Saltation and the P-map*

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Abstract

We define a *saltatory* phonological alternation as one in which sound A is converted to C, leaping over a phonetically intermediate sound B. For example, in Campidanian Sardinian, intervocalic [p] is realized as [β] — leaping over [b], which does not alternate. We argue for two points concerning saltation. First, it does not arise as a sound change; rather, the known cases appear to be restructured phonology, arising through a variety of historical accidents. Second, we propose a new approach to the formal analysis of saltation, based on Zuraw's (2007) idea of *MAP constraints and Steriade's (2001, 2008) notion of the P-map. Under our proposal, saltation is predicted to be disfavored, since by definition it is not P-map-compliant. We support this claim with psycholinguistic and historical evidence.

* [Acknowledgments suppressed.]

1. Introduction

We define **saltation** as a property of phonological alternations:

(1) *Defn.: saltation*

- Let A, B, and C be phonological segments.
- Suppose that for every feature for which A and C have the same value, B likewise has that value; but that B differs from both A and C. Intuitively, B is phonetically 'between' A and C.
- If in some context A alternates with C, but B remains invariant, then the alternation A ~ C is a *saltation*.

Here is an example of saltation, taken from the work of Bolognesi (1998). In the Sestu Campidanian dialect of Sardinian, the voiceless stops /p, t, k/, when occurring in intervocalic[1] position, are lenited to [β ð ɣ]. The following examples illustrate the phenomenon:

(2) *Intervocalic lenition of* /p t k/ *in Campidanian* (Bolognesi, pp. 30-31)

a.	belːu [p]iʃːi	→	belːu [β]iʃːi	'nice fish'
b.	sːu [t]rintaduzu	→	sːu [ð]rintaduzu	'the thirty-two'
c.	dɛ [k]uatːru	→	dɛ [ɣ]uatːru	'of four...'

(3) *Retention of intervocalic* /b, d, g/ (pp. 36-39)

a.	sːu [b]inu	→	sːu [b]ĩu	'the wine'
b.	donːja [d]ominiku	→	donːja [d]ominiɣu	'every Sunday'
c.	dɛ [g]ɔma	→	dɛ [g]ɔma	'of rubber'

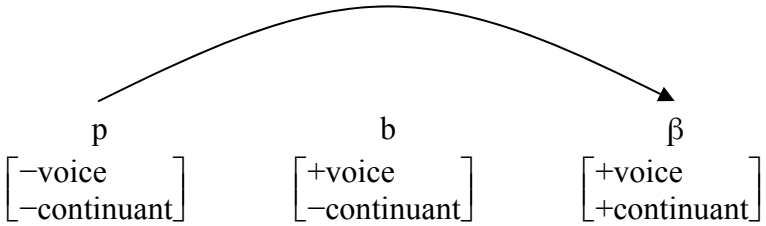
Bolognesi attests to the productivity of the pattern with examples of application to borrowed or recently-introduced words: sːa [p]olonia → sːa [β]olonia '(the) Poland', sːu [t]asːi → sːu [ð]asːi. 'the taxi', sːu [k]omputːɛ → sːu [ɣ]omputːɛ 'the computer' (pp. 32-33, 463). He further notes (p. 36) that the output pattern is maintained consistently: 'Speakers not only do not spirantize voiced stops, but judge this ... as entirely ungrammatical, instead. For them a phrase such as, for example, *saː βɔɾa* could only be the output of underlying *sːa pɔrta* ('the door'), and never of *sːa bɔrta* ('the time'). They claim the second interpretation to be wrong.'

We adopt the term 'saltation' from Minkova (1993) and Lass (1997), who use it in the context of historical sound change; we discuss their claims about diachrony below. 'Saltation' derives from the Latin word for 'leaping'.[2] As can be seen in (4), underlying /p/ leaps over intervening /b/ in arriving at [β]:

[1] More precisely, postvocalic onset position; see (2b). The voiceless affricate /tʃ/ also spirantizes (to [ʒ]), but with lexical exceptions (Bolognesi p. 32); we omit analysis of this segment here.

[2] OED *saltate*: 'f. L. *saltāt-*, ppl. stem of *saltaːre* to dance, frequent. of *saliːre* to leap'.

(4) *The path of saltation in Campidanian*



The concept of saltatory alternation has been discussed before in Lubowicz (2002) and Ito and Mester (2003) under the label 'derived environment effects'. We prefer the term 'saltation' because it is theoretically neutral; it describes the data pattern rather than a proposed mode of analysis.[3]

This article seeks to make two points about saltation. First, we claim that saltation normally has unusual diachronic origins; that is, we think it unlikely that it ever arises as an ordinary sound change as is the case for many other alternations. Second, we offer criticisms of earlier analyses of saltation and propose an alternative, based on the *MAP constraints of Zuraw (2007), which in turn is an implementation of Steriade's (2001, 2008) P-map principle. We defend our analysis with evidence from psycholinguistics and language change.

2. The historical origin of saltation

Minkova (1993) and Lass (1997), studying diachrony, suggest that no *sound change* is ever saltatory. Indeed, Lass suggests that no sound change ever saltates even across a phonologically possible segment, let alone a segment that already exists in a language. It would follow that all existing synchronic saltations are not sound changes and must instead be the result of accidental sequences of accumulated change. In this view, saltation always represents a form of **restructuring**, in the sense of Kenstowicz and Kisseberth (1977: Ch. 2) and similar work.

In the second half of this article, we give evidence suggesting that saltation has a dispreferred status in phonology; in particular, it is downgraded as a hypothesis in phonological learning. This would provide one explanation for why saltation only comes into languages as a historical accident. However, we emphasize that this is only one explanation for the historical behavior of saltation — it is also possible, for instance, that an adequate theory of the mechanism of sound change would make the same prediction. We have no data that provides particular support for a learning-based explanation; hence the rather loose connection between the two halves of our article.

We offer the following taxonomy of origins for saltatory alternations; in what follows, we assume that the pattern that ultimately arises is one in which sound A saltates over B to reach C.

[3] Specifically, Lubowicz's analysis relates saltation to the 'derived environment rules' discovered by Kiparsky (1973); our account makes no such connection.

