Deletion or Epenthesis?

On the Falsifiability of Phonological Universals

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This paper presents a revised typology of consonant epenthesis and explores the theoretical implications of such a typology. Through careful re-analysis, the basis for a proposed universal of coronal preference and dorsal avoidance is shown to be lacking in evidential support. In fact, epenthesis as a verifiable phenomenon - and not just a theory-internal label - is called into question once careful attention is paid to the issue of choosing between epenthesis and deletion as competing analyses of the same data. The ambiguity between multiple possible analyses, and the lack of formal transformations (from 'data' to 'evidence') are shown to be general problems within phonological theory. Phonological ‘universals’ can be invoked to arbitrate between competing analyses, but when the typological evidence for those ‘universals’ is derived from the same data, a problem of circularity arises. In order to break this closed loop, a quantitative evaluation metric is proposed that is theory-independent with regards to substantive universals. This metric is essentially a statistical threshold for learnability (itself empirically testable) that allows for independent testing of certain theoretical claims.

1 Introduction

The hypothesized units of linguistic competence are not directly observable, but must be inferred from physical speech signals through a two part translational process. They are first rendered by the analyst into discrete sequences of abstract symbols; then from these 'surface' forms into abstract mental representations. However, there are no formal and independent principles governing either translation process. Each theory employs its own internal rules for converting data into evidence such that the very evidence used to test the theory is itself partially the product of that theory (cf. Zwicky 1975). Additionally, the process is subject to interpretation by the individual analyst, such that even within a single theory there is not necessarily a consistent methodology applied. That is to say, there exists massive indeterminacy in the assignment of correspondences between acoustic data and transcribed data, and between transcribed data and underlying forms. This paper explicitly addresses the problem of falsifiability in linguistic theory that arises because of this indeterminacy in correspondences.

The problem is illustrated by the in-depth examination of the typological data available as evidence for consonant epenthesis. Consonant epenthesis is chosen for the following reasons: there is well-documented disagreement about what constitutes acceptable evidence of epenthesis (Lombardi 2002; de Lacy 2006), and there exist explicit theoretical predictions about preferred and/or allowed places of articulation for the epenthetic segment (Kean 1975; Paradis &

Prunet 1991; Prince & Smolensky 1993/2004; de Lacy 2006). For these predictions to be falsifiable there must exist some set of data that would be generally acceptable as evidence contrary to the prediction.

In order to close in on this hypothetical set of data, a sample of 56 distinctive language patterns (in 53 different languages) was collected and re-analyzed. For each of these patterns epenthesis was a possible analysis (that is, it had been labeled 'epenthesis' by at least one source). However, re-analysis of the original data provided an assessment of the strength of the evidence in support of that analysis. This assessment was conducted independently of the theoretical claims under investigation by simulating a non-biased learner. In the face of ambiguous data such a learner must effectively choose epenthesis over other possible analyses of the data, particularly deletion. This mirrors the task of the analyst, and the two are taken to be one and the same for the purposes of this paper. The choice of preferred analysis is assumed to be based, in part, on the extent of the pattern (number of participating morphemes), and its robustness (lack of exceptional or non-participating morphemes). From this assumption a consistent, quantitative diagnostic of descriptive adequacy is developed.

What is found is that – for a range of numerical thresholds – consonant epenthesis overall proves to be much rarer than expected. Under even relatively lax criteria fully three-fourths of the sample is rejected as failing to provide sufficient evidence. Furthermore, the predicted preference for coronal over dorsal place of articulation is not found; the surviving set of such languages is too small to support generalizations over place of articulation. This result argues strongly

for the necessity of establishing independent and consistent translation procedures as part of the proper domain of formal linguistic theory.

In the next section the various aspects of the correspondence problem are laid out, and used to argue for a quantitative evaluation metric. In Section 3 two languages of the sample are examined at considerable depth in order to establish a baseline for the dimensions of variability, and the amount of variability along those dimensions. In this section a new statistic is defined: the Maximally Productive Domain (MPD): the largest grammatically (although not necessarily phonologically) based domain in which can be found the best evidence for epenthesis. The characteristics of the typological sample as a whole are given in Section 4, and the full list of diagnostic criteria, including the quantitative measure based on the MPD. In Section 5 the typological results of various MPD-based diagnostics are explored. While the 'observed' epenthesis typology changes depending on the choice of diagnostic, the general result holds regarding the lack of observed preference for coronal over dorsal place of articulation for epenthetic segments, and the general rarity of non-approximant epenthesis over-all. The paper concludes in Section 6 with a summary of the results and discussion of their repercussions for linguistic theory more generally.

2 The Correspondence Problem

In classical rule-based generative theory (e.g., Chomsky & Halle 1968) a process of epenthesis is described in the following general way: X is inserted in the environment following A and preceding B. See (1).

(1) ∅→X/A__B

For consonant epenthesis, the environment will typically be intervocalic, although the rule-based approach does not stipulate this. The classical Optimality-Theoretic formulation, in contrast, conceptualizes one type of epenthesis as driven by a constraint against onset-less syllables (Prince & Smolensky 1993/2004). This is based on the partial ranking in (2).

(2) MAX(V), ONSET >> DEP

OT predicts that consonant epenthesis in these cases should occur word-initially and inter-vocalically (alternatively, the constraint NoHiatus requires onsets only inter-vocalically). Despite the differences in their realizations, in both theoretical frameworks the fundamental issue of identifying epenthesis – that is, deciding that a given set of data corresponds to (1) or (2) – is the same, and it involves a massively many-to-many mapping.

The standard learning algorithm in OT, Recursive Constraint Demotion, requires that inputs (that is, underlying forms), as well as constraints, be pre-specified (Tesar 1995; Tesar & Smolensky 1998; Boersma & Hayes 2001). The more ecologically valid scenario of learning both inputs and rankings at the same time is generally recognized to be a much more computationally difficult task (see work on this problem by, e.g., Jarosz, 2006; Apoussidou, 2007; Merchant 2008; Tesar, 2013). In the first place, the learner must maintain a larger space of possible hypotheses consisting of both inputs and ranking order over constraints. And in the second, they must have an evaluation procedure that allows them to choose between two hypotheses that do equally well in describing the data, but

for distinct sets of inputs.

In fact, even hypotheses that do less well at describing the data must be considered. This is because exceptions are allowed if they are explicitly encoded in the lexicon. For the specific learning/analysis problem of this paper, a choice must be made between an epenthesis analysis with a given set of inputs, a deletion analysis, with differently specified inputs, and a suppletion/morphological analysis in which morpheme pairings are all listed in the lexicon.

2.1 Induction of Underlying Forms

Phonologically conditioned alternations involve a complementary distribution between two or more segments. The mere fact of complementarity, however, does not resolve the question of whether it is segment X that becomes Y in the environment A, or whether it is Y that becomes X in all other environments (¬A) (e.g., either intervocalic lenition, or pre-consonantal strengthening; either assimilative voicing, or assimilative de-voicing; either consonant epenthesis, or consonant deletion).

Analysis B in Table 1 represents the standard analysis of Axininca Campa (an Arawakan language of Peru): [*t*] epenthesis (to break up vowel clusters), and [*a*] epenthesis (to break up consonant clusters) (Spring 1990). However, because of the interdependence of these two processes, there is at least one other self-consistent analysis, namely A: /*t*/ deletion and /*a*/ deletion.

Table 1
Two possible analyses of Axininca Campa, following Spring (1990).

	Analysis	Underlying Representations and Rules	Surface Forms	Gloss
A	/*a*/ deletion	$/ir + kima + piro/ \rightarrow$	*[ikimapiro]*	he truly hears/will hear
		$/ir + N + kima + i/ \rightarrow$	*[iŋkimi]*	
	/*t*/ deletion	$/ir + N + pijat + i/ \rightarrow$	*[impijati]*	he will avenge/truly avenges
		$/ir + pijat + piro/ \rightarrow$	*[ipijapiro]*	
B	/*a*/ epenthesis	$/ir + kim + piro/ \rightarrow$	*[ikimapiro]*	he truly hears/will hear
		$/ir + N + kim + i/ \rightarrow$	*[iŋkimi]*	
	/*t*/ epenthesis	$/ir + N + pija + i/ \rightarrow$	*[impijati]*	he will avenge/truly avenges
		$/ir + pija + piro/ \rightarrow$	*[ipijapiro]*	

Analyses (A) and (B) do equally well in consistency of application of their respective rules (either deletion of both segments, or epenthesis of both segments). And, for both, the division of environments is uniform; e.g., [*t*] appears before vowel-initial suffixes; ∅ appears before consonant-initial suffixes. It is only when the underlying representations are considered in the aggregate that a point of distinction emerges.

It can be shown that analysis (A) requires one of two outcomes for the underlying forms. Either all verbal stems end only in one of /*a*/ or /*t*/, or all verbal suffixes begin only with one of /*a*/ or /*t*/. In either case a fairly large number of morphemes must adhere to a very constrained template (only two phonemes out of an inventory of 20 consonants and 3 vowels). The choice of analysis then hinges on whether or not this is considered too much of a coincidence.

The covert assessment of what I will call the 'Coincidence Condition' pervades phonological analysis, but a formal general-purpose method for

deciding the question does not seem to exist, although various authors have proposed intuitive solutions[1]. It does seem as though most analysts agree that the Coincidence Condition is violated for Axininca Campa (see section 3), but intuitions are less clear, I suspect, for a pattern like Waropen (Held 1942; Anceaux 1961).

Waropen is an Austronesian language spoken in parts of Indonesia and Eastern Papua. Most of the relevant evidence for [*k*] epenthesis in this language involves the verbal person prefixes (the 3rd and 2nd singular deviate from the pattern[2]). The data from Waropen are given in (3), where each participating prefix appears with two verb stems to illustrate the alternation.

[1] Spring (1990:53) writes of Axininca Campa: "The result…would be that while stems begin and end in c's and v's of various qualities, all verbal suffixes would begin with /*a*/ or /*t*/, a clearly undesirable result." For Payne (1981:56-57)

> "The epenthesis solution…avoids the arbitrariness of evaluating between the two deletion solutions. Second, and more important, it explanatorily accounts for the nature of the segments that must be either epenthesized or deleted by rule…there seems to me to be no natural reason why a /*t*/ and an /*a*/ would be deleted rather than any other consonant or vowel…on the other hand, …if a vowel is epenthesized to break up a consonant cluster, it would be natural for that vowel to be the unmarked /*a*/."

Kenstowicz and Kisseberth (1979:87) identify "[a] very general methodological principle". Namely, "if there is a 'pathological' phonetic pattern (i.e., a pattern that disobeys general principles of the language…)…then it is likely that this pattern is the consequence of a rule, rather than a property of the underlying form of the language." (On the other hand, advocates of morpheme structure constraints might argue that just such a rule should apply at the representational level. See, e.g., Kaye 1974).

[2] The non-conforming personal prefixes pattern as follows: the 3SG of 'eat' is [*iano*] and the 2SG is optionally [*aghano*] or [*auano*]. This could be taken as evidence against the prefix-final /*k*/ hypothesis. However, an historically final [*k*] might have deleted and voiced, respectively, in these forms. See Appendix for additional data that suggest certain suffixes in Waropen surface with epenthetic [*gh*].

(3) Waropen (Held 1942; Anceaux 1961)

[kisikikano]	*[kisikira]*
3DL-eat	3DL-go
[kikano]	*[kira]*
3PL-eat	3PL-go
[koisokikano]	*[koisokira]*
3TRL.INC-eat	3TRL.INC-go
[ikano]	*[ida]*
1PL.INC-eat	1PL.INC-go
[sikano]	*[sida]*
1DL.INC-eat	1DL.INC-go
[koisokano]	*[koisoda]*
1TRL.INC-eat	1TRL.INC-go

The epenthesis analysis of the above data is given in (4).

