Towards a typology of stop assibilation*

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Abstract

In this article we propose that there are two universal properties for phonological stop assibilations, namely (i) assibilations cannot be triggered by /i/ unless they are also triggered by /j/, and (ii) voiced stops cannot undergo assibilations unless voiceless ones do. The article presents typological evidence from assibilations in over 30 languages supporting both (i) and (ii). It is argued that assibilations are to be captured in the Optimality Theoretic framework by ranking markedness constraints grounded in perception that penalize sequences like [ti] ahead of a faithfulness constraint that militates against the change from /t/ to some sibilant sound. The occurring language types predicted by (i) and (ii) will be shown to involve permutations of the rankings between several different markedness constraints and the one faithfulness constraint. The article demonstrates that there exist several logically possible assibilation types that are ruled out because they would involve illicit rankings.

1. Introduction

This article examines stop assibilations — defined here as processes that convert a (coronal) stop to a sibilant affricate or fricative before high vocoids, e.g., /t/ is realized as [ts] or [s] before /i/. We propose two properties for assibilation rules that we claim are universal, namely (i) assibilations cannot be triggered by /i/ unless they are also triggered by /j/, and (ii) voiced stops cannot undergo assibilations unless voiceless ones do. The descriptive goal of this article is to test these two claims by examining assibilation processes in a large number of typologically diverse languages. Theoretically we propose that assibilations are to be captured in the Optimality Theoretic framework (henceforth OT; Prince and Smolensky 1993) by ranking phonetically grounded markedness constraints

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penalizing sequences like [ti] ahead of a faithfulness constraint that militates against the change from /t/ to some sibilant sound. The occurring language types predicted by the two universal properties for assibilations referred to above will be shown to involve permutations of the rankings between several different markedness constraints and the one faithfulness constraint. A major claim of the present article is that there exist several logically possible assibilation types that can all be ruled out because they would involve illicit rankings.

The present treatment is important for several reasons. First, we provide additional evidence that phonological assibilations can only be adequately explained by appealing to phonetics (see also Clements 1999; Kim 2001). Our study supplements the afore-mentioned studies, since neither linguist considers the properties in (i) and (ii). Second, we argue that the markedness constraints that trigger assibilations are based in perception and that they are therefore not speaker-driven but listener-driven. In this respect our treatment differs significantly from traditional markedness constraints in OT, which are typically based in articulation. Third, we show how our analysis of assibilations is superior to the one proposed by Kirchner (1998), who attempts to capture this process with a fortition constraint. Finally, our study shows how the OT framework can capture occurring vs. nonoccurring rule types by appealing to a universal constraint hierarchy among markedness constraints whose inherent ranking derives from phonetics (see also Boersma 1998; Hamann 2003, who propose similar hierarchies).

The article is structured as follows. In Section 2 we discuss stop assibilations from the phonetic perspective and show that these processes are characterized by several general properties (based on the findings of Clements 1999 and Kim 2001). In Section 3 we discuss the two universal properties for assibilations referred to above and posit a typology of six language types that we show are attested in a number of languages. By contrast, there are several logically possible assibilation types that will be shown not to be attested. In Section 4 we posit an OT analysis of the typological generalizations presented in Section 3 that accounts for the six occurring assibilation types while simultaneously ruling out the five nonoccurring ones. Section 5 concludes.

2. Stop assibilations

In this section we define what we mean by stop assibilation and then present several universal properties for such processes (discussed by Clements 1999 and Kim 2001).[1]

Stop assibilations (or assibilations for short) are defined here as processes whereby stops become sibilant affricates or sibilant fricatives before high vocoids. Three examples of such rules have been presented in (1).[2]

(1) Three examples of assibilation rules:

a.	t → s / __ i	Finnish (Kiparsky 1973)	spirantization
b.	t → ts / __ i	Korean (Kim 2001)	affrication
	t^h → ts^h / __ i		
c.	t → tʃ / __ i	West Futuna-Aniwa (Dougherty 1983)	posteriorization

We classify the three assibilation processes in (1) according to their output; thus, we call rules like the ones in (1a)–(1c) 'spirantizations', 'affrications' and 'posteriorizations' respectively. Although we are primarily interested in affrications and spirantizations (because these processes are not as well studied as posteriorizations) we include posteriorizations in the typology we posit below for three reasons. First, many languages have processes that have as the output either [ts] or [tʃ]. Second, posteriorizations seem to obey the same kinds of generalizations as affrications and spirantizations, namely the two universal properties referred to in Section 1. And third, the three processes arguably have the same function of avoiding surface sequences like [ti].

Although processes like the ones in (1) can also affect a velar stop (e.g., in Late Latin /k ɡ/ surfaced as [ts dz] before /j/; Pope 1952) and in some rare languages a labial (e.g., in Lahu labial stops and nasals are affricated before /u/; Matisoff 1982: 3), we restrict our typology in Section 3 and the analysis in Section 4 to assibilations that have a coronal stop as the input segment, in particular the input is dental or alveolar, i.e., [+coronal, +anterior] in terms of features.

Assibilations like the ones in (1) can either be lexical or postlexical rules. For example, in Korean (see [1b]) assibilation is lexical because it is restricted to applying within a derived environment and does not affect tautomorphemic /ti/, /t^hi/ sequences. In Quebec French (Cedergren et al. 1991; Kim 2001) the assibilation rule is postlexical because it applies across the board, both within and across words. Since the properties we discuss below hold for postlexical and lexical assibilations we do not see the need to distinguish between the two rule domains. On similar lines we discuss both synchronic rules of assibilation as well as diachronic ones because both types of processes display the properties we discuss below (although see Note 7 below).

The term 'assibilation' is used here in a very narrow sense since we restrict our discussion below to processes like the ones in (1), which share the following three properties (based on the findings of Foley 1973, 1977; Clements 1999; Kim 2001):

(2) Three properties of stop assibilations:
  a. the trigger is some subset of the high front vocoids (i.e., /i j/)
  b. the output is a sibilant (either an affricate or a fricative)
  c. the trigger is to the right of the target

Kim (2001) and Clements (1999) offer a phonetic explanation for the properties of stop assibilation in (2a)–(2c). The creation of sibilants from stops has its phonetic origin in the brief period of turbulence (or 'friction phase') that occurs at the release of a stop into a following high vocoid. Thus, Clements (1999) and Kim (2001) observe that the friction phase that occurs in some languages following the release of an alveolar stop into a high front vocoid is significantly greater than the friction phase of the same stop that is released into a nonhigh and/or nonfront vocoid (see also Ohala 1983). This phonetic explanation is captured directly in the markedness constraints we propose in Section 4.

In (3) and (4) we have listed processes that are not in accordance with our narrow definition of assibilation as they violate one or more of the properties in (2):

(3) Examples of changes excluded by our definition of assibilation:

(3)	a.	t → s / ___ i, u, e, o	Woleaian (Tawerilmang and Sohn 1984: 184)
	b.	t → θ / i ___	Tümpisa Shoshone (Dayley 1989: 407)
	c.	t d → tʃ dʒ / i ___	Pima Bajo (Fernández 1996: 4)
		t → tʃ / i ___	Apalai (Koehn and Koehn 1986: 120)
		t → tʃ / i ___	Basque (Hualde 1991: 108–109)
(4)	a.	t → ts / # ___	Old High German (Penzl 1972)
	b.	t → ts / $_{\sigma}$[___	Danish (Basbøll and Wagner 1985: 67)
	c.	t d → ts dz / ___ s z ts dz ʂ ʐ tʂ dʐ	Polish (Rubach 1994)

In (3a) we have presented an example of a language in which assibilation is not triggered by a subset of the high front vocoids. The process in (3b) is the only example to our knowledge of a process in which a nonsibilant fricative is the output. And in (3c) we have listed three languages in which the trigger is to the left of the stop (this also holds for [3b]). In (4) we give examples of processes that are often referred to as 'assibilations' in the literature but are not conditioned by a vocalic element. The Old High German example in (4a) is a sound change that transpired in the sixth and seventh centuries.[3] The process in (4b) is apparently an allophonic one in Modern Danish. The rule in (4c) is an optional process in Modern

Polish. Processes like these are excluded from our analysis because we focus only on processes like the ones in (1) that are triggered by high (front) vocoids.

3. Typology of assibilations

In this section we present a typology of rules like the ones in (1) on the basis of our investigation of assibilations in over 30 languages (see the appendix for a complete list of the languages discussed in this article and the respective genetic classification). In Section 3.1 we posit a set of ten logically possible assibilation types, only five of which we maintain are actually attested. The five nonoccurring types will be shown to be excluded due to two properties of assibilations we propose below. In Section 3.2 we present examples of all of the occurring assibilation types. (A sixth occurring type will be discussed in Section 4.3).

3.1. *Introduction*

Recall from (2a) that the trigger for stop assibilation is some set of the high front vocoids (i.e., the vowel /i/ and glide /j/). Given the two triggers /i/ and /j/ there are four logical assibilations, which we have listed in (5):[4]

(5) a. Assibilation is triggered by /i/ and (if present) /j/
b. Assibilation is triggered only by /j/
c. Assibilation is triggered only by /i/
d. Assibilation is triggered by neither /i/ nor /j/

Please observe that variable (5a) subsumes two possible language types, namely those in which both /i/ and /j/ trigger assibilation, as well as those in which only /i/ triggers assibilation because there is no /j/ at all (or no /j/ in the assibilation context). By contrast, for variable (5b) both /i/ and /j/ *must* occur in the assibilation context, but only the latter segment triggers the rule. (The mirror image situation holds for variable 5c). Another point concerning the logical assibilation types in (5) is that the /j/ referred to here is intended to include not only the segment /j/ but also secondary palatalization (see Romanian in [11] below).

The second property we discuss concerns the sounds undergoing assibilations, in particular we investigate the difference between voiceless and voiced stops in the input. Thus, given the two input segments /t/ and /d/, four possible assibilations are summarized in (6):

(6) a. /t/ and (if present) /d/ assibilate
    b. Only /t/ assibilates
    c. Only /d/ assibilates
    d. Neither /t/ nor /d/ assibilate

Variable (6a) describes two types of languages. First, languages in which /t/ and /d/ assibilate, and second, those in which only /t/ assibilates because there is no /d/ (or no /d/ in the assibilation context). By contrast, variable (6b) means that /t/ and /d/ must occur in the assibilation context but only the former sound undergoes the rule. (The mirror image generalization holds for [6c]).

Combining the eight variables in (5) and (6) yields sixteen logically possible assibilation types. Four of these sixteen combinations involve variable (6d), i.e., alveolar stops do not assibilate at all (= [6d] + [5a], [6d] + [5b], [6d] + [5c], [6d] + [5d]). We have classified all four of these combinations into one language type, namely type E (see [7] below). Three of the remaining twelve combinations show assibilation without a high front vocoid trigger (i.e., [5d] + [6a], [5d] + [6b], (5d) + [6c]). Examples for these kinds of changes (i.e., those in which the trigger is not some high vocoid) were given under (4). Since these rule types are not topic of the present article we do not include them in our typology in (7). The remaining nine combinations correspond to the additional language types in (7) and (8) (i.e., A–D, F–J). In this typology we have two general categories (to be justified in Section 3.2), namely assibilation types that are occurring (types A–E) and those that are not (types F–J).

