Author/s:
Wilmoth, S;Mansfield, J

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# Inflectional predictability and prosodic morphology in Pitjantjatjara and Yankunytjatjara

**Sasha Wilmoth and John Mansfield**
*University of Melbourne*

**Abstract**

*Lexically stipulated suppletive allomorphy, such as that found in inflection class systems, makes wordforms unpredictable because any one of several exponents may be used to express a grammatical category. However, recent research shows that apparently complex inflectional paradigms can be organised in such a way that knowing one inflected form of a lexeme greatly reduces the uncertainty of other forms (e.g. Ackerman & Malouf, 2013). Further typological work is required to investigate the ways in which inflectional interpredictability is achieved, and what aspects of wordforms may be informative. In this paper we present a case study of interpredictability in verbal inflection in Pitjantjatjara and Yankunytjatjara (Pama-Nyungan; Australia). We show that a combination of suffix allomorphy, prosodically conditioned stem augmentation, and the prosodic structure of verbal roots all conspire to achieve a paradigm that is totally interpredictable: hearing one inflected verb enables a speaker to produce with certainty any other form of that verb. We also provide a detailed description of metrical structure in the language, clarifying previous analyses.*

**Keywords**

Australian languages; Western Desert; Prosodic morphology; Inflectional paradigms; Word and paradigm morphology; Interpredictability; Inflectional classes; Transparency; Entropy

## Abbreviations

| | |
|---|---|
| AUG | augment |
| ANAPH | anaphoric demonstrative |
| ASSOC | associative |
| CAUS | causative |
| CHAR | characteristic |
| FUT | future |
| IMP | imperative |
| INCH | inchoative |
| IPFV | imperfective |
| LOAN | loanword transitiviser |
| MV | medial verb |
| NEUT | neutral |
| NMLZ | nominaliser |
| NOM | nominative |
| NPST | non-past |
| PFV | perfective |
| PROC | process suffix -*kati* |
| PROP | proprietive |
| PRS | present |
| PST | past |
| REDUP | reduplication |
| SEQ | sequential |

# 1 Introduction

Inflectional paradigms often exhibit 'unnecessary' complexity: the set of possible formatives may outnumber the set of grammatical features which can be expressed. This often comes in the form of suppletive suffix allomorphs, which can be phonologically conditioned (Paster, 2006, 2009, 2015), specific to an individual lexeme, or the lexicon may be organised into inflectional classes. A learner of a language with a complex inflectional system must go to some effort in memorising this information on a per lexeme basis where the suppletion is not phonologically conditioned. But this extra effort results in no communicative benefit, viewed purely in terms of semantic or morphosyntactic distinctions conveyed. For this reason, Aronoff calls morphology 'a disease, a pathology of language' (Aronoff, 1998, p. 413).

This view of inflection classes as unnecessarily complex leads to the question of why this complexity arises, how it can be learned, and how it can remain stable in language. Recent research suggests that even when inflectional paradigms have a high degree of 'unnecessary complexity' in the number of possible formatives, they tend to be organised such that unknown wordforms are generally predictable based on those already encountered (Ackerman & Malouf, 2013; Stump & Finkel, 2013). This means languages can be complex in enumerative terms (E-complexity), but relatively simple in the way that the paradigm is organised to facilitate the correct inflection of previously unknown wordforms. The latter dimension of complexity has been called integrative complexity, or I-complexity (Ackerman & Malouf, 2013). This perspective on morphological complexity leads to a new set of questions, including how paradigms achieve this organisation, and what information is leveraged by speakers to facilitate prediction of unknown wordforms.

In this paper, we present a new case study of how paradigms can be organised to enable interpredictability between inflected wordforms. Verbs in Pitjantjatjara and Yankunytjatjara are organised into four inflection classes, and we show that the lexicon is divided among these classes according to the prosodic structure of verbal stems. The combination of suppletive suffix allomorphy, prosodic structure of stems, and prosodically conditioned stem augmentation together correctly predicts unknown wordforms. Although inflectional exponence is highly unpredictable from the point of view of individual wordforms in the absence of other information, every inflectional form of a verb lexeme becomes completely predictable given knowledge of any other form of that lexeme. For example, the past perfective and present tense forms of each class are shown in (1), with annotations indicating bimoraic metrical feet. In the past tense, there are three suffix allomorphs *-ŋu*, *-nu*, *-ɳu*. The forms *-nu* and *-ɳu* uniquely identify the verb as belonging to the n- or l-class respectively. The *-ŋu* allomorph is shared between the Ø- and ng-classes, but in that case, the combination of allomorph and prosodic shape of the stem enables the correct prediction of the verb's class: Ø-class roots end in a complete foot. In the present tense, stem augments *-na* and *-ŋa* distinguish between classes where the suffix *-ɲi* is shared between three of the four classes. Verbal inflection is entirely interpredictable once these three cues are taken into account.

