Acta Linguistica Petropolitana. 2022. Vol. 18.2. P. 282–303
DOI 10.30842/alp23065737182282303

Unified description of Finnish consonant gradation

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Abstract. Finnish consonant gradation and some related phonological processes are described in this paper, using standard generative phonology rules of [Chomsky, Halle 1968] (postcyclic ones). An important feature of the analysis is its build-up in purely phonological terms, using no morphological information whatsoever except placement of morpheme boundaries and their type (word boundary #, clitic boundary =, or formative boundary +) in a phonological string. Thus the rule-based phonology's power is demonstrated on a process which was previously described in one of the three ways: morphologically; through the trademark mechanism of Optimality Theory, interaction of universal violable constraints with language-specific ranking; or via Government Phonology which is based upon well-formedness of CV structures linked to unary phonological features, thus effectively lacking both a derivational component and a treatment for actual melodies observed. This paper is basically a shortened version of my unpublished graduation paper written in Russian [Zelenskiy 2018], where nearly all phonological phenomena of Finnish, rather than merely consonant gradation and related issues, are discussed. Note, however, that this paper also suggests (or, in some cases, hints at) some modifications of the original analysis, so a reader already familiar with the richer analysis may still find this paper worthwhile. Additionally, the set of segments available for Finnish underlying representations of morpheme's exponents is discussed in whole, even in the aspects not directly relevant to consonant gradation, and an important modification, namely that the glottal fricative, *h*, is phonologically not specified for place, is suggested.

Keywords: Finnish language, phonology, consonant gradation, morphology, phonological rule.

Единое описание финского чередования согласных

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Аннотация. С помощью правил стандартной генеративной фонологии описывается поведение финского чередования согласных и некоторых связанных процессов в чисто фонологических терминах, без привлечения иной морфологической информации, кроме деления строки на морфемы и слова. Тем самым мощность процессной фонологии демонстрируется на процессе, ранее объяснявшемся морфологически или через механизмы фонологии управления или теории оптимальности.

Ключевые слова: финский язык, фонология, чередование согласных, морфология, фонологическое правило.

1. Theoretical standpoints

The theory employed here to describe Finnish phonological processes is mostly based on Standard Generative Phonology of Chomsky, Halle [1968] (henceforth — SPE). In particular, the following points 1 to 8 are assumed to be true, with justifications provided as needed here, mostly brief.

1. Segments are bundles of binary [1] articulatory features which can be valued + (plus), − (minus), or unvalued (zero-valued; a segment without a valued feature is called unspecified for the feature); in particular, contra [Kiparsky 1982: 143–145], archiphonemes, that is, segments which are underlyingly unspecified for a feature yet become specified for it in the

[1] Place feature is exceptional in the formalism below: instead of + and −, several values are assumed: labial, coronal, and dorsal; furthermore, [αplace] in two segments presumes identity of such a value not of + or −. Presumably, however, this is but a notational convention; cf. [Chomsky, Halle 1968: 303–304] and [Zelenskiy 2018: 18] (fn. 24).

course of derivation, are allowed (see [Zelenskiy 2018: 12–13, 44] for deconstruction of Kiparsky's empirical argument against them in the cited source). While over the years, various other suggestions were introduced, most of them either should pertain to phonology-phonetics interface rather than phonology proper (such as the entirety of Articulatory Phonology) or are outright against the idea of substance-free phonology (on which, see [Reiss 2018]) — the latter point, in particular, is true of various "feature hierarchies" (at least, in phonology; for this paper, I leave open the question if one can likewise exclude hierarchies of morphosyntactic features such as the one in [Harley, Ritter 2002]).

2. Segment changes other than metatheses are realized via rules of the following format: A → B / X_Y, where A and B are either ∅ (an empty string)[2] or a set of features (partially or fully describing the relevant segment(s)) and X (left context) and Y (right context) are strings (possibly empty) of such sets; Kleene star can be used in the description of X and Y, as well as brackets denoting optionality of a substring's presence and Greek letters for feature value variables (+ or −). The rule-based description is superior to constraint-based description Optimality Theory employs on multiple accounts, including opacity which is crucially abundant in consonant gradation (see [Vaux 2008], inter alia).

3. These rules are not required to be "natural" (again, see [Vaux 2008] for justification).

4. Morpheme boundaries are themselves segments in the string, which appears to contradict many later studies such as, notably, [Rotenberg 1978]. However, those studies are inherently wrong, because they presume access to information of syntactic constituency as the main compensation mechanism for absence of boundary segments, which is unwelcome as the constituency is supposed to be erased by morphological component already, see [Wurmbrand 2016]; cf. also [Scheer 2008] who tries to give such boundaries a phonological meaning. Three such

[2] If A is empty, both B and either X or Y are to be non-empty. The problem of generating multiple B's if X is empty, consists of B's, or ends with B* is supposed to be automatically circumvented by the mechanism of left-to-right checking of a rule's applicability.

segments are assumed: clitic boundary = [+WB,+FB][3], formative boundary + [−WB,+FB], and word boundary [+WB,−FB]; here WB and FB are the two valued features of the boundary segments setting them apart from usual segments (thus providing for their being unpronounced; [Zelenskiy 2018] used an additional [seg] feature). Where the boundary segments come from exactly is a subject for discussion (as SPE's original rule is clearly insufficient) unrelated to the main subject; suffice it to say + is an elsewhere boundary, inserted by spell-out when no other boundary is present.