(5) *Origins of saltation: a taxonomy*

a. *Interposition by borrowing*

A becomes C in some context; B is later interposed when acquired as a new phoneme in loanwords.

b. *Interposition by grammar change*

A becomes C in some context; B is later interposed as a result of grammar change.

c. *Flanking*

A was originally something else (A′) that became C in the alternation context; then A′ changes to A in the non-alternation context; A and C now flank B, forming a saltation.

2.1 Interposition by borrowing

A case of this type is described by Ito and Mester (2003) for Standard German: /g/, occurring in final position following atonic [ɪ], surfaces as [ç] (the allophone of /x/ found after front vowels), as in /ˈkøːnɪg/ → [ˈkøːnɪç] 'king' (cf. [ˈkøːnɪgə] 'kings'). Yet underlying /k/ in this position is invariant: [ˈplastɪk] 'plastic'. The sounds [g] and [ç] differ in voicing, continuancy, and place of articulation; [k] differs from [g] in voicing and from [ç] in continuancy and place; hence by our definition (1) the alternation is saltatory.

Inspection of the cases with [k] after atonic [ɪ] shows that they are cosmopolitan words; Ito and Mester give examples like *Plasti*[k] 'plastic', *Derri*[k] 'name of television detective' and *Bati*[k]; patently late loan words in German.[4] The likely reason that /k/ had previously been missing finally after stressless /ɪ/ was because earlier, historical *k* had been converted to *x* by the Second German Consonant Shift; see e.g. Salmons (2012: 116).

Interposition by borrowing also characterizes two other saltations reported in Lubowicz's (2002) study. In Slovak (Rubach 1993), the sounds [e, o] alternate in a variety of contexts with the diphthongs [ie, uo], thus saltating over [eː, oː]. ([eː, oː] share their vowel quality with [e, o] and share their status as heavy nuclei with [ie, uo]). The long mid vowels are originally almost entirely from loanwords of the usual pan-European character such as [majoneːz] 'mayonnaise' (Rubach 1993:177).

Lubowicz's Polish example is similar: here, underlying /g/ surfaces as [ʒ] before front vowels, skipping over intermediate [ʤ];[5] thus /va[g]+i+ć/ → va[ʒ]+ɨ+ć 'to weigh', but brɨ[ʤ] + ĭk + ɨ → brɨ[ʤ] + ek, not *brɨ[ʒ]+ek 'bridge (game; dim.)'. The forms with invariant

[4] With help from Prof. Armin Mester we have verified this generalization using the Leipzig Online Dictionary, http://wortschatz.uni-leipzig.de.

[5] [g] and [ʒ] differ in continuancy, stridency, and place of articulation; [ʤ] differs from [g] in stridency and place and from [ʒ] in continuancy.

[dʒ] are evidently pan-European loans like the word for ‘bridge’; see Lubowicz p. 245, Rubach (1984:§5.3).

2.2 Interposition by grammar change

We argue that Campidanian (§1) likewise is a case where B was interposed between a pre-existing alternation of the form A → C. But the mechanism is more interesting: it arose from grammar change, or what traditional historical linguistics called ‘analogy’ (Bynon 1977:§1.5).

In our proposal, the Campidanian pattern originated as an ordinary lenition chain, shown schematically in (6):

(6) $\left\{\begin{matrix} p & \rightarrow & b & \rightarrow & \beta \\ b & \rightarrow & \beta & \rightarrow & \varnothing \end{matrix}\right\}$ / V ___ V

That is to say, historical *p* and *b* (and similarly for *t*, *d*; *k*, *g*) weakened intervocalically, while remaining distinct, along same lenition path. *b*, being in the lead, was the first to reach the extreme of full deletion. This was a radical step, in that it created extensive neutralization (all three voiced stops) in a sensitive place, i.e. stem-initial position. [6, 7] When this merger became phonetically complete, the language reached a crisis stage, resolved when a new generation of children refused to accept the extreme alternation and ‘fixed’ the language by restoring the isolation allomorphs post-vocalically. Our scenario is summarized in (7):

(7)

	‘nice fish’	*‘the wine’*	
a.	bɛlːu [p]iʃːi	sːu [b]ĩu	initial stage
b.	bɛlːu [b]iʃːi	sːu [β]ĩu	early lenition
c.	bɛlːu [β]iʃːi	sːu [∅]ĩu	crisis stage — massive stem-initial neutralization
d.	bɛlːu [β]iʃːi	sːu [b]ĩu	post-crisis stage — restructuring

We give the following arguments in support of our scenario.

First, as Bolognesi points out (p. 36, citing Virdis), there are neighboring dialects of Sardinian where the hypothesized stage (7b) is still attested; that is, voiced stops are still realized as voiced fricatives intervocalically. This increases the plausibility that Campidanian also went through such a stage.

[6] In principle, there would have been merger with the historically vowel-initial words as well. However, as Bolognesi notes (p. 216), the historically vowel-initial words — rather like the *h*-aspiré words of French — trigger hiatus resolution processes when a vowel-final word precedes them, whereas the words derived from initial /bdg/ typically do not.

[7] For the privileged Faithfulness status of stem-initial position see Beckman 1997, Casali 1997, and Becker et al. 2012.

Second, historical evidence indicates that the voiced stops that were intervocalic *within morphemes* in Campidanian disappeared entirely (Bolognesi, p. 212); a possible example is [teula] 'shingle' (p. 189), with hiatus; cf. Latin TEGULA 'tile'.[8] This makes sense under our account, since a medial voiced stop would not have any other allomorph from which the underlying form could be recovered.

Third, Bolognesi notes the existence of particular words beginning with voiced stops that, even in contemporary Campidanian, alternate optionally with zero, as in (8).