1. Past perfective:

| | | | |
|---|---|---|---|
| Ø-class: | *pirtji-ngu* | (pirci)$_{\varphi}$-ŋu | wriggle-PST.PFV |
| l-class: | *ampu-n̠u* | (ampu)$_{\varphi}$-ɳu | hug-PST.PFV |
| ng-class: | *tjititi-ngu* | (citi)$_{\varphi}$(ti-ŋu)$_{\varphi}$ | shiver-PST.PFV |
| n-class: | *uuli-nu* | (uː)$_{\varphi}$(li-nu)$_{\varphi}$ | irritate-PST.PFV |

Present:

| | | | |
|---|---|---|---|
| Ø-class: | *pirtji-nyi* | (pirci)$_{\varphi}$-ɲi | wriggle-PRS |
| l-class: | *ampu-n̠i* | (ampu)$_{\varphi}$-ɳi | hug-PRS |
| ng-class: | *tjititi-nga-nyi* | (citi)$_{\varphi}$(ti-ŋa)$_{\varphi}$-ɳi | shiver-AUG.IPFV-PRS |
| n-class: | *uuli-na-nyi* | (uː)$_{\varphi}$(li-na)$_{\varphi}$-ɳi | irritate-AUG.IPFV-PRS |

Maximally transparent systems such as these are often assumed to have a simple internal structure; for example, Czech verbs which have unique suffix allomorphs in each cell of the paradigm (Baerman et al., 2017, pp. 100–101). In this paper we show how maximal transparency can be achieved through a deeply non-canonical and overlapping combination of prosodic structure, suppletive suffix allomorphy, and stem augmentation. Therefore, as well as contributing a more detailed description of metrical structure and verbal inflection than in previous work on Pitjantjatjara/Yankunytjatjara, this paper provides a new case study on how inflectional paradigms can be organised to facilitate predictability.

We begin in §2 by introducing research into paradigmatic interpredictability. In §3, we introduce Pitjantjatjara/Yankunytjatjara (henceforth simply Pitjantjatjara). In order to describe the interpredictability of the inflectional system, we first need to establish our analysis of metrical structure in the language. Thus in §4, we discuss previous accounts of metrical structure and stress in Pitjantjatjara, and evidence for bimoraic metrical feet. Then, in §5, we describe the verbal inflectional system, and show that the four classes are categorically associated with roots of particular prosodic shapes. We also show that some derivational processes can result in verbs of different classes depending on the prosodic structure of the derived stems, implying that the prosodic effects are synchronically active. In §6, we show that the paradigm is organised in such a manner that wordforms are completely interpredictable, and in §7 we use information theoretic measures to quantify the relative contributions of prosodic and segmental cues to this interpredictability.

## 2 Interpredictability of inflected forms

There is a long-standing linguistic tradition of analysing inflectional morphology as relationships between wordforms, whereby knowledge of one form facilitates prediction of another. Paul (1888) formalised this as 'proportional analogies' from one lexeme to another, while didactic grammars identified 'principal parts' as sets of one or more inflected forms of a lexeme that enable prediction of all other forms of that lexeme (Finkel & Stump, 2007, 2009). In recent times there has been a resurgence of interest in the interpredictability of wordforms (for an overview see Blevins, 2016), and especially in the quantification of predictability using information theory (Ackerman & Malouf, 2013; Sims, 2020; Stump & Finkel, 2013). There have also been theoretical developments concerning the role of interpredictability in language learning, processing, and diachrony (Moscoso del Prado Martín et al., 2004; Albright, 2009; Baayen et al., 2011; Carstairs-McCarthy, 2011; Stoll, 2015; Sims & Parker, 2016; Herce, 2020 inter alia).

Ackerman and colleagues (2009) articulate the core of inflectional interpredictability as the Paradigm Cell Filling Problem (PCFP):

> What licenses reliable inferences about the inflected (and derived) surface forms of a lexical item? (Ackerman et al., 2009, p. 54)

While the fundamental question refers to 'surface forms', i.e. whole words, their analysis follows other morphological traditions in distinguishing lexical stems and inflectional exponents, be these either concatenative affixes or stem modifications. They formulate the uncertainty of exponence for a given morphosyntactic feature set (a 'paradigmatic cell') using entropy, a measure in which a higher figure is interpreted as greater uncertainty among a range of possible outcomes (Shannon, 1948). In systems with suppletive suffix allomorphy, individual inflectional forms have some degree of uncertainty in exponence. For example, in Modern Greek, there are several exponents of genitive singular (including *-u*, *-i*, *-is*, and *-as*), and this is an arbitrary fact that must be learnt for each lexeme. However, learners of Greek do not typically attempt to guess an inflectional exponent given only an uninflected lexical stem. Rather, they encounter one or more inflected forms of a lexeme, and they use this information to predict other inflected forms that they have not yet encountered (Ackerman et al., 2009, p. 56; Blevins et al., 2017). The focus of this approach is thus on cognitively plausible models for language learning and use, where language is viewed as a complex adaptive system (Beckner et al., 2009; Blevins, 2016 ch. 8; Blevins et al., 2016; Boyé & Schalchli, 2019). This is in contrast to more idealised models that focus on how wordforms can be computed given a deconstructed database of morphological atoms (e.g. Lieber, 1992; Halle & Marantz, 1993).