(4)	*/kisiki/+/ano/* →	*[kisikikano]* 3DL-eat	*/kisiki/+/ra/* →	*[kisikira]* 3DL-go
	/ki/+/ano/ →	*[kikano]* 3PL-eat	*/ki/ +/ra/* →	*[kira]* 3PL-go
	/koisoki/+/ano/ →	*[koisokikano]* 3TRL.INC-eat	*/koisoki/+/ra/* →	*[koisokira]* 3TRL.INC-go
	/i/+/ano/ →	*[ikano]* 1PL.INC-eat	*/i/+/ra/* →	*[ida]* 1PL.INC-go
	si/+/ano/ →	*[sikano]* 1DL.INC-eat	*/si/+/ra/* →	*[sida]* 1DL.INC-go
	/koiso/+/ano/ →	*[koisokano]* 1TRL.INC-eat	*/koiso/+/ra/* →	*[koisoda]* 1TRL.INC-go

If, in parallel with Axininca Campa analysis (A), the underlying representations are chosen differently, such that the prefix morphemes are given as *{/kik/-, /kisikik/-, /koisok/-, /koisokik/-, /ik/-, /sik/-*}, the analysis changes from epenthesis of [*k*] to deletion of C_1 in consonant clusters. The deletion analysis requires that all of these personal prefixes end in the same segment, namely /*k*/. But the set of morphemes is small, and comprises a homogenous semantic and syntactic

class; furthermore, many of the members already bear a strong phonological resemblance to one another. In this case, the 'coincidence' may be acceptable, such that Waropen would be rejected as a case of 'true epenthesis'. However, individual analysts will differ in their intuitions, especially for border-line patterns.

2.2 Opacity

There is an additional analytic ambiguity at the heart of phonological analysis that results from the fact that the theory has no explicit guidelines for determining how much descriptive work should be done by representations (underlying /*t*/ or inserted [*t*]) versus constraints/rules. Take the case of Maori, an Austronesian language of New Zealand. In Maori no surface forms end in consonants; furthermore, there is no surface alternation evidence (such as that given for Axininca Campa in Table 1) to indicate that any morphemes in Maori are underlyingly consonant-final. Certain verbal forms – such as the causative and reduplicant –, and nominal forms – such as the agentive –, surface with sequences of vowels as in (5) Bauer (1993).

(5)

/whaka + oho/ →	*[whakaoho]*
	CAUS-wake
	'waken'
/haaere/ + RED →	*[haaereere]*
	go-RED
	'go'
/kai + ako/ →	*[kaiako]*
	AGNT-teach
	'teacher'

However, there is a suggestive alternation found in the passive and nominalizing forms. Allomorphs of the passive include: *–a, –ia, -hia,-kia,-tia,-mia,-na,-ina,* etc., paralleled by the allomorphs of the nominalizer: *–ŋa , –aŋa, -haŋa,-kaŋa,-taŋa,-maŋa,* etc., (Hale 1973; Elbert & Pukui 1979).

De Lacy (2003) proposes an analysis in which certain of the observed surface consonants are analyzed as epenthetic in both the passive and nominalized forms (with -/*ia*/ and -/*aŋa*/ as the URs, respectively). The analysis is based on the hypothesis that Maori has both maximal as well as minimal word length restrictions; prosodic words must consist of at least 2 moras, but no more than a single foot – either (H), (L L), or (H L) (but never (L H) or (H H)).

De Lacy's analysis requires the following additional assumptions; root vowels cannot be broken up into different prosodic words (although root consonants can); all prosodic words must start with onsets (unless they are root-initial); all footable material must be footed; and any sequence of two vowels with rising sonority[3] must be heterosyllabic in Maori – other sequences form diphthongs (i.e. heavy nuclei)[4].

[3] De Lacy appears to use a sonority scale based only on vowel height, such that $a > o,e > i,u$.

[4] In terms of ranked constraints: {Lapse_{FT}, *Ft-} are highest ranked, enforcing single-footed prosodic words, and footing of footable material; Wrap(Root, Prwd) is also undominated, preventing root vowels from being broken up into separate prosodic words; Max_{RT} preserves {LHL} roots by dominating AllFtL; OCP also dominates AllFtL and Max, either forcing, or blocking, deletion to avoid a sequence of identical vowels; to explain the metathesis observed in n-final roots, *ni must be ranked above AllFtL – additionally [n] must be transparent to the OCP; Onset_{Prwd} forces epenthesis by out-ranking Max, but only applies to non-roots, and is therefore outranked by Dep-C_{RT} and Max_{RT}; Dep-C outranks Max, such that deletion is the preferred repair if possible; finally the constraint MorphDis rules out candidates in which the passive suffix completely coalesces with the root, a viable candidate for CVCa roots (de Lacy 2003).

In (6) de Lacy's analysis is applied to an example vowel-final root consisting of three light syllables. For roots of this kind /*t*/-epenthesis is predicted to occur in order to avoid a prosodic word with an initial onset-less syllable. The passive suffix, in turn, is forced to appear in its own prosodic word by constraints against multiple feet within the same prosodic word (*Ft-), and unfooted sequences of light syllables ($Lapse_{FT}$).

(6) Maori passive: {LLL} V-final roots

/ma.hu.e + i.a/	*Ft-	$Lapse_{FT}$	$Onset_{Prwd}$	Dep-C	Max
a) {(ma.hu.e).i.a}		*!			
b) {(ma.hu)(e.a)}	*!				*
c) {(ma.hu.e)}{(i.a)}			*!		
d) ☞{(ma.hu.e)}{(ti.a)}				*	

De Lacy's analysis also predicts that for vowel-final words consisting of a {L H} sequence vowel deletion will result instead of consonant epenthesis. See (7). Although the winner incurs a violation of AllFtL, so does the epenthesis candidate b) (an undominated constraint against (LH) feet rules out the candidate *{(ho.ɾo͡i)}{(ti.a)}). The ranking Max_{RT} >> AllFtL rules out candidate c). In contrast, for vowel-final {L L} roots, violation of low-ranked Max allows an output that does not violate AllFtL, e.g., */kite + ia/ → [{(ki.te).a}]*.

(7) Maori passive: {LH} V-final roots

/ho.ɾo͡i + i.a/	*Ft-	Lapse$_{FT}$	Onset$_{Prwd}$	Max$_{RT}$	AllFtL	Dep-C	Max
a)☞{ho.(ɾo͡i).a}					*		*
b) {ho.(ɾo͡i)}{(ti.a)}					*	*!	
c) {(ho.ɾo)}{(ti.a)}				*!		*	*
d) {ho.(ɾo͡i).i.a}		*!			*		

For 4 mora vowel-final roots, the passive is predicted to always surface with epenthetic [*t*]. Even with deletion, the suffix cannot appear in the same prosodic word as the root. High ranked Max$_{RT}$ and the ban on breaking up root vowels across multiple prosodic words (Wrap(Root, Prwd)) block other possible outcomes.

The maximal prosodic word analysis is compelling in that it provides phonological reasons for the observed alternations in the surface realizations of the passive as *–a, –ia, -tia,-na,* and *–ina*[5]*.* It is supported by parallel alternations in the nominalizer: *–ŋa, –aŋa, -taŋa,* and *-naŋa.* It is also strengthened by evidence of maximal word constraints from other parts of Maori phonology.

However, despite how compelling the predictions of this analysis may be for vowel-final roots, it hinges on a distinction that is impossible to verify independently. In order to account for the remaining variation in the passive and nominalized forms de Lacy posits the existence of underlyingly consonant-final roots. Roots of a certain type are predicted to always surface with an epenthetic

[5] The latter two outcomes rely on the constraints OCP and *ni, not discussed here.

[*t*][6]. However, it must be stipulated that all passive forms surfacing with a consonant other than [*t*] contain that consonant underlyingly. The same is true of forms surfacing with [*t*] that are *not* of the predicted root type. See (8).

(8)

/mahue + ia/	*→[mahuetia]*	'remember'
/hoatuŋ + ia/	*→[hoatuŋia]*	'give'
/tonut + ia/	*→[tonutia]*	'still'

The distinction between underlyingly vowel-final roots and underlyingly consonant-final roots of the same prosodic structure cannot, in principle, be verified. Neither can that between surface realizations of [*tia*] that correspond to underlying /*t*/'s and those that don't. The relationships are completely opaque. It is not possible to find data to contradict this hypothesis, because a re-analysis of such data is always possible. By the same token, it is equally impossible to rule out alternative hypotheses, such as the ones in (9), or (10).

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[6]According to de Lacy, these are {LLL}, {LHL} and {HLL} base forms inflected in the passive. However, perusal of the example sentences in Bauer (1993) reveals at least one {LHL} form that takes [*a*] rather than [*tia*]: [*whakaʊ̯tua]* 'reply' (p.417:1838). Additionally, some words are variable, both [*maːtakitakitia*] and [*maːtakitakina*] appear at different points in the text for 'watch'-PASS (p.425:1877 and p.493:2210). The same variability is observed for 'love' PASS, appearing as [*arohaɪ̯na*] and [*arohatia*] (p.396;p.399:1757). The former is not the predicted outcome even for an n-final root (*{(*a.ro.ha.*)}{(*ti.na*)}] violates Linearity and Dep, but maintains the proper Prosodic Word structure).

The passive of "throw" is predicted to be *{pa(ŋaɪ̯)a} because of the OCP constraint against adjacent identical elements within the same prosodic word. However, it surfaces as [paŋaa] (p.471: 2112). There are also instances in Bauer of nominalized forms which do not show the allomorphy predicted by the analysis developed for the passive. */taeʊ̯ + aŋa/* , "arrive"-NOM, should surface as *{(*taeʊ̯.a).ŋa*}, but instead is given as [{(*taeʊ̯.ŋa)*}] (p.60:249). The same is true of [{(*paɪ̯.ŋa)*}], "good"-NOM (p.69: 292)."Toss"-NOM is predicted to surface with epenthetic [*t*], but vowel deletion occurs instead, resulting in [*kowhanaŋa*] which must violate either Lapse_{FT}, *Ft-, or some other constraint on prosodic word structure (p.215: 870); a number of words also show variability between different forms in the nominalized. See the Appendix for additional exceptions.

(9)

/mahue + ia/	→[mahuetia]	‘remember’
/hoatu + ia/	→[hoatuŋia]	‘give’
/tonu + ia/	→[tonutia]	‘still’

(10)

/mahuet + ia/	→[mahuetia]	‘remember’
/hoatuŋ + ia/	→[hoatuŋia]	‘give’
/tonut + ia/	→[tonutia]	‘still’

The opaque analysis in (8) represents another standard practice in linguistic analysis, namely: if a pattern *can* be explained via the grammar, then it *must* be explained via the grammar. This assumption allows one to discard the competing analysis in which all observed consonants are underlying and none are epenthesized (10). That analysis fails to predict that *some* {LLL}, {LHL}, and {HLL} roots surface with [*t*] in the passive and nominalized forms[8]. Taken to its extreme, this approach allows the analyst to complicate the hypothesized grammar to any degree necessary provided the additional apparatus predicts even a single additional data point. But this is not a formal aspect of generative phonology, nor is it necessarily a property of language learners (or a desirable property of a learning algorithm).

2.3 Exceptions

If phonological patterns were largely exceptionless, it might be possible to get away with an overwhelming bias towards descriptive adequacy (maximal predictivity). Instead, all patterns are messy, and the distinction, in practice, is

[8] The ones that are not exceptional, and the ones that are not analyzed as containing different consonants underlyingly, like [*hoatuŋia*], an {LLL} root.

between patterns with fewer exceptions and those with more. However, there is no formal procedure for deciding when a given form is an exception (outside of the analysis), and when it is critical counter-evidence (something that must be explained by the analysis).

Plains Cree, an Algonquian language, has been described as epenthesizing [*t*] (Wolfart 1973). This is observed for a number of prefixes in both the nominal and verbal paradigms. See (11a). However, glide formation sometimes results instead (11b); epenthesis of [*j*] or [*w*] (11c); deletion (11d), or coalescence (11e). There are certain instances of [*h*] epenthesis as well, and cases in which sequences of vowels are allowed to surface.