(8)	[bakːa]	[sːa bakːa] ~ [sːa akːa]	'cow/the cow'	(p. 37)
	[dɔmu]	[sːa dɔmu] ~ [sːa ɔmu]	'house/the house'	
	[gatːu]	[sːu gatːu] ~ [sːu atːu]	'cat/the cat'	

Such alternation is allowed only in 'a restricted number of lexical items' (p. 190), forming a 'closed class' (p. 215). Other words do not allow alternation at all:

(9)	[barːĩa]	[sːa barːĩa], *[sːa arːĩa]	'the drill'	(p. 37)
	[dɔtːori]	[sːu dɔtːori], *[sːu ɔtːori]	'the doctor'	
	[gauŋdʒu]	[sːu gauŋdʒu], *[sːu auŋdʒu]	'the food that can be put on bread'	

An examination of the data throughout Bolognesi's work suggests the following generalization: alternators tend to be words of the core vocabulary, whereas non-alternators are more sophisticated vocabulary.[9] Moreover, alternating forms like (8) have the remarkable property that their ∅-initial allomorphs are employed in *careful*, not fluent, speech (Bolognesi p. 36-7). Both facts suggest that forms like /akːa/ ('cow', postvocalic) are lexically-listed items, preserved as historical relics, much like vowel-shortened English past tenses such as *kept*. This accounts for the limitation of alternation to core vocabulary, since research has shown that it is in core vocabulary that relic forms tend to be retained over time (Bynon 1977:42-3; Bybee 1985:119-120). It also makes sense of the curious limitation of zero-initial allomorphs to careful speech; this plausibly reflects the demands of lexical retrieval for listed forms.[10]

[8] Further examples: [kɔa] 'tail' p. 24 (Latin CAUDA), [nuu] 'knot' p. 24 (NŌDUS), [taula] 'board' p. 31 (TABULA). Forms like [pisːiˈkːɔʁɔɣu] 'psychologist' p.18 or [friɣoɾifːɛɾu] 'refrigerator' p. 33 plausibly reflect phonetically-faithful adaption of cosmopolitan loanwords (Peperkamp et al. 2008); their [ɣ]'s would be represented underlyingly as /k/.

[9] E.g., alternating forms have glosses like 'of', 'want', 'road', 'house'. Non-alternating forms have glosses like 'doctor', 'drill', 'rubber', 'chicory'.

[10] An issue we will not treat in detail is how the irregular forms of (8) should be analyzed in a formal grammar. They do not seem fundamentally different from any other forms of lexical allomorphy, and appropriate theoretical apparatus has been proposed in the literature; see e.g. Mascaró (2004) and John McCarthy's appended commentary for further references. Following this tradition, we suggest that words of the class in (8) have dual lexically listed allomorphs, such as (for 'cow') {/bakːa/, /akːa/}; the appropriate allomorph can be selected with ordinary ranked markedness constraints, e.g. *V[−cont]V (see §4 below) ranked freely against *NO ONSET. MAX ranks high, preventing the loss of /b/ from forms that have only one UR.

The upshot is that, if our arguments are correct, Campidanian saltation was never a sound change; rather, it involved interpolation of the voiced stops in the intermediate position by grammar change. We return to the formal analysis of Campidanian below.

A second instance of saltation through grammar change is offered by Ito and Mester (1997). In the *rendaku* (compound voicing) alternations of Conservative Tokyo Japanese, basic /k/ saltates over /g/ in becoming [ŋ], as in /ori + kami/ → [oriŋami] 'folding paper'. That the alternation is saltatory is shown by forms like /niwa + geta/ → [niwageta] 'garden clogs'.[11] The historical evolution of this pattern is plausibly as follows: (a) *k* was originally voiced by rendaku to *g*, in parallel with other obstruents; (b) *g* then further evolved to [ŋ] intervocalically in the Conservative Tokyo dialect; (c) lastly, *g* was optionally restored in paradigms (grammar change). As Ito and Mester suggest, this could have arisen through promotion of an output-to-output correspondence constraint (Benua 1997) requiring an exact match to [g] in the base form, as in [niwageta]. No base form with [g] is available for [oriŋami], which accounts for its invariant [ŋ].

2.3 Outflanking

Ito and Mester report a saltation in certain Northern varieties of German in which the surface form of underlying /g/ in final position is not the expected [k] (via the well-known process of Final Devoicing) but rather [x], as in [fraːx] 'asked-1 sg.' (cf. [fraːgən] '1 pl.'). Since there are also non-alternating forms with [k] (e.g. [dɪk] 'fat'; inflected [dɪk-ə], this is saltation of /g/ to [x] over [k].

A plausible origin for this case is described by Robinson (2000), relying on earlier work by Zhirmunskii (1962) and Pilch (1996): it appears to be not a consequence of sound change but of hypercorrection. In vernacular varieties of North German, earlier [g] evolved into the spirant [ɣ][12] whenever it followed a vowel; including intervocalically (Zhirmunskii 1962). For these vernacular varieties, sample paradigms would have evolved as in (10).

(10) *North German saltation, phase I: the vernacular dialects*

fragen ~ frag	*dicke ~ dick*	*machen ~ mach*[13]	
g ~ g	k ~ k	x ~ x	pre-North German
ɣ ~ ɣ	k ~ k	x ~ x	Spirantization of /g/ after vowels
ɣ ~ x	k ~ k	x ~ x	Final Devoicing

[11] The latter form may also be pronounced [niwaŋeta]; hence the alternation is not *invariably* saltatory.

[12] Or its partner following front vowels, [j]; velar examples are used here for simplicity.

[13] These forms are schematic and not guaranteed to match actual dialect data. Glosses: 'ask-imperative/infinitive'; 'fat-adjectival inflection/plain form'; 'do-imper./infin'.

According to Pilch (1966), North German varieties are subject to normative influences; he mentions the social 'pressures of educated society'. This influence has given rise to a variety that Pilch calls 'refined' (*vornehm*) North German, exemplified by the paradigms in (11).