An example of inflectional interpredictability can be seen in Warlpiri verbs, with inflected forms illustrated in Table 1.[1] Certain forms licence predictions about certain other forms. For example, knowing the form *ji-ni* 'scold-NPST' allows one to predict *ju-nu* 'scold-PST', since the *-ni* NPST suffix is only found in class V verbs. But knowing the form *nga-rnu* 'eat-PST' leaves some uncertainty as to whether the imperative form should be in *-ka* or *-nja*, since the *-rnu* PST suffix is shared between classes II and IV. Some wordforms have more predictive power than others. The matrix of exponents can thus be modelled as a network of interpredictability among inflected wordforms.

*Table 1. Warlpiri verb inflection classes (Nash, 1980, p. 40, M. Browne, pers. comm.)*

| Infl. class | I<br>'stand' | II<br>'dig' | III<br>'give' | IV<br>'eat' | V<br>'scold' |
|---|---|---|---|---|---|
| NON-PAST | *karri-mi* | *pangi-rni* | *yi-nyi* | *nga-rni* | *ji-**ni*** |
| PAST | *karri-ja* | *pangu-**rnu*** | *yu-ngu* | *nga-**rnu*** | *ju-**nu*** |
| IMPERATIVE | *karri-ya* | *pangi-**ka*** | *yu-ngka* | *nga-**nja*** | *ji-nta* |
| IMM. FUTURE | *karri-ji* | *pangi-ki* | *yi-ngki* | *nga-lku* | *ji-nki* |
| PRESENTATIONAL | *karri-nya* | *pangi-rninya* | *yu-nganya* | *nga-rninya* | *ji-nanya* |

Typological studies suggest that inflectional interpredictability may be relatively similar across languages, in terms of the uncertainty in predicting an unknown wordform

[1] Irregular forms and inter-speaker variation are omitted here (see Nash, 1980, p. 40). Differences in the final vowels of stems, such as *yi-nyi* 'give-NPST' and *yu-ngu* 'give-PST', are due to a vowel harmony process that can apply to both suffixes and stems (see Harvey & Baker, 2005; Nash, 1980, pp. 81, 84–86).

based on an observed one. This is despite the fact that languages vary widely in the number of exponents and inflectional classes, and other measures of predictability such as number of dynamic principal parts (Ackerman & Malouf, 2013; Stump & Finkel, 2013). Some languages exhibit considerable unpredictability in individual forms given only an underlying lexeme, but given knowledge of one inflected wordform, other forms become relatively predictable. The ease of prediction based on another related form is measured by conditional entropy, or average conditional entropy when this measure is extended across a whole inflectional system. Ackerman and Malouf (2013) show that inflectional paradigms in ten diverse languages tend to have an average conditional entropy of around 1 bit or less. The Low Conditional Entropy Conjecture predicts that this pattern will be found in all languages: no matter how much allomorphy of exponence there may be for particular morphosyntactic values, the system as a whole will converge on individual wordforms being predictable based on other known wordforms, with a low degree of uncertainty (Ackerman & Malouf, 2013, p. 436; see also Cotterell et al., 2019). This picture is complicated by some languages which seem to have rampant unpredictability, such as verb classes in Seri (Baerman, 2016); more widespread typological research is required to know if the Low Conditional Entropy Conjecture is truly universal.

These caveats aside, Ackerman and Malouf (2013) describe a striking example of low conditional entropy in Chiquihuitlán Mazatec, where verb inflection exhibits three independent dimensions of exponence: suffix vowel, stem alternation and tone. Exponents of this type have been labelled ‘paradigmatic layers’ (Brown & Hippisley, 2012, p. 71; Baerman 2016; Parker & Sims, 2020), or alternatively, ‘intersecting formatives’ (Mansfield, 2016). Multiplication of allomorphy across paradigmatic layers creates high uncertainty for individual verb forms, with Chiquihuitlán Mazatec exhibiting as many as 94 distinct exponence patterns for a single paradigmatic cell. But some layers are highly predictive of allomorph selection for other layers, with stem alternations being especially predictive of the rest of the paradigm (Ackerman & Malouf, 2013, p. 449). Although paradigmatic layers exhibit a degree of independence in their distribution, they do not co-occur in all possible permutations: an allomorph in one layer will tend to co-occur with a particular allomorph in another layer.

Multi-layered examples such as Mazatec suggest that multiple cues in an input form may conspire to predict an output form, and this receives further support in subsequent studies. Beniamine (2018 p. 161) calculates predictability and predictiveness for distinct tonal and segmental layers of exponence in Chatino verbs (see also Campbell, 2016), and for suffix and lexical accent layers in Russian nouns (see also Brown et al., 1996). Guzmán Naranjo (2020) also studies predictability of Russian noun inflection, using suffixes, stem phonology and lexical semantics as predictive cues. Rather than measuring the conditional entropy of possible target forms, Guzmán Naranjo uses a neural network classifier to predict the target form based on parameters gleaned from an input form. Suffixes alone produce accurate predictions for 72% of forms, but stem phonology is a more powerful predictor, giving 87% accuracy, while the combination of both accurately predicts 95% of forms. Lexical semantics also contributes to predictability, though to a far lesser degree.