(11) Plains Cree

a)	*/o + astotin/* →	*[otastotin]* 3SG.POSS-cap 'his cap'
b)	*/o + i:ki/* →	*[wi:ki]* 3SG.POSS-home 'his home'
c)	*/wajawi: + a:mo + ak/* →	*[wajawi:ja:mowak]* go.outside-towards-3PL 'they run outside (flee)'
d)	*/ni:pa: + ohte: + w/* →	*[ni:pa:hte:w]* during.the.night-travel-3SG 'He walks in the dark'
e)	*/ko:na + ehk/* →	*[ko:nihk]* snow-LOC 'in the snow'

Depending on one's theoretical position the pattern in Plains Cree may or may not exemplify true epenthesis. The situation is the same for any number of

ambiguous patterns. In fact, in turns out that there exists essentially no example that can be said to represent a completely conclusive case of epenthesis; see discussion of Axininca Campa in Section 3. The evidence from a given language may represent only an “apparent epenthesis phenomenon” by virtue of being restricted in domain (only occurring at morpheme boundaries, for example, as in Axininca Campa, or failing to occur at morpheme boundaries, like Larike. See Appendix); by involving multiple ‘epenthetic’ segments (as in Cree, for example); or by involving multiple ‘epenthetic’ segments if none of them acts as a default (as in Kodava). Other potential disqualifiers include phonetically conditioned variation in the epenthetic segment, the existence of vowel-vowel sequences in other paradigms, or the existence elsewhere in the language of alternations that avoid onset-less syllables via deletion rather than epenthesis (all of which are true of Cree) (Lombardi 2002; de Lacy 2006).

For example, de Lacy (2006), and de Lacy & Kingston (2013) make a distinction between legitimate and non-legitimate epenthesis cases by noting that the latter are “severely morpho-syntactically restricted”, whereas the former apply over “broadly defined morphological domains”. Other diagnostic criteria include whether or not epenthesis is a “preferential repair” or whether “suppletion is rife” within the language. Clearly, terms like “severely”, “broadly defined” , “preferential” and “rife” must rely, at root, on comparing relative instances. Linguistic theory is, in fact, full of counting-based diagnostics, but because they are usually not explicitly quantified they are open to interpretation. Does

“severely” restricted mean the process only applies to a single morpheme? 2 morphemes?10?

2.4 The Evaluation Metric

It is not the primary concern of this paper to establish the ‘right’ theoretical definition of epenthesis. Instead, the proposal is to explicitly and systematically consider how data are, and should be, used to support or challenge linguistic theory. This task is made tractable by simplifying the real-world learning/analysis task within a specific restricted domain.

Many of the diagnostic criteria adopted in this section are similar to those advocated by de Lacy & Kingston (2013). This paper is equally concerned with ruling out alternative hypotheses such as deletion, and drawing attention to data that are ambiguous. There are two major differences, however. The first is the quantification of all relevant variables, and the second is the symmetric treatment of positive and negative evidence. The latter is a departure from the classical generativist assumption that any *possible* predictability *must* be assigned to the grammar.

Consider the case where consonant epenthesis is completely predictable whenever a suffix is attached to a root. In a classical analysis two such languages, one with a rich suffixal morphology, say 10 inflectional morphemes, and one with an impoverished system, say 2, would be identical. If productivity can be assumed, then this is the correct result. However, if the same evidence

must be used to infer productivity, then our confidence in the first pattern should be higher than our confidence in the second.

In practice, an analysis may be called into question if there are too many exceptions, or if an alternative analysis reveals hidden predictability among the exceptions. Crucially, this alternative analysis must be a good one. The goodness of a given analysis relies on both its parsimony and its naturalness – how well it accords with what we currently think we know about phonological patterns. Thus there is an implicit trade-off between the complexity of the analysis and how much data it successfully predicts.

Bayes' Theorem is an obvious first choice for quantifying this trade-off. The descriptive adequacy of a hypothesis is straight-forwardly mapped to the conditional probability of the data under the hypothesis, and the complexity/naturalness term can be captured by the prior probability of the hypothesis. The simplicity and ease of interpretation of the method makes it popular in the field of cognitive science generally (cf. Kemp *et al*. 2007; Tenenbaum *et al*. 2007; Chater *et al*. 2006; Kording & Wolpert 2006; Gopnik *et al*. 2004; Kersten & Yuille 2003; Tenenbaum & Griffiths 2001). Probabilistic models of this kind are being adopted more and more in linguistics as well (see, for example, Jarosz, 2006; Riggle, 2006; Wilson & Hayes, 2008; Goldsmith & Riggle, 2010; Zuraw, 2010). Unfortunately, linguistic hypotheses do not necessarily lend themselves to interpretation in mathematical terms, nor do the decision points of mathematical tests necessarily correspond to linguistically meaningful distinctions (see Morley (*ms*): Appendix for an information-theoretic

evaluation of competing stress-assignment grammars).

The two rules “delete C before C”, and “insert C between V’s” on the surface appear to be of roughly the same complexity. In both cases, the environment has to be evaluated. In both cases there is reference to a consonantal target. However, in the deletion case the C must be memorized as part of the UR itself. Thus, for every undergoing word in the lexicon, an additional segment must be memorized. In contrast, the epenthesis rule requires only a single segment to be memorized, the epenthetic consonant[9]. However, it is not known whether the cost of an additional segment within a word of several segments differs from that of an abstract segment forming part of a rule. Nor is there a standard for assessing the costs of exceptions, whether that cost should be a function of the length of the word, or of the number of exceptions already encountered, for example.

A third hypothesis, that speakers adopt a suppletion, or morphological, analysis – memorizing a set of unpredictable allomorphs – requires no rule at all. And if the total number of lexical items that take the inflection is small enough, then it will be ‘cheaper’ than a morphophonological rule, even if that rule is exceptionless (see an early proposal by Hale (1973), expanded upon by McCarthy (1981), and Dresher (1981), Grimshaw (1981), and Lasnik (1981), for rigorous investigation of the evaluation metric in language learning; also Yang (2005) for learning regular and irregular morphological paradigms). Ultimately, human coding costs and memory limitations must be determined empirically (see Summerfield (1981), Goldinger (1996), Remez *et al.* (1997), Clopper & Pisoni

[9] In the absence of universally ranked markedness constraints that determine the segment identity.

(2004), Allen & Miller (2004), and others for evidence of the ability of speakers to store large amounts of linguistic material in memory).

Currently there is no agreement about what constitutes evidence for epenthesis and what does not; this state of affairs makes it impossible to determine what the proper generalizations are, or to assess theoretical claims. At minimum, it is critical that only actual epenthesis patterns be included in a typology of epenthesis. In Section 5 some statistics and decision points will be proposed for the purpose of dividing the languages of the sample into epenthesis and non-epenthesis types. Before doing so, however, two specific languages from the sample will be examined in considerable detail.

3 The Benchmark

It turns out that both Axininca Campa and the Altaic language Buryat provide considerably more, and considerably more consistent, evidence for epenthesis than do most of the other languages of the sample. Thus, they will give a sense of the minimum amount of variability to be expected in natural language epenthesis. Additionally, they will serve as benchmarks for developing a quantitative diagnostic of epenthesis that can be applied to the rest of the languages of the sample.

The morphophonology of Axininca Campa has been previously analyzed by various authors, with varying conclusions (McCarthy & Prince 1994; Lombardi 2002; de Lacy 2006). Not all of these treatments present, or include within their analysis, exactly the same set of data. Since the goal of this paper is to remain as agnostic as possible about the theoretical status of epenthesis, the focus is on

making available all *potentially* relevant data for consideration. This full set is given in Table 2 (as well as the Appendix). What these data show is that there is strong evidence for [*t*] epenthesis in Axininca Campa, but that the process is also restricted in many domains, absent in others, and subject to exceptionality.

In Table 2 documented surface forms are given. Additionally, a rule-type notation is used to indicate a process by which underlying forms are transformed to surface forms. This is used only to indicate the choice of underlying forms (or inputs) that allow the epenthesis analysis. To be clear, this is not a claim that epenthesis is the correct analysis of the pattern. It is an inventory of all data that are consistent with an epenthesis analysis. Only once the totality of all such evidence is considered will we be in a position to assess whether it is sufficient to justify an epenthesis analysis.

All positive evidence (morphemes that can be counted towards an epenthesis analysis) appear on the left-hand side of the table, with the hypothesized URs; all evidence inconsistent with the given epenthesis analysis, on the right. The URs, in the latter case, are chosen to be consistent with those used on the left-hand side of the table.

[*t*] epenthesis has been claimed by both Payne (1981) and Spring (1990) to be a general process in Axininca Campa. However, since exceptions were found – here, and throughout the sample – all affixes were checked. Checking involved, at minimum, finding a form composed of a given affix in an epenthesizing environment, and a form composed of the same affix in a non-epenthesizing environment. The latter is provided in the row directly below the

former for comparison. If this minimum evidence could not be found for a given morpheme, that morpheme was not included in the table (as evidence either for or against epenthesis).

Table 2
Axininca Campa Epenthesis Evidence (Payne 1981; Spring 1990)
The first line under each header contains a form composed of the listed affix in an epenthesizing environment; the next line, a form composed of the affix in a non-epenthesizing environment. Multiple page numbers for a single line usually correspond to data taken from a text, and indicate the location of transcribed surface forms, the provided morphological analysis, the gloss, and the translation. Numbers in parentheses correspond to line numbers.

Axininca Campa: Arawakan [Payne 1981]						
t Insertion			**Other**			
Verbal Suffixes						
Reflexive			**Interruptive**			t͡s
/ir + oti + a/→[hotita]	"he got in (put himself in)"	p.126	/pi + N + koma + ima + i/ [piŋkomat͡simati]	"(you) ready to paddle"	p.123	
cf. /ir + t͡ʃʰik + a/→ [it͡ʃʰika]	"he cut himself"	p.126	cf. /pi + N + t͡ʃʰik + ima + i/ →[pint͡ʃʰikimati]	"(you) ready to cut"	p.123	
Perfect			**Non-Future**			
/no + na + ak + i + ro/→ [nonatakiro]	"I have carried her"	p.109	/no + pisi + i/ [nopisit͡si]	"I swept"	p.122	
cf. /ir + t͡ʃʰik + ak + i + ro/ →[it͡ʃʰikakiro]	"he has cut her"	p.234	cf. /ir + t͡ʃʰik + i + ro/ →[it͡ʃʰikiro]	"he cut it"	p.116	
Progressive			**Adverbializer**			Hiatus
/ir + oti + at͡ʃ + a/→ [hotitatʃa]	"he is getting in"	p.31	/t͡sʰirinii + iti + ini/→ [t͡shiriniitiini]	"at night"	(13) p.177 p.185 p.198 p.220	
cf. /ir + t͡ʃʰik + at͡s + i/→ [it͡ʃʰikiat͡si]	"he is cutting"	p.233				
Departure			**Velar glide deletion**			
/ir + impoi + it͡sʰi + an + ak + a/→[himpoit͡sʰitanaka]	"he followed along behind, in addition, departing"	p.44 p.191 p.209	/ir + aɯ + ak + i + ro/→ [haakiro]	"he has taken it"	p.116	Hiatus
cf. /ir + kant + aβ + ak + aɯ + aij + an + ak + a + ni/→ [ikantaβakaijanakani]	"they said to one another, departing"	p.41 p.188 p.204	cf. /ir + aɯ + aij + ro + ni/ →[haɯaijironi]	"they took it"	p.116	
Modal Plural						

