Structural disparities in Navajo word domains:
A case for LᴇxCᴀᴛ-Fᴀɪᴛʜꜰᴜʟɴᴇss[*]

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1. Introduction

A fundamental goal of linguistic theory is to make sense of language particular facts with universal principles. Optimality Theory (OT; (Prince and Smolensky, 1993), (McCarthy and Prince, 1995)) takes a particular approach towards achieving this goal. In OT, grammars are constructed by ranking well-formedness constraints. The constraints themselves are universal, so they are present and potentially active in the grammar of every language. Because of the universality of constraints, OT is inherently typological: language particular phenomena can only be explained in tandem with the kinds of typological patterns that cross-cut languages.

This article presents a comprehensive analysis of the phonology of Navajo verbs with these considerations in mind. Navajo sound structures, and the morpho-phonemics that refer to them, exhibit an especially rich set of distributional restrictions that provide a rare opportunity for testing principles of phonological markedness. Privileged positions within a word (described directly below) may contain a host of phonological structures that are systematically avoided in other positions.

(1) Structural disparities in Navajo word domains

	Privileged domain	Restricted domain (elsewhere)
Consonants:	full range of Cs in onsets	limited to plain coronals, [ʔ] and [h]
Vowels:	full range [i e o a]	limited to unmarked vowel [i]
Tone:	full range (=contrastive)	toneless (=predictable)
Syllable shapes:	CV, CVC, CVV, CVVC	CV (special case: CVC)

These distributional restrictions account for important gaps in the phonological make-up of the two domains and, further, the types of alternations that may occur in them. For example, many of the phonological processes active in the restricted domain are motivated by a need to form unmarked CV syllables ((McDonough, 1990; McDonough, 1996), (Fountain, 1998)), but these processes do not apply in privileged positions. One important goal of this article is to explain these distributional restrictions within a typologically sound theory of markedness. Special effort is made in the discussion below to establish parallels between the constraints implied by Navajo distributional restrictions and those that form the core of cross-linguistic theories of sound inventories and phonological processes.

A second parallel to be made between Navajo and other languages concerns the environments for the distributional restrictions. It turns out that these restrictions have a morpho-syntactic basis that relates directly to other languages. A Navajo verb is composed of a stem, which typically occupies the final syllable of a word, and a string of prefixes. The prefixes themselves are further divided up into two classes: the so-called disjunct prefixes, which appear in a sequence at the beginning of the word, and the conjunct prefixes, which form a more tightly bound constituent with the stem that they directly precede. Stems and disjunct prefixes form a phonological class that excludes conjunct prefixes in that they constitute the privileged phonological domain identified above, as shown below by the presence of the low vowel a and lexical tone.[1] Conjunct prefixes, on the other hand, are the restricted domain.

(2)   <u>Disjunct</u> # <u>Conjunct</u> = <u>Stem</u>
       /<u>ha</u> + <u>ná</u> # <u>ni</u> + <u>š</u> = <u>ł</u> + <u>čaʔ</u>/   →   <u>ha</u>.<u>ná</u>.<u>níš</u>.<u>čaʔ</u>
       'up' + iter # ncls + 1s = voice + root   'I card it (fluff up) repeatedly'

The parallels with other languages stem from a deeper morpho-syntactic characterization of these phonological classes. As argued in detail in (Rice, 1993; Rice, 2000), disjunct prefixes and stems are classified as lexical categories in contemporary syntactic theory, while conjunct prefixes, conveying essentially grammatical information, are functional categories. The structural disparities in Navajo therefore pattern like a number of other languages in which lexical categories may have richer phonological structure than functional categories and resist regular processes of neutralization (see (Casali, 1997) and (Willerman, 1994)). The second major goal of this article is to argue that a development in the theory of faithfulness constraints, Positional Faithfulness (PF) Theory ((Beckman, 1998), (Lombardi, 1999)), explains this relationship between morpho-syntactic and phonological structure. In particular, it is argued that there are distinct faithfulness constraints for lexical categories and functional categories, and that lexical categories have richer sound inventories because LEXCAT-FAITH takes precedence over FUNCCAT-FAITH. The arguments for PF are especially rich in Navajo, and they therefore contribute to a contemporary debate concerning the benefits and trade-offs of the PF theory of structural asymmetries when compared with an alternative theory, Positional Markedness (PM; (Steriade, 1999), (Zoll, 1998)). The analysis developed before provides especially strong linguistic evidence for PF, as the PM alternative has a number of disadvantages.

The remainder of this article is structured as follows. The next section provides the linguistic and theoretical background for the analysis of verbs. In particular, PF theory is motivated and schematic rankings are given that guide the following analysis, and the morpho-syntactic structures assumed for Navajo verbs are also sketched. Section 3 uses this background to derive the restrictions on conjunct prefixes with universal markedness constraints. The pervasive restrictions on conjunct prefixes are then called upon in section 4 as a way of identifying the phonological processes that apply specifically to disjunct prefixes. It turns out that, with the rampant neutralization in conjunct prefixes, the processes found in the disjunct zone could not take place in the conjunct because the conditions on their inputs and outputs

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[1] All examples mark the relevant morpheme types with the boundaries and underlining conventions shown below. Words are transcribed in a cross between the IPA and the Navajo practical orthography: all the alveopalatals are written with a wedge: /sh/ = [š], /zh/ = [ž] , /ch/ = [č], /j/ = [ǰ], and the voiced velar fricative /gh/ and the glottal stop /'/ are written in IPA, i.e., [ɣ] and [ʔ], respectively. However, stops are written as they are in the writing systems of many Athabaskan languages, which is not IPA. For example, the plain, aspirate, ejective alveolar stops are transcribed here as /d t t'/, which is really [t tʰ t'] in IPA.

cannot be met. Section 5 continues this theme by showing that the processes targeting conjunct prefixes also follow from the inventory restrictions in this domain. The last section considers an alternative analysis in terms of PM and shows that such an analysis either leads to loss of generalization or requires ad hoc devises that do not give insight into Navajo phonology.

2. Background

2.1 Positional Faithfulness Theory

A recurring observation in the analysis below is that the phonological structure of conjunct prefixes stands in specific logical relationships with the rest of the system. In particular, the sound structures of conjunct prefixes are always *a proper subset* of the larger sound inventory, and they are always *unmarked* relative to the rest of the inventory. These two relations are illustrated below with a fragment of the vowel inventory.

(3) A particular subset relation: Disparities in short vowels

    a. Disjunct prefixes/stems: i e o a   į ę ǫ ą
    b. Conjunct prefixes: i

The conjunct vowel i is inside the set of vowels found in disjunct prefixes and stems, so the conjunct vowel inventory is a proper subset of the larger vowel inventory. Furthermore, it is unmarked relative to the rest of the inventory, a fact that is evidenced from a host of languages that choose i as a default segment in epenthesis and reduplication (discussed below). The systematic examination of the Navajo sound system given in section 3 shows that these relations hold across several distinct dimensions of phonological structure.

The logical structure of these restrictions is actually extremely common cross-linguistically. Distributional asymmetries like that illustrated above are routinely encountered in careful descriptions of sound inventories. For example, stressed syllables in Nancowry (Nicobarese) may contain the vowels /i e E Θ ← ↔ a u o /, all of which may be contrastively specified for nasality, but unstressed syllables are winnowed down to just /i u a/ (Radhakrishnan, 1981). Cuzco Quechua presents a case of morphologically sensitive phonotactic distributions: root morphemes may have plain, ejective, and aspirated stops, but affixal morphemes only have unmarked plain stops (Parker and Weber, 1996).

The standard analysis of these distributional restrictions builds on a development in the theory of faithfulness constraints, argued most forcefully in Beckman 1998, called Positional Faithfulness (PF). In PF theory, a set of psycho-linguistically prominent positions are identified and assigned a privileged faithfulness status. This privileged status is encoded by including faithfulness constraints in *CON* (the universal constraint set) that specifically target these prominent positions. Therefore, when a markedness constraint prohibiting the structure ζ is inserted into the schematic ranking below, the position assigned a privileged faithfulness status (Pos) is immune to markedness because of top-ranked $\text{FAITH}_{\text{Pos}}(ζ)$. The impact of markedness is only felt in the complement set of positions (Pos′), because faithfulness to the properties of these positions is subordinated to markedness in the ranking (a result parallel to emergent unmarkedness of (McCarthy and Prince, 1994)).

(4) Canonical ranking for positional privilege analysis
       $\text{FAITH}_{\text{Pos}}(ζ) \gg \text{MARK}(ζ) \gg \text{FAITH}_{\text{Pos′}}(ζ)$

This mode of analysis has been applied to distributional asymmetries in a host of different environments: stressed syllables ((Alderete, 1999), (Beckman, 1998)), onsets (Beckman, 1998), (Lombardi, 1999; Lombardi, 2001), roots ((Alderete, 2001a; Alderete, 2001c), (Beckman, 1998), (McCarthy and Prince, 1995), (Urbanczyk, 1996)), and lexical categories (Casali, 1997).

The fragment of the vowel inventory illustrated above shows that Navajo structural disparities are adaptable to the Positional Faithfulness paradigm, but the details of the analysis are not yet clear. What is the linguistically significant position, or positions, that are correlated with the structural disparities between disjunct and stem morphemes, on the one hand, and conjunct prefixes? The answer to this question comes from a generalization developed originally in (Rice, 1993) on the basis of the structure of Slave verbs and extended in (Rice, 2000) for a larger set of Athabaskan languages.

(5) Rice's generalization

Disjunct prefixes and stems are lexical items; conjunct prefixes are functional items.

This generalization, argued for in more detail below, supports the PF analysis by providing the morpho-syntactic basis for describing the structural disparities. Following the lead of (Casali, 1997), lexical categories (=disjunct prefixes and stems) have a privileged faithfulness status, and they therefore resist the forces of neutralization observed in functional categories (=conjunct prefixes).
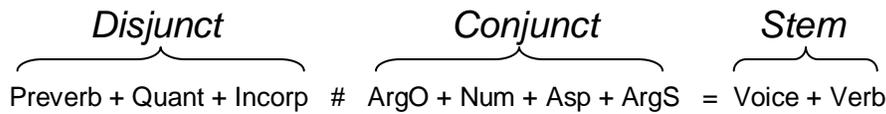
2.2 The Morpho-Syntactic Structure of Athabaskan Verbs

Athabaskan verbs are notoriously complex and display a host of morphological structures that are typologically unusual. Traditionally, these complexities have been accounted for with template morphology, a set of sequentially ordered affix classes that describe the paradigmatic possibilities in a given position and the position of each class relative to another ((Kari, 1989; Kari, 1992); see also (Sapir and Hoijer, 1967) and (Young and Morgan Sr, 1987) = YM, on Navajo). Beyond a basic description of the prefix complex, which encompasses some 12 distinct position classes, template morphology directly describes phenomena that are often ruled out by other theories of morphology, including long distance dependences among morphemes, zero morphemes, and the apparent lack of headed structures (see (Simpson and Withgott, 1986) and (Rice, 2000) for useful discussion).

Building on these results, work over the past twenty years has adapted the complexities identified in the template analysis to contemporary theories of phrase and word structure ((Hale, 1997; Hale, 2001), (Halpern, 1992), (Hargus and Tuttle, 1997), (McDonough, 1990) et seq., (Rice, 1993; Rice, 2000), (Speas, 1990)). The analysis presented below adopts many of the core assumptions from this work, which are encapsulated in the morphological frame below. [2]

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[2] However, certain assumptions are ignored that do not bear directly on the analysis, for example, whether the basic clause structure is left- (Rice, 2000) or right-branching (Hale, 1997; Hale, 2001), if verbs are formed in the lexicon ((Halpern, 1992), (Hargus, 1986)) or in the syntax ((Hale, 1997), (Rice, 2000), (Speas, 1990)), or whether pre-stem morphemes are formal prefixes (Hargus and Tuttle, 1997) or the first member of a compound (McDonough, 1990).