The current study furthers our understanding of how multiple cues contribute to the predictability of inflectional forms, with a particular focus on the predictive role of prosodic stem shape. The interpredictability of Pitjantjatjara inflected forms is somewhat like the multi-layered systems mentioned above, except that prosodic root shape is one of the layers contributing to predictability. Certain paradigmatic cells require a completely footed stem, and if the root does not already meet this requirement then an augment syllable is added, as we saw in (1), e.g. *uːli-na-ɲi* 'tease-AUG-PRS'. The form of this augment syllable also contributes to inflectional interpredictability, alongside root shape and suffix allomorphy.

Pitjantjatjara's prosodic stem shape constraints are similar to patterns described for several other languages (e.g. McCarthy & Prince, 1993; Anderson, 2013; Guekguezian, 2017). The augment syllables, which differ by inflection class, are also similar to a well-known morphological phenomenon, namely thematic elements (Aronoff, 1994; Oltra Massuet, 1999); thematic elements are typically single consonant segments in Pama-Nyungan languages, and are more often called 'conjugation markers' (e.g. Dixon, 1980). However, Pitjantjatjara exhibits an unusual intersection of thematic elements with prosodic augmentation. While this form of prosodic morphology is interesting in itself, its complex layering also challenges the idea that maximally transparent inflectional systems always have a simple internal structure.

# 3 Pitjantjatjara and Yankunytjatjara

Pitjantjatjara and Yankunytjatjara[2] are two closely related dialects of the Western Desert dialect chain, a group of Pama-Nyungan languages spoken over a vast, sparsely populated area of central and western Australia. Pitjantjatjara and Yankunytjatjara are spoken in the north-west corner of South Australia, and neighbouring areas in Western Australia and the Northern Territory. Traditional Pitjantjatjara lands are further to the northwest, and Yankunytjatjara lands are to the southeast. Pitjantjatjara has relatively many speakers for an Australian Aboriginal language, and is spoken at home by over 3,000 people as of the 2016 census (Australian Bureau of Statistics (ABS), 2016); Yankunytjatjara is more endangered (Naessan, 2008). The dialects are mutually intelligible, structurally very similar, and have a great deal of lexical overlap as well, as indicated by the existence of a combined Pitjantjatjara/Yankunytjatjara to English dictionary (Goddard, 2001). The phenomena under discussion are, to our knowledge, no different between the two dialects, so we use the label Pitjantjatjara for the sake of simplicity, although we draw on descriptions of both Pitjantjatjara and Yankunytjatjara (particularly Goddard's (1985) grammar of Yankunytjatjara) and acknowledge that they are considered to be separate languages by speakers. Words used in examples throughout are drawn from work by Goddard and his consultants (1985, 2001), as well as from the first author's fieldwork.

## 3.1 Phoneme inventory

Pitjantjatjara has 17 phonemic consonants, shown in Table 2 with IPA to the left and the official orthography to the right, where the two are not identical. We use IPA throughout this paper for Pitjantjatjara examples.

*Table 2. Pitjantjatjara consonant inventory. Adapted from Tabain and Butcher (2014, p. 190).*

| | | Apical | | Laminal | |
|---|---|---|---|---|---|
| | Bilabial | Alveolar | Post-alveolar | Lamino-dental | Velar |
| Stops | p | t | ʈ ṯ | c tj | k |
| Nasals | m | n | ɳ ṉ | ɲ ny | ŋ ng |

[2] Pronunciation note: due to a process of vowel deletion described in §4.2, the names of the dialects are usually pronounced [ˈpicaɲcara] and [ˈjankuɲcara].

| | | | | |
|---|---|---|---|---|
| Laterals | l | ɭ l̲ | ʎ ly | |
| Tap/trill | r | | | |
| Glides | | ɻ r̲ | j y | w |

There are three vowel types /a, i, u/, with a phonemic length distinction for each, although long vowels occur only in the first syllable of the prosodic word. Monosyllabic words always have a long vowel, suggesting that there is a bimoraic word minimum and that coda consonants are not moraic.

# 4 Metrical structure

In this section, we outline our analysis of metrical structure in Pitjantjatjara. As previous descriptions of metrical structure in the language are not entirely explicit, clarification of this issue is a prerequisite to our analysis of how prosody interacts with the morphological system. The facts most relevant to this paper are that feet in Pitjantjatjara are bimoraic, and constructed from the left edge of the word, and that disyllabic suffixes initiate new feet, leaving occasional unfooted vowels word-internally. In §5, we show that inflection classes are categorically and productively associated with the prosodic structure of verbal stems, once derivational processes such as disyllabic suffixes are taken into account, and that stem augmentation is therefore prosodically motivated. Prosodic shape and stem augmentation are two of the three cues mentioned above which contribute to inflectional interpredictability in Pitjantjatjara.