/ir + N + pisi + aij + i + ni/ →[impisitaijini]		“they will sweep”	p.150	/ir + N + pisi + aij + i + ni/ →[impisiijini]	“they will sweep”	p.150	Deletion
cf. /ir + N + t͡ʃʰik + aij + i + ni/ →[int͡ʃʰikaijini]		“they will cut”	p.150				
Reduplicative (CVCV template)							
ta	/na + RED + βai + ak + i/ →[natanataβaitaki]	“he has continued to carry more and more”	p.143	/aasi + RED + βai + ak + i/→ [aasi aasiβaitaki]	“he has continued to meet more and more”	p.144	Hiatus
Dative				**Distributive**			Deletion
/ir + N + koma + ako + i/→ [iŋkomatakoti]		“he will paddle for”	p.108	/ir + impoi + it͡sʰi + an + ak + a/→ [himpoit͡sʰitanaka]	“he followed along behind, in addition, departing”	p.44 p.191 p.209	
cf. /ir + N + t͡ʃʰik + ako + i/ →[int͡ʃʰikakoto]		“he will cut for”	p.108				
Repetitive				cf. /no + tʰoŋk + it͡sʰi + a + ro/→[notʰoŋkit͡sʰitaβo]	“I finished it also (in addition)”	p.44 p.187 p.200-201	
/ir + N + koma + aa + i/ [iŋkomataati]		“he will paddle again”	p.108				
cf. /pok + aa + i/→[pokaat͡ʃi]		“came again”	p.43	**‘Recently’**			
				/iʃaaβi + iti + ini/→ [it͡ʃaaβiitiini]	“(the sun) getting low”	(142) p.180 p.191 p.208	
Future				**Reflexive Future**			tʃ iija ija ja
/ir + N + koma + i/ [iŋkomati]		“he will paddle”	p.108	/ir + N + kisi + ia/ [iŋkisitʃa]	“he will comb himself”	p.129	
cf. /ir + N + t͡ʃʰiki + i/ →[int͡ʃʰiki]		“he will cut”	p.108	cf. /ir + N + t͡ʃʰik + ia/→ [int͡ʃʰit͡ʃa]	“he will cut himself”	p.129	
Infinitive							
/koma + aantsʰi/ [komataantsʰi]		“to paddle”	p.55	/ir + N + kimi + ia/→ [iŋkimija]	“he will hear himself”	p.129	
cf. /t͡ʃʰik + aant͡sʰi/→ [t͡ʃʰikaant͡sʰi]		“to cut”	p.55				
Receiving				Nominal Suffixes			
/ir + kant + βi + aβ + aɯ + a + ri/→[ikantaβitaβaari]		“he said to the one arriving”	p.47 p.188 p.203	**Diminutive**			
				/hito + iriki/ [hitoiriki]	“little spiders”	p.110	
cf. /no + ɲ + aβ + ak + i + ri + ta/→[noɲaaβakiriita]		“I will see”	(85) p.179 p.189 p.205 p.223	/sampaa + iriki/ [sampairiki]	“little balsas”	p.141	Fusion

Resolved			**'Drink'**			
/ir + aa + aɯ + i/→[aatai]	"he will go back"	p.46	/siŋki + a/ [sint͡ʃa]	"corn drink"	p.128	t͡ʃ
cf. /ir + kant + βi + aβ + aɯ + a + ri/→[ikantaβitaβaari]	"he said to the one arriving"	p.47	/kimi + a/ [kimija]	"squash drink"	p.128	j
Passive			Verbal/Nominal Prefixes			
			1st person singular			
/ir + ii + ai + i + ri/→ [hiitait͡siri]	"that which is named"	p.40 p.196 p.216	/no + ir + i/→[niri]	"I will drink"	p.78	Deletion
cf. /ir + t͡ʃʰik + ai + ak + i + ro/→[it͡ʃʰikaitakiro]	"it was cut"	p.40	cf. /no + saik + i/→[nosaiki]	"I will sit"	p.78	
Purpose			**2nd person singular**			
/no + ojaa + asi + a + ri/→ [nojaatasitari]	"I followed (for the purpose of visiting)"	p.43 p.193 p.212	/pi + iitʰoŋki + i/→ [piitʰoŋkiti]	"you will climb"	p.78	
cf. /ir + kant + asi + a/→ [ikantasita]	"he said (trying very much)"	p.43 p.190 p.270	cf. /pi + saik + i/→[pisaiki]	"you will sit"	p.78	
Reason			**3rd person singular female**			
/βi + tʰa + ant + ap + aɯ + ak + a/→[βitʰatantapaaka]	"therefore he greeted on arrival"	p.43 p.193 p.212	/o + aat͡sik + i/→[aat͡siki]	"she will step"	p.78	
cf. /ir + t͡ʃʰik + ant + aɯ + or + i/→[it͡ʃʰikantaɯori]	"that he cut it"	p.116	cf. /o + saiki + i/→[osaiki]	"she will sit"	p.78	
Time: Early			**1st person plural**			
/o + ɲaa + aman + i/→ [oɲaatamani]	"it dawned (early)"	p.42	/a + ook + i/→[ooki]	"we will abandon"	p.78	
			cf. /a + saiki + i/→[asaiki]	"we will sit"	p.78	
'There and back'			**Plural animate**			
/pi + nosik + ako + aki + i + na/→[pinosikakotakitina]	"(if) you help me pull (there and back)"	(22) p.177 p.185 p.199 p.220	/piront͡si + iti/→[piront͡siiti]	"lightning bugs"	p.181 p.192 p.210 p.225	Hiatus
cf. /a + arii + ant + aki + ia/→[ariitantakit͡ʃa]	"we will go visit and come back"	(4) p.181 p.193 p.211 p.226				
Reciprocal						
/arii + aβ + ak + aɯ + ia/→ [ariitaβakaija]	"have arrived to each other (visited)"	p.41 p.193 p.211				
cf. /ir + kant + aβ + ak + aɯ + aij + an + ak + a + ni/→	"they said to one another, departing"	p.41 p.188 p.204				

[ikantaβakaijanakani]			

Table 2 lists at least 17 verbal suffixes that were verified as consistent with a [*t*] epenthesis analysis[10]. Additionally, there were a handful of verbal suffixes that were exceptions to this pattern. The Reflexive Future illustrated an unpredictable pattern of multiple allomorphs (suppletion). The Non-Future and Interruptive showed epenthesis of an affricate ([*tʃ*] or [*ts*]) – or else a localized pattern of post-epenthesis affrication/palatalization. The Adverbializer produced hiatus when suffixed to vowel-final morphemes. The Distributive and the suffix denoting recency underwent deletion in those environments. The Modal Plural exhibited variation between epenthesis, and deletion that resulted in hiatus. Finally, a process of velar glide deletion produced surface forms exhibiting vowel hiatus.

Table 2 also shows that for suffixes in the nominal paradigm vowel hiatus is either tolerated, results in coalescence (with -/*iriki*/), epenthesis of [*tʃ*], or epenthesis of [*j*] (with -/*a*/). The evidence from reduplication is ambiguous, as [*ta*] is inserted when the reduplicant is too short to satisfy the required template, but no repair occurs when vowel-initial roots are reduplicated (or else the person prefix /*n*/- is repeated when an onsetless syllable would otherwise result).

[10] The set of verbal suffixes for which I was unable to find the relevant forms in Payne (1981): Arrival: -/*ap*/, 1SG.INCL.OBJ: -/*ai*/, Causative: -/*ak*/, Rapid: -/*apaint*/.

Furthermore, in the domain of prefixation, underlying VV sequences typically undergo deletion of the first vowel of the sequence.

It is clear from this evidence that if epenthesis occurs in Axininca Campa then it has a restricted distribution. The question is exactly how this restriction is defined, and whether it is consistent with what is considered diagnostic of epenthesis. A description of the pattern as epenthesis confined to verbal suffix boundaries reveals a morpho-syntactic conditioning which, under certain diagnostics disqualifies the pattern as epenthesis proper (see de Lacy and Kingston, 2013 and de Lacy, 2006). There are also certain verbal suffixes that do not show the expected pattern. Furthermore, sequences of vowels do surface in many Axininca Campa words, in violation of a putative constraint against onset-less syllables.

Despite these qualifications, Axininca Campa provides some of the most robust evidence for epenthesis in the collected sample. For most other languages, the number of observed instances is lower, the number of exceptions is higher, and the domain is more limited. Unless we are content with ruling out epenthesis altogether our criteria cannot be too strict. Minimally, what this will require is determining the point at which acceptable irregularity becomes unacceptable morpho-syntactic conditioning. This will necessitate counting instances; and it will become clear shortly that exactly how the counting is done will affect conclusions regarding the strength of evidence for epenthesis in this, and other languages.

As a direct point of comparison, Buryat has been described as exhibiting [*g*] epenthesis by Poppe (1960) and Rice (2005) (although de Lacy 2006, and de Lacy & Kingston 2013 argue against this analysis). The evidence for and against the epenthetic analysis has been culled from Poppe (1960) and is presented in Table 3. The pattern is complex but phonologically conditioned. In situations of vowel hiatus two different dominant outcomes arise: when the first vowel is short, it deletes; and when the first vowel is long, [*g*] is epenthesized. It should also be noted that what Poppe calls a general phonetic process applies in Buryat which causes the hypothetical epenthetic segment to surface in the following forms: [*g*] before front vowels; the uvular fricative [ʁ] between back vowels, and the uvular stop [ɢ] after front and before back vowels. [*k*] is also described as an allophone of /*g*/ in other contexts. A separate voiceless aspirated velar stop is listed as a marginal phoneme that only occurs in loanwords. Vowel harmony applies, altering the forms of most suffixes.

Table 3
Buryat Epenthesis Evidence (Poppe 1960).
The first line under each header is a form composed of the listed affix in an epenthesizing environment; the next line, a form composed of the affix in a non-epenthesizing environment (unless a suppletive pattern is being described).

Buryat: Altaic [Poppe 1960]						
g Insertion			**Other**			
V: + V						
Nominal Suffixes						
‘of/belonging to’						Suppletion
/ʃere: + ai/→[ʃere:gei]	“of the table”	p.36	/axa + i:n/→[axi:n]	“of the elder brother”	p.36	
cf. /mal + ai/→[malai]	“of the cattle”	p.36 p. 119	/zygi: + n/→[zygi:n]	“of the bee”	p.36	

Reflexive Possessive attached to oblique stem						
/taxaː + aː/→[taxaːgaː]	“own hen”	p.46	/axa + jaː/→[axajaː]	“own tree”	p.46	
cf. /gar + aː/ →[garaː]	“own hand”	p.46	/modon + jaː/→[modojoː]	“own eldest brother”	p.46	
cf. /gar + haː/→[garhaː]	“from the hand”	p.37				
‘along, over’ with reference to motion			Direct Object			
/saː + uːr/→[saːguːr]	“along that side”	p.105	/zygiː + iːji/→[zygiːji]	“the bee” D.O.	p.37	Deletion
cf. /saː + ʃa/→[saːʃa]	“on that side”	p.105	cf. /nojon + iːji/→[nojonːji]	“the prince” D.O.	p.32	
cf. /urda + uːr/→[urduːr]	“along the front side”	p.105				
Reflexive Possessive with pure-relational suffix -tai						
/noxoi + tai + aː/→ [noxiotoigoː]	“together with one’s own dog”	p.47	/morin + tai + jaː/→ [moritojoː]	“together with one’s own horse”	p.47	Suppletion
Adverb from adjective						
/amʒaltatai + aːr/→ [amʒaltataigaːr]	“successfully”	p.104				
cf. /tyrgen + aːr/→ [tyrgeneːr]	“quickly”	p.104				
Instrumental			Plural			
/noxoi + aːr/→[noxoigoːr]	“by means of the dog”	p.21	/mori + d/→[morid]	“horses”	p.34	
cf. /mal + aːr/→[malaːr]	“by means of cattle”	p.39	/ang + uːd/→[anguːd]	“wild animals”	p.34	
			/xʲyrøː + nuːd/→[xʲyrøːnuːd]	“sows”	p.34	
			/axa + nar/→[axanar]	“eldest brothers”	p.35	
Verbal Suffixes						
Perfective gerund			Causative			Suppletion
/uː + aːd/→[uːgaːd]	“having drunk”	p.71	/hun + gaː/→[hungaː]	“to stretch out”	p.99	
cf. /oʃo + aːd/→[oʃoːd]	“having gone away”	p.71	/jaba + uːl/→[jabuːl]	“to make go”	p.100	
cf. /oʃo + ʒa/→[oʃoʒo]	“(while) going away”	p.70	/uː + lga/→[uːlga]	“to make drink”	p.100	
cf. /jaba + ʒa/→[jabaʒa]	“(while) walking”	p.70				
Present imperative: categorical order given to a single person						
/xyleː + iːʃ/→[xyleːgiːʃ]	“wait indeed!” 2 sg	p.60				
cf. /jaba + iːʃ/→[jabiːʃ]	“go indeed!” 2 sg	p.60				
Future						
/xyleː + uːʒab/→[xyleːgyːʒeb]	“I shall wait”	p.60				
cf. /xyleː + nab/→[xyleːneb]	“I wait” PRES	p.57				
cf. /jaba + uːʒab/→[jabuːʒab]	“I shall go”	p.58				
Future imperative						

/xyle: + a:raiʃ/→[xyle:ge:reiʃ]	"wait!" (later) 2sg	p.60	
cf. /jaba + a:raiʃ/→[jaba:raiʃ]	"go!" (later) 2sg	p.60	
Verbal noun of the imperfect			
/bai + a:/→[baiga:]	"he/it was"	p.114	
cf. /jaba + a:/→[jaba:]	"he went"	p.63	V+V:
			Deletion

The epenthesis pattern is observed for certain nominal suffixes, such as the Instrumental. However, there are other morphemes for which suppletive allomorphy results instead (such as the Plural), and others that show a pattern of deletion (such as the Direct Object). The balance of evidence in the nominal domain is not entirely clear since for many suffixes no long-vowel final stem inflections are provided in the source[11]. In verbal suffixes, however, the epenthesis pattern is almost completely exceptionless, with only the Causative failing to conform[12].