5. Rules cannot delete a + or specify its absence in a (left or right) context: if a rule has left (right) context of $X_1X_2…X_n$, the actual left (right) context is $(+)X_1(+)X_2(+)…(+)X_n(+)$. The fact that phonological rules applying inside a morpheme also apply between two morphemes unless the boundary is of a special type is by now a virtually undisputed fact, although specific explanations may vary.

6. Rules can be obligatory or optional and are strictly ordered. This ordering, besides deriving opacity (again, see [Vaux 2008]) is what often creates differences between close dialects; consider the following example, taken from [Hualde, Gaminde 1998: 43–44]: Basque dialects have a rule of *a*-raising after high vowels (as in *lagun-a* (friend-the) 'the friend', pronounced with final [e] or [ɛ]) and a rule of mid vowels raising if they immediately precede any vowel (*beso-a* (arm-the) 'the arm', pronounced with [u] as the second vowel instead of [o]). In some Basque dialects the first rule applies first, thus being inapplicable to *besoa*, and *besoa* is pronounced with final [a]; in others, the ordering is reversed and *besoa* has final [e]. The only exception to the ordering is rules' simultaneous disjunctive application where only one rule of a set is used and elsewhere condition chooses the rule should conflict arise; a special case of simultaneous

[3] SPE has [−WB,−FB] for =; it does not technically (and thus empirically) matter, but see [Zelenskiy 2018: 16] for a justification attempt. One could alternatively set up the three segments as = [−WB,−syll], # [+WB,−syll] and + [−WB,0syll], which would give a nice explanation for = and + becoming indistinguishable with respect to some autosegmental processes as well as only leave one boundary-related feature; deriving that, however, is clearly beyond this paper's scope.

disjunctive application of rules is "mirror context": rules A → B / X_Y and A → B / Y^R_X^R (where ^{R} is for inverted string: $X_1X_2…X_{n-1}X_n^R$ is $X_nX_{n-1}…X_2X_1$), applied simultaneously, are compressed into A → B / >X_Y< (idea is taken from [Kiparsky 1982: 151], citing [Bach 1968], but the notation is mine, as Kiparsky used asterisk, which is used for Kleene star instead).

7. Some morphemes can have special flags which either make a rule inapplicable to them (both as the target (A) and as a part of context) or make optional for them a previously obligatory rule; the flags replace flags such as [native] and [latinate] as the latter come to be technically superfluous, yet loans are allowed to automatically acquire some such flags.

8. At least for Finnish, the rules are applied left-to-right; this article is not a place to discuss whether the pattern is universal cross-linguistically.

However, unlike SPE, which used cycles extensively, all the rules used here are postcyclic; in particular, a rule's context may include a double word boundary (##), and the rule will apply provided all the material of its context belongs to the same phase (in the sense of [Chomsky 2001]). The decision is not (currently) empirical but rather based on theoretical considerations: a theory with cycles would predict either visibility of syntactic structure for phonological interface (which is unwelcome, see the discussion above at point 4) or a derivation not based on phases (since SPE's cycles do not coincide with phases under most definitions of the latter).

In regard to morphology, non-lexicalist, morpheme-based generative perspective is adopted (see [Bruening 2018] for reasoning on the matter), and late realization is assumed; an exact framework, such as Distributed Morphology [Halle, Marantz 1993] or Nanosyntax [Starke 2009], is irrelevant here.

2. Empirical pattern

The data on inflection are taken from two online dictionaries, *suomisanakirja.fi* and *en.wiktionary.org*, as well as from courses of Finnish (using several textbooks such as [Gehring, Heinzmann 2016]); the data on lexical

items and derivation, beyond the two lexicons, are taken from a much larger *kielitoimistosanakirja.fi*. Wiktionary's inflection tables, in turn, are claimed to go back to KOTUS (Institute for Finland's local languages) — although, being free-to-edit, individual items could have been changed (hence why the cross-checking with *suomisanakirja.fi* is near-necessary). Phonetical data have been additionally verified by [Suomi et al. 2008], an in-depth research of Finnish surface phonetics.

Certain Finnish stems and suffixes exhibit a synchronic alternation usually called consonant gradation (or *ptk*-gradation, by the letters of the consonants in "strong" position). In certain contexts (to be discussed below; for now, note that they broadly correspond to being an onset of a closed syllable preceded by a voiced segment[4]) underlying geminate stops, both voiced (found in loanwords, e.g., *blogata* 'blog'[5] — *bloggaa-n* (blog-1SG) 'I blog') and voiceless (e.g. *sirppi* 'sickle' — *sirpi-n* (sickle-GEN) 'of sickle'), degeminate (quantity gradation), whereas underlying single voiceless stops lenite according to *Table 1* (quality gradation) on page 288.

Note that some of the examples in *Table 1* are of *e*-final stems; in the nominative singular, *e* is replaced by *i* (so in *kilpi* 'shield', *arki* 'weekday', *henki* 'spirit'). There are also stems which superficially end with *e*, such as *sade* 'rain'; these actually end in a "ghost consonant" (^{x}) reflected by gemination of a following consonant (both in declension, cf. *sadet-ta* (rain-PART) 'of rain', and before #, cf. *sade*[*k*]-*ko* (rain-Q) 'Rain?' (written *sadeko*); see fn. 23 and [Keyser, Kiparsky 1984], inter alia). The "ghost consonant" is visible for consonant gradation: nominative *sade*^{x} is derived of stem *sate*^{x}, as genitive *satee-n* (rain-GEN) '(of) rain' indicates.

