ms

In comparison, the vowels in the first syllable (stressed) measure on average 111ms in open syllables (i.e. the first vowel in a CVCV(C) foot) and 105ms in closed syllables (i.e. the first vowel in a CVCCV(C) foot), as table 2 shows.

Table 2: Duration of vowel of First Syllable(Stressed) in Estonian (two speakers)

C*V*CV(C)	C*V*CCV(C)
111ms	105ms

Two patterns are apparent in the Estonian data. First, vowels are longer in open syllables than in closed syllables, a common pattern cross-linguistically (Maddieson 1985) and also shared by Ostrobothnian Finnish and Sámi[12]. A two-factor ANOVA for both speakers revealed this difference in duration to be highly significant: speaker 1 ($F[2,250]=82.023$, $p<.0001$), speaker 2 ($F[2,179]=94.160$, $p<.0001$). Second and more interestingly, weak vowels in open syllables are longer than all stressed short vowels. Unpaired t-tests revealed these differences in duration to be highly significant for both speakers. A two-factor ANOVA offered further support for the effect of foot-final vowel lengthening, revealing a highly significant interaction between syllable structure (open vs. closed) and foot position for both speakers: speaker 1 ($F[2,250]=21.441$, $p<.0001$), speaker 2 ($F[2,179]=31.062$, $p<.0001$).[13]

This lengthening effect on unstressed vowels is not observed following a stressed CVVC syllable: e.g. no lengthening of the second vowel in /saast*a*ta/. However, according to Lehtinen (1967), long vowels were only introduced during the pBFS period, developing out of /ij/ and /uw/ diphthongs, and borrowed into the language via loan words late in the pBFS period (Plöger 1982). It is thus quite plausible that CVV and CVVC syllables were not part of the language during the period in which gradation became a productive process. At the very least, long vowels were presumably few and far between at the time gradation developed, leaving CVCV(C) and CVCCV(C) as the predominant foot types during the earlier pBFS period. In both of these foot types, an unstressed vowel in an open syllable is longer than the stressed vowel in its foot. Because these were the predominant foot types in pBFS, I will continue to use the term "foot final vowel lengthening" to describe the lengthened vowels in weak open syllables.

Interestingly, Estonian also displays foot-initial lengthening of consonants (Gordon 1997). Tetrasyllabic data from the same experiment cited above show that consonants in foot-initial position are significantly longer than consonants in syllable-initial but not foot-initial position. For example, the second /t/ in /sata**t**aki/ (shown in boldface) 'even to rain', the initial consonant of the

[12] The southeastern dialects of Finnish discussed in Leskinen and Lehtonen (1985) are exceptional in that vowels in *closed* first syllables, the primary stressed ones, are longer than vowels in *open* first syllables.

[13] Vowels are also lengthened in the closed second syllable of CVCVC feet in Estonian. I assume that the lengthening of vowels in closed weak syllables is a later post-gradation development for a couple of reasons. First, it is not present in Ingrian trisyllables (see section 6.1.3) and second, the lengthening is far is less pronounced in closed weak syllables than in open weak syllables in Estonian.

second foot, is longer than the first /t/. This process of foot-initial lengthening offers further support for the importance of the foot as a prosodic unit in Estonian.

6.1.3. Ingrian foot-final vowel lengthening

Foot-final vowel lengthening is also seen synchronically in several Ingrian dialects and in certain Southern Estonian dialects (Kettunen 1962). In these dialects, etymologically short vowels are long (as long as phonemic long vowels introduced at a chronologically later time) in an open second syllable of trisyllabic words with a CV first syllable: e.g. Ingrian or.raːva 'squirrel' (cf. Finnish orava, Estonian orav). The lengthening of vowels in the unstressed second syllable may be viewed as another instantiation of foot-final vowel lengthening. In section 6.2, I return to the geminate observed between the first and second vowels in Ingrian. In a few Ingrian dialects, lengthening has also applied to geminate consonants and consonant clusters (Laanest 1966: 30), though in many cases the lengthened foot-final vowels have not been preserved: for example, ja**lkk**oja 'leg' partitive sg (cf. Finnish jalkoja), lam**p**ːahan 'sheep' genitive sg. (cf. Finnish lampahan) (See Appendix 2 for further discussion of the Ingrian facts.)