De Lacy and Kingston (2013) argue against an epenthetic analysis in Buryat for the following reasons. Firstly, they state that the pattern is "severely morpho-syntactically restricted". The second argument refers to the default status of the process. Since "deletion is clearly the preferred repair" in Buryat, and "suppletion is rife", [*g*] epenthesis is not the correct analysis.

[11] *-/u:ʃan/* 'of occupation or indication of social group' (p.87); *-/a:ling/*, *-/a:rxin/*,'collectives' (.p87); *-/a:xai/*, *-/u:l/* 'suffixes of the actor' (p.89), *-/a:ri/*, *-/u:r/* 'suffixes of the instrument' (p.89); *-/u:ri/* 'suffix of place of action (p.89), *-/a:l/*, *-/a:n/*, 'suffixes of the act' (p.89), *-/a:/*, *-/a:rga/*, *-/a:dahan/*, *-/a:han/* 'suffixes of the result and object of action' (p.90), *-/a:d/* 'distributive (for numerals) (p.94), *-/u:/*, *-/u:xai/* 'adjectives from verbs (p.96).

[12] No alternations are provided for the 2nd person verbal nominalizer *-/a:ʃa/* (p.67), or the passive *-/a:tai/* (p.64).

From Table 3 it can be seen that many forms are, in fact, consistent with an epenthesis analysis. However, if one takes all root+suffix environments as the domain then there are numerous exceptions in the nominal domain, and short-vowel final roots as a class must be deemed exceptional. Deletion occurs between short-vowel final verb roots and long-vowel initial verbal suffixes in Buryat (Poppe (1960) states that no short-vowel initial suffixes attach to vowel-final stems). If short-vowel final verbal stems are more common than long-vowel final verbal stems then there are more possible environments for deletion than epenthesis. However, even if this turns out to be the case it is not obvious that it should lead to the conclusion that deletion is the preferred repair in Buryat, especially as these are two clearly distinct phonological environments.

As far as suppletion goes, Buryat does seem to have a large number of inflectional alternates, with as many as 16 different suffixes for forming adjectives from verbs, depending on the particular verb. However, if one of these forms is long-vowel initial then it is almost always listed with a *g*-initial alternant that is phonologically conditioned. Because the long-vowel initial allomorph only attaches to a subset of all possible morphemes, the scope of the epenthesis process is smaller than it would otherwise be. However, as far as can be determined from the source, the process is productive within that scope. Furthermore, this kind of suppletion appears to be largely absent from verbal conjugations, a domain that de Lacy & Kingston do not discuss.

Like Axininca Campa, if epenthesis occurs in Buryat it exhibits a restricted distribution. Under different theories of the proper diagnostic of epenthesis one or

both languages may qualify as epenthetic. Some possible diagnostics will be presented shortly. First, to more easily compare the two languages I will define a set of dimensions. The maximally participating grammatical domain [MPD] is taken to be the *largest* domain with the *best* evidence for epenthesis. Without making a decision ahead of time about what constitutes an acceptable domain, this explicitly allows the best evidence to be selected for each language. The choice will be constrained by the necessity that the domain be defined on *some* linguistic basis, although that basis is not required to be strictly phonological. Relative to the MPD four types of morphemes are defined: morphemes that surface consistently with the epenthesis pattern are “participating morphemes” (PM); morphemes whose reflexes are not consistent with epenthesis, even though they meet the prosodic requirements, are “exceptions” (EX); sub-parts of otherwise regularly epenthesizing paradigms that display idiosyncratic behavior are “irregularities” (IRR). Finally all morphemes in the language, without reference to the MPD, that are not consistent with an analysis of epenthesis despite meeting prosodic requirements are “non-participating” (NP).

Converting the evidence from Table 2 gives a tally for Axininca Campa of a least 17 participating morphemes (with verbal suffixation as the MPD). The Modal Plural exhibits variation between forms consistent with epenthesis and forms that are consistent with deletion. It is counted towards the total number of participating morphemes, but also counts as an irregular. In the worst case, there are 6 exceptions, and 13 non-participating morphemes (the 5 verbal suffix exceptions, along with verbal reduplication, plus 2 nominal suffixes, and 5 verbal

prefixes). In the best case, however, the surface affricates in the Interruptive and Non-future can be analyzed as underlying /*t*/'s that are affricated by a later rule.

This analysis results in 19 participating morphemes, 4 exceptions, and correspondingly, 11 non-participating morphemes. From Table 2 we see that instances of onset-less syllables are attested in Axininca Campa. These can occur at the beginnings of words, and as the result of velar glide deletion. Like non-participating morphemes, these words could be used to argue against the default status of the epenthesis process. However, this type of exceptionality was observed in all languages, and so is of limited utility in comparing patterns across different languages; thus the decision was made not to include such data in the epenthesis diagnostic.

For Buryat, the MPD can be taken as verbal suffixation involving long-vowel final roots. For this MPD, the data in Table 3 show a total number of 5 participating morphemes, no irregular forms, and 1 exception. Non-participating forms must include the short-vowel final roots. Again, there are options for how to count these. Each individual morpheme could be counted, or they could be counted as a single class. Poppe (1960) does not provide an inventory of these morphemes, so at least in part for pragmatic reasons, they will count once, resulting in a total of 4 non-participating forms (2 Nominal, 2 Verbal)[13]. If, instead, the MPD is taken as all suffixation involving long-vowel final roots, then the numbers change to 11 participating morphemes, 3 exceptions, and 4 non-

[13] All numbers provided are conservative estimates. A given suffix is only listed if the relevant surface forms are actually transcribed in the source. The most liberal estimate, with the largest MPD, including the 19 undetermined suffixes in Buryat, and the 4 in Axininca Campa, would place the largest *possible* number of participating morphemes as 21 in Axininca Campa, and 30 in Buryat.

participating forms. In this domain, 4 irregulars are counted: the Genitive, Reflexive Possessive attached to Oblique Stem, and Reflexive Possessive attaching to –tai. For each of these inflections there exists a subset of forms that surface consistently with an epenthesis analysis, as well as a subset of forms inconsistent with that analysis.

Defining quantitative metrics that are unambiguously interpretable is clearly not a trivial task. Furthermore, it is necessary to make a decision regarding how to combine these metrics into a single diagnostic. Each choice represents a theory of learning, and of analysis. A theoretical decision has been made, as well, in choosing the set of statistics to keep track of. This is partially principled and partially pragmatic. The assumption is that the chosen statistics are reasonable proxies for a measure of productivity. The decision to count morpheme types rather than tokens, however, is driven largely by the fact that token counts are not available for most of the languages of the sample. Similarly, equating 'dependent' stem types, or the class of vowel-initial roots, to a single morphological class, or counting the process of reduplication, or of compounding, as a 'single-morpheme' exception are *ad hoc* decisions made in the service of implementation. A single lexical form that deviates from a majority pattern, as well as multiple sub-classes of forms that deviate from a minority pattern are classified as irregulars. This is also a pragmatic decision, but one that biases counts towards an epenthesis analysis.

One theory of hypothesis selection is that the relative goodness of each hypothesis is determined only by its performance within the MPD. That is, non-

participating morphemes in other domains are ignored by the learner. Perhaps further the correct metric for diagnosing epenthesis is not simply the total number of participating morphemes, but the ratio of participating morphemes to exceptions. In that case, Axininca Campa can be represented by the ratio 19:4; and Buryat, by the ratio 5:1. A different theory diagnoses epenthesis by comparing participating morphemes to all non-participating morphemes – choosing the MPD based on largest number of participating morphemes rather than ratio. Axininca Campa becomes 19 versus 11 with respect to epenthesis; Buryat, 11 versus 4.

There are innumerable theories of epenthesis that can be defined based on the common constraints that the pattern should be grammatically constrained, phonologically conditioned, and regular. They all produce numerically different results, and thus potentially answer the question regarding the presence of absence of epenthesis differently. At the very least, this result indicates that without exacting descriptions of how the counting should be done application of a given theory of epenthesis will be extremely ambiguous.

For example, de Lacy and Kingston's diagnostic of epenthesis relies heavily on the concept of Phonological Domain. But, beyond the generally accepted members of the Prosodic Hierarchy, there exists no clearly formulated definition of this unit that I am aware of (see Selkirk (1986) on derived Phonological Domains). They seem to consider Root+Suffix and Prefix+Root to be proper Phonological Domains, but not Long-Vowel Root+Suffix, despite the fact that the difference between long vowels and short vowels is often

prosodically significant. Functionally, however, it seems that Phonological Domain is defined primarily by observation; thus any domain within which a phonological process is observed to be restricted is a possible Phonological Domain.

The MPD is based on this broadest interpretation, largely for simplicity's sake. Any explicitly defined and consistently applicable unit will serve as well. Reference to Phonological Domains is nto precluded, provided such domains are explicitly defined. The aim here is to demonstrate what the linguistic evidence for epenthesis looks like when directly compared across languages, and under a single diagnostic.

4 The Typology Revisited

In this section statistics are presented on the entire sample of 56 language patterns. Axininca Campa and Buryat offer some of the most robust evidence for epenthesis in this sample, which means that if they are taken to be questionable examples of epenthesis, then most of the sample will be questionable as well. In Section 5 a number of possible diagnostics are considered. However, a significant portion of the sample can be eliminated prior to this decision. The criteria for doing so have been alluded to previously, but are now explicitly defined.

The full typological sample was constructed in the following way. A subset of the references cited in de Lacy (2006), Lombardi (2002), and Vaux (2001) were used as a starting point for collecting patterns. Additional sources

beyond those cited were consulted as needed. In most cases, at least one grammar was found with sufficient detail to assess the robustness of the proposed pattern. Table 4 indicates the range of epenthetic segments that have been proposed by the above authors (and a few others). The languages analyzed in this paper are indicated by underlining. Not every pattern was investigated, but every effort was made to include each proposed case of [*t*] and [*k*] epenthesis in order to provide the most data for the markedness claim under investigation.

Additionally, a search was performed on the P-base database (Mielke 2007) using the keywords “hiatus” and “insert”. In total, about 130 languages were listed; of these, a large number were instances of vowel epenthesis; another subset was not clearly prosodically conditioned; and others of the languages were already present in the sample. Of the remainder, the vast majority were listed as involving epenthesis of one or more of the set of {*j,w,v,h,ʔ*}. In total, only 10 languages were listed as involving other segments: {fricative*,r,d,n,l,m*}. Of the total set of consonant epenthesis candidates, 7 were included here; these were selected at random, and happened to all involve glide epenthesis. Finally, additional languages were acquired fortuitously as the author encountered citations in various sources. The final sample was comprised of 56 distinct patterns from 53 different languages.

Table 4
Proposed consonant epenthesis languages by segment. Underlined languages were investigated by the author and appear in the Appendix.