(6) Morphological frame for Athabaskan verb (after (Rice, 2000), (Hale, 1997), (Speas, 1990))

$$\underbrace{Disjunct} \qquad\qquad \underbrace{Conjunct} \qquad\qquad \underbrace{Stem}$$

Preverb + Quant + Incorp   #   ArgO + Num + Asp + ArgS   =   Voice + Verb

Disjunct Prefixes

Preverbs: (or incorporated postpositions and adverbs) modify predicates by adding manner and oblique relations like direction, location, and benefaction, e.g., ts'a⇔- 'from', na- 'around', dzi- 'into space'

Quantifiers: adverbial quantifiers, e.g., ná- 'iterative', and nominal quantifiers, like da- 'distributive plural'

Incorporates: incorporated noun stems that represent participant roles (agents, themes) or nonparticipant roles (locations, instruments), and incorporated stems that introduce a second event

Conjunct Prefixes

Object Agreement: marks person and number of the direct object (really internal argument)

Number: (sometimes: 'deictic subject') includes noncanonical subjects like ǰ- (fourth person) and ʔ- 'someone, something (unspecified)'

Aspect: markers of situation and viewpoint aspect

Subject Agreement: marks person and number of the subject

Stem-internal Prefix

Voice: (AKA 'classifiers') markers of voice categories on the verb; may change the thematic structure of verb or be part of the lexical entry of the verb without a thematic function

The key assumption critical to the analysis below is that disjunct prefixes and stems are lexical categories, while conjunct prefixes are functional categories. (Rice, 1993; Rice, 2000) supports this view with the following arguments:

1. *Open versus closed class*: disjunct prefixes (e.g., stem incorporates, adverbials and incorporated postpositions) and stems are open class items; conjunct prefixes are in a closed set (e.g., agreement markers, 'tense', and situation aspect)
2. *Semantic richness* (Napoli, 1993): disjunct prefixes and stems have a semantic richness that conjunct prefixes do not, e.g., they may contribute a thematic role
3. *Grammatical dependence* ((Anderson, 1982), (Bybee, 1985)): conjunct prefixes are always present when a syntactic category is present, unlike disjunct prefixes and stems, which are not obligatorily present in such configurations

Since preverbs, which are usually incorporated postpositions, are not unambiguously open class, arguments 2. and 3. are given as stronger evidence for their status as lexical categories. For example, preverbs contribute to the meaning of a verb word in ways that are far richer than the grammatical meanings of functional items and they exhibit a grammatical independence uncharacteristic of function morphemes. Likewise, quantifiers, such as the event quantifier ná-, are not open class morphemes, but they are not grammatically dependent, hence they are not functional categories.

A host of morpho-syntactic properties therefore point in the direction of grouping disjunct prefixes together with stems: they have a set of traits characteristic of lexical categories. This grouping distinguishes conjunct prefixes from disjunct prefixes and stems, and thereby provides a morpho-syntactic basis for distinguishing Navajo word domains. The next sections build on this analysis to provide an explanation of the phonological consequences of the lex-cat versus func-cat distinction.

3. Explaining Structural Disparities with Universal Markedness

The assumptions motivated above lead to the expectation that lexical categories (i.e., disjunct prefixes and stems) differ categorically from functional categories (= conjunct prefixes) in allowing richer phonological structure and resisting phonological alternations. This section explores the first set of predictions by testing out the PF hypothesis on the sound inventory of these morpheme types.

3.1 Explication of the Hypothesis and its Predictions

Let us return to the distribution of [nasal] introduced in section 2. The vowel inventory of stems and disjunct prefixes has a contrast in nasality, but the conjunct inventory does not. This state of affairs is paralleled in linguistic typology, providing evidence that the restriction against nasality in the conjunct inventory is a consequence of universal markedness. For example, nasal vowels are marked in the sense entailed by the usual implicational markedness hierarchies: if a language has a nasal vowel series, it also has a oral vowel series. In UPSID, a database of sound inventories developed in (Maddieson, 1984), 22% of the languages have a nasal vowel series, while all languages have an oral series. A second useful resource is the study of pronominal systems conducted in (Willerman, 1994). In this study, the sounds of pronominals were compared to the larger sound inventories in 32 languages (sampled from UPSID), revealing significant gaps in inventories of pronominal systems. As for nasality, the ratio of nasal-to-oral vowels was $80/338 = 23.7\%$ in the sound inventories on a whole, but that this ratio was significantly reduced in pronouns: $10/136 = 7.4\%$ ($p < .0001$). While these numbers do not refer to the nasal/oral contrast in a series, it strongly suggests that many languages lose an otherwise important contrast in pronouns, which are proto-typical functional items.

These observations may be interpreted as evidence for the markedness of nasal vowels and for the privileged faithfulness status of lexical categories. In particular, there is a context-free markedness constraint against nasal vowels (8a). *NASALVOWEL is ranked in language particular grammars relative to the faithfulness constraint for [nasal] (8b), developed in correspondence theory (McCarthy and Prince, 1995; McCarthy and Prince, 1999), to describe the distribution of nasal and oral vowels.

(7) Correspondence
Given two strings S_1 and S_2, correspondence is a relation $\Re$ from the elements of S_1 to those of S_2. Elements $\alpha \in S_1$ and $\beta \in S_2$ are referred to as correspondents of one another with $\alpha\Re\beta$.

(8) Markedness and faithfulness for nasality

   a. *NASALVOWEL: no vowels with [+nasal]
   b. IDENT[nasal]: corresponding segments agree in [nasal]

PF theory implies that there are morpho-syntactically segregated IDENT[nasal] constraints, with lex-cat faithfulness ranked at the top. The systematic restriction against nasal vowels in conjunct prefixes therefore can be accounted for by interspersing *NASALVOWEL between the two PF constraints, as illustrated below. Because *NASALVOWEL outranks the faithfulness constraint targeting functional categories, the [nasal] contrast is ruled out in conjunct prefixes:

(9) Conjunct domain: No nasal vowels

	Input		Output	IDT[nasal]$_{LEX}$	*NASVOWEL	IDT[nasal]$_{FUNC}$
a.	/… CṼ$_{FUNC}$ …/	→	… CV …			*
			*… CṼ …		*!	
b.	/… CV$_{FUNC}$…/	→	… CV …			
			*… CṼ …		*!	*

Disjunct prefixes and stems, however, do support a [nasal] contrast. An input nasal vowel is faithfully preserved in these lexical categories (10a), despite the consequences for markedness, because IDENT[nasal]$_{LEX}$ outranks *NASALVOWEL.

(10) Disjunct and stem domains: Oral/nasal contrast in vowels

	Input		Output	IDT[nasal]$_{LEX}$	*NASVOWEL	IDT[nasal]$_{FUNC}$
a.	/… CṼ$_{LEX}$ …/	→	… CṼ …		*	
			*… CV …	*!		
b.	/… CV$_{LEX}$…/	→	… CV …			
			*… CṼ …	*!	*	

The larger result depicted above is that an apparently language particular fact of Navajo (that conjunct vowels are always oral), follows from the limited impact of the universal markedness constraint *NASALVOWEL. Further, cross-linguistic typologies, as implicated directly by Willerman's work on the sounds of pronouns, show that functional categories have weaker faithfulness properties. This observation is encoded directly in the grammar by ranking IDENT[nasal]$_{FUNC}$ at the bottom of the hierarchy. As we shall see in sections 3.2 and 3.3, the restrictions of the conjunct inventory submit quite nicely to an analysis that appeals to universal markedness and positional faithfulness in this way.

Before moving on it is important to clarify the cross-linguistic predictions of the PF program. With the ordering FAITH[ζ]$_{LEX}$ >> FAITH[ζ]$_{FUNC}$ held constant, the logical possibilities for the distribution of some phonological structure ζ are as follows.

(11) Factorial typology

a. ζ banned in language as a whole	*MARK[ζ] >> FAITH[ζ]$_{LEX}$ >> FAITH[ζ]$_{FUNC}$
b. ζ allowed only in lex-cat	FAITH[ζ]$_{LEX}$ >> *MARK[ζ] >> FAITH[ζ]$_{FUNC}$
c. ζ allowed in lex- and func-cat	FAITH[ζ]$_{LEX}$ >> FAITH[ζ]$_{FUNC}$ >> *MARK[ζ]

The ranking in (11b) describes a system, like nasality in Navajo, in which the structure ζ is only permitted in lexical categories. With markedness top-ranked, the structure is prohibited outright in the language (11a), and if it is lowest in the hierarchy, the structure is permitted in all positions in the word (11c).

This typology makes a number of predictions in terms of the logical relations between the inventory of functional categories and the inventory of lexical categories.

(12) Predictions (adapted from (McCarthy and Prince, 1994) and (Alderete et al., 1999))

    a. *Lex-cat/func-cat relation I*: the sound inventory of functional categories must be a subset of the sound inventory of lexical categories

    b. *Lex-cat/func-cat relation II*: any restriction on a lexical category in some language is a possible restriction on functional categories

    c. *Lex-cat/func-cat relation III*: any restriction on a functional category in some language is a possible restriction on a lexical category in another language

It is clear from the typology in (11) why the structures of func-cat must be a subset of the structures of lex-cat (12a). The occurrence of a structure ζ in a func-cat entails the presence of that structure in a lex-cat, i.e., the complement set of positions in a word. PF theory therefore explains the observed subset relation between conjunct morphemes and disjunct/stem morphemes. Likewise, the predictions in (12b-c) flesh out in more detail the markedness relations discussed above for nasality. Since markedness is not segregated along morpho-syntactic lines, we expect to see its effects both in the inventory of functional items (11b) and in the language on a whole (11a). The PF approach to conjunct restrictions therefore predicts that the types of constraints active in the conjunct zone are the same as those which are active in sound inventories in general. The rest of this section demonstrates that this set of predictions is borne out preciously in the analysis of the inventory of conjunct prefixes.

3.2 Confirmation of the Hypothesis

3.2.1 Consonantal Disparities

    The consonants of conjunct prefixes are often said to be restricted phonologically. YM limit the segmental structure of conjunct prefixes to a single consonant plus a vowel (p. 39), and others have further noted that the consonants are severely restricted in terms of the place, manner, and laryngeal contrasts they support (see e.g., (McDonough, 1990) p. 47, and (Hale, 2001) p. 679). These restrictions are validated by a chi-square statistical analysis reported in the appendix. To summarize the results, the observed frequencies of various consonant types in conjunct prefixes deviate significantly from the expected frequencies, supporting the restrictions on conjunct prefix consonants shown below.

(13) Structural disparities in word domains, part I: Consonants

Structures	Disjunct/Stem	Conjunct
a. Stop laryngeal settings	plain, ejective, aspirated stops	plain stops
b. Fricative voicing	voiceless, voiced fricatives	voiceless fricatives
c. Consonant place	Lab, Dor, Cor, Phar	Cor, Phar

While there are three stop laryngeal series in stems and disjunct prefixes, conjunct stops are limited to plain stops. Likewise in fricatives, the otherwise important contrast in [voice] is suppressed in conjunct fricatives, which are always voiceless.[3] Finally, the four-way [place] contrast observed in lexical items is funneled down to just coronals and pharyngeals (i.e., ʔ and

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[3] Navajo is like most Athabaskan languages in having different laryngeal contrasts in stops and fricatives. See (Rice, 1994) for extensive discussion of the theoretical implications of this fundamental fact of Athabaskan languages.

ɦ). Conjunct consonants are therefore significantly restricted in three distinct classes of phonological structure.

From this preliminary arrangement of the data, it is clear that the first prediction of the PF program is borne out: conjunct consonants are always a subset of inventory of disjunct and stem consonants. But are they always the least marked elements of the lex-cat inventory, the second basic prediction of the analysis? The principles inherent to markedness theory, as it has been developed in OT and elsewhere, strongly suggest that this question can be answered affirmatively. Previous work on the markedness of laryngeals provides the constraint set below.

(14) Markedness for laryngeals

    a. *ASPSTOP ((Lombardi, 1997), (Beckman, 1998)): no stops with [asp]
    b. *EJECTIVE ((Lombardi, 1997), (Itô and Mester, to appear)): no stops with [constr.glottis]
    c. *VOICEFRIC (see (Rice, 1994)): no fricatives with [voice]

The above constraints are motivated in these works by their utility in motivating phonological processes or blocking the application of otherwise general processes. For example, aspirates and ejectives are often resolved in coda position and multiple instances of these laryngeals frequently trigger dissimilation. Voiced fricatives are also marked in the sense that they are subject to de-voicing processes when they do not precede a voiced segment. These alternations, therefore, suggest that plain stops are unmarked relative to aspirates and ejectives, and voiceless fricatives are unmarked relative to voiced fricatives.