6.1.4. Foot-final vowel lengthening: a summary

Recall from section 3 that feet in Balto-Fennic-Sámi languages are trochaic, consisting of a strong syllable followed by a weak syllable. If one assumes that, in trisyllabic words, the first and second syllable comprise a foot to the exclusion of the third syllable, the Estonian, Finnish and Ingrian data on vowel duration can be interpreted as a general rule of vowel lengthening applying to vowels in open weak syllables, i.e. foot-final vowel lengthening. If, on the other hand, the final syllable in trisyllabic words were treated as belonging to the same foot as the preceding syllable, a highly unusual rule lengthening vowels in an open middle syllable of a trisyllabic foot would have to be invoked to explain the observed facts. In contrast to this hypothetical and unattested process, lengthening at prosodic boundaries is a well-known phenomenon cross-linguistically. To assume a process of foot-final lengthening would merely extend this common process to a smaller prosodic constituent. In contrast, a process of foot-medial lengthening would have no analog in any other language at any prosodic level. No languages to the best of my knowledge lengthen phrase- or utterance-*medial* segments.

6.2. Consonant length as a function of the following unstressed vowel

According to the fortition account of gradation advocated in this paper, consonants and clusters in pBFS lengthened in response to the lengthening of the immediately following foot-final vowel. Under this scenario, gradation is merely an earlier instantiation of the recurring tendency in the Balto-Fennic and Sámi languages for the length of foot-medial consonant clusters and/or consonants to be a function of the duration of the following vowel. A series of processes, classified under various names (overlengthening, primary gemination, Lagercrantz' "Gesetz der kontrastierenden Korrelation", etc.), are all manifestations of the tendency for a long vowel in a metrically weak syllable to induce lengthening of the preceding consonant.

The clearest manifestations of the correlation between duration of unstressed vowels and the preceding consonant come from gemination processes found in Ingrian, certain Southern Estonian dialects, Eastern Votic (Kettunen 1930), and several Finnish dialects, including Häme, Savo, Ala-Satakunta, and Central and North Pohjanmaa (Paunonen 1973). In these varieties, single consonants between short stressed syllables (where CV = short) and long unstressed vowels have been geminated (10). The long vowels arose through loss of the onset of the following syllable and, in the case of Ingrian and certain southern Estonian dialects, by a process of vowel lengthening in an open second syllable (discussed above in section 6.1.3).

(10)

Central and N. Pohjanmaa	*ka**ll**aa*	'fish' part.sg. (cf. Standard Finnish *kalaa*)
(from Paunonen)	*a**ss**uu*	'he lives' (cf. Standard Finnish *asuu*)
Savo	*ka**ll**oo*	'fish' part.sg.
(from Paunonen)	*hy**vv**ee*	'good' part.sg. (cf. Standard Finnish *hyvää*)
	*ymmärtä**nn**eet*	'understood' pastpart.pl. (cf. Standard Finnish *ymmärtäneet*
Southern Estonian	*hät**tt**ää*	'distress' part.sg. (cf. Standard Eston. *hätä*)
(from Kettunen 1962)	*ha**kk**uu*	'firewood' part.sg.(cf.Standard Eston. *haku*)
	*ka**nn**aa*	'hen' part.sg. (cf. Standard Estonian *kana*)
Eastern Votic	*e**ll**ää*	'he/she lives' (cf. Standard Votic *eläp*)
(from Kettunen 1930)	*va**kk**aa*	'firm' part.sg. (cf. Standard Votic *vakaa*)
Ingrian	*tu**ll**oo*	'he comes' (cf. Standard Finnish *tulee*)
(from Laanest 1966)	*mu**nn**aa*	'potato' part.sg. (cf. Stan.Finn. *muna* 'egg')
	*ko**tt**ii*	'home' illat.sg. (cf. Stan. Finnish *kotiin*)