(11) *North German saltation, phase II: refined varieties*

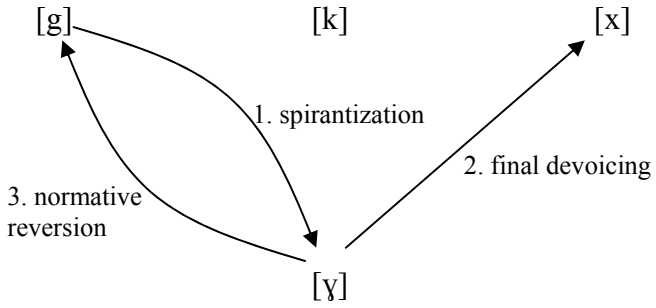
fragen ~	*dicke ~*	*machen ~*
frag	*dick*	*mach*
g ~ x	*k ~ k*	*x ~ x*

As can be seen, in Pilch's Refined North German — which is in fact the variety Ito and Mester describe[14] — [ɣ] is replaced (either optionally or obligatorily) by the normative form [g]; thus *fra*[g]*en* instead of *fra*[ɣ]*en*. Less often, Pilch notes, Refined speakers also southernize forms like *fra*[x] to *fra*[k]. Yet it would seem easier (a surface, perhaps postlexical operation) to cleanse one's speech of all [ɣ]'s by replacing them with [g] than to 'fix' only the [x]'s that derive from /g/ with [k]. When a speaker makes the easy repair but not the hard one, the resulting pattern is the saltation seen in (11).

The realism of this scenario is further increased by the existence of speakers (Armin Mester, personal communication) who produce the Refined North German variants in careful, public contexts, but the vernacular forms in casual contexts with family and friends.

From the diachronic perspective, it can be seen that Refined North German acquired a saltatory alternation through a sort of flanking maneuver: on one flank, historical *g* evolved into [ɣ], thence (in final position only) into [x]. This in itself did not produce saltation; however, a reverse change, the normatively-driven shift of [ɣ] back to [g], moved the alternating pair [g] ~ [x] into a saltatory arrangement with respect to [k]. As with previous cases, saltation was not a direct historical innovation.

(12) *Formation of North German saltation though flanking*

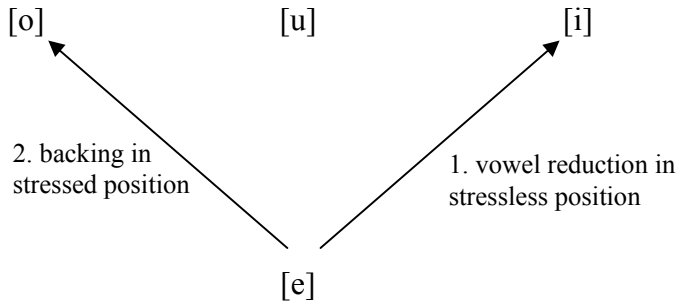


Crosswhite (2000) offers another case of saltation from Russian that likewise can be considered as a case of flanking. Here, phonemic /o/ is reduced to [i] in atonic position when

[14] We will not venture to reconcile Pilch's calling the same variety 'Refined' that Ito/Mester call 'Colloquial'; perhaps standards of refinement have risen during the four decades separating these works.

following a palatalized consonant, with phonemic stressless /u/ remaining as [u] in the same environment. Since [u] is high like [i] and back and rounded like [o], this is saltation. Crosswhite gives the diachronic background: 'This unusual pattern of /o/ > [i] but /u/ > [u] derives historically from the fact that *stressed* /e/ became [o] when preceded by a palatalized consonant but not followed by one: C^{j}éC > C^{j}óC'. In our terms, this is saltation by diachronic flanking, as shown in (13).

(13) *Formation of Russian saltatory vowel reduction though flanking*



Crosswhite also presents evidence that the Russian saltation pattern is no longer productive: it fails to apply in new words, is emphatically rejected in nonce-probe testing, and gives rise to regularizing shifts in the pronunciation of existing words. This fact will be relevant below when we consider the synchronic analysis of saltation.

To sum up our historical survey: the data so far given seem compatible with the view that saltation is never the result of a 'fresh' sound change but is always the result of restructuring. This increases our sense that saltation may be a linguistically disfavored phenomenon, an argument we will return to in §5.

2.4 Three further saltations

We cover three further cases; with these examples, we have listed all instances of saltatory alternation of which we are aware.

2.4.1 Manga Kanuri

The Manga dialect of Kanuri (Schuh 2003, 2005; Jarrett 2007) constitutes the biggest puzzle for our view that saltation cannot arise directly from sound change. In this language, basic /t/ surfaces as [ð] when between two sonorants, saltating over [d], which is invariant in this position. Historically at least, [ð] was an allophone (noncontrastive variant) of /t/, much as in Campidanian. There are also alternations that persist today, as with the nominalizer prefix /kən-/; compare [tà] 'catch (verb)' ~ [kənðâ] 'catch (noun)'; [dóndì] 'sick' ~ [kəndóndì] 'sickness'.

Similarly to the Russian example just given, the Manga Kanuri pattern seems to be breaking down: intervocalic [t] is now phonologically legal in the language and thus contrasts with /ð/; this is attested by about 24 stems with intervocalic [t] in the dictionary of Jarrett (2007), occurring both in European loans and otherwise.

Concerning the history of saltation in Manga Kanuri, we note a particularity of this dialect, namely that the region in which it is spoken was not originally Kanuri-speaking: historically, Kanuri spread westward into areas populated by speakers of Chadic languages, of which Bade and Ngizim still survive as near-islands, now separated from one another by a Kanuri-speaking area (Schuh 2003, 2005; Hutchinson 1981:4). Both Bade and Ngizim include implosive [ɗ] in their phoneme inventories, making it reasonable to suppose that this was true of the now-extinct Chadic varieties that were displaced by Kanuri. Our conjecture is that the Chadic speakers who first adopted Kanuri rendered Kanuri [d] with their own implosive [ɗ].[15] If this [ɗ] was still in place when *t* lenited to [ð] between sonorants; then it was not on the direct path between [t] and [ð] (neither of which are implosive) and the change was therefore not saltatory. Ultimately, the hypothesized Chadic-influenced variety of Kanuri lost [ɗ], shifting it to [d] in conformity with other Kanuri dialects. Thus [d] was interposed between [t] and [ð] (cf. §2.1, §2.2 above), creating the saltation. This account of Manga Kanuri saltation is speculative and the matter deserves further attention.

2.4.2 Suma

Discussing the tonal phonology of Suma, Bradshaw (1995, 1998, 1999) indicates that in the associative construction of this language, a final low tone becomes high when it is preceded by a high tone, resulting in an alternation between a HL pattern and a HH pattern. Bradshaw states that 'nouns with final H or M tones do not alternate' (1998:117); however, no examples of this type are given; nor are the possible historical origins of the claimed saltation discussed.