Seg	Language	Seg	Language
t	Axininca Campa, Maori, Odawa Ojibwa, French, Amharic, Plains Cree, Maru, Finnish, Korean, Kodava	j	Turkish, Uyghur, Greenlandic, various Indic languages, Arabic, Slavic, Tamil, Kodava
k	Maru,Kodava	h	Ayutla Mixtec, Chipewyan, Huariapano, Slave (Bear Lake, Hare), Tigre, Tucanoan, Yagua,Yucatec Maya, Huaripano, Onondaga
g	Mongolian; Buryat	w	Abajero Guajiro, Greenlandic, Arabic, Chamicuro, Tamil
r	English, German, Uyghur, Zaraitzu Basque, Seville Spanish, Anejom, Japanese, Southern Tati	$ʔ$	Chadic, Cupeno, Larike, Misantla Totonac, Mohawk, Tsishaath Nootka, Hawaiian, Arabic, Selayarese, German, Ilokano, Czech, Kisar, Malay, Koryak, Indonesian, Gokana, English, Konni,Tunica, Tubatulabal, Nancowry, Tamil
n	Korean, Greek, Dutch, German dialects, Sanskrit, Murut, Tunica	x	Land Dayak
l	Bristol English, Midlands American English, Motu	$ʃ$	Basque dialects
v	Marathi	$ʒ$	Cretan and Mani Greek, Basque dialects
b	Basque dialects	$ŋ$	Buginese
s/z	French, Land Dayak, Dominican Spanish	$ɴ$	Inuktitut, East Greenlandic, Uradhi, Kaingang

It is important to note that this sample is very much *not* a random sample of languages. It is a sample designed to find the maximum number of true epenthesis patterns by investigating only languages where previous researchers have claimed to observe epenthesis patterns. All available data were reanalyzed by the author, paying particular attention to the number of instances illustrating each pattern, as well as the exceptional and contradictory data. However, in some cases very few data were available from the cited source (and sometimes, even from additional sources). The full set of data used for analysis for each of

the languages in the following tables is available in the appendix (in alphabetical order by language).

4.1 Diagnostic Criteria

The question for each pattern is always whether the evidence is sufficient to support an epenthesis analysis. In (12) are listed the criteria on which the languages of the sample were assessed. These criteria will be considered definitional of epenthesis for the purpose of homogenizing the sample such that the diagnostics can be applied uniformly. A language that fails to meet any of these criteria is automatically disqualified as epenthetic.

(12)

C1. Minimal Repair to satisfy ONSET
C2. Synchronically active [morphological alternations]
C3. Single epenthetic segment (default)
C4. Satisfies Coincidence Condition

C1 requires surface prosodic conditioning, specifically to satisfy a hypothesized onset constraint (alternatively, to break up vowel sequences)[14]. Minimality requires that epenthetic material consist of a single consonantal segment, so epenthesis of a CV syllable, for example, to satisfy a template or minimal-word requirement, will be excluded from consideration. At absolute minimum, analysis of an epenthetic consonant requires an observed alternation between C and ∅. For Axininca Campa, for example, this involves a vowel-initial suffix attaching to

[14] Note that one consequence of this restriction is to disallow the sequential application of rules that could bleed the epenthesis outcome (see data from Odawa Ojibwa in the Appendix for an example of this). Strict rule ordering is required under the following scenarios: if a given surface form exhibits the environment for a rule but does not undergo, or an undergoing form is transformed by a subsequent rule that obscures the original environment. That is to say, ordering of rules is required if rule application is not transparent. It is not unreasonable to assume that this would present a more difficult learning problem than complete transparency; minimally, it requires the explosion of the hypothesis space from all possible singleton rules, to all possible ordered combinations of those rules. And if there is no learning bias for acquiring ordered rules, then opaque forms may be learned as exceptions – at least initially.

both a consonant-final stem, as well as a vowel-final stem, as in (13). If available, it is preferable to have additional evidence confirming the analysis of the stems as vowel-final and consonant-final, respectively. However, this evidence was not always available in the sample, either in principle, as in the case of Axininca Campa where the data is completely symmetric, or simply because such forms were not provided in the source.

(13) Axininca Campa

/ir + N + kim + i/ →	*[iŋkimi]*
	3SG-FUT-hear-FUT
	's/he will hear'
/ir + N + pija + i/ →	*[impijati]*
	3SG-FUT-avenge-FUT
	's/he will avenge'

It is critical to the arguments of generative theory, as well as those in this paper, that the pattern under discussion be a synchronic one. C2 requires that the linguistic data be convincingly analyzable as the product of an active grammar, and not some other mechanism. While an argument can certainly be made for expecting possible sound changes to be restricted in the same way as possible grammars, this is by no means an accepted conclusion. To avoid the complications arising from these cases, potential epenthesis patterns which are restricted to the diachronic realm are excluded from analysis.

In some cases this is clear, as in Maru, which diverged from other Kachin languages by developing stops word-finally, the place of articulation determined by vowel quality (Burling 1966). In other instances it is not so easy to establish the status of a given pattern. Because static patterns – that is, phonotactic observations over lexical items – may easily be the residue of historic processes,

C2 requires that the candidate epenthesis pattern be realized in morphological environments. C3 requires a single default epenthetic consonant, which rules out cases of assimilative epenthesis, discussed below in Table 7. Finally, C4 represents the heart of the proposal of this paper: a quantitative diagnostic to decide the coincidence condition, and select an epenthesis analysis over the alternatives of deletion and suppletion in a consistent manner. C4 will be considered in detail shortly. Before doing so, it is instructive to apply C1-C3 to eliminating candidate patterns beforehand. That several languages of the sample fail to meet even the first two criteria can be seen in Table 5.

Table 5
Languages of the sample that fail one or more of C1, C2

	Seg.	Language	Criterion failure	Source(s)
1	k	Wolof	C1	Ka (1994)
2	k	Danish	C1	Glyn Jones & Gade (1981) Herslund (2002)
3	t	Odawa	C1	Piggott (1980)
4	t	Maru	C1,C2	Burling (1966)
5	t	Amharic	C1	Broselow(1984)
6	r	Uyghur	C1	Hahn (1991) Hahn (1992)
7	$v/w,j$	Marathi	C1	Wali (2005)
8	t,n	Korean	C1	Renaud (1974) Lee (1998)
9	$ʔ$	Larike	C2	Laidig (1992)
10	$ʔ$	Cairene Arabic	C2	Watson (2002)
11	k	Kodava	C1	Ebert (1996)
12	$j,w,ʔ$	Tamil	C2	Christdas (1988)

Tables 7 and 8 contain the languages that fail criterion C3: no single default epenthetic consonant. All these languages can be analyzed as employing epenthesis of multiple segments. In Table 6, those segments are phonologically unpredictable. Conservatively, the analysis for these languages should be

deletion (or suppletion) rather than epenthesis[15]. This set of patterns is contrasted with those of Table 7 in which the segments are conditioned by phonological context. The language patterns in Table 7 are hypothesized to originate from a different diachronic source (see Morley 2012). In synchronic terms this is "assimilative", as opposed to "default", epenthesis[16].

Table 6
Languages of the sample that fail C3; segments unpredictable

	Seg.	Language	Phonological Domain	Source(s)
13	*t,z,p,n,r,l,g,d*	French	Word boundaries	Tranel (1981)
14	*dj,s,k*	Finnish	Transitive verbal loans	Luthy (1973) Sulkaka & Karjalainen (1992)
15	*h,k,l,m, etc.*	Hawaiian	Passive; Nominalizer	Elbert & Pukui (1979)
16	*j,w,t*	Abujhmaria	Suffixation[a]	Natarajan (1985)
17	*w,j*	Sinhalese	Suffixes belonging to certain declension types[a]	Geiger (1938)

[a] Partially predictable by vowel. See Appendix.

What can also be noted about the set of languages in Table 7 is the fact that only a very small set of segments is involved in this type of epenthesis system: [*w*], [*v*], or [*ʋ*] (sometimes [*h*]) – in back vowel contexts – , [*j*] – in front vowel contexts –, and sometimes [*ʔ*] – usually when the two vowels are identical. An example is the pattern in Malay, illustrated in (14). Under suffixation, when the stem-final vowel is /*u*/, [*w*] is epenthesized (14a); when the stem-final vowel is /*i*/,

[15] The analysis of Hawaiian in de Lacy and Kingston (2013) mirrors their analysis of Maori, with [*ʔ*] rather than [*t*] as the "epenthetic" segment. The ambiguity remains the same, with no independent way to differentiate what de Lacy and Kingston analyze as underlyingly vowel-final roots, undergoing epenthesis in the passive (e.g., [*wela*],[*welaʔia*]), and underlying consonant-final roots undergoing deletion in the present (e.g., [*mala*], [*malahia*]). Furthermore, Elbert and Pukui (1979) describe the [*ʔia*] and [*ʔana*] variants in the passive and nominalized forms, respectively, as particles due to their ability to detach from the root.

[16] The exception to this is West Greenlandic, which is perhaps best described as dissimilative epenthesis: the place of the glide disagrees with the place of the surrounding vowels.

[*j*] is epenthesized (14b); and when the stem-final vowel is non-high, or the two vowels are identical, [ʔ] is epenthesized (14c) (Onn 1976).

(14) Malay

(a)	*/bantu + an/* →	*[bantuwan]* relieve-NOM 'relief'
(b)	*/udʒi + an/* →	*[udʒijan]* test-NOM 'test'
(c)	*/məŋ + gula + i/* →	*[məŋgulaʔi]* ACT-sweet-CAUS 'cause to sweeten'

Such patterns could be described as involving a single underlying segment – namely, a glide unspecified for place. Even under this analysis, however, there are fairly clear differences between these patterns and those of 'default' segments. The degree of assimilation is larger, from front to back, versus the lesser variation from velar, to uvular, for example, or alveolar to palato-alveolar. Additionally, glide segments in epenthetic position are likely to have originated from coarticulation between neighboring vowels, whereas non-glide segments have a different historical trajectory (see, e.g., Blevins 2008).

Table 7
Languages of the sample that fail C3; segment predictable

	Seg.	Language	Phonological Domain	Source(s)
18	*j,w,ʔ*	Malay	Suffixation	Onn (1976)
19	*j,w,ʔ*	Wolof	Suffixation	Ka (1994)
20	*j,w,ʔ*	Guinaang	Suffixation	Gieser (1970)
21	*j,w,ʔ*	Karo Batak	V+V[a]	Woollams (1996)
22	*j,w,ʔ*	Hausa	Certain suffixes	Jaggar (2001)
23	*w,j*	Balangao	V+V	Shetler (1976)
24	*w,j*	Dakota	V+V	Shaw (1980)
25	*w,j*	Ao	V+V[b]	Gowda (1975)
26	*w,j*	Manipuri	V+V	Bhat & Ningomba (1997)
27	*w,j*	Argobba	Suffixation[b]	Leslau (1997)
28	*w,j*	Alywarra	word boundaries[a]	Yallop (1977)
29	*v,j*	West Greenlandic	Prefixation involving three or more vowels[ab]	Rischel (1974)
30	*v,j*	Kodava	Suffixation	Ebert (1996)
31	*ʋ,j*	Malayalam	Suffixation	Asher & Kumari (1997)
32	*j,ʔ*	Ilokano	Prefixes	Hayes & Abad (1989)
33	*w,j,h*	Cairene Arabic	Heterogeneous collection of templates and suffixes	Watson (2002)
34	*ʋ,j*	Dutch	Host+Clitic	Booij (1995)

[a] Optional in all environments.
[b]Not completely predictable by vowel. See Appendix.

As discussed above, almost all languages show some degree of exceptionality, or irregularity, within even a fairly robust epenthesis pattern. It has already been shown that certain morphemes in Axininca Campa make up part of a suppletive allomorphy pattern, for example. And, in Turkish (pattern #53; Table 8), the 3rd Singular Possessive surfaces with a 'ghost' [*s*], and the

Genitive, often with a 'ghost' [*n*]. See (15). Note that Turkish requires agreement on several vowel features within a word, accounting for the alternations on the vowel, which is usually assumed to be unspecified in the input.

(15) Turkish

/baba + I/→	*[babasɨ]*
	Father-3S.POSS
	'his/her father'
/lokanta + In/→	*[lokantanɨn]*
	Restaurant-GEN
	'the restaurant's'

Lack of uniformity is the norm, rather then the exception, and it is particularly true when comparing word-initial and morpheme-boundary environments. In fact, only one language seems to epenthesize in both cases, as well as epenthesize the same segment, Misantla Totonac: [*ʔ*] (Pattern #52; Table 8). Similarly, it is rarely the case that the occasional vowel-initial word or syllable does not arise.