(7) Occurring assibilation types:

Language type	Assibilating segment(s)	Trigger(s)	
A	/t (d)/	/i (j)/	6a + 5a
B	/t (d)/	/j/	6a + 5b
C	/t/	/i (j)/	6b + 5a
D	/t/	/j/	6b + 5b
E	none	/i (j)/, /i/, /j/, none	6d + (5a, 5b, 5c, 5d)

(8) Nonoccurring assibilation types:

Language type	Assibilating segment(s)	Trigger(s)	
F	/t (d)/	/i/	6a + 5c
G	/t/	/i/	6b + 5c
H	/d/	/i (j)/	6c + 5a
I	/d/	/j/	6c + 5b
J	/d/	/i/	6c + 5c

The sounds in parentheses in (7)–(8) are intended to capture the optionality described above with respect to variables (5a) and (6a).

The typology in (7)–(8) takes all three assibilation types in (1) into consideration, i.e., affrications, spirantizations and posteriorizations. Thus, we show below in Section 3.2 that these three assibilation types are attested for the occurring types in (7). It is our claim that none of the three assibilation types is attested in the five languages in (8).

We argue here that the nonoccurring language types in (8) are true 'systematic gaps' whose absence can be accounted for with the following two universal properties of assibilations.[5]

(9) Two additional properties of stop assibilations:
  a. Assibilation cannot be triggered by /i/ unless it is also triggered by /j/.
  b. Voiced stops cannot undergo assibilations unless voiceless ones do.

In Section 3.2 we present examples of languages corresponding to the various language types in (7), thereby lending support to the two properties in (9). In Section 4 we present phonetically grounded constraints that account for why the properties in (9) hold.[6]

Property (9a) can be tested by scrutinizing languages with sequences like /tj/ and /ti/ in which assibilation affects /t/. Our study is confounded by the fact that in many assibilating languages there is a strict phonotactic restriction prohibiting /Cj/ sequences (or more generally, any sequence of nonsyllabic segments). It is important to stress here that (9a) cannot be refuted with a language that assibilates /t/ before /i/ and that simply does not have any /tj/ sequences. Thus, this example is not Type G, but instead Type C. A similar point can be made with respect to /t/ and /d/ as inputs. Hence, if a language assibilates /t/ before /i j/ then it can only be classified as Type C if there are /di dj/ sequences that do not assibilate. If this language has no /di dj/ sequences to begin with then this language is not Type C, but instead Type A. Type G and Type C are illustrated in (10a) and (10b) respectively. The language described above with a defective distribution, in which /ti/ assibilates but that does not have /tj/, is classified as Type C (see [10c]).

(10) a. A nonoccurring assibilation rule (Type G):
  /ti/ → [tsi]
  /tj/ → [tj]
  (/di/ occurs but does not assibilate)
 b. An occurring assibilation rule (Type C):
  /ti/ → [tsi]

/tj/ → [tsj]
(/di dj/ occur but do not assibilate)
c. An occurring assibilation rule (Type C):
/ti/ → [tsi]
(/tj/ does not occur; /di/ occurs but does not assibilate)

Some of the sources for the languages we cite do not give enough information pertaining to the occurrence of the relevant segments to determine whether or not there are definitely defective distributions as in (10c). In the following we compare languages for which defective distributions are definitely known not to exist (as in [10b]) with those in which they do (as in [10c]). Languages in which defective distributions are unknown are listed separately.

3.2. *The occurring language types*

In this section we present examples from language types A–E. In our typology we present more than 30 assibilation rules (as defined in Section 2) in a typologically and geographically diverse set of languages (see the appendix). Our survey subsumes the three kinds of assibilations in (1). The assibilations listed below include purely allophonic (postlexical) processes, as well as neutralizing and highly morphologized (i.e., lexical) assibilations. Historical processes are included as well.[7] Although our analysis in Section 4 is only intended to account for the assibilation of anterior sounds before high front vowels, we have also included below assibilations triggered by other vocalic elements (e.g., high back vowels, mid vowels) because these rules seem to obey the same generalizations in (9).

It will become evident below that there is an unequal distribution among language types, in particular, Types A, C and E are represented by many languages whereas only a very small number belong to Types B and D. Among the A, C and E languages it appears that Types A and E outnumber those of Type C. We hypothesize that this unequal distribution is truly systematic and that these patterns would be confirmed by investigating assibilations in additional languages. Since we take the unequal distribution among the various types as systematic and not accidental we discuss a possible reason for it in Section 4.5 below.

3.2.1. *Type A.* Examples of Type A languages have been presented in (11). In the second column we list the corresponding rule type.

(11) Type A languages — Assibilation type

	Type A languages	Assibilation type
a.	Quebec French (Cedergren et al. 1991)	affrication
b.	Kpándo (Vhe) dialect of Gbe (Capo 1991: 99ff.)	affrication
c.	Romanian (Chitoran 2001)	affrication, spirantization
d.	Nishnaabemwin (Valentine 2001: 86ff.)	posteriorization
e.	Nyakyusa (Labroussi 1999: 341)	spirantization
f.	Runyoro-Rutooro (Rubongoya 1999: 27)	spirantization
g.	Japanese (Itô and Mester 1995)	affrication, posteriorization
h.	Sorbian (Wowčerk 1954: 24–25)	posteriorization
i.	Shona (Brauner 1995: 13)	affrication, spirantization
j.	Ikalanga (Mathangwane 1999: 80ff.)	affrication
k.	Papago (Hale 1965)	posteriorization
l.	Plains Cree (Wolfart 1973: 79)	affrication
m.	Wai Wai (Hawkins 1998: 160)	posteriorization
n.	West Futuna-Aniwa (Dougherty 1983)	posteriorization
o.	Blackfoot (Frantz 1991: 16, 26)	affrication
p.	Finnish (Sulkala and Karjalainen 1992)	spirantization
q.	West Greenlandic (Fortescue 1984: 333)	affrication

A straightforward example of a Type A language is illustrated with the data in (12) from Quebec French (see [11a]; data from Kim 2001: 91):

(12) Stop assibilation in Quebec French:

Standard French	Quebec French	Gloss
[ti]pe	[tsi]pe	'type'
[di]x	[dzi]x	'ten'
[tj]ens	[tsj]ens	'(I) hold'
[dj]eu	[dzj]eu	'god'

The data in (12) show that /t d/ assibilate to [ts dz] before /i/ and /j/.

A second example of a Type A language is illustrated with the (historical) process of assibilation in the Kpándo (Vhe) dialect of Gbe (see [11b]). In the first column the relevant sequences in Proto-Gbe are presented (in their underlying form) and in the corresponding line of the second column the same sequences in the daughter language Kpándo (Vhe) (data from Capo 1991: 99–100, 104–105).[8,9]

(13) Stop assibilation in the Kpándo (Vhe) dialect of Gbe:

	Proto-Gbe	Kpándo (Vhe)	Gloss
a.	*-tĩ	[atsi]	'tree'
	*tĩ	[tsi]	'be fed up'
	*dĩdĩ	[dzidzi]	'be far'
b.	*tjã	[tsja]	'to choose'
	*djɔ	[dzɔ]	'happen'

In (13a) it can be observed that /t d/ assibilate to [ts dz] before /i/. That the palatal glide /j/ triggers the same process is shown in (13b). (In the second example in [13b] the palatal glide /j/ was deleted after triggering assibilation of the preceding /d/).[10]

Stop assibilation in Romanian (see [11c]) is illustrated with the examples in (14a) (from Chitoran 2001: 187). Recall from Section 3.1 that the secondary palatalization is included in the 'j' contexts in (5). The effects of the rule can be observed in the third column, in which it is shown that /t/ assibilates to the affricate [ts] when it bears the plural marker of secondary palatalization and that /d/ spirantizes to [z] in the same context.[11]

(14) Stop assibilation in Romanian:

a.	[munte]	'mountain'	[munts^j]	'mountains'
	[soldat]	'soldier'	[soldats^j]	'soldiers'
	[brad]	'fir tree'	[braz^j]	'fir trees'
b.	[mult]	'much'	[mults-ime]	'crowd'
	[krud]	'cruel'	[kruz-ime]	'cruelty'

The additional examples in (14b) (Ioana Chitoran, personal communication, November 2004) illustrate that /t d/ assibilate before certain [i]-initial suffixes.

The Algonquian language Nishnaabemwin in (11d) has a lexical process of posteriorization whereby /t d/ surface as [tʃ dʒ] before morphemes that start with /i ɪ j/ (Valentine 2001: 86ff.):

(15) Stop posteriorization in Nishnaabemwin:

a.	/mɑːd-jɑː/	[mɑːdʒɑː]	'leave/take off'
	/biːd-ɪ-bɪzɔ/	[biːdʒbɪzɔ]	'come driving'
	/ɑpiːt-ɪ-gɪ/	[piːtʃgɪ]	'grow to such extent'
b.	/biːd-ɑː-dɑge/	[biːdɑdge]	'come swimming'
	/ɑpiːt-ɑː/	[piːtɑː]	'have height to such extent'

In (15a) examples are given in which posteriorization affects /d/ before /ɪ j/ and /t/ before /ɪ/.[12] The examples in (15b) illustrate that the /t d/ in the final two stems in (15a) surface as such before a morpheme beginning with anything other than a high front vocoid. Valentine is explicit that a /j/ following /t/ also causes palatalization (2001: 88) but no example is provided. The Bantu language Nyakyusa in (11e) has a lexical process whereby certain morphemes beginning with a high front vocoid cause the spirantization of /t d/ to [s] (Labroussi 1999: 341), e.g., the causative morphemes -*i*- [j] and -*isy*- [ɪsj]. For example, the stems -*end*-*a* 'walk' and -*pond*-*a* 'forge, beat' change to [–eːs-j-a] 'cause to walk' and [ɔmpoːs-i] respectively. No examples are provided in which /t/ spirantizes before /ɪ j/, although Labroussi (1999) is explicit that they should undergo the rule. Runyoro-Rutooro in (11f) spirantizes /t/ to [s] and /nd/ to [nz] if affixes are added that begin with /i e j/ (Rubongoya 1999: 27). In Japanese (11g; Itô and Mester 1995: 825ff.) /ti/ surfaces as [tɕi], e.g., /kat-i/ 'win' (infinitive) is realized as [katɕi], and /di/ as [dʑi], e.g., in the loanword *dilemma* as [dʑiɾemma]. The high back vowel [u] (= [ɯ] in a narrow transcription) causes affrication of the preceding alveolar stop, thus /kat-u/ 'win' (pres.) surfaces as [katsu]. Japanese has no native sequences of [tj] or [dj], but loanwords show that /j/ after alveolar stops also triggers posteriorization (Itô and Mester 1995: 837), e.g., *tube* [tɕuːbu], and *juice* [dʑuːsu].[13] Sorbian ([11h]; Wowčerk 1954: 24–25) palatalizes /t d/ before /i j/, e.g., *hró[d]* 'castle' vs. *na hró[dʒ]e* 'on the castle' (from /d-j/), *hró[dʒ]ik* 'small castle' (from /d-i/) and *skó[t]* 'cattle' vs. *w sko[tʃ]e* 'in the cattle' (from /t-j/), *kru[t]y* 'firm' vs. *kru[tʃ]iši* 'more firm' (from /t-i/).