Such situations are called "backwards gradation" because nominative exhibits the "weak" (lenited or degeminated) shape of the stem; stems ending

[4] Finnish has no branching onsets, barring stop-sonorant word-initial onsets in new loanwords such as *presidentti* 'president'; older loanwords such as *risti* 'cross' have simplified such onsets (here — **kr*). Also note that, as follows from this wording, word-initial segments never undergo consonant gradation.

[5] It is a reasonable question to ask why we see no geminate in the noun *blogi* 'blog' — while for voiceless borrowed nouns, final geminates like in *abortti* 'abortion' are abundant. I do not currently have an answer.

Table 1. Finnish patterns of quality consonant gradation

lenition pattern	NOM	GEN (-n)	translation
k → ∅	*laki*	*la.i-n*	‘law’
t → d [6]	*rata*	*ra.da-n*	‘way’
p → v	*kilpi*	*kil.ve-n*	‘shield’
k → j / R_e [7]	*arki*	*ar.je-n*	‘weekday’
k → v / U_U	*luku*	*lu.vu-n*	‘number’
t → r / r_	*parta*	*par.ra-n*	‘beard’
t → l / l_	*aalto*	*aal.lo-n*	‘wave’
t → n / n_	*hinta*	*hin.na-n*	‘price’
p → m / m_	*lämpö*	*läm.mö-n*	‘heat’
k → ŋ / ŋ_ [8]	*henki*	*hen.ge-n*	‘spirit’

with “fleeting” *s* (such as *kuningas* ‘king’, genitive *kuninkaa-n* (king-GEN) ‘(of) king’) exhibit the same pattern, as do stems ending with “fleeting” *t* (such as *immyt* ‘virgin’, genitive *impye-n* (virgin-GEN) ‘(of) virgin’). Nominal stems with long vowels, however, do not alternate: *vapaa* ‘free’ has genitive *vapaa-n* (free-GEN) ‘(of) free’, not **vavaa-n*. Quantitative and qualitative gradation are, obviously, both subject to being “backwards”: alongside *sade* we have *ape* ‘(horse) food’, genitive *appee-n* (food-GEN).

In cluster *hk* not followed by *e*, there is generally no quality consonant gradation; some nouns, like *nahka* ‘skin’, exhibit it optionally (*naha-n*

[6] Note that Finnish *t* is dental laminal whereas *d* is alveolar apical [Suomi et al. 2008] and that, barring recent loanwords, the latter has a limited distribution indicating that it is always a result of consonant gradation which, of course, does not preclude its inclusion. See also *Section 3.1*.

[7] In some idiolects, *ä* is a possible right context for *k* → *j*, cf. *hylä-tä*^{x} or *hyljä-tä*^{x} (abandon-INF) ‘(to) abandon’ and *hylkää-n* (abandon-1SG) ‘I abandon’ (nominal examples are unavailable), as proven by both being listed in all the three dictionaries mentioned above (with the latter marked “dated”). The following description ignores this variation.

[8] In orthography, [ŋ:] (=[ŋŋ]) is reflected as *ng*, [ŋn] as *gn*, [ŋk] as *nk*; these are the only contexts for [ŋ], barring final [ŋ] (also written *ng*) in loanwords.

or *nahka-n* (skin-GEN) '(of) skin'). Cluster *ht*, on the other hand, undergoes gradation normally; cf. *tähti* 'star' and *tähde-n* (star-GEN) '(of) star', an *e*-final stem (cluster *hp* is never found in Finnish words).

As noted before, single stops never undergo lenition after *s* or a non-homorganic stop (cf. *risti* 'cross' and *risti-n* (cross-GEN) '(of) cross', *matka* 'travel' and *matka-n* (travel-GEN) '(of) travel')[9]. Geminates are always degeminated after *s*, not just in consonant gradation contexts, cf. *puhuttiin* (talk-IMPERS.PST) 'there was talking' and *pes-tiin* (wash-IMPERS.PST) 'there was washing'.

Consonant gradation is found not only in the nominal system, but in the verbal system as well. Stems ending with a short vowel (including the exceptional verbs *teh-dä*^{x} (do-INF) 'to do' and *näh-dä*^{x} (see-INF) 'to see', whose "vowel" stems end with *-ke*) exhibit consonant gradation in first person indicative (both singular (ending *-n*) and plural (ending *-mme*); both present and past), second person indicative (both singular (ending *-t*) and plural (ending *-tte*); both present and past), second person imperative singular, and connegative (the last two both have ^{x} as their ending), as well as all impersonals (except for *teh-dä*^{x} and *näh-dä*^{x}, which use consonantal stems in that position). Other verbal stems which exhibit vowel-stem vs. consonant-stem alternation have the *ptk*-gradation in the final syllable: vowel stem has a "strong" (non-lenited/-degeminated) onset of penultimate syllable corresponding to a "weak" onset in consonant stems where the syllable is final (this alternation is likewise called a "backwards" one because infinitives exhibit consonant stems; and, just like in the nominal system, qualitative and quantitative gradation are both subject to this,