Table 8 gives the subset of the sample that pass criteria 1-3. C4 will be assessed using the set of morpheme types defined in the previous section. For reasons of brevity the irregular forms are left out. In column 4 the maximally participating grammatical domain (MPD) is given, followed by the count of Participating Morphemes (PM) in that domain. The total number of Non-participating Morphemes (NP) – in any domain that meets the prosodic requirements – is listed in the next column. Finally, Exceptions (EX) are defined as those morphemes that fall within the MPD but fail to participate (as defined

previously, and as distinct from lexically irregular items)[17]. The Exceptions will always be a subset of the Non-Participating Morphemes.

Table 8
Languages of the sample that pass C1-C3

	Seg.	Language	MPD	PM	NP	EX	Source(s)
35	/k/	Dakota	3rd personal plural	1	5	0	Shaw (1980)
36	/t/	Maori[a]	Prosodically defined root types in the Passive & Gerund	2	2	2	Hale (1973) Bauer (1993) De Lacy (2003)
37	/r/	S. Tati		1	3		Yar-Shater (1969)
38	/t/	Cree	personal possessive prefixes	14	14	2	Wolfart (1973)
39	/n/	Dutch[b]	ə-final host+clitic	17	3	0	Booij (1995)
40	/k/	Waropen	verbal person prefixes	7	5	2	Anceaux (1961) Held (1942)
41	/g/	Buryat	Verbal Suffixes and long-vowel final stems	5	4	1	Poppe (1960)
42	/t/	A. Campa	Verbal Suffixes	19	11	4	Payne (1981)
43	/ɣ/	Greek	Verbal Suffixes	2	7	1	Newton (1972) Malikouti-Drachman (2009) Joseph & Philippaki-Warburton (1987)
44	/w/	Chamicuro	Prefixes	1	4	3	Parker (1989)
45	/j/	SE Armenian	1-syllable words	4	6	0	Vaux (1998)
46	/j/	Uyghur	verbal suffixes	1	5	5	Hahn (1991) Hahn (1992)
47	/ʔ/	Nancowry	Nominal affixation	1	5	3	Radhakrishnan (1981)
48	/ʔ/	Tsishaath Nootka	V+V	2	4	4	Stonham (1999)
49	/ʔ/	Cupeño	V+V	3	5	5	Crowhurst (1994) Hill (2005)
50	/ʔ/	Selayarese	V+V;V=V	5	1	0	Mithun & Basri (1986)
51	/ʔ/	Tubatulabal	V+V	7	5+	5+	Voegelin (1935)

[17] Even with these explicitly defined terms, there are complications in counting data (see previous section). For a process that occurs only for personal prefixes attached to "dependent" stems, are non-dependent stems exceptions, or non-person prefixes? How should we count entire processes (as opposed to morphemes) that are exceptional in this way, such as a pattern in which epenthesis occurs in compounding, but not reduplication? Is failure of epenthesis to occur in word-initial position a single exception, or should an exception be counted for each vowel-initial lexeme? Even if we had clear answers for those questions, we do not always have access to the necessary data. What this means is that even with the level of explicitness that has been implemented in this paper we can still only hope to provide conditional estimates or ranges. Thus counting itself is open to ambiguity and subject to theory-internal considerations. This is yet another reason to be cautious about universalist claims based on typology.

52	ʔ	Misantla Totonac	V+V	15+	9+	9+	Mackay (1994, 1999)
53	j	Turkish	Suffixation	21	10	10	Underhill (1976) Lewis (1967)
54	j	Berber	Suffixation	7	2	2	Guerssel (1986) Hdouch (2008) Jilali (1976)
55	ʔ	Tamil	compounds	1	0	0	Christdas (1988)
56	ʔ	Malay	prefixation	2	0	0	Onn (1976)

[a]Adopting the analysis of de Lacy (2003). The exceptions listed are exceptions under that analysis. Non-conforming words in the passive and nominalizer are counted as Irregulars, and do not appear in this table. The behavior of compounds with linking –*aa*- and reduplicants are each counted as a single exception since neither appears to undergo epenthesis for any forms, or reflect the predicted prosodic word structure.
[b]Optional variant of three possible repairs.

Prior even to determining a diagnostic threshold, it can be seen that fewer than half of the patterns in the original sample meet basic definitional criteria. This typology of epenthesis diverges quite drastically from the reported secondary sources. With the addition of the quantitative diagnostic the 'attested' epenthesis patterns become fewer still. The exact distribution of this typology will depend strongly on where the threshold for coincidence is set and exactly how the given statistics are used to calculate the coincidence diagnostic. Conclusions regarding the typology of consonant epenthesis will therefore also strongly depend on those factors. However, as will shortly be shown, there is no clear cut distinction that can be made along the coronal/dorsal divide that can be used to devise a diagnostic that consistently passes the former, but consistently fails the latter. This result has ramifications for posited universal laws of markedness.

5 Results

If epenthesis is a possible phonological operation then it is necessary to specify under what circumstances such an analysis will be chosen by the learner under

actual learning conditions, i.e., ambiguous, non-exceptionless input. Without help from a Universal Grammar, this learner cannot automatically rule out certain hypotheses, such as [k] epenthesis. And with or without help from a UG component, the learner must minimally be able to decide that epenthesis is a better analysis than deletion (i.e., that it would be too much of a coincidence that all encountered words either started or ended with the same segment).

Throughout this paper, the model of the learner has been used to motivate the choices of the analyst as well. Under the assumption that the job of the analyst is to deduce the 'correct' analysis of the linguistic data – the actual representations of the native speaker – the grammar in question must be learnable from primary data. Of course, it does not automatically follow that such a learner be substantively naïve. As the well-known Poverty of the Stimulus argument goes, human language is unlearnable from primary data without help from an innate Universal Grammar component. Part of the proof of such a claim, however, must be independent evidence that UG-banned grammars are unattested. If the contents of UG are themselves determined in large part from typology, and the analysis of the typology is determined by assumptions about UG, then there is a clear circularity problem. This paper assumes minimal prior knowledge in order to avoid biasing the results. All language types are assumed to be learnable, although epenthesis might not be the grammar learned under the specific input.

The numbers in Table 8 are meant to provide the means for determining the likelihood of a grammar of epenthesis being acquired[18]. Exactly what to count, how to count it, and how to combine those counts will all be part of a particular theory of learning. This paper has no particular commitments to those specifics. Adoption of different learning models will, naturally, lead to different specific interpretations of the typology. However, certain implications remain relatively unchanged. That is, a decision to diagnose one of the languages of the sample as epenthesis will necessitate the identical diagnosis for certain other languages, and vice versa.

Consider the hypothetical learner who compares the ratio of participating morphemes to all morphemes within the MPD[19], and requires that the value be greater than or equal to 65%. This arbitrarily chosen threshold results in the typology of Table 9, and the following distribution of observed epenthetic segments:

(16) t (2); n (1); k/g (3); r (1); j (2); $ʔ$ (3)

[18] Certain languages in the sample retain a degree of ambiguity even with respect to the proposed quantitative analysis. Take the case of Plains Cree. Prefixes in both nominal and verbal paradigms involve [t] epenthesis, and number 14 in total. It turns out, however, that all the prefixes belong to the class of possessive pronoun, that the verbal prefixes are largely homophonous with the nominal prefixes, and half the forms within a single paradigm involve circumfixation, where the prefixal component is identical with another bare prefix form in the paradigm (see Appendix). This calls into question the uniqueness of these morphemes, and whether they can count equally towards the number of participating morphemes. One might, conservatively, put the count of unique participating morphemes at 3, not 14. The situation is similar for Waropen, where the similarity of the class of person pronouns raises the possibility of a deletion rather than an epenthesis analysis. Furthermore, the [n] epenthesis pattern in Dutch as described in Booij (1995) occurs only for schwa vowel contexts. Additionally, it is only one option among two other possible repairs: epenthesis of [$ʔ$] across word boundaries (when enclitization fails to happen), or schwa deletion.

[19] In general, a straight count of participating morphemes will bias a diagnostic towards languages with richer morphological systems, or even morphological systems for which there are more comprehensive available data. One way to avoid such a bias is to take a ratio as the relevant measure, a ratio, for example, of participating morphemes to total number of morphemes. This will act to normalize the languages to be compared to a certain degree.

This diagnostic reflects something about the generality of the pattern, but it also includes languages like Dakota, for which there is only one attested participating morpheme. Epenthesis in Dakota can only be described as general within the very specific domain of one morpheme. The diagnostic (of both the learner and the analyst) would need to be made more restrictive to exclude this pattern. At the same time, the diagnostic may be too restrictive in excluding languages like Misantla Totonac and Turkish, both of which exhibit very high rates of participation, but which are penalized for being morphologically rich and complex systems.

Table 9
PM/(PM+EX) ≥ .65

	Seg.	Language	Phonological Domain	PM	NP	EX
35	k	Dakota	3rd personal plural	1	5	0
37	r	S. Tati		1	3	
38	t	Cree	personal possessive prefixes	14	14	2
39	n	Dutch[b]	ə-final host+clitic	17	3	0
40	k	Waropen	verbal person prefixes	7	5	2
41	g	Buryat	verbal suffixes on long-vowel final stems	5	4	1
42	t	A. Campa	Verbal Suffixes	19	11	4
45	j	SE Armenian	1-syllable words	4	6	0
50	$ʔ$	Selayarese	V+V;V=V	5	1	0
54	j	Berber	Suffixation	7	2	2
55	$ʔ$	Tamil	compounds	1	0	0
56	$ʔ$	Malay	prefixation	2	0	0

[b] Optional variant of three possible repairs.

As an indirect measure of the size of the domain, one can add a threshold for the absolute number of participating morphemes. The diagnostic that requires a

65% participation threshold, as well as at least a 5 morpheme attestation rate, for example, eliminates patterns with marginal evidence like Dakota, Southern Tati, Standard Eastern Armenian, Tamil and Malay. To include Misantla Totonac and Turkish, a disjoint diagnostic is needed. Such a diagnostic is given in (17).

(17) Epenthesis is considered the best analysis for patterns that have a participation ratio of at least 65% and an absolute number of at least 5 participating morphemes. Otherwise, only patterns with more than 10 participating morphemes are best analyzed as epenthesizing.

The resulting distribution consists of Cree, Dutch, Waropen, Buryat, Axininca Campa, Selayarese, Berber, Misantla Totonac, and Turkish. The epenthetic distribution is given in (18).

(18) t (2); n (1); k/g (2); j (2); $ʔ$ (2)

What is true of both diagnostics is that the number of qualifying languages is quite small. The hypothetical learner classifies the majority of patterns as static lexical features, or as alternations due to deletion, suppletion, or assimilative epenthesis (multiple, phonetically predictable segments). Imposing a quantitative diagnostic reduces the epenthesis typology to only from about 9 to 13 total instances. This small number makes generalizations difficult. It can be seen, however, that [t] epenthesis cannot be said to dominate in either case. There are equal numbers of [t] and [k] epenthesis under both diagnostics, as well as the laxest threshold which passes all languages in Table 8. If [t], [n] and [r] are grouped into a coronal class, then (16) becomes a 5 coronal: 3 dorsal

distribution. (17) gives a 3 coronal: 2 dorsal distribution, and no threshold gives 5 coronal: 4 dorsal. Here there is a numerical coronal advantage, but it is not large.

Under either of the above diagnostics the outcome does not provide overwhelming support for the theoretically universal preference for coronal place of articulation (Kean, 1975; Paradis & Prunet, 1991; de Lacy, 2006)[20]. Under the strictest of these theories, dorsal epenthesis should be altogether impossible – but at least one instance survives under each of the above thresholds. However, one can deliberately set the diagnostic to eliminate all dorsal epenthesis. There are a number of ways to do this, but it will turn out that there is no way to selectively target only the dorsal epenthesis patterns.

One way to eliminate Buryat (one of the strongest dorsal epenthesis contenders) is to make a strict requirement regarding invariable phonetic realization of the epenthetic segment[21]. Keeping only the most basic prosodic requirements (which will continue to rule out the languages in Table 7), but removing all other restrictions, this move will result in the exclusion of both Buryat

[20] This is not to suggest that there might not be evidence for a [*t*] preference in other phonological domains, or that markedness plays no role in grammar, only that the markedness scale in which /*t*/ ⟆ /k/ cannot be argued for on the basis of the epenthesis data presented here.