2.4.3 Campidanian II

See §4.4 below.

3. Theories of saltation

3.1 Why saltation cannot be derived in classical Optimality Theory

By 'classical' Optimality Theory we mean Prince and Smolensky (1993) as modified by the Correspondence Theory of McCarthy and Prince (1995). We repeat here arguments from Lubowicz (2002) and Ito and Mester (2003).

Consider first Campidanian. When /p t k/ shift to [β ð ɣ] in intervocalic position, they become voiced; in standard OT this will follow if a Markedness constraint banning intervocalic voiceless sounds (*V[−voice]V) outranks the opposing Faithfulness constraint for voicing, IDENT(voice). In addition, when shifting to [β ð ɣ] /p t k/ become [+continuant]. This will follow if a Markedness constraint banning intervocalic stops (*V[−cont]V) outranks the opposing Faithfulness constraint for continuancy, IDENT(continuant). As shown in (14), a grammar that respects these rankings will generate (to cover just the bilabial case) [VβV] from underlying /VpV/:

[15] For an instance where implosives have been employed in loan adaptation of foreign words with voiced stops, see Smith and Haabo (2007) on Saramaccan.

(14)

/VpV/	*V[−voice]V	* V[−cont]V	IDENT(−voice)	IDENT(cont)
☞ VβV			*	*
VbV		*!	*	
VɸV	*!			*
VpV	*!	*		

However, since V[−cont]V outranks IDENT(continuant), then /VbV/ will likewise surface as [VβV], which is incorrect:

(15)

/VbV/	*V[−voice]V	* V[−cont]V	IDENT(−voice)	IDENT(cont)
☞ *VβV				*
VbV		*!		
VɸV	*!		*	*
VpV	*!	*	*	

Thus, there is a ranking contradiction: V[−cont]V must outrank IDENT(continuant) in order to let /p/ go all the way to [β], but IDENT(continuant) must outrank V[−cont]V in order to keep intervocalic /b/ unaltered.

Now consider the general case, /A/ → [C] with intermediate unchanging B. We assert that rankings that send A to C will also wrongly send B to C. For given our definition of saltation in (1), the Faithfulness violations incurred in changing B to C are a subset of those incurred in changing A to C. Thus, the Faithfulness constraints cannot prevent B from changing to C. Moreover, the same end cannot be achieved by assigning a sufficiently low ranking to the Markedness constraints that favor changing B to C; under this strategy, A would wrongly change to B rather than C. Such considerations suggest that analyzing saltation is in general beyond the scope of classical OT.

3.2 The constraint-conjunction approach

If classical OT cannot treat saltation, what can? Lubowicz (1998, 2002) proposed to employ *local constraint conjunction*, in the sense of Smolensky (1995).[16] This solution was carried over by Crosswhite (2000) for Russian and by Ito and Mester (2003) for German. The crucial idea is to conjoin a markedness constraint with a faithfulness constraint, which for Campidanian would work as in (16).

(16) *A conjoined constraint for Campidanian*

*IDENT(voice) & *V[–continuant]V

[16] Specifically, we mean constraints that penalize candidates that are simultaneously "bad in two respects"; for the alternative of penalizing candidates that are bad in *either* of two respects, see Crowhurst and Hewitt (1997), Downing (1998), and Crowhurst (2011).

This constraint says that a segment should not be simultaneously unfaithful (with regard to IDENT(voice)) and marked (with regard to *V[–continuant]V]). Intuitively this can be expressed as the prescription, 'do not be an intervocalic stop if you already violate faithfulness to [voice].' Under this setup, intervocalic /p/ cannot surface as at [b], though voicing-faithful /b/ is allowed to do so. In (17) are tableaux illustrating this point.

(17) *Saltation with conjoined constraints*

a. Conjoined constraint forces /p/ *to become* [β]

/apa/	ID(vce) & *V[−cont]V	*V[−vce]V	ID(voice)	ID(cont)	*V[–cont]V
☞ aβa			*	*	
*apa		*!			*
*aba	*!		*		*

b. /b/ *is stable*

/aba/	ID(vce) & *V[−cont]V	*V[−vce]V	ID(voice)	ID(cont)	*V[–cont]V
☞ aba					*
*aβa				*!	

However, as Ito and Mester (1998) originally pointed out, the cost of this solution for phonological theory as a whole is extremely high: it leads to a broad license for marked entities to be favored over unmarked ones, contrary to typology. We demonstrate this here with our own example, constructing a hypothetical language whose phonology is highly implausible.

We assume some garden variety constraints: (a) a Markedness constraint, *[−sonorant, −voice], banning voiced obstruents (e.g., Lombardi 1999); (b) an opposed Faithfulness constraint, IDENT(voice); (c) a Markedness constraint banning triple consonant clusters *CCC;[17] (d) an opposing Faithfulness constraint, MAX(C). We assume that our language in the normal case forbids voiced obstruents (as in Hawaiian), hence employs the ranking *[−sonorant, −voice] >> IDENT(voice). We also assume that our language permits triple clusters, so that MAX(C) >> *CCC. Now we conjoin Markedness and Faithfulness constraints to create IDENT(voice) & *CCC, and rank the resulting constraint above *[−sonorant, −voice]. The result is that in our hypothetical language, voiced obstruents are allowed, but only when they occur as part of a triple cluster. The tableaux demonstrating this are given in (18).

[17] This could be replaced by syllable-based constraints; the point of our example would not change.

(18) *Deriving voiced obstruents only in triple clusters with a Lubowiczian conjoined constraint*

a. Voiced obstruents disallowed in simple cases

/ba/	IDENT(voice) & *CCC	MAX(C)	*[–son, +voice]	*CCC	IDENT(voice)
☞ pa					*
*ba			*!		

b. Voiced obstruents allowed in triple clusters

/apdka/	IDENT(voice) & *CCC	MAX(C)	*[–son, +voice]	*CCC	IDENT(voice)
☞ apdka			*	*	
*apka		*!			
*aptka	*!			*	*

We certainly know of no language that permits voiced obstruents only in triple clusters and do not expect to encounter one. At the very least, it is grossly counterintuitive to think that appearance in a highly marked configuration (CCC) would permit the appearance of segments otherwise illegal.