In Sámi, an historical process of "overlengthening" (discussed in Korhonen (1981: 153-7) illustrates the same principle of strong syllable lengthening. Overlengthening applied after the break-up of pBFS to turn original geminates into overlong consonants in certain paradigms. Overlengthening occurred when an intervocalic onset of the third syllable was lost and the vowels of the second and third syllable coalesced to form a single long vowel. This created an imbalance in the new foot whose weak syllable now contained a long vowel. By the same process which originally triggered gradation, Sámi lengthened the consonant immediately preceding the new long vowel in order to restore balance to the foot. The process of overlengthening is illustrated in (11).

(11) Sámi Overlengthening

early pBFS (pre-gradation):	*go.tujɨst	'soot' elat.sg.
late pBFS (post-gradation):	*got.tuɹjɨst	
Sámi stage 1:	*got.tuɹjɨst	
Sámi stage 2:	*got.tuɨst	
Sámi stage 3:	*got.tuust	
Sámi stage 4:	*gott.tuust	
Sámi stage 5:	*gott.tust	

First, during the pBFS period, gradation applied before foot-final lengthened vowels in pBFS. Later, certain intervocalic consonants were lost between vowels of the second and third syllables (stage 2), thereby creating new phonemic long vowels (stage 3) which were longer than foot-final lengthened vowels. These new long vowels then triggered lengthening of the preceding consonant (stage 4) in a process identical to gradation. Later, the new long vowels shortened, if they were high (stage 5).

The most compelling evidence for gradation fed by foot-final lengthened vowels comes from Ingrian, in which a process identical to gradation has occurred. In Ingrian, the lengthening of foot-final vowels in trisyllabic words (discussed in 6.1.3) has directly led to the gemination of a preceding consonant: Ingrian oɹ.raːva 'squirrel' (cf. Sámi oar.re, Finnish orava, Estonian orav). Following traditional scholarship (e.g. Wiklund 1915), the process of lengthening of the consonant

preceding the lengthened unstressed vowel may be considered an attempt to ensure the prominence of the stressed syllable. Because the vowel in the weak open syllable was lengthened, the strong syllable had to be lengthened in order to maintain its prominence relative to the weak syllable. This process of foot-final vowel lengthening and concomitant lengthening of the preceding consonant is the same process argued in this paper to have originally motivated gradation.

Although the results and the environments for the lengthening rules discussed in this section vary from language to language and dialect to dialect, the principle underlying the processes is the same across the language family. When the unstressed syllable is lengthened, the stressed syllable is lengthened to offset the additional weight of the unstressed syllable. This process of prominence enhancement stems from the universal tendency for languages to eschew feet in which the stressed syllable is lighter than the unstressed syllable.

It may be added that this avoidance of light + heavy feet is still seen synchronically in the placement of secondary stress in Finnish which skips a light third syllable and migrates onto a heavy fourth syllable at the cost of disrupting the alternating stress pattern (Sadeniemi 1949). This avoids the creation of a suboptimal light + heavy foot over the third and fourth syllables. PBFS dealt with weight imbalances in a different manner, by making the stressed syllable of the foot longer, a repair strategy which also preserved the alternating stress pattern.

7. Comparison of the fortition account and the traditional lenition approach

Both the traditional accounts and the fortition-only based analysis of gradation argued for in this paper account for the attested synchronic reflexes of gradation, albeit in slightly different ways. The traditional account relies on both lenition before closed syllables and then across-the-board lengthening before open unstressed syllables, whereas the fortition-only account relies only on fortition as the basic mechanism of gradation. In this section, the relative merits of each account will be compared; first, on the basis of their relative abilities to derive the synchronic facts, and then on the basis of the naturalness of the processes posited in each account.