These markedness observations are consistent with observations from sound inventories, again drawing from (Maddieson, 1984). The relative frequencies of stop series also support the assumption that plain stops are unmarked: 91.8% of the languages in UPSID have a plain stop series (i.e., unaspirated voiceless), but only 28.7% have aspirated stop series and 16.4% have ejectives. These numbers are not absolute, but there is a strong trend for plain stops in languages that have either aspirates or ejectives, as predicted by the markedness constraints above. UPSID also reveals a strong cross-linguistic bias for voiceless fricatives over voiced fricatives. As for the fricatives in Navajo, the voiceless counterpart is always more common, as represented in the following ratios for voiceless-to-voiced fricatives: s/z = 266/96 = .36, š/ž = 146/51 = .34, x/ɣ = 75/40 = .53.[4] While these numbers do not require implicational markedness relations of the type suggested by the stop classes, the higher frequency of voiceless fricatives, across segment classes, is at least consistent with the findings in alternations. Cross-linguistic trends in sound inventories, therefore, also lend support to the markedness assumptions embodied in the constraints in (14).

All that is left in the analysis of laryngeal restrictions is to plug the markedness constraints above into the canonical ranking for positional privilege effects:

(15) Rankings for laryngeal restrictions in conjunct prefixes

    a. Aspirated stops: IDENT[asp]$_{LEX}$ >> *ASPSTOP >> IDENT[asp]$_{FUNC}$
    b. Ejectives: IDENT[constr.glottis]$_{LEX}$ >> *EJECTIVE >> IDENT[constr.glottis]$_{FUNC}$
    c. Fricative voicing: IDENT[voice]$_{LEX}$ >> *VOICEFRIC >> IDENT[voice]$_{FUNC}$

As with the constraint against nasal vowels illustrated above in 3.1, these consonantal restrictions fall out naturally as a consequence of universal markedness.

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[4] The laterals are omitted because Navajo does not have phonetic structures consistent with the data organization of lateral fricatives in UPSID.

The analysis of the [place] limitations on conjunct prefixes is somewhat different, however, because markedness principles do not neatly partition the phonological space into 'marked' versus 'unmarked' classes. Rather, as has been argued extensively in the OT literature ((Alderete et al., 1999), (Lombardi, 1997; Lombardi, 2001), (Prince and Smolensky, 1993)), markedness observations for [place] are characterized on a scale, encoded in OT grammars as a fixed ranking.

(16) Place Markedness Subhierarchy

     *PL\LAB, *PL\DOR >> *PL\COR >> *PL\PHAR

This fixed ranking, or 'subhierarchy', predicts that labials and dorsals are more marked than coronals, and coronals are in turn more marked than pharyngeals. The evidence for this order is supported by sound inventories (see especially (Prince and Smolensky, 1993)), but the strongest arguments come from the analysis of the content of epenthetic elements and fixed segments in reduplication processes. These default elements are often either coronals or pharyngeals, which supports the relative unmarkedness of these [place] specifications as a function of the ordering given above (see especially (Alderete et al., 1999) and (Lombardi, 1997; Lombardi, 2001)). The important point is that the analysis of these phenomena entails that labials and dorsals are marked relative to coronals and pharyngeals. Returning to Navajo, the [place] restrictions on conjunct prefixes can thus be explained by interrupting the Place Markedness Subhierarchy with the relevant faithfulness constraints for [place], as shown below.

(17) [place] restrictions in conjunct prefixes

     IDENT[place]ₗₑₓ >> *PL\LAB, *PL\DOR >> **IDENT[place]ₓᵤₙc** >> *PL\COR >> *PL\PHAR

With the interspersing of PF constraints and the markedness hierarchy above, lex-cats will have a four-way [place] contrast, while func-cats will only have two [place] contrasts, namely unmarked coronal and pharyngeal specifications. Place restrictions, therefore, can also be explained within a larger typological perspective on markedness, expressed in this case as a fixed ranking.

Three distinct dimensions of consonantal structure have been shown to confirm the predictions of the PF analysis. In all three types discussed above, i.e., stop laryngeal settings, fricative voicing, and consonantal place, it was shown that the structures allowed in conjunct prefixes are a subset of the larger sound inventory, and further, that conjunct consonants are always the least marked members of this inventory. These restrictions are explained in the PF paradigm by appeal to a cross-linguistically motivated theory of consonantal markedness. The next subsection shows that the PF program also makes the correct predictions for vowel disparities.

3.2.2 Vowel Disparities

It is also often noted that vowel structures are significantly restricted in conjunct prefixes. Starting again with YM, it is observed (p. 39) that, with very few exceptions,[5] conjunct prefixes

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[5] The exceptions include the areal prefix ho/ha-, and a handful of thematic prefixes, e.g., yí-, 'directed at (in combination with ni-)'. YM's account does not cover the positions for aspect prefixes or subject markers (their VII and VIII). If it did, it would need to exempt future and optative forms, because they introduce ee and ó, respectively, and first person duoplural ii(d)- and second person duoplural oh-. It is assumed here that these morphological categories involve more complex morphology than simple affixation, and so the marked

are only composed of the vowel i. This restriction is also implicit in a standard generative analysis of conjunct prefixes, namely that conjunct prefixes are simply single consonants and that a regular process of i-epenthesis enables these consonants to be grouped into well-formed syllables ((Speas, 1990), (Faltz, 1998)).[6] To validate these restrictions, chi-square statistics were used again to identify significant gaps in the distribution of vowel features (see appendix). The statistical analysis is consistent with these observations from the Navajo literature, supporting the restrictions on conjunct vowels shown below.

(18) Structural disparities in word domains, part II: Vowels

Structures	Disjunct/Stem	Conjunct
a. Vowel quality:	i e o a	i
b. Length:	short, long	short
c. Nasality	oral, nasal	oral
d. Tone:	marked (=high), unmarked	unmarked

As with the consonant restrictions, stems and disjunct prefixes are composed of structures that are prohibited in conjunct prefixes. Thus, while the former have a four-way contrast in vowel quality, conjunct prefixes only have i. Further, lex-cats have a contrast in length, nasality, and tone, but the conjunct prefixes lack these contrasts, having only short oral toneless i. Therefore, like conjunct consonants, conjunct vowels are limited to a subset of the structures of the larger inventory.

The constraints below correctly characterize the conjunct vowel i as the unmarked member of the vowel inventory.

(19) Vowel markedness

a. REDUCE ((Kirchner, 1996), cf. (Steriade, 1995)): minimize the duration of vowels
b. *LONGVOWEL (Rosenthall, 1994): vowels must not be long (e.g., $\mu \geq 2$)
c. *NASALVOWEL (see (Walker, 1998)): vowels must not have [+nasal]
d. *TONE ((Myers, 1997), (Yip, 1999), (Zoll, 1997)): vowels must not have tone (e.g., H tone)

Evidence for these markedness assumptions again comes from cross-linguistic work in both inventories and alternations. Implicational markedness relations indicate that nasal vowels and long vowels entail the presence of their oral and short counterparts, respectively. The structures targeted by the constraints above are also often neutralized by phonological processes: a sequence of long vowels or high-toned syllables are often resolved in regular processes of dissimilation. The relative unmarkedness of the high front vowel i is evidenced by its frequent choice as the output of vowel epenthesis (Steriade, 1995) and as a phonologically determined fixed segment in reduplication (Alderete et al., 1999). Because i typically has a shorter intrinsic duration than other vowels, REDUCE favors this vowel over all others.

Markedness theory again provides the right constraints for explaining the conjunct restrictions. When inserted between the morpho-syntactically segregated faithfulness constraints, these constraints give the correct results.

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phonological structures they introduce go beyond the standard markedness-faithfulness interactions that constitute OT grammars (see (Alderete, 2001b; Alderete, 2001c) for significant discussion of this class of phenomena).

[6] The stipulation that conjunct prefixes are composed of a single consonant, however, is both unnecessary and unwanted; see 5.1 for explicit discussion.

(20) Rankings for restrictions on vowel structures in conjunct prefixes

    a. Vowel Quality: IDENT[high, back]$_{LEX}$ >> **REDUCE** >> IDENT[high, back]$_{FUNC}$
    b. Length: IDENT[weight]$_{LEX}$ >> ***LONGVOWEL** >> IDENT[weight]$_{FUNC}$
    c. Nasality (repeated): IDENT[nasal]$_{LEX}$ >> ***NASALVOWEL** >> IDENT[nasal]$_{FUNC}$
    d. Tone[7]: IDENT[tone]$_{LEX}$ >> ***TONE** >> IDENT[tone]$_{FUNC}$

The predictions of the PF analysis are therefore confirmed by the limitations on conjunct vowels. Four different dimensions of phonological markedness again require the phonological structure of conjunct prefixes to be unmarked relative to the complement set of structures afforded elsewhere. In total, therefore, consonants and vowels provide very strong evidence for the claims inherent to the PF hypothesis.

4. Implications for Alternations I: Disjunct Neutralizations

What are the implications of the inventory restrictions discussed above for alternations in Navajo? In OT, the inventory is constrained with the same tools used to motivate phonological processes, i.e., language particular markedness-faithfulness interactions. Because of this, the implications for alternations are significant. This section and the next examine the consequences of the rankings given in section 3 for the processes that affect disjunct and conjunct prefixes. The basic finding is that the same privileged faithfulness status for lex-cats found in the inventory is also motivated by alternations, providing further empirical support for the PF thesis.

4.1 Ranking Schema

       Neutralizations in OT involve the domination of context-free markedness by faithfulness and the domination of faithfulness by a context-sensitive markedness constraint, as shown below (see (Kager, 1999) and (McCarthy, 2002) for further study).

(21) Canonical ranking for neutralizations

    MARK/POS(ζ) >> FAITH(ζ) >> MARK(ζ)

The domination of context-free MARK(ζ) means that the structure ζ is allowed in some contexts; otherwise, there would be no contrast to neutralize. The subjugation of FAITH(ζ) by the context-sensitive markedness constraint MARK/POS(ζ), on the other hand, prohibits ζ in a particular context. For example, an otherwise general contrast in voicing can be neutralized by the context-dependent markedness constraint, *VC̥V, which prohibits intervocalic voiceless obstruents.

       Positional faithfulness adds domain-sensitivity to neutralization by assigning faithfulness properties to specific domains. The effects of markedness can thus be restricted to a particular morpho-syntactic or phonological domain. This strategy predicts a set of dynamic neutralization processes that are sensitive to morpho-syntactic structure, as schematized below.

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[7] This restriction on conjunct tone is orthogonal to whether or not there is intrinsic low tone (YM, (Sapir and Hoijer, 1967), cf. (McDonough, 1999)). Whatever the correct analysis of tone is, the markedness constraint against any specified tone gives the right results in this case.

(22) Dynamic neutralizations with morpho-syntactically segregated faithfulness

    a. Func-cat neutralization
        $\text{FAITH}_{\text{LEX}}(\zeta)$ >> $\text{MARK/POS}(\zeta)$ >> $\text{FAITH}_{\text{FUNC}}(\zeta)$ >> $\text{MARK}(\zeta)$

    b. All-category neutralization (with lex-cat bias)
        $\text{MARK/POS}(\zeta)$ >> $\text{FAITH}_{\text{LEX}}(\zeta)$ >> $\text{FAITH}_{\text{FUNC}}(\zeta)$ >> $\text{MARK}(\zeta)$

    c. Lex-cat neutralizations
        $\text{MARK/POS}(\zeta)$ >> $\text{FAITH}_{\text{LEX}}(\zeta)$ >> $\text{MARK}(\zeta)$ >> $\text{FAITH}_{\text{FUNC}}(\zeta)$

The ranking in (22a) describes a system in which func-cats have a contrast in ζ, but it is prohibited in the specific position banned by MARK/POS(ζ). In the next section, a set of syllable structure related phonological processes are shown to specifically target conjunct prefixes as a consequence of this ranking. Disjunct prefixes, however, are not affected, because $\text{FAITH}_{\text{LEX}}(\zeta)$ dominates MARK/POS(ζ).