The example is easily generalized as follows. Assume two Markedness constraints, MARKEDNESS I and MARKEDNESS II, which are independent and can be violated in the same location. Assume also a FAITHFULNESS I constraint, opposed to and dominated by MARKEDNESS I, implying that in normal circumstances forms violating Markedness I may not surface. Assume further that FAITHFULNESS II is ranked above MARKEDNESS II, so that forms violating MARKEDNESS II are allowed. Lastly, assume that the conjoined constraint MARKEDNESS II & FAITHFULNESS I dominates MARKEDNESS I. The full set of rankings assumed is as in (19).

(19) *A problematic constraint ranking*

MARKEDNESS II & FAITHFULNESS I >> MARKEDNESS I >> FAITHFULNESS I,
FAITHFULNESS II >> MARKEDNESS II

The result will be a language in which MARKEDNESS I can be violated only when MARKEDNESS II is also.[18] This abstract schema can be cashed out as a panoply of bad typological predictions, for instance, the existence of languages in which nasalized low vowels are confined to stressless syllables; front rounded vowels occur only in hiatus, contour tones are limited to creaky vowels, and so on. It is patently the case in phonology that adding a marked context does not make it easier to violate a markedness constraint; often it makes it harder (which is why conjoined Markedness constraints often make sense; Ito and Mester 2003). For this reason, we feel that it would be sensible to ban Markedness-Faithfulness conjunctions from phonological theory

[18] Linking up our two examples: MARKEDNESS I = *[–son, +voice], FAITHFULNESS I = IDENT(voice), MARKEDNESS II = *CCC, FAITHFULNESS II = MAX(C).

entirely; this was proposed by Ito and Mester (1998:13) under the title 'Restriction on Conjoinability'.[19]

4. The analysis of saltation using P-map theory

Hoping to avoid opening the formal floodgates, we suggest a different approach. For reasons to be given later, we think the appropriate theory is one that *disfavors* saltation, but does not actually render it impossible.

*4.1 Framework: *MAP( ) cum P-map*

Zuraw (2007) has proposed to augment the theory of faithfulness beyond the simple constraint types of McCarthy and Prince (1995). In her approach, a constraint of the form ***MAP(*x*, *y*)** assesses a violation to a candidate if a segment belonging to natural class *x* in the input is mapped to a corresponding segment in natural class *y* in the output.[20] An aspect of Zuraw's theory that will be essential here is that unlike in classical correspondence theory with IDENT( ) constraints, *MAP constraints can be **non-minimal**; specifically, they do not require that the corresponding segments *x* and *y* differ in just one feature. Thus, for instance, one could assume a *MAP constraint that penalizes input-output pairs like /p/ ~ [β], which differ in both voicing and continuancy.

The theory is thus made more powerful; in compensation, it is constrained in substantive terms. Zuraw suggests that the natural rankings of *MAP constraints are largely determined by phonetics. Specifically, Zuraw adopts from Steriade (2001, 2008) the principle of the **P-map**, or perceptual map, which encodes the perceptual distance between all segment pairs in all contexts. In this approach, the *MAP constraints are assigned a default ranking as follows: *MAP constraints banning changes that cover a larger perceptual distance are assigned a default ranking higher than constraints banning smaller changes. This ranking preference is taken to be a learning bias in UG; however, given sufficient evidence in the ambient language, it is possible for learners to subvert the default rankings (Zuraw 2007:297).

The basic prediction of the *MAP-cum-P-map proposal — that phonetically-salient alternation is disfavored related to less-salient alternation — is supported by a wide variety of evidence. Zuraw uses it to explain the preferred locations for infixes in initial clusters of Tagalog: they occur where the phonetic change induced in the stem is least salient. Similarly, Fleischhacker (2001, 2005) and Shademan (2002) give evidence that in epenthesis alternations, it

[19] It is evident that Ito and Mester changed their views after writing their 1998 ms., apparently motivated by the need to analyze saltation. We think they were right the first time, and offer an alternative account of saltation in the next section.

One further note on Markedness-Faithfulness conjunction: Baković (2000) suggests it as a solution to the well-known 'majority rules' problem in harmony and assimilation (Lombardi 1999). In light of the argument summarized in this section we are reluctant to accept his solution, since purely Faithfulness-based solutions also exist (e.g., Lombardi's). In addition, the empirical generalization that 'majority rules' phenomena are never found may actually be false; see [Anonymous] (in preparation).

[20] Zuraw permits *MAP( ) constraints to include contexts; for present purposes context-free *MAP constraints will suffice.

is preferred to place the epenthetic vowel in the location that changes the stem least saliently. Wilson (2006) explains the direction of generalization taken by participants in an artificial language study — they generalize in to novel cases with less phonetically salient alternation, but not to novel cases where alternation is more salient. Similar experiments, showing that people have difficulty in learning arbitrary phonological alternations that are phonetically extreme, have been carried out by Skoruppa et al. (2011) and by Stove et al. (2013). Lofstedt (2010) shows that in Swedish vowel length alternations, paradigm gaps have arisen in precisely those cases where the distance between long-short vowel pairs is phonetically greatest, owing to concomitant differences of vowel quality. In language acquisition, children are observed to innovate non-adult-like forms that diminish degree of alternation in the paradigm (Hayes 2004, citing Kazazis 1969, Bernhardt and Stemberger 1998). Lastly, there is evidence that in historical change, phonologies are sometimes restructured by a new generation of learners in a ways that reduce the phonetic distance of an alternation (Kiparsky 1982).

4.2 Basics of the proposed analysis

Consider now how the *MAP-cum-P-map approach would be applied to the problem of saltation. The idea is that, given sufficient data to override a learning bias, the system permits rankings that make it possible to analyze saltation. In particular, a *MAP constraint banning correspondence at a greater phonetic distance could be exceptionally ranked below a *MAP constraint banning correspondence as a lesser, subset distance. For Campidanian, the required unnatural ranking is *MAP(b, β) >> *MAP(p, β).[21] Intuitively, this ranking means that is it less bad for voiceless stops to alternate with voiced fricatives than it is for voiced stops to do so, despite the phonetic distances involved. This is what permits /p/ to spirantize but not /b/. The crucial tableaux are given in (20).