[9] Adjective *pitkä* 'long' has comparative *pite-mpi* (long-CMPR) 'longer', not **pitke-mpi*, and *k* is likewise absent from some other derivatives of the root. This, however, is considered an allomorphy unrelated to *ptk*-gradation in synchronic description. One of the empirical reasons is that elsewhere assibilation ($d \rightarrow z \rightarrow s$ rule, see fn. 17) precedes and counterfeeds (*halus-i-n* (want-PST-1SG) 'I wanted' does not further have a gradation of the *-s-*) consonant gradation but *pitkä*'s superlative is *pisin*, which, if the absence of *k* were caused by gradation, would mean that consonant gradation fed assibilation. More generally, there is no reasonable way the phonology of *pitkä* could be made different from that of *matka*.

compare *blogata* above, *peitota* ‘thrash’ — first singular *peittoa-n* (thrash-1SG) — and *muodota* ‘shape’ — first singular *muotoa-n* (shape-1SG)).

Plural oblique nominal forms induce further complications (cf. *harak(k)o-i-hin* (magpie-PL-ILL) ‘into magpies’, but, as partitive variation shows (cf. *harakko-j-a* and *harako-i-ta* (magpie-PL-PART) ‘of magpies’), the solution lies in the plural oblique morpheme (*-i-*/*-j-* as opposed to *-t* of nominative plural, as in *haraka-t* (magpie-NOM.PL) ‘magpies’) either “perceived” as a consonant or not, not in the gradation [Zelenskiy 2018].

Comparative suffix *-mpA-* and action noun suffix *-ntA-* undergo exceptional gradation before nominalization suffix *-UUs*: e.g., *ale-mpi*[10] (low-CMPR) ‘lower’ underlies *ale-mm-uus* (low-CMPR-NMN) ‘inferiority’, not **ale-mp-uus*, whose genitive is *ale-mm-uude-n* (low-CMPR-NMN-GEN) ‘(of) inferiority’, not **ale-mp-uude-n*.

Consonant gradation was previously analyzed in Stratal Optimality Theory (e.g., [Kiparsky 2003]) and Government Phonology [Pöchtrager 2001]. In the latter paper, the lenition is considered merely a unary feature’s loss as specific mappings from phonology to phonetics are non-trivial in that theory. Notably, back when rule-based phonology ruled the field, [Keyser, Kiparsky 1984] did not try to give a full description of consonant gradation, only giving its context’s metrical definition; likewise, [Kiparsky 2003] only looks closely at quantity gradation (presumably, because Optimality Theory expects uniform results, while quality consonant gradation is diverse). The phenomenon is thus arguably phonologically underdescribed, especially in rule-based phonology.

3. The analysis

3.1. Underlying segments

Aside from the boundary segments described in *Section 1*, the segments assumed to be available for underlying representations are shown,

[10] The suffix exceptionally becomes *-mpi* in nominative singular, like *e*-final stems do; see [Zelenskiy 2018: 52].

with their feature specifications, in *Tables 2* and *3*. Note, in particular, that the *d* in *Table* 3 assumes dental *d̪* not equivalent to surface alveolar *d*[11], which can also be underlying in loanwords such as *addiktio* ‘addiction’ (I remain agnostic as to what feature makes them different; same pertains to *s* and *š*, where the latter is only found in loanwords); this dental *d* is always removed by later rules, see also fn. 17.

Table 2. Finnish vocalic underlying segments

all +syll,+voiced	front	high	low	round	back
a	−	−	+	−	+
ä					−
A					0
o			−	+	+
ö					−
O					0
e				−	
e (of *nalle*-stems)[12]	+				
i		+			
Y[13]				+	
U	−				
u					+
y					−
V	0				

[11] There is no surface voiced sibilant in Finnish; letter *z* is usually pronounced as *ts*, as in *kamikaze* [kamikatse] ‘kamikaze’. See also fn. 5.

[12] This stem-final segment, unlike the other *e*, does not become *i* word-finally and forms plural like *i*-stems; the example word is *nalle* ‘teddy bear’, illative plural *nalle-i-hin* (teddy_bear-PL-ILL) ‘into teddy bears’, not **nalliin* like *koip-i-in* (leg-PL-ILL) ‘into legs’. Most stems of the declension are Swedish proper names like *Kalle*; however, *itse*[x] ‘self’ ([x] is added by a later rule, omitted here) and *kolme* ‘three’ also follow the pattern.

[13] This segment is only encountered in some loanwords like *analyysi* ‘analysis’; informally speaking, this is surface *y* behaving like *i* for purposes of plural allomorphy and vowel harmony. See [Zelenskiy 2018: 17, 43].