[21] As mentioned above, the epenthetic segment in Buryat varies in place and manner according to its context: [ɡ] before front vowels; the uvular fricative [ʁ] between back vowels, and the uvular stop [ɢ] after front and before back vowels. I argue that this process is best described as phonetic, rather than phonological, and does not disqualify Buryat from inclusion in Table 8 under C3. This decision is based on the following considerations. The pattern of assimilation is quite distinct from that seen in the languages of Table 7; the varying phonetic surface forms are transparently related to an underlying place of articulation that, at the very least, is further back than coronal. Furthermore, phonetic assimilation is likely to be more pronounced for velar than coronal segments. Many studies find a large coarticulatory influence on velars from following vowels (e.g., Fowler, 1984). This is also reflected in the asymmetrical misperception rates for velars versus coronals (Winitz *et al*., 1971; Plauche *et al*., 1997; Guion, 1998). Thus, an asymmetry between the velar and coronal places of articulation might be expected on phonetic grounds alone, as distinct from the universal phonological principles that are of interest here. Finally, descriptions of phonetic processes are often missing from standard grammars such that our confidence that other languages in Table 8 do not also show similar levels of assimilation should not be overly high.

and Greek – where the segment is contextually realized as [j]. Note that this will also change the numbers for Axininca Campa to 17 participating morphemes, 13 non-participating, and 6 exceptions (changing the affricates to exceptions). However, this does not affect its classification under this diagnostic. As can be seen in (19), this restriction alone does not eliminate all cases of [k] epenthesis, nor does [t] emerge as significantly more likely than other segments.

(19) t (3); n (1); k/g (2); j (4); $ʔ$ (8); r (1); w (1)

There is another strategy that could target Buryat for exclusion: disallowing phonological domains defined by vowel length. Aside from being rather arbitrary, this criterion once again leaves behind Dakota and Waropen as [k] epenthesis candidates. Furthermore, it seems to suggest that any kind of conditioning is out. If so, then epenthesis becomes almost vanishingly rare within the sample.

Another strategy is to deliberately set the absolute threshold of participating morphemes at 8 – although this excludes all but the most morphologically rich languages. The result is the set of languages in (20)[22]. It can be seen that setting the threshold to eliminate [k] epenthesis affects the distribution across the board. While it is true that dorsal epenthesis languages have now been eliminated, the total numbers are considerably smaller than before, making generalizations even less warranted. The situation only worsens

[22] Although, with the MPD chosen as long-vowel final root suffixation, Buryat has 11 participating morphemes.

if we conservatively remove the somewhat ambiguous cases of Cree and Dutch (see footnote 18), leaving only one instance each of [*t*], [*j*] and [ʔ] epenthesis.

(20) Axininca Campa (*t*), M. Totonac (*ʔ*), and Turkish (*j*)

Finally, an attempt can be made to apply the criteria of de Lacy (2006), de Lacy and Kingston (2013) to the languages in Table 8. This will be somewhat speculative as the criteria in those sources are not always explicit. My best guess is that the theory requires that there be no Exceptions (or at least a very small number), and that the number of Non-Participating Morphemes must be below some threshold (such that epenthesis can be designated the default). I also suspect that many of the cases of 'irregularity' would be characterized as suppletion, lowering the total numbers of participating morphemes. Additionally, the relevant domain must not be morpho-syntactically restricted. I am unable to determine how this is defined, only that the authors consider the following to be allowable domains: Root+Suffix, Prefix+Root, Root+Root, Root+Clitic, Prosodic word+Prosodic word, and Reduplication.

In Greek, it appears that deletion is the preferred "repair", which may be true for Tubatulabal suffixation as well. In Tamil the process of epenthesis in compounds is optional, which may disqualify it. However, an epenthesis analysis may be possible for vowel reduplication in Tubatulabal, and reduplication in Nancowry (see Appendix). Prefix+root epenthesis in Malay is not disqualified based on the available evidence.

In terms of having the requisitely low number of exceptions, Berber might qualify; epenthesis can be interpreted as the default despite certain exceptions in

the Root+Suffix domain. Waropen has only a few exceptions to the Prefix+Root pattern. In Plains Cree there are a number of exceptions and non-participating morphemes; however, in the domain of Nominal Prefix+Root, epenthesis is arguably the default. In Misantla Totonac there are roughly as many exceptions as participating morphemes, however, and epenthesis and deletion appear equally supported, but arbitrarily morphologically divided[23]. Turkish has a number of exceptions involving deletion, but many more participating morphemes and would probably qualify. Axininca Campa is allowed as a 'default' epenthesis pattern in the Verbal Root+Suffix domain despite certain exceptions. Buryat, under their accounting, likely counts 4 participating morphemes, and 2 exceptions. Epenthesis is judged not to be the language default, however, by the fact that deletion occurs for all short-vowel final roots. Despite the fact that de Lacy (2003) analyzes Maori as epenthesizing, it is not clear how epenthesis could be characterized as the default for the language. According to the data collected in the Appendix, Maori has as many participating morphemes as exceptions. In the passive and nominalizer, de Lacy (2003) posits an epenthetic [t] under certain prosodic conditions. However, for the same prosodic conditions, epenthesis does not seem to occur in either compounding or reduplication[24]. The final result, I believe, looks like the typology in (21). Unfortunately, the majority of

[23] Despite the fact that Misantla Totonac provides unambiguous epenthesis evidence (over deletion. See (13)). The non-default nature of the pattern calls for a 'suppletion' analysis under de Lacy's theory (what Hale (1973) refers to as a 'morphological analysis').

[24] One can, presumably, find analytic ways to reconcile the surface forms due to reduplication (e.g., aligning the reduplicated form to the left edge of the prosodic word outranks having an onset at the beginning of a prosodic word), and compounding (e.g., deletion is blocked for the linking morpheme –aa- due to a high-ranked faithfulness constraint) but the absence of supporting epenthesis or deletion evidence in these domains should affect our confidence in the generality of the process described in the passive. As far as the question of 'default status' goes, one might reasonably characterize both Hawaiian and Maori as default 'particle' languages since there is very little concatenative morphology in either one.

the represented languages likely only qualify because there were few data on the processes in question; this raises the concern that had more data been available, exceptions and irregularities might have revealed themselves.

(21) t (2); k/g (1); j (2); $ʔ$ (3)

The nature of the epenthesis typology is a product of the particular diagnostic chosen; it is a product of one's theory of epenthesis. And even when those theories seem well-defined the outcome may prove open to interpretation. Typological data is not, in fact, objective data, but what this paper has referred to as 'evidence': the product of a particular analysis applied to data. What this means is that arguments from typology cannot be taken at face value but must be assessed with respect to how they were created. But this does not mean that a typology can be anything at all. There exist quantitative methods to assess the amount of evidence in support of any given analysis, and to decide a competition between two or more possible analyses of the same data.

Using such a statistical method, this section has explored a range of possible interpretations of the typology. Under any of these specific theories the following results hold. Default and productive epenthesis of consonantal segments is rare. Furthermore, little to no preference for any particular segment is observed. Out of the original 56 patterns, 17 fail to meet minimum requirements for epenthesis (Tables 6 and 7); another 17 provide evidence of 'assimilative epenthesis': with multiple, phonetically predictable segments breaking up vowel sequences (Table 7); and only 22 remain as candidates for statistical testing (Table 8). Using the threshold proposed in (17), only 9 of these

languages actually meet the general statistical learning requirements of this paper.

Acceptance of this result means that the case for a universal preference for [*t*] epenthesis (especially over [*k*]) has been greatly over-stated in certain quarters. And, in fact, the case for epenthesis at all (for the given definition of that term), may have been significantly over-estimated as well. Within the margins of sampling error, and under a range of diagnostics, 'impossible' patterns like [*k*] epenthesis are about as likely as the 'preferred' [*t*] epenthesis (and perhaps most other non-approximant segments); but neither are particularly likely at all.

6 Discussion

While remaining agnostic about whether epenthesis in fact has any psychological reality, the goal of this paper has been to set up a reasonably plausible scenario in which a learner *could* learn an epenthesis pattern. Critically, this has been done by directly pitting the epenthesis hypothesis against the deletion hypothesis. This is clearly a simplification of the learning problem, but it effectively illustrates the ambiguity inherent in determining correspondences between surface forms (linguistic data) and what are taken to be underlying forms (linguistic evidence). The current lack of a formal theoretical procedure for this stage of linguistic analysis is what lies at the root of the controversy that persists over whether universalist claims have been falsified or not. This is true

for the question of the existence of dorsal stop epenthesis, as well as the possibility for a preference for codas over onsets (Breen & Pensalfini 1999), lack of syllable structure in general (Hyman 2011), neutralization of stop contrasts to the aspirated (rather than plain voiceless) member of the pair (Vaux & Samuels, 2005), and other 'impossible' phonological patterns.

Within any scientific discipline there will be disagreement about the proper interpretation of data, as well as the theoretical ramifications of a given interpretation. What is critical is that there exists, for any proposed theory, an identifiable set of conditions in the real world which, if they were to obtain, would be generally accepted as falsifying that theory. In other words, the range of disagreement between individual theorists must be constrained in some way.

This paper has been a first attempt to develop a general diagnostic for identifying such conditions regardless of phonological specifics. This diagnostic is based on principles of learnability and bears a strong similarity to probabilistic decision metrics, and statistical tests of significance. I argued that this was necessary for a relatively unbiased learner faced with noisy – non-exceptionless – data, as well as for an analyst faced with the same. The vast disparity between the typological findings of this paper and certain claims regarding that typology should make us wary of universalist claims that are made without reference to the size, constitution, reliability, or analysis of the language sample on which those claims are based.

Additionally, this paper comprises the first part of a three-pronged approach to the study of consonant epenthesis. Given a typology, it must be the

case that that typology was reached through some series of diachronic changes. And, furthermore, that the results of diachronic change were learned by subsequent generations, such that the synchronic grammars of the current generation of speakers reflects the typology.

Morley (2012) maps out some of the logically necessary conditions for a set of diachronic processes to transform into a synchronic grammar of epenthesis (following on work by Blevins, 2008). Based on their historic trajectories, a taxonomy of four different types of synchronic pattern is proposed. The first dimension splits 'pre-epenthesis' patterns from full epenthesis; the first share part of the hypothesized trajectory for epenthesis patterns, and have the potential to become epenthesis in future given the right conditions. The orthogonal dimension of the taxonomy refers to the original source of the pattern: either deletion of pre-final, and pre-consonantal consonants (which requires re-analysis or 'rule inversion'), or failure to compensate for vowel-to-vowel coarticulation. The second route applies to what has been called assimilative epenthesis (Table 7). For full epenthesis systems, the two routes are hypothesized to require the same mechanism: learner generalization, differing only in the identity of the default epenthetic consonant.

The third paper in the series tests the predictions of the learning model via artificial grammar learning experiments performed with human participants (Pepperkamp et al., 2003; Saffran & Thiessen, 2003; Newport & Aslin, 2004; Gerken, 2006; Wilson, 2006; Kapatsinski, 2010, and many others). Preliminary results support the distinction between coarticulation-based and reanalysis-

based synchronic patterns (Morley *in press*). Learners on average are also found to be reluctant to generalize their input. The rarity of non-approximant epenthesis found in the typology, as well as the rarity of default patterns generally is supported by these results.

The three-methodology approach is part of a larger program for testing the emergence of linguistic universals from the processes of language transmission and change. First, the facts to be explained are established; then a model is developed of how such facts might have come about; and finally, experimental tests of that model are conducted. Situating synchronic linguistic analysis within a larger framework involving diachrony, learning theory, and processing offers the chance for new insight into linguistic competence. The goal is not to discard generative theory, but to continue to develop it by spurring re-examination of some of the most fundamental assumptions of theoretical linguistics.

Acknowledgements

This work was supported by an NSF IGERT grant to the Johns Hopkins department of Cognitive Science, a Department of Education Javits Fellowship to the author, and a Targeted Investment in Excellence award from the OSU College of Humanities. I would like to thank Paul Smolensky for helping make this work come about. Thanks also to Beth Hume, Cynthia Clopper, Adam Buchwald, and Jenny Culbertson for their comments and suggestions. Matt Goldrick deserves thanks for being excellent in every way. Although the paper ended up going in a quite different direction I am sincerely grateful to Brett Hyde for his generosity and advice. Peter Culicover deserves credit for providing the light at the end of the tunnel.

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