The traditional account would appear to offer a more direct account of the Finnish alternations than the fortition account. Recall that in Finnish, geminate stops are in alternation with single voiceless stops and single voiceless stops alternate with single voiced stops (or otherwise lenited segments) (*pappi* vs. *papista*; *lapa* vs. *lavasta*), and non-plosive consonants do not undergo paradigmatic alternations (*kumma* vs. *kummasta*; *nimi* vs. *nimestä*). This dichotomy between plosives and other consonants is directly captured in the traditional account which assumes that gradation originally applied only to stops in pBFS. By contrast, the fortition-only approach must assume that gradation in consonants other than plosives was levelled in Finnish. Furthermore, the Finnish alternations are captured directly by the lenition account, without the need to posit additional later processes, as is necessary in the fortition account.

At closer look, however, only the latter advantage may be claimed by the traditional account. There is phonetic evidence that all consonants, not just plosives, underwent gradation, despite orthographic conventions which suggest the contrary. At least some sonorants and fricatives which are transcribed identically differ in length according to whether they occur in the onset of a closed or an open syllable. This distinction is most clearly seen in /s/ and /m/ in the dialect of standard Finnish reported in Lehtonen (1970), henceforth Jyväskylä Finnish, and in /m/ in Ostrobothnian Finnish (Laurosela). For example, in Jyväskylä Finnish, /s/ is 15% longer before an open syllable than before a closed syllable. Differences of approximately the same magnitude are seen in Laurosela's measurements of singleton and geminate sonorants and fricatives before open versus closed syllables. These systematic synchronic distinctions in allophonic consonant duration provide evidence for an historical process of gradation affecting *all* consonants. Furthermore, in Ostrobothnian Finnish, clusters before open syllables are generally longer than those before closed syllables, suggesting that clusters also originally underwent gradation in an earlier stage of Finnish.

In summary, the Finnish phonetic patterns are suggestive of an earlier productive gradation system in all consonants and clusters, as the fortition-only account, but not the traditional account, predicts.

Turning to the advantages of the fortition-only account, it seems to offer a more straightforward account of the Sámi data than the traditional approach, since it assumes that all of the length distinctions present in Sámi were already present in the late proto-language. By contrast, the traditional account must posit an additional rule of lengthening applying to all consonants before unstressed open syllables in Sámi.

In summary, in the traditional account, the parsimonious account of Finnish gradation in the stop series comes at the price of complicating the Sámi account. In the fortition-only account, on the other hand, the Sámi data is explained at the cost of necessitating the adoption of an additional process reducing all stops in Finnish by one grade. Evaluating the merits of both approaches is difficult, but there are, I believe, reasons to prefer the fortition account.

First, although both accounts require two processes to get the facts in both Sámi and Finnish, the fortition-only approach would appear to rely on more plausible processes. To get the Sámi facts, the traditional account must assume two processes, lenition and then fortition. While a fortition rule seems phonetically quite plausible and indeed is the crucial element in the account proposed in this paper, the lenition rule would not appear to be well grounded phonetically. One would not *a priori* expect the lenition of a voiceless stop in the onset of a syllable bearing increased "stress" (the closed weak syllable) since the increase in articulatory effort associated with stress would likely also extend to the onset, encouraging fortition, not lenition. De Jong (1995), for example, has found that consonants in the onset of stressed syllables in English are hyperarticulated relative to their counterparts in unstressed syllables. Furthermore, consonants in the onset of stressed syllables are often longer than in the onset of unstressed syllables (see Fant, Kruckenberg and Nord 1991 for evidence from Swedish, French and English; Gordon 1997 for Estonian). Lastly, plosives in the onset of stressed syllables tend to have a longer period of aspiration than plosives before unstressed vowels, cross-linguistically; for example, Swedish (Lindqvist 1972; Löfqvist 1980), English (Lisker and Abramson 1967; Klatt 1975; Cooper 1991), Finnish (Laurosela 1922), etc. Aspiration is the result of a glottal *abduction* gesture, whereas the vocal folds must be *adducted* in order for voicing to occur. It is unclear how the cross-linguistic tendency toward vocal fold *abduction* in stops before stressed vowels can be reconciled with the glottal *adduction* required for the voicing of stops before the "stressed" vowels in pBFS posited in the traditional analyses of gradation.