Examples (11i)–(11q) are classified as such due to defective distributions of either the glide, the voiced alveolar stop, or both. For example, assibilation as diachronic process occurred in the development of Shona (see [11i]), in which Proto-Bantu */ti̧/ changed to [tsi] after a vowel and to [si] word initially (Brauner 1995: 13; Mathangwane 1999: 88), see [16a]. Proto-Bantu */di̧/ changed to [tsi], see (16b). A palatal glide did not seem to occur in assibilation context in Proto-Bantu, see Guthrie (1967–1971, vol. 2 appendix C and D).

(16) Stop assibilation and spirantization in Shona:

	Proto-Bantu	Gloss	Shona	Gloss
	Proto-Bantu	Gloss	Shona	Gloss
a.	*–ti̧ma	'displant'	[–sima]	'transplant'
	*–ti̧nde	'grass'	[sinde]	'grass'
	*piti̧	'hyena'	[sʋitsi]	'spotted hyena'
b.	*–di̧ba	'pont'	[dziʋa]	'pont'

A similar diachronic process occurred in the development of Ikalanga (Mathangwane 1999: 80ff.), in which Proto-Bantu */ti̧ di̧/ is realized as [tsʰi dzi]. In nonassibilating contexts, Proto-Bantu */d/ changed to [l], leading to opaque present day assibilations caused by the causative morpheme *–i*, e.g., [gala] 'sit' vs. [gadza] 'cause to sit' (Mathangwane 1999: 85).

Papago (also called O'Odham; see [11k]) posteriorizes /t d/ to [tʃ dʒ] before the high vowels /i u/ (Hale 1965: 299ff.). The glide [j] only occurs in Spanish loanwords and as an epenthetic glide or glided vowel /i/ (Hale 1965: 296), but not after /t d/.[14] In Plains Cree in (11l) /t/ assibilates before /i iː/ and before the palatal glide (Wolfart 1973: 79). The output of this assibilation is a sound that ranges from 'a blade-alveolar to a dorso-laminal affricate' (Wolfart 1973: 79). Since Plains Cree has no /d/ that could potentially assibilate we classify it as a Type A language. The situation is the same for the Amazonian language Wai Wai (see [11m]), which has a lexical process that posteriorizes /t/ to [tʃ] before /i e j/, e.g., /ti-irko/[15] → [tʃirko] 'fix/make it' (Hawkins 1998: 160), but that has no /d/ that could potentially assibilate. A purely allophonic rule converting /t/ to [tʃ] or [dʒ] before /i j/ holds in West Futuna-Aniwa (see [11n]), e.g., the definite article /ti/ is realized as [tʃi] and /tia/ 'to hit' as [dʒa] (Dougherty 1983: 7), but /d/ does not exist in this language. Based on alternations between [t] and [ts] Frantz (1991: 25) posits the rule 't → ts /__i' for Blackfoot (see 11o).[16] Blackfoot has no /d/ but a palatal glide, which does not occur in postconsonantal position (with the exeption of the glottal stop). In Finnish (11p) there is a lexical rule spirantizing /t/ in stems that end in *–te* before the nominative morpheme *–i* and the plural morpheme *–i*, e.g., *sute vs. susi* 'wolf (ess. — nom.)' (Sulkala and Karjalainen 1992). Finnish has neither j-initial morphemes that could potentially trigger the rule, nor a /d/ that could potentially undergo it.[17] In West Greenlandic (see 11q) singleton and geminate /t/ are assibilated to [ts] and [tts], respectively, before /i/ but this language has no /d/, and /j/ only occurs intervocalically (see Fortescue 1984: 335; Dorais 1986: 45).

The following 11 languages are possible examples of Type A languages. The reason they cannot be definitively classified as Type A languages is that the respective authors are unclear on whether or not there are defective distributions like the ones described in the preceding paragraph.

(17)	Possible Type A languages	Assibilation type
	a. Fongbe dialect of Gbe (Lefebvre and Brousseau 2002: 21)	affrication
	b. Taiof (Ross 2002b: 426ff.)	affrication
	c. Mongo (Spaandonck 1964: 192)	posteriorization
	d. Cheyene (Davis 1962: 36)	affrication, posteriorization

e.	Maori (Bauer 1993: 530ff.)	affrication
f.	Samoan (Mosel and Hovdhaugen 1992: 20)	affrication
g.	Axininca Campa (Spring 1992: 339)	affrication
h.	Korean (Kim 2001)	affrication
i.	Sonora Yaqui (Dedrick and Casad 1999: 30)	posteriorization
j.	Ancient Greek (Sommerstein 1973: 15)	spirantization
k.	Koyra Chiini and Humburi Senni (Heath 1999a: 34)	posteriorization

In the Fongbe dialect of Gbe /t d/ optionally affricate before /i/ in rapid speech (Lefebvre and Brousseau 2002: 21), e.g., /ti/ [tsi] 'squeeze', /dĩ/ [dzĩ] 'be very good'. Lefebvre and Brousseau (2002) mention no examples with /t/ or /d/ followed by /j/, but Capo (1991: 104) transcribes the equivalent of Proto-Gbe /tj/ sequences as [tʃj] for the Fon dialects.[18] In light of the diverging sources, we cannot decide on whether Fongbe shows assibilation before palatal glide or not. In Taiof /t/ assibilates to [ts] before /i/ and /d/ to [dz] before /i u/, with an optional posteriorization to [tʃ] and [dʒ], respectively (Ross 2002b: 426ff.).[19] The occurrence of a glide after /t d/ cannot be excluded, since consonant clusters stem from reduplication of monosyllabics, and /j/ occurs in syllable-initial position. Ross's (2002b) data, however, do not contain an example. In Mongo the nominalizing suffix *–i* causes the posteriorization of /t/ and /ⁿd/ (Spaandonck 1964: 192), e.g., /-lot-/ 'flee' vs. [-lotsi] 'fugitive', and /-kɛⁿd-/ 'go' vs. [-kɛⁿdzi] 'traveller'. Since the data available to us do not include any *–j* initial suffixes, we cannot exclude *j* as a possible trigger of posteriorization. Cheyenne changes /t/ to [ts] or [tʃ] before an /i/ (Davis 1962: 36), /j/ does not seem to occur in this language. Maori has neither /d/ nor /j/, and /t/ assibilates to [ts] before /i/ (with an optional realization as [tç]), e.g., *iti* 'small' is pronounced as [itsi] or [itçi] (Bauer 1993: 530ff.). Bauer (1993: 533) explicitly mentions the gliding of /i/ to [j] after a consonant, though no examples of gliding after /t/ are included in the data; thus, we cannot infer whether a glide causes assibilation as well. In Samoan (17f), /t/ is affricated to [ts] before /i/ (Mosel and Hovdhaugen 1992: 20). Like Hawaian, this language has no underlying glide, but the authors do not explicitly state that the [j] that arises due to glide formation (1992: 25) feeds affrication. In Axininca Campa the morphologically conditioned process of assibilation (referred to by Spring 1992: 339 as 'affrication') is only triggered by the nonfuture tense marker /i/, e.g.,

/no-kant-i/ → [nokantsi] 'I said'. Spring does not report that assibilation is triggered by any /j/-initial morphemes. In Korean, like Axininca Campa, assibilation is a derived environment rule that is triggered by suffixes beginning with /i/ (see Kim 2001), e.g., before the nominative suffix /i/ in /mat-i/ → [madzi] 'first child' and before the adverbial suffix /i/ in /kat^h-i/ → [kats^h-i] 'together'.[20] Kim lists no /j/-initial suffixes that could potentially trigger the rule. In the Uto-Aztecan language Sonora Yaqui (see 17i) /t/ is palatalized to [tʃ] if followed by an /i/-initial morpheme, e.g., [wiːkit] 'bird' vs. [wiːkitʃim] 'birds' (Dedrick and Casad 1999: 30). (This language has no /d/ that could potentially undergo the rule). In the list of suffixes presented in their chapters on morphology Dedrick and Casad (1999) list only one beginning with /j/, i.e., the cessative aspect marker /-jaáte/. However, the authors do not present any examples in which a stem ending in /t/ combines with this morpheme. In Ancient Greek (see 17j) /t d/ spirantize to [s] in the context V __ iV (Sommerstein 1973: 15), e.g., [plûːtos] 'wealth' vs. [plúːsios] 'wealthy', but no examples are provided with a /j/ in the assibilation context.[21] According to Heath (1999a: 34) Koyra Chiini and Humburi Senni (see 17k) underwent a diachronic process whereby /t/ changed to [tʃ] before /i/, e.g., [tʃi] 'be' in Koyra Chiini and Humburi Senni has the cognate [ti] in the neighboring language Koyraboro. /j/ does not occur after a stop due to a very restricted set of consonant clusters (geminates and clusters of nasal or liquid as first consonant). However, no example with /d/ is given, and in Heath's (1999b) grammar of Koyra Chiini, this diachronic process in not mentioned at all.

3.2.2. *Type B.* Type A languages can be contrasted with Type B languages, in which only the palatal glide but not /i/ triggers the rule. Three examples of Type B languages have been provided in (18):

(18) Type B languages — Assibilation type

a.	West Slavic (Carlton 1990)	affrication, spirantization
b.	Sanskrit (Misra 1967: 142)	posteriorization
c.	Latvian (Forssman 2001: 97)	posteriorization

The West Slavic example in (18a) requires some comment. According to Carlton (1990: 114) Proto-Slavic *t and *d assibilated in the various daughter languages before *j, e.g., in West Slavic *t surfaced as [ts] while *d surfaced in the West Slavic languages Polish and Slovak as [dz] and other West Slavic languages as [z] (i.e., Czech, Sorbian). We follow the explanation presented in Carlton (1990: 114), namely *t and *d before *j surfaced as affricates in West Slavic and the change from voiced affricate to [z] in Czech and Sorbian was a later development. Although no examples are provided for *t and *d before *i, the discussion in Carlton implies that assibilation does not occur in this context. Modern Slovak and Polish are usually described as having a morphologically conditioned rule (called Iotation), which converts /t d/ to [ts dz] before /j/ only (Rubach 1993: 117ff.). If the historical process described above is correct then this suggests that Modern Slovak and Modern Polish inherited the rule.