      Flipping the ordering of the two highest constraints in (22a) yields all-category neutralization of words with ζ in the marked position (22b). While the two domains do not differ in violations of MARK/POS(ζ), these neutralizations may also show a positional asymmetry, as evidenced by the retention of phonological structure in the lex-cat and alternation in the func-cat. For example, as discussed in 5.3, morphemes in Navajo do not have conflicting [anterior] features, i.e., there are no disharmonic stems or prefixes. However, when a lex-cat combines with a func-cat with a different [anterior] specification, the feature of the func-cat is changed. This result therefore reveals a positional bias in terms of the output of the phonological process, an analysis entirely parallel to previous analyses of so-called 'root-controlled' processes ((Alderete, 2001a), (Beckman, 1998), (McCarthy and Prince, 1995), (Ringen and Vago, 1998), (Ringen and Heinämäki, 1999)).

      A third expected ranking consequence involves neutralization specifically in lex-cats. In the ranking in (22c), $\text{FAITH}_{\text{LEX}}(\zeta)$ is inserted between context-specific and context-free markedness, producing the effect that a structure otherwise allowed in lex-cats is neutralized in a specific environment. Remarkably, all of the processes that directly target disjunct prefixes follow from this ranking, as demonstrated in the next section. Roughly speaking, because of the significant neutralization of phonological structure in conjunct prefixes, the logical possibilities for neutralization are far greater in the disjunct zone; the conditions on the processes affecting disjunct prefixes simply cannot be met by the structure provided in the conjunct domain.

      The four above constraints can be ranked in three more orderings (holding $\text{FAITH}_{\text{LEX}}(\zeta)$ >> $\text{FAITH}_{\text{FUNC}}(\zeta)$ constant), completing the factorial typology of this system.

(23) Completing the typology (non-dynamic effects)

    a. Unrestricted contrast in lex-cat, no contrast in func-cat
        $\text{FAITH}_{\text{LEX}}(\zeta)$ >> $\text{MARK/POS}(\zeta)$ >> $\text{MARK}(\zeta)$ >> $\text{FAITH}_{\text{FUNC}}(\zeta)$

    b. All-category contrast
        $\text{FAITH}_{\text{LEX}}(\zeta)$ >> $\text{FAITH}_{\text{FUNC}}(\zeta)$ >> $\text{MARK/POS}(\zeta)$ >> $\text{MARK}(\zeta)$

    c. All category neutralization
        $\text{MARK/POS}(\zeta)$ >> $\text{MARK}(\zeta)$ >> $\text{FAITH}_{\text{LEX}}(\zeta)$ >> $\text{FAITH}_{\text{FUNC}}(\zeta)$

Because the two markedness constraints in the above orderings work in a unified block, they do not have the rankings required for alternations shown in (21). For this reason, these orderings are non-dynamic. (23a), for example, is just an elaboration on the privileged faithfulness status of

lex-cats (see section 3), a status that is extended to suppress the effects of context-sensitive markedness. Marked structure is ruled out altogether in func-cats by (23a), so it cannot be neutralized. Likewise, for (23c), the banned structure ζ is prohibited in all positions, so there is no structure to neutralize in an unfaithful mapping (see for example the list of 'Rules Involving General Structure' of Faltz 1998 for many examples of this kind). In (23b), by contrast, both faithfulness constraints dominate both markedness constraints, so there are no unfaithful mappings involving the marked structure. Because the last two rankings do not bear on the issues developed here, however, they will not receive any further attention.

One caveat of the above ranking schema is that the limitations on the distribution of stems in Navajo make it impossible for certain structures to arise in stems. For example, the canonical shapes for stems are CVC, CVV, or CVVC. Because of the general absence of suffixed structures in the language, this means that the phonological contexts that stems occur in are quite limited. Furthermore, many processes affecting disjunct prefixes occur in the 'pre-stem syllable', i.e., the syllable that precedes the syllable dominating the segments of the stem. Clearly stems cannot occur in this context. Another structure commonly resolved in disjunct neutralizations is a VV sequence, but because stems are usually the final syllable of the word, they do not occur pre-vocally. Thus, while PF theory predicts a grouping of stems and disjunct prefixes in alternations because they are both lexical categories, the restricted morpho-syntactic distribution of stems precludes testing this prediction to its limits.

4.2 Disjunct Neutralizations

The table below lists the regular and productive processes that specifically target disjunct prefixes. These processes can be separated into three basic classes: those that are purely phonological, i.e., they apply whenever their phonological environment is met (25a-b), processes that are morphologized in the sense that they only apply in certain morphological categories (categories orthogonal to the disjunct/conjunct labels), and morpho-phonological, which are essentially phonological processes that refer to a morphological context, namely the pre-stem syllable. The degree to which a process refers to a morphological category or the degree to which a process is morphologized is entirely orthogonal to the claims made below, however, so these labels have only a descriptive purpose.

(25) Disjunct neutralizations ((Faltz, 1998), (Kari, 1976), (YM 39-40))[8]

a.	VV-Resolution (phonological)	í + ii → íi	F-RD-2b	
		í + o → ó	F-RD-2c	cf. K-II-62
b.	Fronting (phonological)	a → e / ___ i	F-RD-2a	K-II-67
c.	Raising (morphologized)	na → ni / ___ ...	F-RD-3	K-III-45, III-152
d.	ʔa Adjustments (morpho-phonological)	a → Ø / ʔ___ii, o, oo	F-RD-4b	cf. K-II-72
		a → ii / ʔ___C [$_{Stem}$	F-RD-4a	ibid.
		a + y$_{Obj}$ → ii / ʔ___C	F-RD-4c	ibid.
e.	Pre-Stem Lengthening (morpho-phonological, i.e., in the 'pre-stem syllable')	a → aa	F-RD-1a	see K-II-46 in 2.73
		i → ee	F-RD-1c	
		í → é	F-RD-1b	

Returning to the predictions of PF, why is it that these processes specifically target disjunct morphemes? The answer to this question is immediately apparent when we examine the inputs and outputs of these processes. All but the last process target structures that are not part of the func-cat inventory, so their structural description cannot be met in the conjunct zone. Most of the processes above target the low vowel a or high-toned í, but conjunct prefixes are not composed of these vowels (because of markedness-faithfulness interactions presented in section 3.2.2), so the apparent domain-specificity follows naturally from the limitations on the conjunct inventory. Indeed, the only process that acts on a structure allowed in conjunct prefixes is Faltz's RD-1c, but it outputs a different structure prohibited in conjunct prefixes, long ee, so it too is predicted not to be possible.

The explanation of domain-specificity therefore stems from the constraint ranking given in 4.1 for disjunct neutralizations (22c) and the inventory restrictions on the phonological structure of conjunct morphemes entailed by this ranking. To illustrate, consider the analysis of fronting (25b). This process requires a constraint against the vowel sequence ai, which must be top-ranked to motivate an unfaithful mapping. In particular, it must outrank lex-cat faithfulness to [back], as shown below.

(26) Explaining domain specificity, part I

Input: a$_{Lex}$ i	*a i	IDENT[back]$_{LEX}$	REDUCE
a i	*!		*
→ e i		*	*

IDENT[back]$_{LEX}$ must in turn outrank REDUCE, the context-free markedness constraint prohibiting vowels other than i, because lex-cats may have these vowels (see 3.2.2). This is not the case with func-cats, so context-free REDUCE dominates func-cat faithfulness. Because of this ranking, an input a in a conjunct prefix will not be mapped onto e, but rather i, as illustrated below.

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[8] In order to facilitate access to the data and arguments motivating these processes, each process is indexed with the rules used in Faltz and Kari's works: F-RD-*n* is 'Rule Disjunct number *n*' for Faltz and the chapter number-object number is the index for Kari's rules, e.g., K-II-62 = the object (62) in chapter two of (Kari, 1976). Both of these works provide excellent appendices and chapter summaries that bookmark where the rules are introduced in the text.

(27) Explaining domain specificity, part II

Input: a_{Func} i	*a i	IDENT[back]$_{\text{LEX}}$	REDUCE	IDT[back]$_{\text{FUNC}}$
a i	*!		*	
e i			*!	*
→ (i) i				*

There are ways to restrict the lexicon such that conjunct prefixes do not have a (see (Tesar and Smolensky, 2000) on separating lexicon learning and grammar learning), but even if we allow the input sequence above, it will not give the mapping associated with fronting, as desired. The unification of the analysis of inventories and alternations inherent to OT therefore explains both the gaps in the conjunct inventory and the observed domain-specificity of fronting; the limitation of fronting to disjunct vowels is a natural consequence of the inventory restrictions on the conjunct zone. Given the analysis of the conjunct vowel inventory in section 3, the results could not be otherwise.

We have seen that the apparent domain specificity of the disjunct neutralizations is a direct consequence of the enlarged inventory of structures made available in lexical categories. In general, the analysis as it has taken shape thus far does not allow domain-specificity of an arbitrary nature, arbitrary in the sense that it makes no connection to the inventories of lexical and functional categories. This prediction is sketched below.[9]

(28) Impossible lex-cat-specific phonological process

For S_{LEX}, a structure $\in$ lex-cat inventory, S_{FUNC}, a structure $\in$ func-cat inventory, I_{LEX}, an input for a lex-cat morpheme, I_{FUNC}, an input for a func-cat morpheme, and a constraint hierarchy **CH**,

no **CH** can map $S_{\text{FUNC}} \in I_{\text{LEX}}$ onto S_{FUNC} and fail to do so with $S_{\text{FUNC}} \in I_{\text{FUNC}}$.

For example, the PF analysis could not produce a process that maps si onto ši only in disjunct prefixes. Both conjunct and disjunct prefixes allow these structures, so there is no way to account for an unfaithful mapping of si to ši only in lex-cats. The explanation of domain specificity offered by PF therefore gives a natural account of the observed phonological alternations within a restrictive framework of how alternations can be relegated to domains.

5. Implications for Alternations II: Conjunct Neutralizations

Recall from the discussion above that conjunct neutralizations follow from the ranking below.

(29) Canonical ranking for func-cat neutralization (repeated from (22a))

$$\text{FAITH}_{\text{LEX}}(\zeta) \gg \text{MARK/POS}(\zeta) \gg \text{FAITH}_{\text{FUNC}}(\zeta) \gg \text{MARK}(\zeta)$$

In general, the domain-specificity of conjunct prefixes follows from the domination of $\text{FAITH}_{\text{FUNC}}(\zeta)$. Conjunct-specific processes therefore follow from inherent limitations on conjunct

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[9] One way of circumventing this prediction is via Local Conjunction (Smolensky, 1993) of func-cat faithfulness and a constraint against the output of the phonological process, e.g., $\text{FAITH}_{\text{FUNC}}(\text{ant})$ & *š for the palatization case sketched below. This strategy, however, is at odds with a common assumption that Local Conjunction must respect fixed rankings (see (Alderete, 1997) for motivation of this principle for the Place Markedness Subhierarchy). If one makes this assumption, the corresponding conjunction for lex-cat faithfulness ranked above ($\text{FAITH}_{\text{FUNC}}(\text{ant})$ & *š) will remove the artificial domain-sensitivity from this hypothetic system.

prefix structures that are not felt in the disjunct zone. This strategy is employed below in a comprehensive study of conjunct prefix phonology.

5.1 Conjunct Neutralizations

The regular and productive processes targeting conjunct prefixes are given below.