In contrast, the rule reducing all stops by one grade in Finnish which is necessary in the fortition-only account seems plausible given aerodynamic and perceptual factors. Overlong stops are exceedingly rare in languages of the world, probably for the same reason bilabial stops cross-linguistically have longer closures than velar stops. Maximum air pressure levels are reached quicker behind the smaller velar closure than behind the larger bilabial closure. The buildup of pressure triggers the release of the oral closure, either by forcing the articulators apart, or, perhaps more likely, by triggering a feedback mechanism which signals that the closure should be released (Ian Maddieson, p.c.). Pressure levels behind an overlong closure would reach their maximum long before the release of the closure and would thus run afoul of the mechanism, feedback or mechanical, which triggers release. Shortening all stops would eliminate the need for the extra effort necessary to preserve the overlong closure and would also preserve the gradation alternations. For this reason, the Finnish reduction of all stops by a grade seems to be a plausible method of maintaining contrasts while minimizing articulatory effort. Perhaps even more importantly, it also has a perceptual benefit in that a contrast which relies on voicing and manner of articulation cues in addition to duration is more robust than one which relies solely on length differences.

The fact that gradation does not affect non-plosive consonants and clusters other than sonorant + stop clusters in Finnish also has a perceptual basis. Maintaining contrasts in non-plosives is

difficult given the relative paucity of acoustic cues available to render the contrast perceptually salient. While stops may be differentiated along several acoustic parameters (e.g. burst intensity, voicing and duration), it is either impossible or more difficult to exploit these distinctions in other segments, such as fricatives or sonorants

One final advantage of the fortition account is its explanation of Ingrian long vowels in weak open syllables in trisyllabic words. Under the traditional account, there does not appear to be a plausible explanation for the Ingrian facts. As mentioned earlier in section 6.1.3. under the fortition-only account, Ingrian vowel length is viewed as the same process of foot-final vowel lengthening and concomitant foot-balancing operative in the original gradation process and still widely found throughout the Balto-Fennic-Sámi language family. In Sámi and Finnish, the difference in vowel length between open and closed weak syllables created by foot-final vowel lengthening has been eliminated in favor of simpler duration systems, as follows.

In Sámi, Finnish and Estonian, syncope processes introduced phonemic long vowels in unstressed syllables, thereby introducing another length difference in unstressed syllables. In order to simplify the quantitative system, Finnish and Sámi eliminated the difference in vowel duration conditioned by the openness vs. closedness of the syllable, but preserved the more important phonemic length contrast. Estonian, on the other hand, shortened the newly introduced phonemic long vowels in unstressed syllables, and was thus more easily able to preserve the subphonemic difference in duration between vowels in open and closed unstressed syllables.

In summary, an approach which relies on fortition as the principal process driving gradation appears to be more plausible on grounds of phonetic naturalness than an account which employs lenition as the basic mechanism behind gradation. Furthermore, the fortition-based approach offers an account for the Ingrian data, which is difficult to derive in a lenition-based theory of gradation. Although both approaches require additional developments to arrive at the synchronic languages, the later processes necessary in a fortition account emerge as plausible responses to aerodynamic and perceptual demands.