Table 3. Finnish consonantal underlying segments

all −syll	front	voiced	cont(inuous)	nas(al)	lat(eral)	place
p	0	−	−	−	0	labial
b		+				
m				+		
v			+	−	−	coronal
f		−				
s (š)						
z		+				
n			−	+		
d				−		
t		−				
r		+	0	−	+	
l						
h	−		+		0	0
j	+					dorsal
γ	−		−		0	
g						
ŋ [14]				+		
k		−		−		

Importantly, diphthongs are argued to be created in the course of derivation — in other words, underlying representations always have vocalic segments as syllabic, as reflected in the first cell of *Table 2*. This includes diphthongs which start with the high segment, such as *uo* in *vuoda* ‘can’: as their behavior in past tense of verbs and oblique plural of nouns clearly indicates, these are derived from long mid monophthongs (*ee* → *ie*, *oo* → *uo*, *öö* → *yö*; this happens to be the same as their historical source), see

[14] Evidence for **underlying** ŋ, barring loanwords like *magnetti* ‘magnet’, is sparse; see [Zelenskiy 2018: 45–48]. However, nasal assimilation derives new instances of ŋ in cluster *nk* before consonant gradation (as in *Helsinki* → *Helsiŋki*), which then turned some instances of ŋk to *ng* [ŋŋ] (as in *Helsinkissa* → *Helsiŋkissa* → *Helsiŋŋissa*). See also fn. 8.

fn. 19. Segment signs (except *ŋ* and *γ*) are taken from orthography not IPA, which allows me to continue writing examples in orthography; underlying *h*, for instance, is actually IPA's *ɦ*[15], and *v* is more approximant-like than *f*[16] [Suomi et al. 2008].

A special notational convention is also used: while # and, presumably, = are actually [−syll], in rules [−syll] shall only refer to non-boundary [−syll] segments (mostly those in *Table 3*), whereas a special symbol, @, indicates the {[−syll],#,=} class (cf. fn. 3).

3.2. Set of the relevant rules

The description below only features rules which are directly relevant; for the full set of rules, see [Zelenskiy 2018: 101–107] (Appendix 1, which is bilingual Russian-English). In particular, vowel harmony is supposed to have already happened. The rules, furthermore, are given in the order of their application, which avoids some potential misunderstandings about the ruleset's work.

First of all, *d* becomes *t* after a *d*:

(1) $d \rightarrow$ [−voiced] / *d*_.

Then, clusters *dt* and *dk* (found, e.g., in consonantal stems[17] of verbs like *halu-ta*^{x} (want-INF) 'want', whose underlying form is *halud+dAh* (with the second *d* becoming *t* by an even earlier rule), and of nouns with

[15] And in [Zelenskiy 2018], glottal place feature is assumed for *h*; this, however, proves to be both wrong (for *h* does not participate in nasal place assimilation, which required a special patch for words like *vanha* 'old') and superfluous. Note also that the surface allophony of orthographical *h* is huge [Suomi et al. 2008].

[16] The segment *f* is, like *š* or branching onsets, also only found in new loanwords; older loanwords like *kahvi* 'coffee' do not retain *f*'s. Same pertains to *b* and *g*.

[17] I disagree with [Keyser, Kiparsky 1984]'s stance for vowel deletion in "consonantal" stems. In particular, there are minimal contrasts: e.g., stem of the word whose genitive is *haahten* 'ship' has a consonantal version *haaht-* and a vocalic version *haahte-*, which predicts both their nominative (*haaksi* vs. *haahti*) and partitive

"fleeting" *t* like *immyt* 'virgin', whose underlying form is *impyd*) undergo devoicing (e.g., *halud-tah* becomes *halut-tah*, and *halud-kaa* (want-IMP.PL) 'Want!' becomes *halut-kaa*, which is the surface form):

(2) [−cont,−nas] → [−voiced] / _[−voiced].

Application example for (1) and (2): (*halud+dAh* → by vowel harmony) *halud+dah* → *halud+tah* → *halut+tah* (by (10a) and ^{x}-related rules → *halut+a*^{x}) (want-INF).

Then, final *e* becomes *i* (see *Table 1* for examples; on −front in the description see fn. 12):

(3) [−low,−round,−front] → [+high,+front] / [+syll][−syll][−syll]*_#.

Then, non-intervocalic dorsals palatalize before *e* unless preceded by a nasal; the ordering of the rules can be seen because of the word *veli* 'brother', genitive *velje-n* (brother-GEN) '(of) brother': were the order of (3) and (4) reverse, the nominative would be[18] **velji*, as the stem's underlying form is *velɣe*.

(4) [dorsal] → [+front] / [−nas,+voiced,−syll]_[−low,−high,−round].

Application examples: *velɣe+n* → *velje+n* (brother-GEN); *arke+n* → *arkʲe+n* (by (10a) → *arje+n*) (weekday-GEN).

(*haahta* vs. *haahtea*) forms. This contrast is unexpected if "consonantal" stems are actually vocalic.

The *d* in these particular stems is assumed instead of *t* because, unlike true *t*, it undergoes (7b) and the assibilation rule *d* → *z* (→ *s*) not listed in this paper, as in *halus-i* (want-PST) 'He/she wanted' (compare *Dakota* and *bikonditionaali* 'biconditional' which do not become surface **Dakoa* and **bikondiionaali*). A near-minimal pair for *d* and *t* is *huutaa* 'shout', past form *huusi* (indicating underlying d) vs. *hoitaa* 'care', past *hoidi* (indicating underlying *t*). A more complete account of assibilation is beyond the scope of this paper which is set to describe rules pertaining to consonant gradation (either directly or by modifying its context or, as (21), both), while assibilation does not normally change context of gradation. See also fn. 9.