Pitjantjatjara and other Western Desert languages have been described as having the following locations for stress (by, for example, Douglas, 1957; Glass & Hackett, 1970; Goddard, 1985; Hansen & Hansen, 1969, 1978; Langlois, 2004; Marsh, 1969; Rose, 2001; some minor differences in analyses are summarised by Tabain et al., 2014):

- Primary stress on the first syllable of the word (including the first syllable of reduplicated stems);
- Secondary stress on odd numbered syllables thereafter;
- Secondary stress on the first syllable of disyllabic suffixes;
- Final syllables do not bear stress.

These descriptions refer to secondary stress as occurring on odd-numbered syllables, with no special mention made of quantity sensitivity in words with a long initial syllable.[3] On the contrary, we analyse feet in Pitjantjatjara as bimoraic, not disyllabic, as illustrated for the Pitjantjatjara verb *taːncakaɳi* 'lever out'. This analysis accords with all the evidence discussed in this paper.

2. (ˈtaːn)$_{\varphi}$(caka)$_{\varphi}$-ɳi 'lever out-PRS'

A phonetic analysis of Pitjantjatjara by Tabain et al. (2014) has cast doubt on the existence of secondary stress, which is posited in most previous descriptions. However, there is evidence for metrical structure apart from the presence or absence of secondary stress.

One such source of evidence is a process of vowel deletion which is pervasive in connected speech (see Wilmoth et al., under revision for detailed discussion). Goddard (1985) describes patterns of deletion of 'weak vowels', where a weak vowel is 'defined as an unstressed vowel that: (i) follows an unstressed vowel, and (ii) precedes a stressed vowel' (Goddard, 1985, p. 14). We here propose a more explicit prosodic analysis for this deletion pattern, reformulating the targeted syllables as unfooted. In traditional Pitjantjatjara and Yankunytjatjara, unfooted vowels in open syllables can be deleted when the consonants on either side of the vowel are homorganic, and the syllable is internal to a prosodic phrase.

The phrase-internal condition means that deletion is more likely to apply at word-internal positions, or word-finally if another word follows in a tightly bound phrase such as an inclusory construction[4]. Word-internal unfooted vowels can be produced by derivational

[3] This has led to the assumption that feet are strictly disyllabic and quantity insensitive in some of the typological and theoretical literature regarding stress in Pintupi, a closely related language that neighbours Pitjantjatjara to the north/northwest. Pintupi stress has in fact been discussed in some detail by several authors, including but not limited to: Kager (1992, 1999), Hayes (1995), Gordon (2002, 2011), Apoussidou (2006, 2007), Heinz (2006, 2007), Pruitt (2008, 2010, 2012), McCarthy & Pruitt (2013), and Stanton (2014). It is likely that Pintupi, like Pitjantjatjara, is not an example of a quantity-insensitive stress system with both a bimoraic word minimum and strictly disyllabic feet.

[4] An inclusory construction, briefly, is a noun phrase in which two referring expressions, one referring to a member of a set and the other a pronoun referring to the superset, are juxtaposed (Hale, 1966; Singer, 2001). For example, *ɲuntu ŋali ɲina-ɲi* '2SG.NOM 1DU.NOM sit-PRS', 'you and I – the two of us – are sitting'.

suffixes, compounding and reduplication, as each of these morphological operations initiates a new foot, i.e. 'metrical reset'. We list some examples from Goddard (1985) in example (3).[5]

| | | | | | |
|---|---|---|---|---|---|
| 3. | (a) | (jami)$_\varphi$-ɲa | (cana)$_\varphi$ | (jamiɲ)$_\varphi$(cana)$_\varphi$ | 'those people including Yami' |
| | | Yami-NOM | 3PL.NOM | | |
| | (b) | (kulpa)$_\varphi$-ɲca(-canu)$_\varphi$ | | (kulpaɲ)$_\varphi$(canu)$_\varphi$ | 'after having returned' |
| | | return-NMLZ-SEQ | | | |

In these cases, the unfooted vowel is usually deleted because there are homorganic or identical consonants on either side. Word-internal deletion patterns provide evidence for metrical reset by disyllabic suffixes. If a disyllabic suffix attaches to a base that cannot be completely footed, we find deletion of the final vowel of the base (3b). This suggests that the disyllabic suffix does not prosodify together with the base, as this would rescue the base's final syllable from being unfooted.

Deletion does not occur at all when a word is completely footed. Vowels are not deleted in contexts such as those in (4), even though the consonants on either side are homorganic, and the vowel is internal to a prosodic phrase.

| | | | |
|---|---|---|---|
| 4. | (talca)$_\varphi$(-cara)$_\varphi$ | *(talc_)$_\varphi$(cara)$_\varphi$ | offshoot-PROP |
| | (kaka)$_\varphi$(ʎaʎa)$_\varphi$ | *(kaka)$_\varphi$(ʎ_ʎa)$_\varphi$ | pink cockatoo |
| | (paɲa)$_\varphi$ca | *(paɲ_)$_\varphi$ca | that one (ANAPH) |
| | (kura)$_\varphi$(ɲi-ca)$_\varphi$ | *(kura)$_\varphi$(ɲ_ca)$_\varphi$ | ahead-ASSOC ('first one') |

The patterns of deletion also fit with our analysis of feet as bimoraic. Vowel deletion can occur in the second syllable of a word if the first syllable is long, as in (5).