APPENDIX 1: LATER DEVELOPMENTS IN THE BALTO-FENNIC-SÁMI DAUGHTER LANGUAGES

The original output of gradation has been obscured in the daughter languages due to a number of factors. First, there was probably some phonetic drift in all the languages which altered the original output of gradation. Furthermore, segment durations may have been adjusted to render them more distinctive from a perceptual standpoint, especially as the conditioning factors which triggered gradation were lost in many languages. Other factors such as loss of a segment in the word may also have contributed to the readjustment of segmental durations. One change common to virtually all languages was the lenition of the weakest grade of voiceless stops to a voiced stop or fricative (or tap in the case of Finnish coronals in many dialects) or its complete deletion, depending on the surrounding vowels and the place of articulation; e.g. Estonian tavast, Finnish lavasta, Sámi lobest/lovest . This process of lenition plausibly served to aid a contrast which had previously relied solely on length.

In modern varieties of Balto-Fennic-Sámi, the additional length was subsequently prone to language-specific readjustments similar to those undergone by the intervocalic consonants. These chronologically later developments are summarized as follows.

In standard Finnish sonorant + plosive clusters, most of the lengthening migrated to the plosive: Finnish pal**kk**a vs. pal**k**asta and jal**k**a vs. jalasta, with deletion or lenition of the stop in the weakest grade, following the intervocalic pattern. Further, in Finnish, gradational alternations were extended to positions other than foot-internally, after the morphologization of gradation: e.g. mansikka ‘strawberry’ vs. mansikasta ‘strawberry’ elat. sg.

Sámi speakers added additional length to the first member of all clusters. In Sámi sonorant + geminate stop clusters, the additional lengthening of the sonorant had the effect of shortening the geminate; late pBFS *palˈkˑkaː > *pallkˑkaː > pallkaː. The geminate was then analogically shortened in the weak grade form as well: *palkkasta > palkast , in order to avoid a complex alternation in which the /l/ was longer in the strong grade than in the weak grade, but the /k/ was longer in the weak grade than in the strong grade.

In the language which became standard Estonian, the lengthening introduced by gradation was localized to the last member of the strong syllable: pBFS *jalˈkˑaː > Estonian jalllk, pBFS *palˈkkˑaː > Estonian palkkk. Additionally, tautomorphemic geminates shortened after long syllables (CVC or CVV): pBFS *palk.kasta > Estonian pal.kasta; pBFS *lauttat 'stables' > Estonian lautat.

In most Balto-Fennic languages, unlengthened single stops which formed the second member of clusters were subsequently either assimilated to the preceding consonant, became a glide, or were deleted when the preceding consonant was a sonorant (e.g. Finnish jalasta Estonian jalast < late pBFS *jalkasta; Finnish sillasta Estonian sillast < late pBFS *siltasta 'bridge'). Which of these lenition processes occurred depended on the preceding consonant, the following vowel, and the particular language. In many Sámi dialects single voiceless stops became lenis or voiced following a sonorant consonant; Sámi jallga < late pBFS *jalˈkaː.

Many other segmental developments, too many to document here, occurred in the three thousand year history from pBFS to modern times. These include syncope and apocope processes in all three languages, the shortening of geminates after long vowels in Estonian, analogical levelling in all languages, not to mention many other vowel and consonant shifts and mergers. For a detailed account of these developments and others, the reader is referred to a number of sources, including Korhonen for Sámi, Hakulinen for Finnish, Raun and Saareste (1965) for Estonian, and Laanest (1975) for Balto-Fennic in general.

APPENDIX 2: FOOT-FINAL VOWEL LENGTHENING IN INGRIAN

The Ingrian pattern of foot-final vowel lengthening is complicated by the fact that foot-final lengthened vowels were phonemicized as long vowels *only in trisyllabic words.* In disyllabic and trisyllabic words, vowels which had been in foot-final position were phonemicized as short vowels. This lengthening asymmetry seen in vowels is correlated with a similar asymmetry in consonants. Consonants which were lengthened by gradation before foot-final lengthened vowels were phonemicized as geminates in trisyllabic words, but singletons in disyllabic and tetrasyllabic and longer words. The durational correlation between foot final vowels and the preceding consonant is sensible from a phonetic and phonemic of view. Phonetically, those foot-final vowels which were longest (i.e. those in the second syllable of trisyllabic words) caused the greatest amount of lengthening in the preceding consonant. The longest vowels and consonants were then phonemicized as long vowels whereas those which were not as long were treated as phonemic short vowels. The phonemicization of duration in Ingrian is schematized below in (12).