According to Misra (1967: 142) in Sanskrit (i.e., Old Indo-Aryan) /tj dj/ developed into geminate post-alveolar affricates, e.g., Sanskrit /satja/ 'truth' and /vidjut/ 'lightning' were later realized as /sattʃa/ and /biddʒi/ respectively. Although no examples are provided for *t and *d before *i the discussion in Misra implies that assibilation does not occur in this context. Significantly, this change was only triggered by the palatal glide and not by /i/.

In Latvian (18c; Forssman 2001: 97) [tʃ dʒ] derive historically from /tj dj/, e.g., [latʃa] 'bear (gen. sg.) (from *latsjaː, which itself derives from /tj/).

3.2.3. *Type C.* Type C languages (in which /t/ assibilates before /i/ and (if present) /j/) are listed in (19).

(19)		Type C languages	Assibilation type
	a.	Hittite (Kimball 1999: 287ff.)	posteriorization
	b.	Dutch (Booij 1995: 79ff.)	affrication, spirantization
	c.	Woleaian (Tawerilmang and Sohn 1984: 184)	spirantization
	d.	Kosraean (Lee and Wang 1984: 406)	spirantization
	e.	Solomon Islands languages (Tryon and Hackman 1983: 77)	affrication, spirantization
	f.	Tawala (Ezard 1997: 29ff.)	spirantization
	g.	'Ala'ala (Ross 2002a: 347ff.)	spirantization

In all of the Type C languages in our survey but two (i.e., Hittite [19a] and Dutch [19b]) /t/ assibilates before /i/, but /j/ either does not occur at all or it does exist but it never surfaces after /t/ (as in 10c). As we noted above in Section 3.1 the preponderance of (10c) examples over (10b) is simply indicative of the fact that many assibilating languages like the ones discussed below ban Cj sequences.

According to Kimball (1999: 287ff.) Indo-European *t assibilated to a (posterior) affricate before /i j/ in Hittite (see 19a), e.g., the suffix *-tjo- in [hante-tʃja] 'last', and [haːntʃ] 'in front' (from an earlier form with a final */i/). Kimball (1999) does not provide examples of an unassibilated *di. However, see Luraghi (1997: 4), who has the word [edi] 'on this side'.

Dutch (see [19b]) is a language with a lexical rule that turns /t/ into [s] or [ts] after certain (Latinate) suffixes that start with [i] or [j] (Booij 1995: 79ff.). These morphemes are *–i*, *–io* [ioː] ~ [joː], *–iaan* [iɑːn] ~ [jɑːn], and *–ion* [iɔn] ~ [jɔn]. Examples are provided in (20), in which /t/ surfaces as [s] after a consonant (see [20a]) and as [ts] or [s] intervocalically (see [20b]).

(20)	a.	akt-ie	'action'	[ɑksi]
		president-ieel	'presidential'	[presidɛnsjel]
		akt-ief	'active'	[ɑktiːf]
		president	'id.'	[presidɛnt]
	b.	relat-ie	'relation'	[relatsi] ~ [relasi]
		rat-io	'ratio'	[ratsijoː] ~ [rasjoː]
		relat-ief	'relative'	[relatiːf]
		rat-ificeer	'to ratify'	[ratifiseːr]

Significantly, /d/ does not change before suffixes that otherwise trigger assibilation of /t/, e.g., *kome[d]-ie* 'comedy' (Booij 1995: 79, Note 30).

The remaining languages in (19), all Austronesian languages in the Oceanic branch, are classified as Type C because of defective distributions. For example in Woleaian (see [19c]) there was a diachronic process of assibilation that converted Proto-Oceanic *t into [s] before /i u e o/, as in (21) (Tawerilmang and Sohn 1984: 184):[22]

(21)	Proto-Oceanic		Woleaian	
	*tama	>	tama	'father'
	*ʔatop	>	aso	'thatch'
	*mate	>	mase	'to die'
	*tika	>	sixa	'bad, angry'
	*ʔatun	>	asu	'louse'

Proto-Oceanic had a /j/, but allowed only CV syllables (Lynch et al. 2002: 65). A similar process transpired in the history of Kosraean (see [19d]; Lee and Wang 1984: 406), in which Proto-Oceanic *t surfaced as [s] before front vowels (but *d was not affected). Tryon and Hackman (1983: 77) note that assibilation also affected Proto-Oceanic *t in the Solomon Islands languages (19e) Vaghua, Varisi, Ririo and Sengga (also known as Central-East Choiseul), all spoken on the island of Choiseul. In the first of these languages the assibilation was an affrication that went into effect before high vowels and in the final three it was an assibilation triggered by /i/.[23] In all of these so-called Choiseul languages Proto-Oceanic *d surfaced as [r], a trait it shares with the neighbouring language families New Georgia and Santa Isabel. But none of the latter languages underwent assibilation, which leads us to the conclusion that the change of *d to [r] preceded assibilation, and therefore the Choiseul languages had no /d/ to assibilate. Tawala (see 19f; Ezard 1997) underwent a diachronic process whereby /t/ was fricativized to [s] before the high front vowel /i/. According to Ezard (1997: 30), "the dialect variation of some forms reflect this rule", e.g., [emota] ~ [emosi] 'one', [hota] ~ [hosi] 'only'. By contrast, /d/ remained unchanged, cf. *badila* [badila] 'the name of a native almond'. Tawala has also a palatal glide, but does not allow other than (C)V syllables, thus a potential sequence tjV to trigger spirantization does not occur. Synchronic processes of assibilation are also common in Oceanic languages. For example, in 'Ala'ala (see [19g]; Ross 2002a: 347ff.) spirantization creates the allophone [s] from /t/ before /i/, e.g., /ʔiti/ 'upward' surfaces as [ʔisi] but /aʔate/ 'women' as [aʔate]. /d/ remains unchanged in this language, e.g., /nodi/ surfaces as [nodi] 'coughs' (Ross 2002a: 348). 'Ala'ala has no underlying palatal glide, and though glide formation from /i/ occurs, it takes place in initial and intervocalic position only (2002a: 348).

The following four languages are possible examples of Type C languages, since the respective authors are unclear on the possible defective distributions.

(22)	Possible Type C languages	Assibilation type
a.	Italian dialects (Tuttle 1997: 26ff.; Cordin 1997: 261)	posteriorization
b.	Arosi (Lynch and Horoi 2002: 562)	spirantization
c.	Turkana (Dimmendaal 1983: 8–9)	spirantization
d.	Ambae (Hyslop 2001: 16–17)	spirantization

In the Northern Venetian dialect of Italian (see [23a]), /t/ palatalized before /i/ and /j/. Thus the Old Venetian form [tiol] 'he removes' is now realized as [tʃol], and [tjɛni] 'hold' as [tʃeŋ] (Tuttle 1997: 26). Tuttle (1997: 30) reports that the inflectional plural marker *-i*, which became a glide before vowels in rapid speech and was later lost, palatalized the preceding /t/ in Ticino. Examples are *quanti* 'how much' (pl.) that is realized as [kwɛntʃ] and *alti* 'high' (pl.) as [altʃ] or [ɛltʃ]. In the Trentino dialect a similar process must have taken place, as the example *gatti* 'cats' [gatʃ] from Cordin (1997: 261) suggests. Neither Tuttle nor Cordin explicitly state that /d/ was not palatalized, nor are examples found that prove this point. Furthermore, we do not know whether glide formation occurred before or after the process of palatalization. For this reason we have to classify the Italian dialects as possible Type C language. A further possible Type C language is Arosi (22b), in which the contrast between /t/ and /s/ is neutralized to [s] before /i/ (Lynch and Horoi 2002: 562). A glide [j] occurs only intervocalically in this language. Though Lynch and Horoi (562) do not include any examples with [di] sequences, they do not mention any restriction against this sequence or an assibilation rule changing /d/ in this context, either. In Turkana (see 22c) Dimmendaal (1983: 8–9) reports that /t/ spirantizes to [s] before suffixes beginning with a front vowel, e.g., /a-kɪ-mat/ [akɪmat] 'to drink' vs. /a-mat-ɪ/ → [amasɪ] 'I am drinking'. Although this language has a /j/, no examples are provided with a suffix beginning with /j/ that occurs after a stem ending in /t/. Since /d/ is not explicitly excluded from the assibilation and no counterexamples with nonglided [di] sequences are given, we cannot safely classify Turkana as a Type C language. According to Hyslop (2001: 16–17, 26) in all dialects of Ambae (see [22d]; Vanuatu) except for Lolokaro a fricative [s] developed from Proto-Oceanic /t/ before /i/, as in (23):

(23) Stop spirantization in Ambae:

Proto-Oceanic		Ambae	Gloss
*tibo-	>	sibo-	'self'
*pati	>	βesi	'four'

Proto-Oceanic *d became a prenasalized voiced alveolar stop [^{n}d] in the dialects of Ambae in all contexts, e.g., *didiu* 'ant' is realized as [^{n}dɪ^{n}diɯ] (Hyslop 2001: 31) but it is not clear from the discussion in this work whether or not /d/ was present at the point in time when /t/ assibilated.

3.2.4. *Type D.* In Type D languages /t/ assibilates before [j]. Examples are provided in (24). The lack of Type D languages that exhibit spirantization and posteriorization is probably accidental, due to the small number of languages belonging to this category.

(24)

Type D languages	Assibilation type
a. Latin (Pope 1952)	affrication
b. German (Hall 2004)	affrication

Stop assibilation in Latin is illustrated in (25). According to Pope (1952: 129ff.) and Jacobs (1989: 117ff.) /t/ affricated to [ts] before /j/ in the course of Late Latin. Pope (1952: 129) writes that the change is attested as early as the fourth century. This development is illustrated with the examples in (25) from Pope (1952: 130):

(25) Stop assibilation in Late Latin:

*fortja	>	*fortsja	'force'
*faktjone	>	fatsun	'manner'

In contrast to the assibilation in (25), Pope (1952: 129) notes that the same process did not affect /dj/.[24] The nonassibilation of /ti/ is illustrated with the examples [santir] 'to feel' (from *sentire) and [ortie] 'nettles' (from *urtika).

Stop assibilation in German is illustrated with the data in (26) (from Hall 2004). That this is a regular process of the language and not simply an inheritance from Latin is discussed in that source.

(26) Stop assibilation in German:

Negation	[nega'tsjoːn]	'negation'
negativ	['neːgatiːf]	'negative'
Konsortium	[kɔn'zɔɐtsjʊm]	'syndicate'
Konsorten	[kɔn'zɔɐtən]	'gang'

In these examples we can observe an assibilation of /t/ to [ts] before /j/. The example *negativ* in the second column is important because it shows that the rule is not triggered by the vowel /i/. Examples like *Studium* [ʃtuːdjʊm] 'studies (sg.)' show that assibilation only affects /t/ and not /d/.