| | | | |
|---|---|---|---|
| 5. | (ɲaː-ŋ)$_\varphi$ku | (kuɭu)$_\varphi$(kuɭu)$_\varphi$ | (ɲaːŋ)$_\varphi$(kuɭu)$_\varphi$(kuɭu)$_\varphi$ |
| | what-ERG | also | 'The whats-it-called [did it] too' |

## 5 Inflection classes and stem augmentation

Metrical structure has more typologically unusual effects in Pitjantjatjara verb inflection, with regard to stem augmentation and the assignment of verbs to different classes. Pitjantjatjara verbs are obligatorily marked with suffixes indicating seven different TAM

[5] Although (3a) is presented by Goddard as non-geminate, i.e. *ŋajukaca*, more recent data recorded by the first author suggests that vowel deletion does in fact lead to geminate consonants across word boundaries.

categories and two types of nominalisation. Two of these TAM categories involve direct suffixation to the verb root (the 'bare stem'), while the other five TAM categories and nominalisations require stem augmentation before suffixation. Verbs select different allomorphs for both TAM suffixes and stem augments, producing four inflection classes, labelled Ø-class, l-class, n-class and ng-class by Goddard (1985) following Dixon (1980). Table 3 illustrates the allomorphy patterns of the four classes.[6] There is no marking of participants on the verb. The IMP.PFV and PST.PFV suffixes appear with the bare stem, and these suffixes have distinct allomorphs in all classes. The remaining suffixes are mediated by augmentation in the n-class and ng-class, while no augmentation is required in the Ø-class and l-class. There are two types of augmentation, which result in an 'IPFV stem' and a 'NEUTral stem' (stem here referring to the lexical root plus any augmentation). These augments have been described as remnants of historical TAM suffixes (Dench, 1996; Koch, 2014). The present-day TAM suffixes themselves have more consistent forms across the classes, except for in the l-class. The IPFV stem is glossed as such because all the suffixes which follow it have an imperfective meaning; while the IPFV augment *na~ŋa* may have once been a TAM suffix, it is no longer sufficient in itself to produce an inflected verb. The NEUT stem does not align with any particular grammatical category: it is found in the FUTure tense (which also has modal properties), the CHARacteristic (an agent nominalisation/habitual aspect), the action nominalisation (NMLZ, mostly used for non-finite subordination), and the medial verb (MV) form used in clause chains. The NEUT augment (*nku~ŋku*) was historically a future tense suffix, with the same origin as the present day *-(l)ku* future tense suffix. As an augment, it has been semantically bleached and now has a primarily prosodic function in Pitjantjatjara.

*Table 3. The Pitjantjatjara verbal inflection paradigm, reproduced from Goddard (1985, p. 90)*

[6] There are four lexically specific minor deviations from this paradigm. One example is *ɲa-* 'see', which follows the ng-class pattern, except that it has a neutral augment *-ku* instead of *-ŋku*. The MV suffix allomorph is *-la* for *ŋalku-* 'eat' (l-class), as well as *ŋaɻa-* 'stand', and *pica-* 'come' (both Ø-class).

Previous descriptions (Goddard, 1985; Eckert & Hudson, 1988, inter alia) include an additional pattern in the l-class whereby the retroflex /ɳ/ in suffixes becomes an alveolar /n/ following /i/-final stems, for example *-ni* in *witi-ni* 'catch-PRS' instead of *-ɳi* in *ampu-ɳi* 'hug-PRS'. This is more likely not part of the phonological representation but a result of the retroflex~alveolar distinction being nearly indistinguishable in nasals following /i/ (Tabain et al., 2020). We treat the l-class PRS suffix as /-ɳi/ underlyingly regardless of preceding vowel.

| | | Ø-class<br>waŋka- ‘talk’ | l-class<br>ampu- ‘hug’ | n-class<br>cu- ‘put’ | ng-class<br>u- ‘give’ |
|---|---|---|---|---|---|
| Bare stem | IMP.PFV | waŋka | ampu-la | cu-ra | u-wa |
| | PST.PFV | waŋka-ŋu | ampu-ɳu | cu-nu | u-ŋu |
| IPFV stem | PRS | waŋka-ɲi | ampu-ɳi | cu-na-ɲi | u-ŋa-ɲi |
| | IMP.IPFV | waŋka-ma | ampu-nma | cu-na-ma | u-ŋa-ma |
| | PST.IPFV | waŋka-ŋi | ampu-ɳingi | cu-na-ŋi | u-ŋa-ŋi |
| NEUT stem | FUT | waŋka-ku | ampu-lku | cu-nku-ku | u-ŋku-ku |
| | CHAR | waŋka-pai | ampu-lpai | cu-nku-pai | u-ŋku-pai |
| | NMLZ | waŋka-ɲca | ampu-nca | cu-nku-ɲca | u-ŋku-ɲca |
| | MV | waŋka-ra | ampu-ɻa | cu-nku-la[a] | u-ŋku-la |

[a] Monomoraic n-class roots take *-nku-la*, but polymoraic n-class roots take *-ɻa* here. For details see §6.1.