(30) Conjunct neutralizations ((Faltz, 1998), (Kari, 1976), (McDonough, 1990) et seq., YM, pp. 39-41)[10]

a.	i-Epenthesis (phonological)	$\emptyset \rightarrow i / C \_\_\_ C$	F-RC-1, M90/96
b.	y-Vocalization (phonological)	$y \rightarrow i / V \_\_\_ C$	F-RC-2
c.	VV-Resolution (phonological)	$V \rightarrow \emptyset / \_\_\_ V$	Kari 1976: 38-39
d.	Coronal Harmony (phonological)	$C \ldots C_{STEM}$ $\diagdown \quad \mid$ $[\alpha ant]$	F-RC-4, K-II-81/83, M91
e.	Tone Spread (phonological)	H $\mid \diagdown$ $V\#CVC\ [_{Stem}$	K-II-39, M99, cf. F-RC-8
f.	ni-Absorption (morpho-phonological)	$C + ni_{2sg} \rightarrow C\acute{\imath}$	F-RC-3, K-II-11, cf. M90[II-2.19]
g.	a-Epenthesis (morphogized)	$\emptyset \rightarrow a / \hbar_{unspec}\_\_\_ C$	F-RC-5, cf. K-II-72
h.	hΩ-Vocalization (morphologized)	$h\Omega_{obj} + C \rightarrow hV(C)$	F-RC-6
i.	h-to-y (morphologized)	$h_{seriative} \rightarrow y / C \_\_\_$	F-RC-9a, cf. K-II-13
j.	ǰ-Spirantization (morphologized)	$V + \check{\jmath}_{4per} + CV \rightarrow V\check{z}.CV$	F-RC-7

As is true of most generative analyses, the actual substance of a process, and whether it is needed at all, depends in many cases on the assumptions one makes about the underlying representation of specific morphemes. For example, (Faltz, 1998), following (Speas, 1984), tends to represent conjunct prefixes as single consonants, which motivates epenthesis (30a). On the other hand, (Kari, 1976) and YM tend to specify conjunct prefixes as Ci, which requires only vowel deletion (30c) to produce the correct surface forms. Following arguments presented in (McDonough, 1990), p. 134 ff., I assume that both processes are active, essentially because epenthesis cannot predict the quality and distribution of conjunct vowels. Theoretically, however, this assumption is of little consequence, since both epenthesis and VV-Resolution are needed in the OT analysis presented below.[11]

Another comment worth making is that many of the processes shown above are associated with specific morphemes (30f-j). This morpheme-specific phonology leads one to wonder if there is a more natural morphological analysis. For example, (McDonough, 1990), pp. 40-42, re-analyzes the (in)famous rule of ni-Absorption as a phonologically governed pattern of allomorphy. Because the morphological nature of these processes is not entirely understood at this time (though see (Hargus and Tuttle, 1997) for insightful analysis into the grammatical requirements on tense marking), I focus below on the syllable structure related processes, specifically (30a-c). This is sensible, I judge, because many of the morpheme-specific processes have clear connections to syllable structure, whether they have a phonological or morphological analysis. Furthermore, the application of the PF thesis to the syllable structure motivated processes works in a similar way to its application to Coronal Harmony and Tone Spread, so a

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[10] These processes are indexed with the same labeling conventions used for the disjunct processes, except for McDonough's work, which is referred to on a paper-by-paper basis, e.g., M96 = McDonough 1996.

[11] In OT, there are no language particular restrictions on inputs, so the grammar must have a means of contending with both CC and VV sequences, which requires both of these processes.

focus on the former makes the discussion more concise. What follows presents a comprehensive analysis of the syllable structure processes (5.2) with more speculative discussion of the residual processes in 5.3.

5.2 Processes Motivated by Syllable Structure

5.2.1 Conjunct Syllables and Epenthesis

A fundamental observation exhibited in the phonology of conjunct prefixes is that they are organized into simple CV syllables, or 'core syllables', that lack complex onsets, VV sequences, and codas ((McDonough, 1990; McDonough, 1996), (Fountain, 1998)).[12] Indeed, i-Epenthesis (30a), VV-Resolution (30c), and many of the morphologized processes (30f-i), cf. (30j), constitute a veritable conspiracy of phonological processes that converge on the core syllable. Epenthesis supports this generalization by breaking up consonant clusters that would otherwise create a coda consonant (because the general ban on complex onsets requires the first C of the cluster appear in a coda). i-Epenthesis has a systematic exception, however, which must be illustrated before exemplifying the process with alternations. The syllable directly preceding the stem can in fact have a coda consonant, as shown below with the first person singular prefix š̱- in the subject agreement slot (31a) and the final C of the second person duoplural prefix (31b).

(31) Exceptions to the prohibition on codas: the pre-stem syllable

    a. /n̲a̲ # š̱ = n̲é̲/   →   naaš̱.né   'I play'

    b. /n̲a̲ # o̱h = n̲é̲/   →   nao̱h.né   'You (duopl) play'

Non-pre-stem consonant clusters composed of conjunct consonants, on the other hand, trigger i-Epenthesis. For example, if first person š̱- is preceded by the object prefix n̲-, epenthesis is employed as a way of avoiding syllabifying the latter in a coda (32a). Likewise, two single consonant prefixes, the noun class marker d- 'relates to arms/legs (32b) and the terminative n-(34c), trigger epenthesis when they appear directly before the C-initial n-imperfective, but not before V-initial prefixes (the data organization is from (McDonough, 1996)).

(32) Epenthesis to resolve conjunct CCs[13]

    a.   /h̲a̲ # n̲ + š̱ = l̲ + t̲e̲e̲h̲/   →   ha.n̲i̱š̱.t̲e̲e̲h̲   'I'm carrying you (sg) up'

        cf. /y̱á̱ # š̱ = t̲i̲ʔ̲/   →   y̱á̱š̱.t̲i̱ʔ̱   'I speak'

    b.   /d̲ + n̲i̱š̱ = l̲ + č̲í̱í̱d̲/   →   … d̲i̲.n̲i̱š̱.č̲í̱í̱d̲   'I trip him' YM 325

        cf. /d̲ + i̲š̱ = l̲ + č̲í̱í̱d̲/   →   d̲i̱š̱.č̲í̱í̱d̲   'I extend my arm' YM 333

    c.   /n̲ + n̲i̱š̱ = l̲ + k̲a̲a̲d̲/   →   n̲i̱.n̲i̱š̱.k̲a̲a̲d̲   'I take them to a location' YM 650

        cf. /t̲a̲a̲h̲ n̲ + i̲š̱ = l̲ + k̲a̲a̲d̲/ →   t̲a̲a̲h̲ n̲i̱š̱.k̲a̲a̲d̲   'I drive them (to water)' YM 659

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[12] This assumption is also implicit in many of the descriptive statements about prefix shape (YM: 39) and the underspecificational analysis of conjunct prefixes as singleton consonants ((Speas, 1984), (Faltz, 1998)).

[13] The resolution of triconsonantal clusters exemplified here with the voice prefixes is beyond the scope of this paper. It is clear, however, that the motivation for the observed deletion is consistent with a general constraint in the language prohibiting complex onsets and codas, which is accounted for below with the markedness constraint *COMPLEX.

VV-Resolution supports core syllables too, which will be exemplified in 5.2.4. Any analysis of conjunct syllabification will require processes that produce CV syllables, while exempting the pre-stem syllable from epenthesis.

The analysis of core syllables is a well-studied problem in OT. It involves the language-particular rankings of the constraints given below (see especially (Fountain, 1998) for conjunct core syllables in OT).

(33) Operative constraints (see (Prince and Smolensky, 1993), (McCarthy and Prince, 1995))
    a. NOCODA: syllables must not have coda consonants
    b. ONSET: syllables must have an onset
    c. *COMPLEX: syllables must not have complex onsets or codas
    d. DEP: output segments must have input correspondents ('no insertion')
    e. MAX: input segments must have output correspondents ('no deletion')

Given that Navajo has no complex onsets or codas, *COMPLEX must dominate either DEP or MAX (the decision is not relevant to the matters at hand). The resolution of CCs by epenthesis further shows that MAX$_{FUNC}$ >> DEP$_{FUNC}$, and that the coda avoidance constraint NOCODA in turn dominates faithfulness.

(34) Syllable structure constraints motivate epenthesis

Input: /ha # n̥ + C̥… /	NOCODA	FAITH$_{FUNC}$
han̥.C̥…	*!	
→ ha.ni̥.C̥…		*

It turns out that the faithfulness constraint dominated by NOCODA is not simply DEP, because contact epenthesis relative to a disjunct prefix does not submit to such an analysis. Before proposing an analysis of conjunct syllables, therefore, it is necessary to compare conjunct and disjunct syllables.

5.2.2 Disjunct Syllables

In contrast to non-pre-stem conjunct syllables, disjunct prefixes may have coda consonants, as exemplified below.

(35) Coda consonants in disjunct domain
    a. /bi + k'i + dah # ʔa + s̥ = dá(h) + í/   →   bi.k'i.dah.ʔas̥.dá.hí
        3s + prev + adv # 3unspec + 1s = root + N   'chair'

    b. /ʔaaʔ # di̥ + yi̥ = ʔá/   →   ʔaaʔ.di̥iʔá
        prev + der + asp + root   'I made a touchdown'

    c. /… soh + da # hw + dee = béež/   →   doo soh.da.ho̥.déé.béež da
        … suffer + distpl # areal + prog = root   'It is despairing (for a number of us)'

    d. /hašt'e # Ø + š̥ = łééh/   →   haš.t'eeš̥.łééh
        'ready' # 1sg = root   'to place it in good order'

The above examples show that a disjunct prefix can be composed of a CVC sequence in which the second consonant appears in coda position, unlike non-pre-stem conjunct prefixes. These prefixes, such as dah- and soh-, may appear either at the end of the disjunct zone (35a-b) or internal to it (35c-d).

The contrast between resolution of CCs in the conjunct domain and retention of codas in disjunct prefixes supports the central contention of the PF thesis: domain restrictions stem from the privileged faithfulness status of lexical categories. That is, the absence of coda avoidance in disjunct prefixes stems from higher ranking lex-cat faithfulness, following the ranking schema in (22a).

It turns out that the specific analysis of this basic insight is not entirely obvious, because the 'null hypothesis', involving the anti-insertion constraint DEP, does not cover all of the facts. Epenthesis into the juncture between the disjunct and conjunct prefixes, for example, does not necessarily violate DEP for lexical categories, as illustrated below.

(36) Morphemic affiliation of epenthetic vowel?

Input: $/?_1aa_2?_3 \# d_4i_5 + \dots /$	DEP$_\text{LEX}$	NOCODA	DEP$_\text{FUNC}$
$?_1aa_2.?_3i_n.d_4i_5\dots$	?		?
→ $?_1aa_2?_3.d_4i_5 \dots$		*	

There are ways of requiring epenthetic vowels inserted at the disjunct#conjunct juncture to have an affiliation with the preceding lexical category (see (Kim, 2001) for a constraint-based analysis of a parallel type of 'stem absorption'), which would correctly rule out the losing candidate above. However, it is not clear that such a solution has cross-linguistic appeal.

The alternative developed below, which will be shown to have several important consequences in Navajo, is that epenthesis into a lexical category, or at a juncture between a lex-cat and a func-cat, violates a constraint on lex-cat contiguity. Assuming that morphemes themselves have a linear order (on which see (Horwood, 2002) and (Zuraw, 2000)), contact epenthesis interrupts the contiguity of the sequence of lexically specified segments:[14]

(37) Epenthesis interrupts lexical contiguity

Input form   Output candidates

$/?_1aa_2?_3 \# d_4i_5 + \dots /$ → $?_1aa_2?_3.d_4i_5 \dots$ *Preserves lexical contiguity*

                                              *$?_1aa_2.?_3i_n.d_4i_5\dots$ *Epenthesis interrupts contiguity*

In the mappings above, the segments $?_3$ and d_4 form a contiguous string in the input, but epenthesis disrupts this contiguity. Such mappings violate the faithfulness constraint, CONTIGUITY$_\text{LEX}$, which, as defined below, prohibits the separation of a pair of contiguous segments in the input if one of them is in a lexical category.

(38) CONTIGUITY$_\text{LEX}$ (CONTIG$_\text{LEX}$, after (McCarthy and Prince, 1995; McCarthy and Prince, 1999))
   Let x, y ∈ Input and x' and y' ∈ Output, and x or y ∈ Lex-Cat.
   If x$\Re$x' and y$\Re$y', and x and y form a contiguous string in the input,
       then x' and y' must form a contiguous string.

When ranked above NOCODA, CONTIG$_\text{LEX}$ correctly prohibits epenthesis as a way of syllabifying a disjunct consonant as an onset:

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[14] See (Pater, 1999) for a parallel analysis of the avoidance of nasal substitution with root-initial consonants.

(39) Coda maintenance in disjunct domain

Input: /ʔaaʔ# di + yi = ʔá̧/	CONTIG_{LEX}	NOCODA	CONTIG_{FUNC}
ʔaaʔi.dii.ʔá	*!		*
→ ʔaaʔ.dii.ʔá		*	

Clusters composed of two conjunct consonants, however, do get resolved by epenthesis because CONTIG_{LEX} has no force in this context, and the corresponding constraint for functional categories is dominated by NOCODA, as shown below.