An additional example of a Type D language may be certain dialects of Albanian. Buchholz and Fiedler (1987: 38) note that /tj/ surfaces as [ts] in Central Albanian, but the authors write that this process only occurs in certain words.

3.2.5. *Type E.* Type E languages are those in which no segments assibilate. Our main descriptive goal in this article has been to find examples of languages with assibilations, so we do not claim to have an extensive list of Type E languages. However, we do maintain that languages belonging to Type E are extremely common. One example of a Type E language is Chamorro (see [27a]). According to Topping's (1973) description of the phonology there are no processes in this language resembling assibilations as defined in Section 2. Although Lahu (see [27b]) is one of the few languages in which labials assibilate (recall Section 2), this language has no process of assibilation in which the input is a coronal stop (Matisoff 1982). We speculate here that certain language families (and possible linguistic areas) tend *not* to assibilate /t d/.[25] The indiginous languages of Australia (see Dixon 1980 for a survey) are an instance of such a language family. Two examples of Australian languages are provided in ([27c], [27d]). In neither of these descriptions is reference made to assibilation processes.

(27) Type E languages:
   a. Chamorro (Topping 1973)
   b. Lahu (Matisoff 1982)
   c. Nhanda (Blevins 2001)
   d. Gaagudju (Harvey 2002)

A possible reason for the lack of spirantizations and affrications in Australian languages might be that the typical Australian language does not have fricatives or affricates (i.e., [s] and [ts]). Note that the ban on sounds like [s] and [ts] in typical Australian languages is also enforced at the level of grammar where allophonic rules go into effect (i.e., postlexically).

4. A formal analysis

In this section we present a formal OT analysis of the typology in Section 3.2. Specifically, we show that assibilation is captured by ranking one or more markedness constraint ahead of a faithfulness constraint that militates against changing the feature [strident]. It will be argued below that the markedness constraints required to capture assibilations are grounded in phonetics and that a (phonetically motivated) universal ranking can be posited that rules out all of the nonoccurring language types in (8). The occurring language types in (7) (discussed in Section 3.2) will be shown to involve the ranking of the one faithfulness constraint with respect to the universal ranking for markedness constraints. In the following analysis we only restrict ourselves to the assibilation of alveolar stops before high fronts vocoids. Other kinds of assibilation processes (e.g., those in which the process is triggered by other vowels, those in which velars form the input) require markedness (and/or faithfulness) constraints not discussed below.

4.1. *Phonetically grounded markedness constraints*

Clements (1999: 287ff.) observes that a sequence of voiceless alveolar stop followed by a high vowel often results in a transitional noise between the two segments, but no noise is present if the stop is released into a nonhigh vowel. The cause of this transitional noise is the narrow stricture of the high vocoid after the *t* release that generates turbulent airflow. This observation was experimentally tested by Kim (2001) with Korean sequences of heteromorphemic /t+i/ (which undergoes the process of affrication), and monomorphemic /ti/, /tu/, /te/ and /ta/. Her results show that the friction noise is longest for the heteromorphemic sequence with a truly affricated *t*. The remaining contexts can be ordered according to their length of friction from longest in /ti/ to /tu/ to /te/ to shortest or almost nonexistent in /ta/.[26] Kim supplemented these results with a discussion of X-ray data from Quebec French to attest the point that a high tongue body for following vowels in alveolar stop-vowel sequences favours transitional noise. Clements states that for a language to develop a rule of affrication or posteriorization, the frication noise has to be "reassigned" to the initial stop segment (1999: 288). Clements further assumes that the transitional noise in such sequences is not universally present, but "it is just necessary that it appear[s] with sufficient frequency in some contexts in a given language for it to come to the attention of speakers" (1999: 289).

We adopt Clements's and Kim's findings that the transition noise in these sequences is generated due to the stricture of the following high vocoid. We also follow Clements in the assumption that this noise is reinterpreted by the speaker/listener as belonging to the preceding stop in cases of assibilation. We depart from Clements with respect to the nonuniversality of the noise, since we posit that in contrast to sequences of *t* plus nonhigh vowels, sequences of *t* plus high vocoid *always* create strident noise, although its amount might be language specific and dependent on context and other criteria such as aspiration of the stop. An example of such a context is morpheme-internal vs. heteromorphemic position; hence, in Korean the friction phase of the /t/ in heteromorphemic /at+i/ sequences is considerably longer than in tautomorphemic /ati/ sequences (Kim 2001: 100). Another context is before a high vs. a nonhigh vowel. For example, in Korean the friction phase of /t/ in (tautomorphemic) /ati/ is longer than in tautomorphemic /ate/ and /ata/ (Kim 2001: 100).

Thus, we argue that the friction noise in /ti/ and /tj/ sequences follows automatically from their articulation. But the perception and reassociation of this friction noise as belonging to the preceding stop is language dependent and can be expressed in the perceptual markedness constraints (28a) and (28b).[27]

(28) Two perceptual markedness constraints:
  a. *ti: interpret the friction noise in the realization of /ti/ as [tsi].[28]
  b. *tj: interpret the friction noise in the realization of /tj/ as [tsj].

Markedness constraints that refer to perceptual or auditory information are not new in phonology; see, for instance, Flemming's (1995) MinDist constraints and Steriade's (2001) correspondence constraints that are based on a perceptibility map (the so-called 'P-map'). Kirchner (1998: 117ff.) also posits perceptually based markedness constraints in his account of assibilations; see the discussion of his proposal and how it differs from the present one in section Section 4.3 below. The two constraints in (28) are similar to the constraint *[ti] proposed by Kenstowicz (2003: 19), which he employs for the palatalization process in Lauan Fijian and paraphrases as the knowledge of Lauan speakers that /ti/ is realized as [tʃi] (see below for more discussion on this example). But whereas Kenstowicz's constraint is purely speaker driven, the two constraints in (28) are foremost listener oriented: the listener reinterprets the friction noise as belonging to the stop and consequently produces underlying /ti/ as [tsi].

The constraints in (28) only militate against forms without friction noise, e.g., [ti] and [tj] respectively, which would lose out to [tsi] and [tsj]. Note that candidates that involve a vowel change (e.g., [tse]) satisfy both *ti and *tj. This point illustrates the necessity of (vowel) faithfulness constraints (see Section 4.2 below for discussion and tableaux).

For the two constraints in (28) we propose the universal ranking in (29):

(29) A universal ranking:
*tj ≫ *ti

The universal ranking in (29) is based on the following argumentation. [i] and [j] can be assumed to differ either articulatorily (with the glide having a more narrow constriction) and/or aerodynamically (with the glide requiring stronger air pressure). The articulatory difference results in the same amount of air as for the high front vowel passing through a more narrow constriction in a /tj/ sequence, the difference in air pressure results in more air passing through the same constriction. Both arguments lead to a longer time for the air to be released into the glide, resulting in longer frication noise, which is attested by the findings by Hall et al. (2006), in which the friction phase in German and Polish nonce words with /tj/ sequences was significantly longer than that in nonce words with /ti/ sequences. This observation can be expressed as universal ranking between the two markedness constraints in (28) as in (29). Similar universal constraint rankings grounded in phonetics are proposed by Boersma (1998) and Hamann (2003).[29] In differentiating between the influence of the palatal glide and a high front vowel on the duration of friction noise and expressing this in separate constraints (28b) and their universal ranking in (29), we differ from Clements' and Kim's approaches, who treated /i/ and /j/ on a par.

Furthermore, both Clements and Kim restricted their predictions and investigations to voiceless stops. In Section 3, however, it was shown that voiced stops also undergo assibilation in a number of languages. For the voiced stops, the two constraints *dj and *di can be stated (see [30]). Like the constraints in (28), the ones in (30) express the perceptual markedness of the relevant sequences:

(30) Two perceptual markedness constraints:
   a. *di: interpret the friction noise in the realization of /di/ as [dzi].
   b. *dj: interpret the friction noise in the realization of /dj/ as [dzj].

Since the articulatory and the aerodynamic differences between the vowel /i/ and the glide /j/ stay the same independent of the nature of the preceding stop, we posit the universal constraint ranking in (31).

(31) A universal ranking:
   *dj ≫ *di

This ranking is also attested in Hall et al.'s (2006) experimental study with German and Polish alveolar stop-high vocoid sequences in nonce words, in which the friction phase in /dj/ sequences was significantly longer than that in /di/ sequences. The same study showed that /dj/ and /di/ sequences were always significantly shorter than /tj/ and /ti/ sequences. That sequences with voiced stops generally show less friction is attributable to two factors. First, the vibrating vocal cords of the voiced stop allow less air to build up behind the constriction in the vocal tract than when the vocal cords are open for the voiceless stops. As a consequence, there is less air pressure at the release of the voiced stop and thus less frication noise generated. Furthermore, voicing of stops requires a difference between subglottal and supraglottal pressure (in order to let the vocal folds vibrate), which is usually maintained by pharyngeal expansion and larynx lowering (Kent and Moll 1969; Perkell 1969; Bell-Berti 1975). Pharyngeal expansion also results in less air pressure at the constriction and less friction at the stop release (Ohala and Riordan 1979).[30]

Taking these aerodynamic observations and the findings by Hall et al. (2006) into account, the constraint *tj has to be ranked above its counterpart for the voiced stop, *dj, and *ti similarly needs to outrank *di. It is not clear whether or not the friction phase is longer in /ti/ sequences than in /dj/ sequences; we therefore suggest that the two constraints *ti and *dj are not universally ranked with respect to each other.[31] Taken together, the two constraint hierarchies from (29) and (31) produce the following universal ranking:

(32) A universal ranking:
   *tj ≫ {*ti, *dj} ≫ *di

In sum, the markedness constraints posited above are based on the listener's inclination to parse the perceived friction noise as belonging to the stop. This idea differs significantly from traditional markedness constraints in OT that are speaker driven, only, see the discussion of Kirchner's (1998) approach in Section 4.3.

4.2. *An OT analysis*

The typology we present below relies on the interaction between the universal ranking of the four markedness constraints in (33) with the following faithfulness constraint:

(33) A faithfulness constraint:
IDENT-[STRID]

The faithfulness constraint in (33) belongs to the IDENT family; it penalizes the change from nonstrident (e.g., /t/) to strident (i.e., [ts], [s], or [tʃ]). We assume, following several authors, e.g., Jakobson et al. (1952), LaCharité (1993), Rubach (1994), Clements (1999), and Kehrein (2002), that stops differ from the corresponding affricates in terms of the feature [strident]. According to this view a stop like /t/ is [−strident] and an affricate like /ts/ is [+strident]. The analysis of any assibilation process requires that some markedness constraint(s) be ranked ahead of the faithfulness constraint in (33). This point is illustrated in the tableau in (34), in which the change from /atia/ to [atsia] is shown:

(34) /atia/ → [atsia]:

	/atia/	*ti	IDENT-STRI
a.	[atia]	*!	
b.	☞ [atsia]		*

In the analysis that follows we do not distinguish between the three outputs of the assibilation processes in (1), i.e., spirantization with [s], affrication with [ts] and posteriorization with [tʃ]. Instead we only discuss the manner change of stop to some strident sound (indicated as [ts] in the following tableaux) without specifying the exact phonetic realization. The different outputs (i.e., [ts] vs. [s] vs. [tʃ]) require additional constraints that are not important for capturing the typology in Section 3.2.