Canonically, lexemes are assigned to inflection classes in a purely stipulative fashion. But there are many instances where phonological or semantic factors are involved in class assignment (Corbett, 2009; Stump, 2015), and Pitjantjatjara is an example of this. Goddard (1985, p. 89) observes that class membership correlates strongly with transitivity and ‘mora parity’. The general pattern is that verb roots with ‘mora parity’, i.e. even numbers of morae, are assigned to the Ø-class and l-class, while those with uneven mora counts are assigned to n-class and ng-class. It is therefore the uneven-count roots that receive stem augmentation in those inflectional categories that require the IPFV stem or NEUT stem. Examples of the stem types for verbs in each class are given in Table 4.

*Table 4. Examples of stem forms according to inflection class*

| | Bare stem | IPFV stem | NEUT stem | Gloss |
|---|---|---|---|---|
| Ø-class | inka- | inka- | inka- | ‘play’ |
| | tulcungaɻakati- | tulcungaɻakati- | tulcungaɻakati- | ‘kneel down’ |
| l-class | manci- | manci- | manci- | ‘get’ |
| | pakalciŋa- | pakalciŋa- | pakalciŋa- | ‘make grow’ |
| n-class | a- | a-**na-** | a-**nku-** | ‘go’ |
| | kawali- | kawali-**na-** | kawali-**nku-** | ‘lose’ |
| ng-class | pu- | pu-**ŋa-** | pu-**ŋku-** | ‘hit’ |

| | | | |
|---|---|---|---|
| ti:lpu- | ti:lpu-**ŋa-** | tiilpu-**ŋku-** | 'knock together' |

We propose that this pattern arises not from mora-counts as such, but from metrical feet in which these are grouped as bimoraic units. Inflectional suffixes that appear with IPFV or NEUT stems can be characterised as aligning to the right edge of a bimoraic metrical foot. Stem augments (*-na* ~ *-ŋa* AUG.IPFV, *-nku* ~ *-ŋku* AUG.NEUT) ensure this pattern is maintained when the root does not produce complete footing. For example, PST.PFV suffixes do not always align to the right edge of a foot, but PRS suffixes do. This is ensured by augmentation shown in (1), repeated here as (6).

6. Past perfective:

| | | | |
|---|---|---|---|
| Ø-class: | *pirtji-ngu* | $(\text{pirci})_{\varphi}$-ŋu | wriggle-PST.PFV |
| l-class: | *ampu-n̠u* | $(\text{ampu})_{\varphi}$-ɳu | hug-PST.PFV |
| ng-class: | *tjititi-ngu* | $(\text{citi})_{\varphi}(\text{ti-ŋu})_{\varphi}$ | shiver-PST.PFV |
| n-class: | *uuli-nu* | $(\text{u:})_{\varphi}(\text{li-nu})_{\varphi}$ | irritate-PST.PFV |

Present:

| | | | |
|---|---|---|---|
| Ø-class: | *pirtji-nyi* | $(\text{pirci})_{\varphi}$-ɲi | wriggle-PRS |
| l-class: | *ampu-n̠i* | $(\text{ampu})_{\varphi}$-ɳi | hug-PRS |
| ng-class: | *tjititi-nga-nyi* | $(\text{citi})_{\varphi}(\text{ti-ŋa})_{\varphi}$-ɳi | shiver-AUG.IPFV-PRS |
| n-class: | *uuli-na-nyi* | $(\text{u:})_{\varphi}(\text{li-na})_{\varphi}$-ɳi | irritate-AUG.IPFV-PRS |

To further substantiate our analysis, the following section investigates Goddard's 'correlation' of moraic structure and inflection class. As we show below, the association of moraic structure and inflection class is not a correlation but actually a categorical rule, once the structure of complex stems is taken into account.

## 5.1 Substantiating the correlation

We produce an initial test of Goddard's proposed mora-count correlation by tabulating data from the largest available dictionary (Goddard, 2001).[7] The results are illustrated in Table 5. Ambitransitive verbs (*N*=6) have been excluded; the transitive category also includes ditransitives.

[7] This table was generated by a Python script running over the electronic version of Goddard (2001).

*Table 5. Number of verbs in each class in Goddard (2001), grouped by transitivity and number of morae in stem.*

| | Even no. of morae | | Odd no. of morae | | Even total | Odd total |
|---|---|---|---|---|---|---|
| | Intransitive | Transitive | Intransitive | Transitive | | |
| Ø-class | **174** | 40 | 18 | 2 | **215** | 20 |
| l-class | 55 | **316** | 0 | 8 | **371** | 8 |
| n-class | 3 | 7 | 41 | **194** | 10 | **235** |
| ng-class | 0 | 9 | **128** | 76 | 9 | **204** |

The cells shown in bold are those containing verbs with the most common mora parity and transitivity for each inflection class. This table confirms Goddard's (1985) claim that the correlation with mora parity is stronger than the correlation with transitivity; for example, there are 55 intransitive l-class verbs, but only 8 with an odd number of morae. There are therefore just 47 out of 1072 verbs (4.4%) that appear to violate moraically driven class assignment. However, these apparent exceptions can be shown to fit a metrical account on closer inspection, taking into account either reduplication, disyllabic suffixes or compounding.