[18] Final *-lji* is, albeit marginally, possible in Finnish, as word *detalji* 'detail' shows. Plural forms of this word also show this sequence of segments, as *e*-final stems lose the final *e* before plural *i*: *velj-i-ä* (brother-PL-PART) 'of brothers'.

Similarly, (optional) *j* after some diphthongs with *I* appears in hiatus (though it is not reflected in writing) via palatalization of an underlying dorsal by another rule, (5): cf. *haiku* 'smoke' and *hai*([*j*])*u-n* (smoke-GEN) '(of) smoke'.

(5) [dorsal] → [+front] / [+syll,−front][+high,−round]_[+syll].

Application example: *haiku+n* → *haiku+n* (by (10a) → *haiju+n* (smoke-GEN); see fn. 26).

Note that (4) and (5) create palatal(ized) [k^j] and [g^j] which are not found on surface; later on, rule (19) depalatalizes non-lenited stops.

Multiple rules related to plural allomorphy follow; a tentative discussion can be found in [Zelenskiy 2018: 30–31, 54–67, 103–104]. Full retelling of the analysis would lead the discussion far astray from the phenomenon at hand. In particular, many of the rules solve the unrelated problem of deducing the behavior of final *a*'s in nominal stems as there are seven types, exemplified by *hopea* 'silver', *koira* 'dog', *kala* 'fish', *omena* 'apple', *apina* 'monkey, ape', *apila* 'clover', and *harakka* 'magpie', as well as unique cases of *tanhua* 'stockyard', declining either like *hopea* or like *apina*, and *aneurysma* 'aneurysm', declining either like *koira* or like *kala*; see [Anttila 2002], [Kiparsky 2003] and *Table 4*. Their relation to consonant gradation is reflected in plural oblique morpheme (underlying *j*) becoming either *i* (syllabic) or *i̯* (non-syllabic, but otherwise having the same features as *i*), sometimes with variation, as *harakka* shows: *harakko-j-a* has *i* while *harako-i-ta* has *i̯* (for *tta*-final stems, some

Table 4. Finnish *a*-final nominal stem types

NOM.SG	PL-PART	translation of stem
hopea	*hope-i-ta*	silver
koira	*koir-i-a*	dog
kala	*kalo-j-a*	fish
omena	*omen-i-a*/*omeno-j-a*/*omeno-i-ta*	apple
apina	*apino-i-ta*	monkey, ape
apila	*apilo-j-a*/*apilo-i-ta*	clover
harakka	*harakko-j-a*/*harako-i-ta*	magpie

show the same variation as *harakka* but some belong to different types, like the name *Anitta* of type *kala*). Later on, diphthongization rules convert such *i*'s to *i̯*'s (syllabic *i* after a vowel is only found if *γ* must be in-between, as in *la.i-n* (law-GEN) '(of) law').

Then, *z* of stems with "fleeting" *s* like *kuningas* 'king', underlying *kuninkaz*, becomes *h* if intervocalic by rule (6), as its genitive *kuninka-za-n* → *kuninkaha-n* (surface form *kuninkaa-n*) (king-GEN) '(of) king' illustrates. That *z* is not immediately deleted is seen not only in consonant gradation, but also in the stem *mies* 'man', whose underlying form is *meez*[19] and surface genitive is *miehe-n* (man-GEN) '(of) man'.

(6) $z \rightarrow h$ / [+syll]_[αhigh][20].

After that, two rules, (7a) and (7b), apply simultaneously and disjunctively, left-to-right; thus (7b) may feed (left context of) (7a):

(7) a. $d \rightarrow t$ / [+syll][−syll][−syll]* [+syll][+voiced,+cont,−front][αhigh]_[+syll];

b. $d \rightarrow \gamma$ / [+syll][−syll][−syll]*[+syll]_[+syll].

Note that the fact that a certain context does not belong to the first syllable is not shown via syllabic structure but via segmental specification of the left context [+syll][−syll][−syll]*: a vowel followed by one or more consonants. Relevance[21] can be shown by *puhu-dah* (talk-INF) '(to) talk' which becomes *puhu-γah* (and later *puhu-a*^{x}) not **puhu-tah*

[19] The so-called "rising" diphthongs *ie*, *uo*, *yö* are derived from first-syllable mid long vowels, both historically and in synchrony [Zelenskiy 2018: 68]. Cf. *hi.e-n* (sweat-GEN) '(of) sweat' and monosyllabic *mies* 'man'.

[20] This notation means "any segment specified for [high]", encompassing vowels and their non-syllabic versions (*i̯* and *u̯*).

[21] Notably, [Zelenskiy 2018: 71, 104] has a mistake in the rule: while the example is shown correctly, the rule (7a) (there — 9.9.2) is incorrectly set as $d \rightarrow t$ / [−syll][+syll][+voiced,+cont,−front][αhigh]_[+syll], which would demonstrably work on *puhu-dah* (which by later rules would then become surface **puhuda*^{x} instead of *puhua*^{x} 'speak'), overriding (7b) as its context is more specific.

(which would lead to surface **puhu-da*ˣ) and, conversely, *tä-dä* (this-PART) ‘of this’ which becomes *tä-tä*, not **tä-γä* (→ **tä-ä*).