Given the universal markedness constraint hierarchy in (32) the process of assibilation is captured by ranking at least one of these constraints ahead of the IDENT constraint in (33). This ranking is illustrated in (35)–(38) for a Type A language (e.g., Quebec French). In these tableaux the only crucial ranking is that all four of the markedness constraints outrank the one faithfulness constraint. Evidence for the ranking among the markedness constraints (e.g., *tj ≫ *ti) was discussed in (32) above. It is shown below how these rankings rule out the nonoccurring language types.[32]

(35) /atja/ in Type A languages:

	/atja/	*tj	*ti	*dj	*di	IDENT-STRI
a.	[atja]	*!				
b.	☞ [atsja]					*

(36) /atia/ in Type A languages:

	/atia/	*tj	*ti	*dj	*di	IDENT-STRI
a.	[atia]		*!			
b.	☞ [atsia]					*

(37) /adja/ in Type A languages:

	/adja/	*tj	*ti	*dj	*di	IDENT-STRI
a.	[adja]			*!		
b.	☞ [adzja]					*

(38) /adia/ in Type A languages:

	/adia/	*tj	*ti	*dj	*di	IDENT-STRI
a.	[adia]				*!	
b.	☞ [adzia]					*

In these tableaux it can be observed that all four markedness constraints outrank the one faithfulness constraint.

The analysis described above for Type A languages in (35)–(38) cannot predict why *ti violations are repaired by assibilation, since there are other theoretically possible avoidance strategies. One obvious example would be the change from /i/ in /ti/ to some other vowel. Thus, the question is why [atsia] is the optimal output form for the input /atia/ in (36) and not [atua] or [atea]? We account for the fact that vowel changes are the dispreferred repair strategy for sequences like /ti/ by positing that there is a high ranked IDENT constraint present in (35)–(38) that militates against a change in vowel quality. Since the kind of vowel changes described above are not the kind of repair strategy one encounters in the languages of the world, we argue that this IDENT constraint is universally ranked ahead of all of the four MARKEDNESS and IDENT constraints in

(35)–(38). In his discussion of posteriorization in Fijian, Kenstowicz (2003: 20) posits precisely such a constraint to account for the fact that the optimal output for a sequence like /ti/ is [tʃi] in Fijian and not [te]. To account for the fact that no language allows vowel quality changes to repair sequences like /ti/, Kenstowics posits a universal ranking in which the IDENT constraint militating against a vowel change outranks the IDENT constraint that militates against the change from /t/ to [tʃ].[33]

The occurring language types posited above in (7) are summarized in (39) with a corresponding example. In (40) we have repeated from (8) the nonoccurring language types.

(39) Occurring assibilation types:

		Assibilating segment(s)	Trigger(s)	Example
	A	/t (d)/	/i (j)/	Quebec French
	B	/t (d)/	/j/	Romanian
	C	/t/	/i (j)/	Hittite
	D	/t/	/j/	Latin
	E	none	none	Nhanda

(40) Nonoccurring assibilation types:

		Assibilating segment(s)	Trigger(s)
	F	/t (d)/	/i/
	G	/t/	/i/
	H	/d/	/i (j)/
	I	/d/	/j/
	J	/d/	/i/

The universal hierarchy in (32) together with the faithfulness constraint IDENT-[STRI] yield six rankings, five of which correspond to the occurring language types in (39). Here and below a nonranking between the constraints in indicated with the curly brackets.[34]

(41)

		Language type	Ranking
	a.	Type A	*tj ≫ {*ti, *dj} ≫ *di ≫ IDENT-STRI
	b.	Type B	*tj ≫ *dj ≫ IDENT-STRI ≫ *ti ≫ *di
	c.	Type C	*tj ≫ *ti ≫ IDENT-STRI ≫ *dj ≫ *di
	d.	Type D	*tj ≫ IDENT-STRI ≫ {*ti, *dj} ≫ *di
	e.	Type E	IDENT-STRI ≫ *tj ≫ {*ti, *dj} ≫ *di

The sixth logically possible language type is the ranking *tj ≫ {*ti, *dj} ≫ IDENT-STRI ≫ *di. This language type is discussed in Section 4.3 below, where we show that it is in fact attested.

The five language types in (40) do not occur because they would require rankings that are not in harmony with the universal rankings in (32). This point is made clear in (42):

(42) Nonoccurring language types:

	Language type	Illicit ranking
a.	Type F	{*ti, *di} ≫ IDENT-STRI ≫ {*tj, *dj}
b.	Type G	*ti ≫ IDENT-STRI ≫ {*tj, *dj, *di}
c.	Type H	{*dj, *di} ≫ IDENT-STRI ≫ {*ti, *tj}
d.	Type I	*dj ≫ IDENT-STRI ≫ {*ti, *tj, *di}
e.	Type J	*di ≫ IDENT-STRI ≫ {*ti, *tj, *dj}

An examination of the rankings in (42) reveals that they all violate at least one of the universal rankings in (32). Thus, Type F requires (by transitivity) that {*ti, *di} outrank {*tj, *dj} and Type G that *ti outrank *tj. Types H–J are nonoccurring because they would require *dj and/or *di to outrank *tj and/or *ti.

4.3. *An alternative account*

In this section we discuss Kirchner's (1998) OT analysis of assibilation. In his account, a LAZY constraint is employed, which militates against too much effort on the part of the speaker. As Kirchner himself (1998: 116ff.) shows, this constraint alone is not sufficient for an account of assibilation processes, since every assibilated output involves more articulatory effort than a nonassibilated one. To solve this problem, a so-called fortition constraint is introduced, "which serve[s] to enhance the salience and robustness of perceptual distinctions" (Kirchner 1998: 26). According to Kirchner (1998: 117), a sequence such as /ti/ is automatically produced with some friction, which is in accordance with the position taken in the present article. Therefore, Kirchner represents the output candidates of an underlying form /ti/ as [t^si] (with a weakly fricated release) and [tsi] (with a true affricate), see the tableau in (43). This representation includes perceptual phonetic detail (namely the transitional friction noise) in an OT production tableau, which is traditionally employed to compare articulatory inputs to articulatory outputs (recall Note 32).

(43) /ti/ → [tsi] according to Kirchner (1998):

	/ti/	*[+fric release, −strident]	LAZY
a.	[t^si]	*!	
b.	☞ [tsi]		*

In this tableau, the highly ranked fortition constraint *[+fricated release, −strident], militating against fricated releases that are not strident, selects the candidate [tsi] as the winner, since this candidate has a strident release. The speaker thus actively decides for the strident output [tsi] to enhance a perceptual distinction, as the definition of fortition constraints implies.

However, it is not clear from Kirchner's treatment which perceptual distinction is meant to be enhanced by this output. In [tsi] the friction is without question more salient than in [t^{s}i], but why should the output be maximally salient with respect to friction if the underlying form has no friction at all? The approach applied in the present article assumes instead that the production of an affricate is preceded by a perceptual misclassification, thus the speaker just produces what he or she interpreted as a listener. Furthermore, with Kirchner's constraints, the restriction on occurring and nonoccurring language types with respect to assibilation cannot be predicted, since the segment undergoing assibilation is not included in the constraints. Again, the present approach is superior since it proposes separate constraints for each possible input and an inherent ranking of these constraints, which automatically excludes impossible language types.

4.4. *Additional language types*

As noted in Section 4.2 above the constraints posited predict a sixth language type, which we refer to below as Type E′:

(44)	Language type	Type E′
	Ranking	*tj ≫ {*ti, *dj} ≫ IDENT-STRI ≫ *di
	Effect	t, d assibilate before j; t assibilates before i

In the final row of (44) it can be seen that the ranking for Type E′ describes a 'mixed' system in the sense that it captures two separate processes, namely one that assibilates /t d/ before /j/ and the other that assibilates /t/ before /i/. In this respect Type E′ is very different from Types A–D, which all describe a single process each. Note that Type E′ is essentially a Type B language that also has a process assibilating /t/ before /i/. We are aware of only one Type E′ language, namely English (see below); however, we speculate that additional examples might be found among the Type B languages.

The English examples in (45a) illustrate that /t d/ surface as [tʃ dʒ] before /j/-initial suffixes and the ones in (45b) that the same kind of process takes place across words (especially before the words *you* and *your*) in casual speech.[35] Importantly, neither of the two processes in (45a)–(45b) goes into effect before a morpheme beginning with a high front vowel, e.g., *wha[t] if*, **wha[tʃ] if*.

(45) Assibilation in English:

a.	perpe[tʃ]ual	(cf. perpe[t]uity)
	resi[dʒ]ual	(cf. resi[d]ue)
b.	wha[tʃ] you	
	ha[dʒ] you	
c.	democra[t]	democra[s]y
	presiden[t]	presiden[s]y
	vacan[t]	vacan[s]y
	luna[t]-ic	luna[s]y
	here[t]-ic	here[s]y
	poli[t]-ics	poli[s]y
d.	proso[d]-ic	proso[d]y
	melo[d]-ic	melo[d]y

Besides the posteriorization process in (45a)–(45b), English has a separate process that assibilates /t/ to [s] before /i/. Several alternating pairs have been listed in (45c) that motivate this process. Importantly, the process in (45c) does not affect [d], as illustrated in (45d).

In addition to the language type in (44), there are five further examples of mixed languages, but in contrast to Type E′, these five additional mixed types are all nonoccurring. The additional nonoccuring language types are listed below in (46).

(46) Five additional nonoccurring language types:

	Assibilating segment(s)	Trigger(s)	Illicit ranking required
a.	/t/	/i j/	{*tj, *ti, *di} ≫ IDENT-STRI ≫ *dj
	/d/	/i/	
b.	/t/	/i/	{*ti, *di, *dj} ≫ IDENT-STRI ≫ *tj
	/d/	/i j/	
c.	/t/	/i/	{*ti, *dj} ≫ IDENT-STRI ≫ {*tj, *di}
	/d/	/j/	
d.	/t/	/j/	{*tj, *di, *dj} ≫ IDENT-STRI ≫ *ti
	/d/	/i j/	
e.	/t/	/j/	{*tj, *di} ≫ IDENT-STRI ≫ {*ti, *dj}
	/d/	/i/	

As was the case in (43) each of the additional language types in (46) is nonoccurring because it would violate the universal constraint rankings in (30). Thus, the ranking {*tj, *ti, *di} ≫ *dj in (46a) violates the universal ranking *dj ≫ *di and in (46b) and (46c) *ti ≫ *tj is the opposite of the proposed ranking *tj ≫ *ti. The ranking in (46d) requires *di to be ahead of *ti, but it was argued above that *ti ≫ *di is universal. Finally, (46e) requires *di to outrank *dj.