(12) Foot-final vowel lengthening in Ingrian

	Disyllables	Trisyllables	Tetrasyllables and longer
Late pBFS	lapˈaˈ	orˈaˈva	orˈaˈvanˈaˈ
Early Ingrian	lapˈaˈ	orːaːva	orˈaˈvanˈaˈ
later Ingrian	lapa	orːaːva	oravana

First, gradation applied during the late pBFS period in all words. Then, in the early Ingrian period, foot-final vowels and the preceding consonant underwent additional lengthening in trisyllabic words, but not in disyllabic and tetrasyllabic words. Finally, at the stage of phonemicization in later Ingrian, the longest vowels and consonants (those in trisyllabic words) were phonemicized as long segments, while the other ones were not.

Two different factors presumably led to the asymmetry in Ingrian foot-final vowel lengthening. First, the less substantial lengthening effect seen in tetrasyllabic words has a phonetic explanation in terms of the overall length of words. Cross-linguistically, segment duration is typically inversely correlated with word duration: the longer the word, the shorter segments are generally. This tendency has been noted in many languages, including Estonian (Krull 1992) and Lule Sámi (Engstrand 1987b). Krull's measurements reveal that differences in segment duration become smaller in longer words, as the range of duration values is compacted. For example, the duration of the first vowel in the word /sata/ is 88ms, while this same vowel in an identical surrounding environment is 83ms in /satamaleki/, a 6% difference in duration. By comparison, the second vowel in /sata/ is 169ms, compared to 131ms for the same vowel in /satamaleki/, a difference of 29%. It is thus not surprising that lengthening was inhibited in tetrasyllabic words.

In disyllabic words, foot-final vowel lengthening plausibly was inhibited by the proliferation of phonemic long vowels in the final syllable of a number of grammatical forms (e.g. illative case, partitive case, first infinitive, third person verb endings-- see Laanest 1966). These long vowels, not present in pBFS, came into existence in Ingrian, when a single intervocalic /h/ or voiced dental fricative was lost: e.g. pBFS *lapˈaˈ-da > early Ingrian *lapˈaa. partitive sg. In most cases, this syncope process affected consonants in the onset of final syllables. This syncope process created many phonemic length contrasts in the final syllable of words alongside the foot-final phonetically lengthened vowels: matˈoˈ 'worm' nom.sg. containing a foot-final lengthened vowel vs. matˈoo 'worm' part.sg. containing a long vowel arising through syncope. In order to make the new phonemic length contrast more salient, the phonetically shorter of the two types of long vowels, the foot-final lengthened ones, were further shortened: matˈoˈ 'worm' nom.sg. > matˈo. Also, the phonetically lengthened consonants preceding the once foot-final lengthened vowels were shortened in order to make the phonemic contrast in consonant duration more salient: matˈo 'worm' nom.sg. > mato (cf. matto 'rug' nom.sg.). Subsequently, the phonetically lengthened consonants preceding phonemic long vowels were further lengthened as part of the foot balancing process discussed in section 6.2: early Ingrian *lapˈaː > later Ingrian *lappaː.

Because syncope of onsets in *non-final syllables* was far less common than in final syllables, there was less pressure to preserve a phonemic contrast in vowel duration in this environment, which included the second syllable of trisyllabic words. For this reason, foot-final vowels in non-final syllables (including the second syllable of trisyllabic words) could freely lengthen with less threat of disturbing a phonemic contrast in duration.

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