(20) *Deriving Campidanian as a marked option with* *MAP( )

a. /p/ *becomes* [β] *intervocalically*

/apa/	*MAP(b, β)	*V[−cont]V	*MAP(p, β)	*MAP(p, b)
☞ aβa			*	
*apa		*!		
*aba		*!		*

b. /b/ *is stable*

/aba/	*MAP(b, β)	*V[−cont]V	*MAP(p, β)	*MAP(p, b)
☞ aba		*		
*aβa	*!			

[21] In our constraint names we use bilabial phonetic symbols like [p] as shorthand for natural classes; '[p]' denotes [−sonorant, −continuant, −voice], '[b]' denotes [−sonorant, −continuant, +voice], and '[β]' denotes [−sonorant, +continuant, +voice].

It is clear from the tableaux that for the analysis to work we must have *MAP(b, β) >> *V[−continuant]V (to block spirantization of /b/) and also *V[−continuant]V >> *MAP(p, β) (so that /p/ will spirantize). By transitivity, this yields *MAP(b, β) >> *MAP(p, β), in violation of the P-map. Thus, although Campidanian is a possible phonology, it is claimed to be harder for language learners, since it requires a ranking that is not P-map-compliant.

4.3 The analysis done more carefully

To make sure our analysis works, we redid it with additional candidates and constraints. In addition to the core cases /apa/ → [aβa] and /aba/ → [aba], we must make sure that (a) /p/ and /b/ are stable when not intervocalic: /pa/ → [pa], /ba/ → [ba]; (b) [β] will not surface except when derived by spirantization from /p/. For the latter, we follow the principle of the Rich Base (Prince and Smolensky 1993, §9.3), requiring that illegal forms surface as something legal. In particular, hypothetical /βa/ must surface as some legal form, which (as it turns out) our analysis predicts to be [pa], and /aβa/ must likewise surface as something legal, which (as it turns out) our analysis predicts to be [aβa].

A full analysis should also include the third logically possible constraint regulating correspondence between [p b β], namely *MAP(p, b). We included this but required (as the P-map principle does, in the absence of overriding data) that it be ranked higher than *MAP(p, β).[22]

As candidates we included all three possible output consonants ([p b β]) for all of our input forms, which cover all three consonants in both initial and intervocalic environments. We also assumed for present purposes that the *MAP constraints are symmetrical, so that /pa/ → [ba] and /ba/ → [pa] are equally penalized by *MAP(p, b).

We executed the analysis using OTSoft 2.3.2 (Hayes, Tesar and Zuraw 2013), which ranked the constraints using Recursive Constraint Demotion (Tesar and Smolensky 1995), suitably constrained to respect the a priori ranking *MAP(p, b) >> *MAP(p, β). The resulting tableaux are given in (21).

(21) *Full tableau set for the Campidanian *MAP( ) analysis*

a. *Lenition of intervocalic* /p/

/apa/	*V[−voice]V	*MAP(b, β)	*V[−cont]V	*β	* MAP(p, β)	* MAP(p, b)	*b
☞ aβa				*	*		
aba			*!			*	*
apa	*!		*				

[22] As Norval Smith has pointed out to us, the analysis will work even if *MAP(p, β) is outright removed; we include it here to make explicit how the analysis deviates from the P-map.

b. *Intervocalic* /b/ *is stable*

/aba/	*V[−voice]V	*MAP(b, β)	*V[−cont]V	*β	* MAP(p, β)	* MAP(p, b)	*b
☞ aba			*				*
aβa		*!		*			
apa	*!		*			*	

c. *Initial* /p/ is *stable*

/pa/	*V[−voice]V	*MAP(b, β)	*V[−cont]V	*β	* MAP(p, β)	* MAP(p, b)	*b
☞ pa							
ba						*!	*
βa				*!	*		

d. *Initial* /b/ *is stable*

/ba/	*V[−voice]V	*MAP(b, β)	*V[−cont]V	*β	* MAP(p, β)	* MAP(p, b)	*b
☞ ba							*
pa						*!	
βa		*!		*			

e. *Rich base* '/β/' *indistinguishable from* /p/ *when initial*

/βa/	*V[−voice]V	*MAP(b, β)	*V[−cont]V	*β	* MAP(p, β)	* MAP(p, b)	*b
☞ pa					*		
βa				*!			
ba		*!					*

f. *Rich base* '/β/' *indistinguishable from* /p/ *when intervocalic*

/aβa/	*V[−voice]V	*MAP(b, β)	*V[−cont]V	*β	* MAP(p, β)	* MAP(p, b)	*b
☞ aβa				*			
aba		*!	*				*
apa	*!		*		*		

For rigor's sake we determined the ranking argumentation not by hand but by using the Fusional Reduction Algorithm of Brasoveanu and Prince (2011), as implemented in OTSoft. Applied to the winner-loser pairs contained in the tableaux, the Fusional Reduction Algorithm yielded a simple pattern consisting of one strictly ranked chain of length six, plus one unranked constraint.

(22) *Rankings for the Campidanian *MAP analysis*

a. *Main chain of rankings*

*MAP(b, β) >> *V[−cont]V >> *β >> * MAP(p, β) >> * MAP(p, b) >> *b

b. *No ranking required*

*V[−voice]V

Intuitively, the ranking arguments are as follows. *MAP(b, β) must dominate *V[−cont]V in order to avoid spirantization in (21b) /aba/. *V[−cont]V must dominate *β, because although [β] is generally avoided in the language, it is tolerated in order to avoid a spirantization violation ((21a)). *β must dominate *MAP(p, β) (equivalent to *MAP(β, p), under our assumption of symmetry), because in our analysis the Rich Base candidate /βa/ surfaces as [pa] ((21e)). *MAP(p, β) must dominates *MAP(p, b) under the theoretical assumption that language learners adopt P-map-compliant rankings whenever evidence to the contrary is not present. *MAP(p, b) dominates *b, the normal ranking in languages such as Campidanian where voicing in obstruents is phonemic; see (21d). The constraint *V[−voice]V, though it *can* be placed top of the rankings (it is unviolated in winners), actually could be ranked anywhere at all; indeed, for the data given, the analysis works when *V[−voice]V is removed from the constraint set.[23]

The analysis succeeds in ruling out any unattested patterns of alternation. If any forms are assigned underlying /β/, they will surface with [β] intervocalically and [p] elsewhere — thus, exactly like underlying /p/. If Campidanian learners capriciously chose an underlying form with /β/, it would be undetectable in their speech, which is what we want. Appropriate rankings of the *MAP( ) constraints involving voiceless fricatives could likewise render any underlying /ɸ/ harmless.