4.5. *Frequency*

As noted above in Section 4.1 the distribution among the six occurring language types is not equal, since many languages fall into the A, C and E category, and only a few in B, D and E′ each. What is more, Type C appears to be less common than Type A and Type E. We hypothesize that these proportions are not due to chance and therefore propose an explanation below.

We argue here that the unequal distribution among language types — in particular the crosslinguistic preference of {A, C, E} over {B, D, E′} — can be accounted for by considering whether or not the natural class of vowels and glides (i.e., [i j]) is captured by the markedness constraints. When the constraints *ti and *tj (as well as *di and *dj) are ranked together above or below the one faithfulness constraint then we see this as evidence that [i j] function together as a unit. By contrast, if *ti and *tj (as well as *di and *dj) are ranked on opposite sides of faithfulness then this means that [i j] do not function together as a natural class. This point can be illustrated with each of the six occurring language types in (39) and (41) to determine whether or not the natural class [i j] is respected. This is shown in (47), where we list each of the six occurring language types in the first column. In the second column '+' or '–' indicates whether or not the respective language respects or does not respect the natural class [i j] (which we symbolize here as 'i/j').

(47)

Language type	i/j
Type A	+
Type B	–
Type C	+
Type D	–
Type E	+
Type E′	–

The table in (47) indicates that Types A, C and E are the three language types in which the natural class [i j] is respected and that Types B, D and E′ are the three where [i j] are not treated as a class. The lower frequency of Type B, D, and E′ languages can therefore be interpreted as a consequence of the tendency in the languages of the world to treat [i j] as a unit. That this natural class is important is substantiated by the fact that [i] and [j] are virtually the same sound from the point of view of articulatory phonetics (recall the discussion in Section 4.1 above). In addition, many linguists have shown that [i] and [j] are positional variants in various languages, suggesting that these two sounds are — at least in the unmarked case — one at the underlying level.

A second generalization concerning frequency is that within the A/C/E category languages of Type A and Type E seem to be more common than those belonging to Type C. This generalization can be expressed by considering the natural class of /t d/ (represented as 't/d' below), which would be satisfied if the constraints *ti and *di (as well as *tj and *dj) are ranked together with respect to the faithfulness constraint. An examination of the rankings for Type A and Type E reveals that both of these languages satisfy the t/d natural class but this is not the case with Type C.

To summarize, the six occurring language types can be arranged in a harmonic scale, which corresponds to frequency. (See Prince and Smolensky 1993, who argue that markedness relations for segment types can be arranged in a scalar fashion, e.g., COR ≫ LAB, which says that coronal is less marked than labial. Note that markedness in this sense is also often correlated with crosslinguistic frequency).

(48) $\left\{\begin{array}{c}\text{Type A}\\ \text{Type E}\end{array}\right\} \gg \{\text{Type C}\} \gg \left\{\begin{array}{c}\text{Type B}\\ \text{Type D}\\ \text{Type E}'\end{array}\right\}$

What this scale says is that Type A and Type E are the most harmonic assibilation types, which we interpret to mean that they are the most common ones in the languages of the world. We hypothesize that given a large enough sample of assibilations Type A and Type E will predominate over the other types. Based on our typology Type C is slightly less common than Type A and Type E but much more common than Type B, Type D and Type E′. Again, only future research can (dis)confirm the crosslinguistic predictions made by the hierarchy in (48).

5. Conclusion

In this article we proposed two new universal properties for assibilation rules and presented typological evidence from assibilations in over 30 languages supporting them. We argued that assibilations are to be captured in the OT framework by ranking markedness constraints grounded in perception that penalize sequences like [ti] ahead of a faithfulness constraint that militates against the change from /t/ to some sibilant sound. The six occurring language types were shown to involve permutations of the rankings between several different markedness constraints and the one faithfulness constraint. The article demonstrated that there exist several logically possible assibilation types that are ruled out because they would involve illicit rankings.

There are several questions referred to in the preceding paragraphs that are worth further investigating in the future. For example, one might want to establish a typology for assibilation processes that affect velar sounds (e.g., '/k/ → [tʃ] / __ i') similar to the one posited above in Section 3 for assibilations with a coronal as an input. Our assumption is that the properties for assibilation established in (9) would hold for these additional processes as well. A future study dealing with assibilations might want to consider more fine-grained vocalic contexts. For example, in the present study we restricted our analysis to high, front, unrounded vocoids, but, as we noted above, assibilations can be triggered by other vowels as well, e.g., /y/, /u/, /e/. We suggest provisionally that the vocalic triggers can be arranged in a hierarchy according to the likeliness that they trigger assibilation, e.g., /j/ > /i/ > /y/ > /u/ > /e/ etc. Clearly, this hierarchy can only be (dis)confirmed with evidence from natural languages.

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Appendix

Table 1. *Index of languages*

Language	Family	Geographical area	Source
'Ala'ala	Austronesian (Oceanic)	Papua New Guinea	Ross (2002a)
Albanian	Indo-European (Albanian)	Albania	Buchholz and Fiedler (1987)
Ambae	Austronesian (Oceanic)	Vanuatu (Ambae islands)	Hyslop (2001)
Apalai	Carib	Brazil (Paru Leste River)	Koehn and Koehn (1986)
Arosi	Austronesian (Oceanic)	Solomon Islands	Lynch and Horoi (2002)
Axininca Campa	Arawakan	Peru (Pachitea River)	Spring (1992)
Blackfoot	Algic (Plains)	Canada (Alberta)	Frantz (1991)
Chamorro	Austronesian	Guam	Topping (1973)
Cheyenne	Algic (Plains)	USA (Montana)	Davis (1962)
Danish	Indo-European (Germ.)	Denmark	Basbøll and Wagner (1985)
Dutch	Indo-European (Germ.)	The Netherlands	Booij (1995)

Table 1 (*Continued*)

Language	Family	Geographical area	Source
English	Indo-European (Germ.)	United Kingdom etc.	Luick (1921)
Finnish	Uralic (Finno-Ugric)	Finland	Kiparsky (1973)
Gaagudju	Australian	Australia	Harvey (2002)
Gbe (Ewe)	Niger-Congo (Kwa)		
– Kpándo (Vhe) dialect		Ghana	Capo (1991)
– Fongbe dialect		Benin	Lefebvre and Brousseau (2002)
German	Indo-European (Germ.)	Germany	Hall (2004), Penzl (1972)
Greek (Ancient)	Indo-European (Hellenic)	extinct	Sommerstein (1973)
Greenlandic (West)	Eskimo-Aleut	Greenland	Fortescue (1984), Dorais (1986)
Hittite	Indo-European	extinct	Kimball (1999)
Humburi Senni	Nilo-Saharan (Songhay)	Mali	Heath (1999a,b)
Italian	Indo-European (Romance)	Italy	Tuttle (1997), Cordin (1997)
Ikalanga	Niger-Congo (Bantu)	Botswana	Mathangwane (1999)
Japanese	isolate	Japan	Itô and Mester (1995)
Kashmiri	Indo-European (Indo-Iran.)	India	Wali and Koul (1997)
Kinyamwezi	Niger-Congo (Bantu)	Tanzania	Maganga and Schadeberg (1992)
Korean	isolate	North and South Korea	Kim (2001)
Kosraean	Austronesian (Oceanic)	Caroline islands	Lee and Wang (1984)
Koyra Chiini	Nilo-Saharan (Songhay)	Mali	Heath (1999a)
Lahu	Tibeto-Burman	Thailand	Matisoff (1982)
Latin	Indo-European (Italic)	extinct	Pope (1952), Sommer (1948)
Latvian	Indo-European (Baltic)	Latvia	Forssman (2001)
Maori	Austronesian (Oceanic)	New Zealand	Bauer (1993)
Mongo (Lomongo)	Niger-Congo (Bantu)	Congo	Spaandonck (1964)
Nadroga (Fijian)	Austronesian (Oceanic)	Fiji	Lynch et al. (2002)

Table 1 (*Continued*)

Language	Family	Geographical area	Source
Nhanda	Australian	Australia	Blevins (2001)
Nishnaabemwin (Ojibwe)	Algic (Algonquian)	Canada (Ontario)	Valentine (2001)
Nyakyusa	Niger-Congo (Bantu)	Tanzania	Labroussi (1999)
Papago (O'odham)	Uto-Aztecan (Tempiman)	USA (Arizona)	Halle and Clements (1983)
Pima Bajo	Uto-Aztecan (Tempiman)	Mexico	Fernández (1996)
Plains Cree	Algic (Algonquian)	Canada	Wolfart (1973)
Polish	Indo-European (Slavic)	Poland	Rubach (1994), Carlton (1990)
Quebec French	Indo-European (Romance)	Quebec	Cedergren et al. (1991)
Ririo	Austronesian (Oceanic)	Solomon Islands	Tryon and Hackman (1983)
Romanian	Indo-European (Romance)	Romania	Chitoran (2001)
Runyoro-Rutooro	Niger-Congo (Bantu)	Uganda	Rubongoya (1999)
Samoan	Austronesian (Oceanic)	Western Samoa	Mosel and Hovdhaugen (1992)
Sanskrit	Indo-European (Indo-Aryan)	extinct	Misra (1967)
Sengga	Austronesian (Oceanic)	Solomon Islands	Tryon and Hackman (1983)
Serbo-Croatian	Indo-European (Slavic)	former Yugoslavia	Kordić (1997)
Shona	Niger-Congo (Bantu)	Zimbabwe	Brauner (1995)
Slovak	Indo-European (Slavic)	Slovakia	Carlton (1990)
Sonora Yaqui	Uto-Aztecan (Sonoran)	Mexico (Sonora)	Dedrick and Casad (1999)
Sorbian	Indo-European (Slavic)	Germany	Wowčerk (1954)
Southern Kongo	Niger-Congo (Bantu)	Angola	Halle and Clements (1983)
Taiof (Saposa)	Austronesian (Oceanic)	Papua New Guinea	Ross (2002b)
Tawala	Austronesian (Oceanic)	Papua New Guinea	Ezard (1997)
Tümpisa Shoshone	Uto-Aztecan (Numic)	USA (California)	Dayley (1989)
Turkana	Nilo-Saharan	Kenya	Dimmendaal (1983)

Table 1 (*Continued*)

Language	Family	Geographical area	Source
Vaghua	Austronesian (Oceanic)	Solomon Islands	Tryon and Hackman (1983)
Varisi	Austronesian (Oceanic)	Solomon Islands	Tryon and Hackman (1983)
Wai Wai	Carib (Northern)	Brazil	Hawkins (1998)
West Futuna-Aniwa	Austronesian (Oceanic)	Vanuatu (Futuna Islands)	Dougherty (1983)
Woleaian	Austronesian (Oceanic)	Caroline islands	Tawerilmang and Sohn (1984)