The remaining *d* and *z* are devoiced; [Zelenskiy 2018: 75–77] shows there to be two distinct rules for that, but the analysis is arguably modifiable if *s*-stems (like *nainen* ‘woman’) are treated somewhat differently, which allows for localization IN to have underlying *s* rather than *z*, which, in turn, erases the crucial argument for splitting of the rules, namely that *ke-t=kä* (who-PL=KA) ‘who (plural)’, like *ke-tä* (who-PART) ‘of whom’, lacks the final *ne* of the stem *kene-* ‘who’ while *kene-ssa* (who-INESS) ‘in whom’ does not. Thus, for the sake of simplicity, a single rule is assumed here:

(8) [coronal,−nas,αcont] → [−voiced].

Application example: (*meez* → see fn. 19) *miez* → *mies* ‘man’.

Note that the rule does not apply to the underlying alveolar *d* of words like *addiktio* ‘addiction’ discussed above, even though it does not immediately follow from the formula itself; to make it explicit, one would have to refer to the feature distinguishing *d̪* and alveolar *d*.

Nasal assimilation rules follow, the chief among them (9) (modified from [Zelenskiy 2018: 78, 105] to be inapplicable to [ŋ] in words like *magnetti* ‘magnet’), working across any word boundaries. There are some additional rules for additional effects before sonorants (e.g., reverting assimilation in words like *kanjoni* ‘canyon’ while allowing for *nj* → *jj* assimilation across word boundary), but they do not concern us here.

(9) [+nas,0front] → [αplace] / _[βWB]*[αplace].

Application example: *o+n##pitkä* → *o+m##pitkä* (assimilation across word boundary is not reflected in orthography but confirmed by [Suomi et al. 2008]) (be-3SG long) ‘is long’.

The main consonant gradation rules (10a) and (10b) follow, applying simultaneously-disjunctively:

(10) a. [−cont,−voiced] → [+cont,+voiced] / [+voiced]_[+syll][+syll]* [−syll]@;

b. [−nas,−cont,αplace] → ∅ / [−nas,−cont,αplace]_[+syll] [+syll]* [−syll]@.

Application examples for (10a): (*blogg*+Ad+dAh → by vowel harmony, (1) and (2)) *blogg+at+tah* → *blog+at+tah* → *blog+at+ah* (→ *blogat+a*^{x}) '*blog*-VRB-INF'.

Application example for (10b): *kilpe+n* → *kilve+n* (shield-GEN).

Obviously, (10a) corresponds to quality gradation and (10b) corresponds to quantity gradation. Note that this turns *p* into *v*, *t* into *z*, *k*^{j} into *j*, and *k* into *γ*; of these, only *v* and *j* may ever end up in surface forms.

A special rule, (11), treats the special case of *UUs* suffix discussed above, whose underlying form begins with *UhU*; [Zelenskiy 2018: 81] assumes it to be the third rule in the simultaneous-disjunctive tuple of consonant gradation, but this is, while possible, not necessary. Note the morpheme boundaries + on each side of the suffix undergoing gradation.

(11) [−cont,−voiced,αplace] → [+cont,+voiced] / +[+nas,αplace]_+ [+high,+round]h[+high,+round].

After nasals (including the special case above), the result is nasals; as there are no *mv* combinations (aside from two compounds, where # intervenes), nor *nke* → *ŋje* gradation [22], the following rule suffices:

(12) [αplace,+voiced,+cont] → [+nas,−cont] / [αplace,+nas]_.

Application example for (11) and (12): (*ala+mpA+UhUs* → by vowel harmony and some other rules irrelevant here) *ale+mp+uhus* → *ale+m-v+uhus* → *ale+mm+uhus* (by (18) → *ale+mm+uus*) (low-CMPR-NMN) 'inferiority'.

Partitive of the words ending with *γ*, like *sade*^{x} 'rain' (underlying stem is *sateγ*) ends in *-ttA* [23] (like *sadet-ta* (rain-PART) 'of rain'); a special rule takes care of that [24]:

[22] Note that *nj* is a possible sequence of segments (e.g., *kanjoni* 'canyon'), but with no place assimilation (*nj* has coronal *n*, neither **ŋj* nor something like **ŋʲj*).

[23] Traditional textbooks (such as [Gehring, Heinzmann 2016: 70]) often assume *-ttA* to be the ending in such forms, but this is unjustified: the first *t* is the same ^{x} as in *sade*^{x}*-ko* → *sade[k]-ko* (rain-Q) 'Rain?'

[24] This rule may not be necessary if the rules for ^{x} realization mentioned below can treat this case.

(13) $\gamma \rightarrow t \,/\, \_t$.

Application example: (*sateγ+ta* → by (10a)) *sazeγ+ta* → *sazet+ta* (by (16) → *sadet+ta*) (rain-PART).

Cluster *hk*, unless palatalized, generally does not undergo *ptk*-gradation, yet some words like *nahka* 'skin' have it optionally. I reflect this by adding the rule (14) and marking words like *nahka* to make the rule optional for them (such marking is available, see *Section 1*).

(14) $\gamma \rightarrow k \,/\, h\_$.

Application example: (*nahka+n* → by (10a)) *nahγa+n* → (optionally, for this word) *nahka+n* (skin-GEN)

The surface results of *t*'s lenition are, as we have seen in *Section 2*, quite diverse; yet, aside from (12), two more rules suffice to achieve the observed results: (15) takes care of *rt* → *rr* and *lt* → *ll*, and (16) handles the rest.