(40) Non-contiguous sequences in conjunct domain

Input: /ha # n + C… /	CONTIG_{LEX}	NOCODA	CONTIG_{FUNC}
han.C…		*!	
→ ha.ni.C…			*

Understood as a faithfulness effect governed by input contiguity, the possibility of epenthesis is explained within the positional faithfulness paradigm. The ban on codas in conjunct prefixes follows from context-free markedness (i.e., NOCODA), and the limitation of this markedness effect to conjunct prefixes stems from the segregation of faithfulness properties by lexical and functional categories. The apparent domain-sensitivity of epenthesis, therefore, has the same analysis as that given for the inventory restrictions on functional categories.

The logical structure of CONTIG_{LEX} raises an important typological issue that should be addressed before moving on. The condition on being in a lex-cat in (38) is disjunctive. This disjunction is essential in Navajo because it prohibits epenthesis at morpheme edges if only one morpheme is a lex-cat. But lex-cats aside, this is exactly the location of epenthesis predicted with a context-free contiguity constraint, as there are languages that funnel epenthetic elements to morpheme edges (McCarthy and Prince, 1993), (Kenstowicz, 1994)). The typological import of Navajo is therefore that it requires the disjunctively structured CONTIGUITY_{LEX} in addition to context-free CONTIGUITY, which, via standard ranking solutions, accounts for the typological feature of allowing contact epenthesis.

5.2.3 Extending the Analysis: Some Apparent Exceptions

Recall that the syllable preceding the stem syllable has a special status: it may have a coda contributed by a conjunct prefix.

(41) Pre-stem syllable exemption (repeated)

/na # ş̌ = né/ → naaş̌.né 'I play'

As a first person singular subject marker, ş̌- is clearly a functional category, so its ability to appear in a coda position seems to be an exception to the ban on conjunct codas. When the formal characteristics of this context are examined more carefully, however, this case is not an exception at all under the present analysis. A prefix contributing a coda consonant in the pre-stem syllable will always be adjacent to the stem or the voice prefix (AKA 'classifier'), which are canonical lexical categories (see 2.2). The pre-stem syllable is therefore the mirror image of a syllable at the disjunct-conjunct juncture: it is special by association with a neighboring lexical category. As shown below, epenthesis for the purpose of making an onset violates high-ranking lex-cat CONTIG, which correctly blocks epenthesis.

(42) Pre-stem syllable exemption with CONTIG_{LEX}

Input: /na # š = né/	CONTIG_{LEX}	NOCODA	CONTIG_{FUNC}
na.ši.né	*!		*
→ naaš.né		*	

Conjunct codas in the pre-stem syllable are an unavoidable consequence of the appeal to lex-cat contiguity advocated here, so this case provides further support for the basic analysis.[15]

A second apparent exception involves the so-called 'fourth person' prefix ǰ-, a morpheme classified by (Rice and Saxon, 1994) and (Rice, 2000) as a 'number subject' and referred to as a 'deictic subject' in the traditional Athabaskan literature. This morpheme is usually classified as a conjunct prefix, but, as illustrated below, it may in fact appear in coda position with concomitant spirantization (because ǰ is not allowed in codas; see section 5.2.4 below).

(43) Number subject ǰ- in coda position

/da # ǰ + doo = čah/   →   daž.doo.čah 'They (distpl) will cry'

If ǰ- is a conjunct morpheme, and therefore a functional category, this case would indeed constitute a problem for the analysis as it has been laid out thus far. However, a number of peculiar properties of this class of subjects set it apart from the other conjunct prefixes, which are consistent with a re-classification of this morpheme as a lex-cat.

The systematic differences between number subjects and other subjects occurring in the AgrS slot in (6) above have been noted by a number of researchers ((Hale, 2001), (Rice, 2000), (Rice and Saxon, 1994), (Willie, 1991)). These properties include differences in discourse function, surface position in the prefix complex, morphological relationships with other morphemes, semantic relationship with syntactic context, and importantly, obligatoriness. The last characteristic is significant because it is used by (Rice, 2000) to motivate the morpho-syntactic differences between disjunct/stem morphemes and conjunct prefixes. As explored in detail in (Rice and Saxon, 1994), a major difference between number subjects and AgrS subjects is that the latter are obligatory but number subjects are not. The meanings associated with number subjects can be achieved by omitting them and using other morphemes. This type of grammatical independence is used to distinguish lex-cats from func-cats, for example, in motivating the lex-cat classification for the iterative prefix ná- (see section 2.2). The grammatical independence of number subjects suggests, therefore, that they are in fact lex-cats and that they should pattern with other disjunct prefixes in their phonological behavior. I propose that this analysis is what accounts for the ability of ǰ- to appear in codas: it is a lex-cat and therefore triggers lex-cat faithfulness. The apparently exceptional behavior of this morpheme is not exceptional at all.

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[15] The extension of this analysis to coda maintanence in pre-stem syllables that have lost a voice prefix is not entirely straightforward, because wholesale deletion of the conjunct coda with the voice prefix, e.g., /…C=C+C/ → Ø Ø C, also violates CONTIG_{LEX} but satisfies NOCODA. However, double consonant deletion appears to be a more egregious violation of CONTIG_{LEX}, because the resulting discontiguous sequence in the output corresponds to segments that are farther apart in the input. The problem of formalizing this intuition is left for subsequent research.

5.2.4 Asymmetries in VV-Resolution

To conclude our discussion of syllable-related processes, let us consider a process that resolves VV sequences in the conjunct zone. As argued in (Kari, 1976), pp. 38-39, conjunct prefixes differ systematically from disjunct prefixes in the treatment of VV sequences. In the conjunct domain, the sequence V_1V_2 is resolved by deleting V_1 (44a). VV sequences arising at the disjunct#conjunct boundary, on the other hand, are not resolved (44b).

(44) Asymmetries in VV-Resolution

    a. Conjunct domain: $CV_1 + V_2C \rightarrow CV_2C$

        s̱i̱ (destruct)   /s̱i̱ + o̱h = ł + x̱é/   →   s̱o̱ł.x̱é 'You (duopl) kill it'

        ḏi̱ (inceptive) /ḏi̱ + o̱h = ḇááh/   →   ḏo̱h.ḇááh 'You (duopl) start to war'

    b. Disjunct/conjunct border: $CV_1 \# V_2C \rightarrow CV_1V_2C$

        ḏa (dist. pl)   /ḏa # o̱h = č̱a/   →   ḏao̱h.č̱a 'You (distpl) cry'

        ṉá (iterative) /ṉá # o̱h = ḏliš/   →   ṉáo̱h.ḏliš 'You (duopl) paint it repeatedly'

        ṉa ('around') /ṉa # i̱i̱D = ṉé/   →   ṉei̱i̱ʔ.ṉé 'We're (duopl) playing'

Both of the input V_1V_2 sequences above are permissible sequences in Navajo, according to the syllable template given below.

(45) Syllable template ((Sapir and Hoijer, 1967), (Faltz, 1998), (McDonough, 1990), (YM: xv))

    $C_1V_1(V_2)C_2$

In this template, if V_1 is not identical to V_2, V_2 must be i or o, so ai, ei, oi, ao, eo, io are possible diphthongs. Also, C_2 must be a plain stop of the set /d g/, a coronal fricative /s z š ž l ł/, the nasal /n/, or a glottal /ʔ h/. This characterization of Navajo syllables means that the input VV sequences of the conjunct prefixes in (46a) are not inherently ill-formed, and so VV-Resolution is not blocked in (44b) because of output requirements on syllable structure.

The markedness constraints motivating VV-Resolution are given below.

(46) NoDiphthong (Rosenthall, 1994)

    No syllable internal V_1V_2 where $V_1 \neq V_2$

(47) PersistV$_2$

    For two vowels in the input, x and y, if x and y are linear adjacent and x precedes y,

        then y must have a correspondent in the output.

NoDiphthong is the markedness constraint banning diphthongs. PersistV$_2$, given correspondence theoretic format above, expresses the typologically robust generalization that VV resolution strategies prefer retention of V_2, all other factors being equal (see (Rosenthall, 1994) et seq. and (Casali, 1997) for discussion). These independently motivated markedness constraints conspire to produce the correct pattern of VV resolution in the conjunct domain, as illustrated below.

(48) VV-Resolution in conjunct domain

Input: /di̧ + o̧h = bááh/	PersistV$_2$	NoDiphthong	Max$_{FUNC}$
dih.bááh	*!		
dio̧h.bááh		*!	
→ do̧h.bááh			*

Because NoDiphthong dominates Max$_{FUNC}$, the input VV must be resolved. PersistV$_2$ also correctly predicts that the first vowel of the sequence will be deleted, favoring the winner shown above. VV-Resolution therefore exhibits the same pattern of positional privilege displayed by epenthesis: universal markedness constraints dominate faithfulness, in this case the anti-deletion constraint Max$_{FUNC}$, producing unmarked syllable structure in the conjunct domain.

The effects of universal markedness are stymied, however, in the disjunct domain because of higher-ranking lex-cat faithfulness constraints, as depicted below.

(49) Failure of VV-Resolution in disjunct domain

Input: /da # o̧h = ča/	Max$_{LEX}$	PersistV$_2$	NoDiph
a. dah.ča		*!	
b. do̧h.ča	*!		
c. → dao̧h.ča			*

The first case is ruled out by PersistV$_2$, which saves the conjunct vowel from deletion (49a). The second case (49b) reveals a role for lex-cat faithfulness: Max$_{LEX}$ prohibits deletion of the first vowel contributed by the disjunct prefix. The winner is therefore the form that retains the lex-cat vowel, at the expense of producing a marked diphthong.

Another way to resolve the VV sequence sketched above is with consonant epenthesis. This strategy is actually employed in Navajo to supply an onset to a V-initial conjunct prefix at the beginning of a word, e.g., /o̧h = ł + teeh/ → wo̧łteeh 'You (duopl) lie down' (see (Faltz, 1998), (McDonough, 1990; McDonough, 1996)). The avoidance of such a strategy at the disjunct#conjunct border reveals an additional role for Contig$_{LEX}$, the constraint employed in 5.2.2-3 to prohibit contact epenthesis. As shown below, lex-cat contiguity also prevents consonantal epenthesis to resolve the input V$_1$#V$_2$ sequence, showing another role for this crucial constraint.
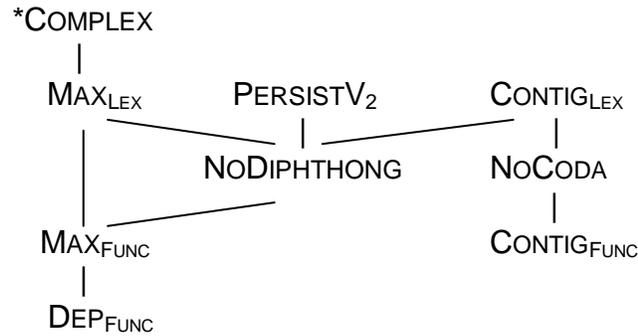
(50) Effects of contiguity in VV-Resolution

Input: /da # o̧h = ča/	Contig$_{LEX}$	NoDiph
dawo̧h.ča	*!	
→ dao̧h.ča		*

In yet another corner of the prefix phonology, therefore, the division between faithfulness constraints prescribed by the PF program explains apparent domain-sensitivity.

The rankings below summarize the constraint system as it has been developed thus far.

(51) Summary ranking for syllable structure related processes

$$*\text{COMPLEX}$$
$$|$$
$$\text{MAX}_{\text{LEX}} \qquad \text{PERSISTV}_2 \qquad \text{CONTIG}_{\text{LEX}}$$
$$| \qquad | \qquad |$$
$$\text{NODIPHTHONG} \qquad \text{NOCODA}$$
$$| \qquad |$$
$$\text{MAX}_{\text{FUNC}} \qquad \text{CONTIG}_{\text{FUNC}}$$
$$|$$
$$\text{DEP}_{\text{FUNC}}$$

The constraint hierarchy above is consonant with the core thesis of positional faithfulness. The constraints motivating the syllable-related processes, NODIPHTHONG and NOCODA, are universal markedness constraints, appealed to extensively in language particular analyses. By inserting these universal constraints between the lex-cat and func-cat faithfulness constraints, the resistance of lexical categories to regular processes is explained. Just as with the analysis of the sound inventory, therefore, the PF analysis of alternations has broad cross-linguistic implications.