Notes

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1. In addition to the two studies mentioned above the previous literature on stop assibilations includes Foley (1973, 1977) and Bhat (1978). It should be noted that the often cited typological study of Bhat (1978) does not discuss the issues we treat below.
2. In the present article we represent affricates as a sequence of stop plus (homorganic) fricative, e.g., /ts dz tʃ dʒ/.
3. In addition to the word-initial context in (4a) /t/ was assibilated to [ts] in other environments as well, e.g., after /r/ in words like *her[ts]a* (cf. the English cognate *heart*). In addition, /p/ and /k/ surfaced as the corresponding affricates.
4. In the ensuing analysis we employ slants '/.../' to denote the input to assibilation and not to the underlying representation. Thus, the segment we transcribe below as '/j/' could either be an underlying /j/ that triggers assibilation, or it could be a /j/ that forms the input to assibilation but that itself derives from some other sound, e.g., /i/. The same point holds to the triggers /t/ and /d/ in (6) below.
5. Foley (1973, 1977) proposes what he seems to consider a universal generalization for assibilations that is equivalent to (9a), but he only discusses examples from English and French in support of it. To our knowledge no one to date has proposed (9b).
6. We noted above in Section 2 that our study is restricted to assibilations in which the input consists of an (oral) stop, but we hypothesize that the same generalizations holds for 'assibilations' in the broad sense of the word. For example, our impressionistic view of processes that change a velar stop into a postalveolar affricate (i.e., /k/ → [tʃ] before a front vowel) suggests that property (9a) also holds. (9a) may also subsume processes of posteriorization in which the input is some sound other than a nonstrident stop, e.g., fricatives like /s z/, as well as nasals and laterals. It may even hold for processes not commonly characterized as assibilations, e.g., the change from /θ/ to [s] before /i, iː, j/ in Plains Cree (Wolfart 1973: 79). One might also want to speculate that (9a) should be generalized to all glides and high vowels and not simply /i/ and /j/. We

also hypothesize that (9b) is valid for processes like the ones in (4) above, in which the trigger is not a vocalic element. Further research is therefore required to determine the extent to which (9a) and (9b) hold for other phonological processes.

7. There is a general problem with admitting historical assibilations, namely it is not always clear what the intermediate stages were, or what the chronology was. For example, if /tj/ changes to [tsj] at a later stage and /dj/ does not, one would not necessarily have to conclude that this is a Type B language because the /di/ might have undergone the same change to [dzj] followed by a subsequent change to [zj]. In the present section we include historical examples only if the source includes enough information to classify the language unambiguously into the language types presented above. If the source does not include enough information then we list the historical examples separately.
8. Throughout this article we use transcriptions that are in accordance with the IPA; hence, in certain examples the symbols in our sources are replaced with the equivalent IPA sounds. For example, in (13) Capo's [y] = [j] and his [t^s d^z] = [ts dz]. In the data in (13) and in following all tones have been omitted in examples from tone languages.
9. Capo (1991) posits a synchronic assibilation rule for Proto-Gbe, according to which the underlying forms (as in the left column in 13) are realized as [tʃ] and [dʒ]. If this process did indeed exist in Proto-Gbe, then Kpándo inherited and modified the rule.
10. According to Hyman (2003: 56ff.) most Bantuists (e.g., Guthrie 1967–1971; Meussen 1967) assume Proto-Bantu to have had seven vowels. These vowels included the distinction between i̧ and i, and u̧ and u, which correspond phonetically to [i ɪ u ʊ], respectively. A large number of Bantu languages have merged *i̧ /*i, and *u̧/*u to yield the 5 vowel system /i e u o a/. All 5 vowel Bantu languages except Lengola (Stappers 1971) 'fricate' stops before *i̧ and *u̧, as do some 7 vowel languages.

    It is also interesting to consider Bastin's (1983) remarks on the following hierarchy of frication contexts for Bantu languages:

    a. before tautomorphemic i̧
    b. before causative suffix *-i̧-
    c. before nominalizing suffix *-i̧
    d. before perfective suffix *-i̧d-

    This hierarchy means that d implies c, c implies b and b implies a.

    Bastin's hierarchy manifests itself in at least three ways. First, frication may be totally lacking in a context lower in the hierarchy while present in the higher contexts. Second, frication may be optional or affect only certain roots in the lower context. Finally, all consonants may be fricated in a higer environment vs. fewer consonants in the lower.
11. Chitoran (2001: 185ff.) treats the process of stop assibilation in (14) as a part of a larger process she calls 'palatalization', which shifts the place of articulation for other segment types, e.g., /s/ surfaces as [ʃ] when secondarily palatalized.
12. The triggers are deleted by a separate process. The initial [ɑ] in the final example in (15a) and (15b) similarly deletes by an independent rule.
13. As was rightfully pointed out to us by an anonymous reviewer, the input for the Japanese assimilation of the English loanword *tube* is assumed to be British English [t^hju:b], not American English [t^hu:b]. Our source for this language (Itô and Mester 1995) does not comment on this word.
14. Spanish loans do not undergo posteriorization in Papago, e.g., [tianda] 'store' and [tʃokola:di] 'chocolate'.
15. The prefix-final /i/ is dropped.

16. We would like to thank Fernando Zuñiga for bringing the Blackfoot data to our attention.
17. According to Sulkala and Karjalainen (1992: 365ff.), [d] was introduced into standard Finnish only in the 19th century as pronunciation of the letter *d*, earlier pronounced as [ð]. This segment only occurs in intervocalic word-medial position, as the weak form of /t/ in consonant gradation.
18. The transcriptions by Capo probably reflect the diachronic rule of posteriorization that applied in Proto-Gbe, recall Note 10, whereas Lefebre and Brousseau describe an optional synchronic process.
19. The assibilation of /t/ seems to be a diachronic process in Taiof, whereas assibilation of /d/ is still productive synchronically.
20. In the example [madzi] the effects of an independent allophonic process of intervocalic voicing can be observed.
21. According to Sommerstein (1973: 28ff.), classical Attic can be assumed to have had an assibilation rule that turned /t d/ into [ts dz] before the (then deleted) glide /j/, with later changes of /dz/ to [zd], of preconsonantal /ts/ to [s] and of prevocalic /ts/ to [tt]. This might explain the lack of /j/ after coronal stops in Greek.
22. Oceanic is an example of a language family in which a significant number of languages have assibilations (typically affrications and spirantizations). In our typology we have only included a handful. For references in which assibilations in Oceanic languages are posited see Ross (1988) (for the Western Oceanic Linkage branch) and Tryon (1976) (for Central-Eastern Oceanic).
23. For Varisi and Sengga assibilation occurred word initially only, whereas in Vaghua and Ririo it also occurred word internally, with the respective outputs [ts] and [tʃ] (Tryon and Hackman 1983: 77).
24. Word-initial /dj/ surfaced first as a voiced palatal stop [ɟ] and then later on as [dʒ]; intervocalically /dj/ went to [ɟ] and then to [j]; see also Sommer (1948), who agrees that there was a stage in the history of Latin with [ɟ].
25. By contrast, an inspection of the literature in Section 3 reveals that assibilation rules are overrepresented in certain language families. For example, a significant number of Oceanic languages are attested with affrications and spirantizations (recall Note 22) and Bantu languages with posteriorizations (recall Note 10).
26. The difference in friction length between /ti/ and /tu/ was statistically not significant in Kim's (2001) experiment.
27. No markedness constraint for /tu/ sequences is included, since the present article is not concerned with assibilation before high back vowels.
28. The nature of the friction noise is not relevant for the following discussion. Clements (1999) claims this friction to be spectrally similar to the fricative noise of a postalveolar fricative [ʃ]. Judging from perception, it seems more similar to the alveolopalatal fricative [ɕ], which finds confirmation in the articulatory closeness of tongue position for [i] to [ɕ]. The intepretation of the transitional noise as belonging to the stop could result in either of the affricates [tʃ], [tɕ] or [ts]. We assume that other factors than mere acoustic quality of the transition noise, such as already existing fricatives or affricates in the language in question, determine the outcome of the perceptual integration process. In a perceptual experiment Ćavar and Hamann (2003) compare the perceptual similarity of [ti] with [tɕ] and [tʃ] and showed that listeners judged the [ti] to be more similar to [tɕ].
29. Contrary to the present analysis, both Boersma (1998) and Hamann (2003) pose underlying perceptual representations and a distinction between production and perception grammar. Such an OT production grammar contains perceptual faithfulness con-

straints and articulatory markedness constraints. An example for the latter are *DISTANCE constraints (Boersma 1998: 150; Hamann 2003: 172), which refer to the articulatory distance between different positions of an articulator, and which can be universally ranked as *DISTANCE (x, z) ≫ *DISTANCE (x, y) if the distance between x and z is greater than that between y and z ((z – x) > (y – x)).

30. The higher subglottal pressure and lower intraoral air pressure for voiced stops compared to voiceless stops has been attested for example by Netsell (1969) for American English.
31. The acoustic investigation of German and Polish described in Hall et al. (2006) supports the ranking *ti ≫ *dj for these two languages. We leave open whether or not this ranking is universal.
32. As is common use in OT, both input form and output candidates are given as articulatory representations. For the assibilation cases and the perceptual constraints at hand, it is more precise to distinguish articulatory forms from corresponding perceptual forms, as done by Boersma in his Functional Phonology model (1998 et sequel.). Applying this approach to the tableau in (35), the articulatory candidate [atja] would have the corresponding perceptual form |at^{s}ja|, and [atsja] the perceptual form |atsja|.
33. Note that in a rule-based system one would also want to account for the fact that '/t/ → [tʃ] / __ i' is an example of a natural phonological process, as oppposed to '/i/ → [e] / t __'.

    A question we leave open for further study is whether or not vowel changes are truly not attested as repair strategies for /ti/ sequences. See Kenstowicz (2003) for some discussion.

    Other repair strategies, such as the change from /ti/ to [ki], [pi] etc. are ruled out with additional (universally) high ranked IDENT constraints.
34. Technically speaking a 'nonranking' between two constraints implies two separate rankings, e.g., for Type A in (41a) two rankings:

    (i) *tj ≫ *ti ≫ *dj ≫ *di ≫ IDENT-STRI
    *tj ≫ *dj ≫ *ti ≫ *di ≫ IDENT-STRI

    Importantly, both rankings in (i) yield the same effect.
35. We follow tradition in English phonology in assuming that the suffixes in examples like the ones in (45a) are /j/-initial, even though this segment does not surface in many dialects. It should also be noted that the process in (45a) only affects foot-internal /t d/, since these segments are not palatalized before a /j/-initial suffix that begins a foot, e.g., the underlined *t* in *perpetuity* (see Borowsky 1990).

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