For other cases of saltation, similar analyses can easily be constructed. The common theme is the non-default ranking of a *MAP( ) constraint that bans a long 'phonetic path' of alternation below a *MAP( ) constraint that bans a subset of this path.

4.4 A second saltation in Campidanian

For completeness, we mention that Campidanian possesses a second saltatory alternation. The voiced geminate stops [bː, dː, gː], which are themselves normally derived from underlying clusters, are in a state of free variation: sometimes they are realized as such, but more often they are lenited to [β, ð, ɣ], thus merging with underlying [p, t, k] (Bolognesi, p. 48). Since (as before) singleton [b, d, g] do not lenite, this is another saltation: [bb] - [b] - [β]. The diachronic origin of this saltation is the same as before; namely the restoration of [b] in intervocalic position by grammar change.[24]

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[23] It is needed in the phonology as a whole to account for cases like /asa/ → [aza]; Bolognesi, p. 149.

[24] Smith et al. (1991) suggest that geminate lenition is determined by stress, but note "exceptions … which we cannot explain;" our own impression is that such exceptions are fairly numerous. The hypothesis of free variation is supported by Bolognesi p. 497, where the underlying sequence /pɔtia**t** **b**i/ 'can see' is realized in the same discourse first as [poðia **β**iɾi] then as [poðia **bː**iɾi] (the [ɾi] syllable is epenthetic; Bolognesi p. 448).

Smith et al. also take the view that Campidanian "geminates" are not actually long phonetically. Bolognesi (1998) is uncertain on this point, though he does transcribe surface distinctions between, e.g., [b] and [bː]. Plainly, phonetic study would be useful.

We have found that it is not hard to model this saltation with the same basic devices used above; the essential aspect of the analysis is a non-P-map compliant ranking, *MAP(bb, β) >> *MAP(b, β). Full tableaux and Hasse diagram may be obtained from the article web site.[25]

5. Evidence for a learning bias in saltation

Under our analysis, Campidanian is a 'marked language,' because to learn its phonology a child must overcome default rankings based on the P-map. In some instances, data from language change indicate that saltation may indeed be hard to learn: as already mentioned, Crosswhite (2000) documented ongoing synchronic breakdown of the Russian [o] - [u] - [i] saltation, and in Manga Kanuri the formerly allophonic relationship of [t] and [ð] has broken down with the admission of new forms showing intervocalic [t]. Yet we cannot always expect to see such traces: it may well be that adult speakers of languages with saltation are often exposed to such extensive data that they do learn their language successfully; in particular we noted above (§1) Bolognesi's argument that Campidanian saltation is productive.

To assess our claim of acquisition difficulty, the most direct approach would be to observe young children in the course of learning languages with saltation. For instance, we might expect that children learning Campidanian would be likely to make errors such as wrongly converting /b/ to [β] in intervocalic position.[26] Sadly, it would be difficult to verify this point, since it appears that very few if any young children are still learning this language (Bolognesi, Chap. 1).

Another tack would be to test acquisition of saltation by young adults learning an artificially contrived language. This research is taken up by [Anonymous for review] (2013; submitted): [Anonymous]'s English-speaking participants were shown sample alternations indicating that /p/ should spirantize (to [v]) intervocalically and /b/ should not; nevertheless, when tested on novel forms they frequently spirantized /b/ anyway. Control experiments demonstrated that the learning errors were specifically due to saltation and not to other factors such as rule overgeneralization.

[Anonymous]'s study also included a modeling component. In outline, the model works as follows: first, data from an earlier perception experiment (Wang and Bilger 1973) were used to construct a quantitatively-accurate P-map representing the perceptual distance between the target consonants. Following Wilson (2006), this P-map was used as the basis for establishing Gaussian priors for a learning simulation in the framework of maxent grammar (Goldwater and Johnson 2003). The learning data for the simulation were precisely the set of forms used in the artificial language experiment. The learned grammar was tested on the same data with which the human subjects were tested, and achieved a fairly close approximation of human performance. Moreover, [Anonymous]'s study revealed a preference for [b ~ v] alternations relative to [f ~ v] alternations, a difference which was accurately predicted by the greater perceptual similarity of [b] - [v] relative to [f] - [v].

[25] Note to reviewers: please obtain these materials if desired from the editors.

[26] Bolognesi (1998, p. 36) reports that Campidanian-speaking adults make this error — but only rarely.

The main consequence of this work in the present context is that the *MAP-cum-P-map approach to saltation that we have proposed can be made completely explicit using computational simulation. The P-map-based learning bias is quantifiable and matches the experimental data; hence our assertion that saltation is a marked state in phonology is not an empty claim. A harder task for the future will be to use the same acquisition model in attempting to account for the historical changes that create or destroy saltation; for example, the change that created the Campidanian pattern (§2.2), or the changes that appear to be leveling out saltation in Russian and Manga Kanuri.

6. Conclusion

This article has made two main points. Our historical studies provide support for Minkova and Lass's implicit claim that saltatory alternations always arises from diachronic restructuring rather than directly from sound change. We have also argued that a learning-bias approach using Zuraw's *MAP-cum-P-map approach appears to be more promising than the Lubowiczian theory employing conjoined constraints: *MAP-cum-P-map is supported as a learning bias by [Anonymous]'s experiments and avoids the problem of gross overgeneration faced by conjoined constraints.

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