5.3 Discussion of other Conjunct-Specific Processes

While a comprehensive analysis of conjunct neutralizations is beyond the scope of this article, it is interesting to try to extend the core ideas of the PF analysis to the rest of the processes listed in (30). For example, most of the morphologized processes in (30) (i.e., (30f-h), cf. (30i), and y-Vocalization (30b)) resolve CCs, which can be viewed as additional evidence for the high-ranked status of NOCODA. y-Vocalization is interesting in this light because it appears to reveal an additional ordering among the syllable structure constraints. The input for this process is schematically VyC, so, whatever the outcome (deletion aside), a marked syllable structure will result: a coda consonant if no process at all, or a diphthong with vocalization. The observed mapping y → i can thus be analyzed with the domination of FAITH(y → i) by NOCODA, which must also dominate NODIPHTHONG.

Coronal harmony (30d) also relates to the central thesis, but it reveals a different kind of positional privilege. A high-ranking markedness constraint must dominate both lex-cat and func-cat faithfulness to [anterior], because different specifications are not allowed in a word, even in stems and disjunct prefixes (McDonough, 1991). When a conjunct prefix and stem, for example, have conflicting [anterior] specifications, the specification of the prefix harmonizes with the stem, e.g., yismas 'I'm rolling away', cf. yišteeh 'I handle it'. The analysis of this type of stem-controlled alternation also falls out from the privileged faithfulness status of lex-cats, through a constraint ranking in which lex-cat faithfulness is actually dominated. Plugging the markedness constraint triggering harmony, AGREE[anterior] (see (Lombardi, 1999)), into the schematic ranking from (22b) correctly produces neutralization in the conjunct domain.

(52) Lex-cat-controlled [anterior] harmony

Input: /yiš̱ + mas/	AGREE[anterior]	IDENT_{LEX}[anterior]	IDENT_{FUNC}[anterior]
yiš̱mas	*!		
yiš̱maš		*!	
→ yiš̱mas			*

The only difference between the ranking above and those from 5.2 involving neutralizations of syllable structure is that, here, the top-ranked markedness constraint is actually in force in lex-cats, prohibiting disharmonic stems and disjunct prefixes. Furthermore, the examples of progressive harmony given in (Kari, 1976) pp. 84-85, show that conjunct prefixes can receive a [anterior] specification from disjunct prefixes, as predicted by the grouping of disjunct prefixes and stems together as lex-cats. The availability of lex-cats at both ends of the word produces a pattern of 'outside-in' spreading, showing that both types of lex-cats can override the featural properties of func-cats.

Finally, Tone Spread (30e) also seems to be in line with the basic analysis, as this process always spreads progressively onto a conjunct vowel. I assume, therefore, that the blocking of spreading onto a disjunct vowel follows from the high-ranked status of lex-cat tonal faithfulness. As shown in section 3, disjunct prefixes are distinguished from conjunct prefixes in having a contrast in tone, which requires elevating lex-cat tone faithfulness. Perhaps the immunity of pre-stem disjunct vowels to Tone Spread is also an effect of lex-cat faithfulness. A caveat with this analysis is that it may not be possible to spread onto pre-stem disjunct vowels for other reasons, since disjunct vowels are usually lengthened in this context and Tone Spread only affects short vowels. A check of the lexical resources does not turn up any disjunct prefixes that would supply the right phonological structure for Tone Spread, so this problem will have to be left for further research.

6. Discussion of An Alternative: Positional Markedness

The discussion thus far has treated all structural disparities in Navajo as a consequence of positional faithfulness. There is an alternative mode of analysis, however, that enriches markedness theory instead of faithfulness. In Positional Markedness (PM) Theory (see especially, (Steriade, 1999) and (Zoll, 1998)), markedness effects are assigned to specific environments in a word and asymmetries arise through the interaction of markedness constraints and context-free faithfulness. In PM, the absence of nasal vowels in conjunct prefixes, for example, can be attributed to a constraint that prohibits nasal vowels specifically in functional categories, *NASALVOWEL/FUNC. How does one decide between these very different types of analyses?

In the literature on inventory asymmetries, there are certain types of evidence that suggest a clear preference for one of these two possibilities. For example, phenomena that require reference to lexical representations seem to require PF, since markedness constraints by definition do not have this power.[16] Linguistic typologies also provide important arguments for

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[16] See, for example, the analysis of the avoidance of stressing epenthetic vowels in (Alderete, 1999) or the account of the transfer of root height features in (Walker, 1997), both of which require reference to input structure, and, accordingly, call for positional faithfulness.

PF or PM, depending on the range of observed phonological processes called upon to resolve marked structures. In general, a heterogeneous set of processes as a response to marked structure is indicative of positional markedness, since markedness itself says little about how to resolve marked structure. On the other hand, a significant gap in the range of 'repairs' suggests positional faithfulness, because PF theory does not posit a constraint against the marked structure (see especially (Lombardi, 2001) for discussion of this problem for [voice] and [place] restrictions in codas, and (Zoll, 1998) for a PM analysis of heterogeneity of process in Hamer). Systems in which a phonological asymmetry is found in both inventories and alternations, as (Beckman, 1998) observes in the distribution of nasality in Guarani, also support an analysis in terms of positional faithfulness, because the two types of evidence cannot be cogently analyzed without reference to inputs, whence the role for faithfulness.[17]

Consideration of the learnability of distributional asymmetries also informs the PF/PM debate. It has been shown by a number of researchers that PF differs from PM in that PF analyses of inventory asymmetries allow for certain ranking decisions involving faithfulness constraints that may commit the learner to a grammar that over-generates ((Hayes, to appear), (Prince and Tesar, to appear), (Smith, 2000)). Problems such as these are troubling, since it is generally assumed that learning takes place of the basis of positive evidence, so if the learner does select a grammar that over-generates, no amount of additional data will be inconsistent with this incorrect grammar.[18] Putting aside the above linguistic arguments, one might reasonably conclude that this over-arching problem with PF points in the direction of positional markedness, at least in contexts where both analyses are possible. The discussion below, however, shows that this position is not tenable for Navajo, because many of the structural disparities discussed above do not submit to a cogent analysis in the PM paradigm.

6.1 Argument 1: Duplication of [place] Markedness Subhierarchy

Recall that conjunct prefixes differ from disjunct and stem morphemes in disallowing labials and dorsals.

(53) Subset relation for [place]

    a. Disjunct prefixes/stems: Lab, Dor, Cor, Phar
    b. Conjunct prefixes: Cor, Phar

In the PF analysis, this fact is explained by interrupting the Place Markedness Subhierarchy with morphologically segregated faithfulness, as shown below.

(54) Positional Faithfulness analysis: Interruption of Place Markedness Subhierarchy

    IDENT[place]_{LEX} >> *PL\LAB, *PL\DOR >> **IDENT[place]**_{FUNC} >> PL\COR >> *PL\PHAR

The absence of labials and dorsals in the conjunct therefore follows from domination of IDENT[place]_{FUNC} by context-free markedness.

In the PM alternative, the Place Markedness Subhierarchy itself must be modified, since PM refines markedness constraints rather than faithfulness constraints. The assignment of

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[17] (Zoll, 1998) also argues that blocking of derived phonological structures supports a PM analysis, but this argument is weakened by the lack of discussion of alternative analyses. Moreover, it is clear that this type of pattern also supports PF: see for example (Alderete, 2001a) for an analysis of the blocking of derived structure in Cupeño pre-accentuation that can only be due to positional faithfulness.

[18] Though recent work (Alderete and Tesar, 2002) shows that over-generation problems such as these are not just a consequence of the special/general relationship among faithfulness constraints.

markedness effects to specific domains when markedness relations are expressed in a harmony scale is standardly achieved through hierarchical alignment (Prince & Smolensky 1993), as computed below.

(55) Alignment of two harmony scales

- **D**$_{Cat}$: FUNC-CAT ≻ LEX-CAT
  D$_{Place}$: PHAR ≻ COR ≻ DOR, LAB

- **H**$_{Func}$: PHAR/FUNC ≻ COR/FUNC ≻ DOR/FUNC, LAB/FUNC
  H$_{Lex}$: PHAR/LEX ≻ COR/LEX ≻ DOR/LEX, LAB/LEX

- **CH**$_{Func}$: *DOR/FUNC, *LAB/FUNC >> *COR/FUNC >> *PHAR/FUNC
  CH$_{Lex}$: : *DOR/LEX, *LAB/LEX >> *COR/LEX >> *PHAR/LEX

The output of this alignment procedure is two orderings for lexical and functional categories. The ordering of the func-cat hierarchy relative to the lex-cat hierarchy is determined by the Navajo data (though there are theoretical assumptions relevant to this ordering as well). The markedness constraints banning [place] specifications in functional categories must be top-ranked in order to prohibit marked labials and dorsals in func-cats. As shown below, context-free faithfulness is dominated by the markedness constraint banning these structures, which, in turn, dominates all other place markedness constraints.

(56) Positional Markedness analysis

*DOR/FUNC, *LAB/FUNC >> **IDENT[PLACE]** >> *COR/FUNC >> *PHAR/FUNC …

… >> *DOR/LEX, *LAB/LEX >> *COR/LEX >> *PHAR/LEX

The PM analysis, however, unnecessarily duplicates the markedness relations inherent to the Place Markedness Subhierarchy; the orderings in the lex-cat hierarchy are totally irrelevant. Put another way, the generalization that dorsals are more marked than coronals, etc., is stated more than once by the grammar, once for functional categories and again for lexical categories. This duplication of effort is a necessary consequence of PM theory because it works directly on markedness theory, and markedness for [place] is expressing through fixed rankings. When compared with the PF analysis, therefore, PM leads to loss of generalization.[19]

6.2 Argument 2: VV-Resolution Asymmetries

The second and third argument against the PM analysis involve examining two syllable structure related phenomena. As exemplified in 5.2.4, conjunct and disjunct prefixes respond differently to VV sequences: V_1 of a V_1V_2 sequence is deleted if it is from a conjunct prefix, but it is retained if it is from a disjunct prefix.

(57) Vowel resolution strategies revisited

a. Vowel deletion in conjunct ($V_1 \in$ conjunct prefix): $CV_1 + V_2C \rightarrow CV_2C$
b. No deletion at $V_1\#V_2$ border: ($V_1 \in$ disjunct prefix): $CV_1 \# V_2C \rightarrow C V_1\#V_2C$

The salient generalizations are therefore that V_2 is never deleted, and that the vowels of conjunct prefixes cannot support diphthongs (except under duress). The first generalization is already

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[19] One might object to this argument by locating a unitary generalization in the meta-linguistic scales that hierarchical alignment works on. Such scales, however, do not constitute grammars, and it is grammars that reflex the linguistic competence of markedness relations associated with [place] features.

accounted for with PERSISTV$_2$. PM theory accounts for the second with a constraint like the following:

(58) NODIPHTHONG/FUNC
        Diphthongs cannot be composed of vowels $\in$ func-cat

In the conjunct domain, these constraints work together to predict the correct pattern of vowel deletion, as illustrated below.

(59) Vowel deletion in the conjunct

Input: /CV$_1$ + V$_2$C/	NODIPHTHONG/FUNC	PERSISTV$_2$	MAX
CV$_1$C		*!	*
CV$_1$V$_2$C	*!		
→ CV$_2$C			*

But when V$_1$ is occupied by a disjunct vowel, this ranking makes an incorrect prediction (signified by the eight ball), because the two constraints conspire to weed out the disjunct vowel, which is in fact retained.

(60) No vowel deletion at the disjunct#conjunct border

Input: /CV$_1$ # V$_2$C/	NODIPHTHONG/FUNC	PERSISTV$_2$	MAX
CV$_1$C		*!	*
CV$_1$V$_2$C	*!		
❽ → CV$_2$C			*

The most straightforward analysis offered by PM is therefore not descriptively adequate. In order to make this analysis work, an additional stipulation is needed, namely that the initial vowel of a diphthong cannot be from a functional category (contrary to the requirements of PERSISTV$_2$). With this re-formulation of NODIPHTHONG/FUNC, the second form above, CV$_1$V$_2$C, will win, since it no longer violates the PM constraint.
        This additional stipulation, however, is entirely unnecessary in the PF analysis (depicted in tableaux (48-50)). As discussed in 5.2.4, the observed asymmetry follows naturally from interspersing context-free markedness between the PF anti-deletion constraints: MAX$_{LEX}$ >> NODIPHTHONG >> MAX$_{FUNC}$. The PF analysis does not require an ad hoc targeting of V$_1$, and it is therefore to be preferred for this reason.