(15) $z \rightarrow [0\text{cont},\alpha\text{lat}] \,/\, [0\text{cont},\alpha\text{lat}]\_$;

(16) $z \rightarrow d$.

Application examples: (*parta+n* → by (10a)) *parza+n* → *parra+n* (beard-GEN); (*rata+n* → by (10a)) *raza+n* → *rada+n* (way-GEN); see also the example for (13).

Allophones of *h* are calculated; the details are irrelevant, but, importantly, there exists a step in the derivation where *h* is voiceless before any voiceless consonant (despite the fact that on surface we see, e.g., *tähti* 'star' with its *h* quite voiced). At that moment, rule (17) applies, simplifying many triconsonantal clusters, including clusters with geminates such as *stt* or *htt*. This provides for no quantity gradation after *s* or *h* (see *Section 2* on *pes-tiin* (wash-IMPERS.PST) 'there was washing' vs. *puhu-ttiin* (talk-IMPERS.PST) 'there was talking').

(17) $[-\text{voiced},-\text{cont}] \rightarrow \varnothing \,/\, [-\text{voiced}]\_[-\text{voiced}]$

Application example: (*pes+ttA+i+Vn* → by a series of vowel-related rules unlisted here) *pes+tt+i+in* → *pes+t+i+in* (wash-IMPERS-PST-IMPERS).

Afterwards, prevocalic *h* (both underlying and derived from *z*) is deleted after a short vowel — unless the vowel belongs to the first syllable, cf. *tä-hän* (this-ILL) 'into this', not **tä-än*. This superficially closes some syllables; hence forms like (*kuninkahan* →) *kuninkaa-n* (king-GEN) '(of) king' are "opaque", as they have no consonant gradation in a syllable which is closed on surface (note that this still does not refer to syllabic structure per se, which is supposed to mostly be built later on).

(18) $h \rightarrow \varnothing$ / [+syll][−syll][−syll]*[+syll]_[+syll].

Application example: (*kuninkaza+n* → by (6)) *kuninkaha+n* → *kuninkaa+n* (king-GEN).

As promised, rule (19) depalatalizes those k^j and g^j which did not become *j*, as there are no surface palatal(ized) stops[25] in Finnish:

(19) [−cont,+front] → [−front].

Application example (simplified):[26] (*haiku* → by (5)) *haik^{j}u* → *haiku* 'smoke'.

Some rules for [x] surface realization follow. Then, to get *UvU* from *UγU*, the following rule applies:

(20) $\gamma \rightarrow v$ / [+syll,+high,+round]_[+high,+round].

Application example: (*luku+n* → by (10a)) *luγu+n* → *luvu+n* (number-GEN).

Finally, remaining *γ* are deleted:

(21) $\gamma \rightarrow \varnothing$.

Application example: (*laki+n* → by (10a)) *laγi+n* → *lai+n* (law-GEN); note that the result is bisyllabic (see fn. 26).

[25] Neither oral nor nasal; therefore, the [−cont,+front,−nas] → [−front] rule found in [Zelenskiy 2018: 85, 106] is too specific.

[26] The example is simplified in the important but ultimately unrelated aspect of diphthongization *ai* undergoes; the only relevant thing about diphthongization is that it follows (18) and precedes (21).

These 21 rules[27], combined with rules for determining the plural oblique allomorph and *h* allophones, are enough to describe the seemingly complicated phenomenon of consonant gradation.

4. Conclusion

This paper's goal is twofold. First, it illustrates the power of rule-based phonology in explaining complex language patterns with simple rules of unified format, thus building foundation for a more specific framework using such rules as a general framework of phonology and, more broadly, of linguistics. Secondly, it describes in explanatory terms (and thus explains) a long-standing empirical issue of consonant gradation, whose traditional formulations look either hopelessly diachronic or full of exceptions — and quite often both.

Abbreviations

. — syllable boundary (in examples); → — becomes (in synchrony); 1, 2, 3 — 1, 2, 3 person; A — either a or ä; CMPR — comparative; cont — continuous; GEN — genitive-accusative; ILL — illative; IMP — imperative; IMPERS — impersonal form (traditionally called "passive"); INESS — inessive; INF — infinitive; KA — Finnish clitic added to some monosyllabic pronominal forms; lat — lateral; nas — nasal; NMN — nominalization; NOM — nominative; PART — partitive; PL — plural; PST — past tense; Q — question clitic; R — l, r, or h; seg — segmental; SG — singular; SPE — Chomsky, Halle 1968; syll — syllabic; U — either *u* or *y*; VRB — verbalizer; ^{x} — surface "ghost" consonant in the end of a word (underlying *γ* or *h*); @ — either a [-syll] non-boundary segment or a [+WB] boundary segment. On rule notations other than → see *Section 1*, on underlying segment signs see *Section 3.1*.

If the gloss would coincide with the translation (barring possible .NOM), it is omitted, so that one would not observe things like *sirppi* (sickle) 'sickle'. Likewise, .SG is always omitted from glosses (but combinations such as 1SG are retained), and infinitives may be written in a similar way when they represent a group of forms not just themselves.

[27] Or, rather, 23 rules, given that (7) and (10) each encompass two rules.

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