6.3 Ad hoc Extraprosodicity
        The final argument is based in the PF analysis of coda asymmetries, repeated below.

(61) Coda consonant possibilities

    a. No codas inside conjunct zone: /VC+CV/ → VCiCV
    b. Codas allowed inside disjunct zone/stems: /VC#CV/ → VC.CV, /VC+CV#/ → VC.CV
    c. Codas allowed in pre-stem syllable: /VC=CVC/ → VC.CVC

The basic generalization is that conjunct consonants cannot appear in coda position, unless they are in the pre-stem syllable. Putting the exceptional pre-stem syllable aside, this generalization supports the introduction of a func-cat specific NOCODA constraint.

(62) NoCoda/Func

   No coda consonants ∈ func-cat

This constraint can correctly motivate epenthesis internal to the conjunct domain, as depicted below for a C̲+C̲ cluster.

(63) Positional Markedness drives epenthesis

Input: /V̲C̲+C̲V/	NoCoda/Func	Dep	NoCoda/Lex
V̲C̲.C̲V	*!		
→ V̲.C̲i.C̲V		*	

However, the PM constraint does not exempt the pre-stem syllable in any way, so conjunct codas are incorrectly resolved through epenthesis.

(64) Problem: Pre-stem syllable

Input: /V̲C̲=C̲V/	NoCoda/Func	Dep	NoCoda/Lex
V̲C̲.C̲V	*!		
❽ → V̲.C̲i.C̲V		*	

To remedy this situation, it is necessary to stipulate that the pre-stem syllable is 'extraprosodic' in some non-standard way (McDonough, 1990). This move is surely unmotivated cross-linguistically, however, because extraprosodicity as a descriptive device is limited to peripheral elements. Since the stem syllable is usually the penultimate or final syllable, this move entails stating that the penultimate or antepenultimate syllable is outside the domain of normal syllabification.

   Once again, this ad hoc stipulation is not necessary in the PF analysis. As shown in 5.2.3 (in (39), (40), and (42)), the pre-stem syllable exemption follows as a natural consequence of top-ranked Contig_Lex, the constraint responsible for precluding contact epenthesis in general.[20] In sum, the analysis of the pre-stem syllable exemption also shows that the PF analysis is superior to the PM analysis.

6.4 Discussion

   The arguments presented above for Navajo are similar in spirit to the argument developed in (Beckman, 1998) for PF on the basis of nasality in Guarani. In her analysis, Beckman shows that if one is to avoid the use of positional faithfulness constraints and instead rely exclusively on PM, certain metrical structures for demarcating the domains of [nasal] spread are required that are totally unmotivated in the language. The arguments presented in 6.1-3 make this point as well, because the PM analysis is forced into assumptions that are only needed to account for the data at hand. The structural disparities documented in this article therefore provide a rich set of linguistic evidence for the positional faithfulness program.

   Another point that can be made about the case of Navajo is that distributional asymmetries are quite ubiquitous and encompass almost every aspect of phonological structure. This 'wholesale' distributional difference between lex-cats and func-cats is predicted by PF theory, but is somewhat inconsistent with the PM program. PM constraints reflect substantive

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[20] Context-free contiguity is of no use, however, to the PM analysis, since it would actually predict contact epenthesis, contrary to fact.

constraints on specific combinations of linguistic structure, often motivated by findings in phonetic theory and psycho-linguistics. For example, the notion of phonetic salience developed in (Steriade, 1999) motivates substantive restrictions on specific laryngeal features, with each feature having intrinsic structural limitations. However, structural disparities in Navajo, which extend throughout the phonological inventory, do not appear to have this same functional motivation.

This argumentation does not, on the other hand, show that PM constraints are unnecessary in general and that they can therefore be excluded from *CON*. Proponents of PM theory have shown rather convincingly that UG requires PM constraints. For example, many of the arguments presented in favor of PF constraints cut both ways: linguistic typologies also require PM, as argued by (Lombardi, 2001) for [place] restrictions on codas and (Zoll, 1998) for the heterogeneity of process in Hamer. Indeed, some PF analyses do not work at all without PM, as argued for example in (Walker, 1997) on the basis of feature transfer in Esimbi. Finally, as pointed out in (Kager, 1999), it is impossible to describe one of the most basic distributional patterns, complementary distribution, without context-sensitive markedness. Complementary distribution entails non-overlapping environments for some phonological structure, which means that the distribution is not contrastive and therefore not the job of faithfulness constraints. When one combines these issues with the learnability basis for favoring PM discussed above, it would seem that different types of evidence point in the direction of maintaining both PF and PM constraints as integral parts of the constraint component of *CON*.

7. Conclusion

A fundamental goal of linguistic theory is to make sense of language particular facts with universal principles. The analysis of Navajo verbs presented in this article achieves this goal by appealing exclusively to independently necessary markedness and faithfulness constraints in Optimality Theory. This analysis, and the discussion of a plausible alternative in section 6, support a number of conclusions:

1. *Unification of analysis of inventories and alternations*: the differences between lex-cats and func-cats found in both sound inventories and alternations are explained with the same basic toolbox in OT, i.e., markedness-faithfulness interactions.
2. *Universal markedness*: the structural disparities between lexical and functional categories follow from universal markedness constraints.
3. *Lex-cat faithfulness*: the observed relationship between morpho-syntactic properties (i.e., the lexical/functional distinction) and phonological properties receives a natural account in PF Theory with lex-cat faithfulness.
4. *Domain-specificity:* is explained as a direct consequence of the PF thesis; all behavior characteristic of disjunct or conjunct morphemes can be described in relation to the lexical/function distinction.
5. *PF distinct from PM*: certain distributional asymmetries, like those found in Navajo, require PF constraints that are distinct from PM constraints.

Appendix: chi-square analysis of the prefix data

This appendix provides a statistical analysis of the frequencies of selected phonological structures occurring in the two prefix classes relevant for this study, the disjunct and conjunct prefixes. In general, the finding is that the deviations of actual frequencies of these structures from expected frequencies (based on semi-random distribution; see below) generally support the distributional restrictions frequently observed in Navajo linguistics.

The statistical analysis is supplemented by two additional files, available electronically on ROA together with the PDF file of this article:

<navdisp_prefixData.xls>: this file contains all of the prefixes used in the analysis, itemized in a row on an Excel spreadsheet. Each prefix is classified according to the assumed phonological characteristics.

<navdisp_prefixData_notes.txt>: this file explains the methods of classification used in the above Excel spreadsheet and motivates some of the analytical decisions necessary to these classifications.

This data can be used to validate the analysis proposed here or to explore other linguistic questions in Navajo.

The prefix data were drawn from (Young and Morgan Sr, 1987), specifically from the prefix chart on page 37-38 and the ensuing lists (pp. 39-139), and their phonological classifications and templatic positions are included in the Excel spreadsheet. There are two problems with this method of the data collection: (i) the prefix data were not, strictly speaking, collected at random, which is required for this type of analysis, and (ii) Young & Morgan tend to enumerate large numbers of morphemes, even when they have the same phonetic form. Problem (i) is inherently problematic and represents a limitation of this study, but it can be said that Young & Morgan's prefix list was compiled over a long period of time, roughly 50 years, and so the list is semi-random in the sense that data points were sampled over an extended time period. I dealt with problem (ii) by removing all homophones that occurred in the same template slot in an adjusted list. Significantly, there were no substantive differences in the results of the chi-square analysis of the adjusted list from the unadjusted list, except in the tables for vowel length and nasality, which have rather low baselines anyway.

The tables below list the actual frequencies of the phonological structures under analysis, next to the expected frequencies in parentheses, and the χ^2 statistics with associated P values are given in each table header. Starting first with the consonants, the analysis reveals significant deviations from expected frequencies for place, laryngeal features, and the features distinguishing affricates from non-affricates (Tables 1-3), but no significant deviations for the features distinguishing voiced and voiceless fricatives (Tables 4). For the voiced fricatives, the extremely low number of voiced fricatives precludes any real conclusions, as chi-square statistics are generally not reliable with such a small number of observations. We may note, however, that of the seven observed voiced fricatives, all of them are in a disjunct prefix, which is consistent with the assumed restriction against conjunct voiced fricatives.

Table 1. Consonantal place features: χ^2 = 14.140, df = 3, p ≤ 0.01

Prefix Type	Lab	Cor	Dors	Phar	Total
Disjunct	5 (5.8)	117 (127)	26 (19)	46 (42.3)	194
Conjunct	3 (2.2)	57 (47)	0 (7)	12 (15.7)	72
Total	8	174	26	58	266

Table 2. Laryngeal settings in stops: χ^2 = 24.663, df = 2, p ≤ 0.001

Prefix Type	Plain	Asp	Eject	Total
Disjunct	51 (62.4)	34 (27.2)	23 (18.4)	108
Conjunct	27 (15.6)	0 (6.8)	0 (4.6)	27
Total	78	34	23	135

Table 3. Affricates: χ^2 = 4.198, df = 1, p ≤ 0.05

Prefix Type	Non-affricate	Affricate	Total
Disjunct	170 (174.5)	24 (19.5)	194
Conjunct	72 (67.5)	3 (7.5)	75
Total	242	27	269

Table 4. Fricative Voicing: χ^2 = 3.396, df = 1, n.s. (p ≤ 0.10)

Prefix Type	Voiceless	Voiced	Total
Disjunct	35 (37.1)	7(4.9)	42
Conjunct	18 (15.9)	0 (2.1)	18
Total	53	7	60

As for the vowels, Tables 5, 6, and 8 show significant deviations from expected frequencies for vowel quality, vowel length, and tone, respectively. The interpretation of the vowel quality data is to be taken with a grain of salt, however, because the high number of observations of i in conjunct prefixes is due in part to the specific assumption made by Young & Morgan to specify this vowel. As discussed in 5.2, other analyses posit single consonant prefixes that receive an epenthetic i, so i is not necessarily part of the conjunct morpheme under analysis. However, the purpose of the chi-square statistic is to find significant gaps in the distribution of these vowels so that observations about markedness can be made. If it turns out that the epenthesis analysis is correct, the same observations can be made in the analysis presented in section 5, since markedness also predicts the quality of the epenthetic vowel.

Vowel length, however, does not deviate significantly from the expected frequencies in the adjusted data sample without homophones (see above): $\chi^2 = 2.811$, $P \leq 0.10$, and there are no significant deviations for nasality in either the adjusted ($\chi^2 = 0.189$, $P \leq 1.0$) or unadjusted data samples (Table 7). I believe that these findings are also due to the small baselines, since there are only 7 observations for nasal vowels and 19 for long vowels. What can be said is that there is only one observation in each case of the marked feature in a conjunct prefix, which can be viewed as consistent with a restriction on this feature in conjunct prefixes.

Table 5. Vowel Quality: χ^2 = 82.197, df = 3, p ≤ 0.001

Prefix Type	i	e	o	a	Total
Disjunct	55 (86.9)	10 (7.2)	12 (10.8)	104 (76.1)	181
Conjunct	66 (34.1)	0 (2.8)	3 (4.2)	2 (29.9)	71
Total	121	10	15	106	252

Table 6. Vowel Length: χ^2 = 5.33, df = 1, p ≤ 0.025

Prefix Type	Short	Long	Total
Disjunct	163 (167.4)	18 (13.6)	181
Conjunct	70 (65.6)	1 (5.4)	71
Total	233	19	252

Table 7. Vowel Nasality: χ^2 = .686, df = 1, n.s. (p ≤ 1.0)

Prefix Type	Oral	Nasal	Total
Disjunct	175 (176)	6 (5)	181
Conjunct	70 (69)	1 (2)	71
Total	245	7	252

Table 8. Tone: χ^2 = 24.335, df = 1, p ≤ 0.001

Prefix Type	NonHigh	High	Total
Disjunct	101 (117.8)	80 (63.2)	181
Conjunct	63 (46.2)	8 (24.8)	71
Total	164	88	252

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