Goddard found that some verbs with disyllabic derivational suffixes do not conform to a metrical principle, if it is calculated by treating the derived stem as an indivisible whole (1985, p. 92). We propose that most derivational processes, including suffixation, compounding and reduplication, bring about 'metrical reset', forming their own feet and thus nullifying the morpho-prosodic effect of any preceding material. Metrical reset by disyllabic suffixes has been attested for other Australian languages (e.g. Dixon, 1977). This hypothesis neatly accounts for all the 47 exceptions in the tabulations. Examples of metrical reset due to disyllabic suffixes initiating new feet are given in (7); here, despite the odd numbers of morae, suffixation ensures the verb stems end in a complete foot. These are therefore assigned to the Ø- or l-class, according to the particular derivational suffix.

| | | | | |
|---|---|---|---|---|
| 7. | Ø-class: | (iwa)$_{\varphi}$ra(-kati)$_{\varphi}$-ɲi | track-PROC-PRS | 'go back and forth' |
| | l-class: | (ika)$_{\varphi}$ri(-ciŋa)$_{\varphi}$-ɳi | laugh-CAUS-PRS | 'make laugh, amuse' |
| | l-class: | (caː)$_{\varphi}$ta(-mila)$_{\varphi}$-ɳi | start-LOAN-PRS | 'start' |

Compounds and reduplicated stems are also assumed to involve metrical reset, explaining further apparent exceptions. Many verbs are formed by compounding some base followed by a verb root (one of *cu-* 'put', *pu-* 'hit', *ɲina-* 'sit', *ŋaɻa-* 'stand', *ŋari-* 'lie', *ɲa-* 'see'). The class of the resulting verb is determined by the final compounding root, and where this compounding root is monomoraic, stem augmentation is used to produce a completely footed host for inflectional suffixes. Examples where the initial base of the compound has an unfooted syllable are given in (8) (these have not been exhaustively glossed as many of the initial bases do not have a clear meaning independently).

| | | | |
|---|---|---|---|
| 8. | Ø-class: | $(ita)_{\varphi}$ra(-ŋaɻa)$_{\varphi}$-ɲi | 'do skipping dance step' |
| | n-class: | $(inti)_{\varphi}$ɻiny(-cu-**na**)$_{\varphi}$-ɲi | 'pinch' |
| | ng-class: | (ŋaŋka)$_{\varphi}$li(-pu-**ŋa**)$_{\varphi}$-ɲi | 'form rainclouds' |
| | ng-class: | (ŋapa)$_{\varphi}$ri(-ɲa-**ŋa**)$_{\varphi}$-ɲi | 'go out to look for someone who should be arriving' |

Reduplication behaves similarly to compounding with respect to prosodic stem augmentation (cf. Inkelas & Zoll, 2005), and accounts for four apparent exceptions: *akuɻi~akuɻiri-* 'sweat', *ajini~ajiniri-* 'act silly', *iluɻu~iluɻuri-* 'feel miserable', and *kucupa~kucupari-* 'have something happen to one, usually with the implication of something bad'. These are all Ø-class verbs derived with the inchoative -(*a*)*ri* (see §5.2.2). They fit the general rule because reduplication results in two phonological words, with stress and footing resetting on the first syllable of the reduplicant. The stem therefore ends with a complete foot.

Between these patterns, all of those 47 apparently 'exceptional' verbs are neatly accounted for once their internal morphological structure is taken into account. Thus, all members of the Ø- and l-classes end in complete feet, while all members of the n- and ng-classes end in an unfooted syllable. In the following section we show that this is synchronically relevant and productive.

## 5.2 Productivity

### 5.2.1 Causatives

There are several ways of deriving different types of causatives in Pitjantjatjara. One highly productive process has three different realisations depending on the phonological shape of the nominal root which is to undergo derivation (Goddard, 1985, pp. 113–115). Nominal roots ending in a consonant take a suffix *-ma* and are assigned to the n-class. For example, *pukuɭ(pa)*[8] ‘happy’ becomes *pukuɭ-ma-na-nyi* ‘happy-CAUS-AUG.IPFV-PRS’, meaning to please someone. Nominal roots ending in a vowel have no further affixation to show that they are causative (i.e. they are zero-derived). They are assigned to the l-class or n-class, depending on whether they are completely footed or incompletely footed respectively. Examples of l-class verbs based on completely footed nominal roots are given in (9a–c); n-class verbs based on incompletely footed roots are given in (9d–f), with the IPFV augment ensuring suffixes are aligned to foot boundaries.

| | | | | |
|---|---|---|---|---|
| 9. | a. | (ninti)$_{\varphi}$-ɳi | knowledgeable-PRS | ‘teach, show’ |
| | b. | (ila)$_{\varphi}$-ɳi | near-PRS | ‘pull’ |
| | c. | (katu)$_{\varphi}$-ɳi | high-PRS | ‘lift’ |
| | d. | (kucu)$_{\varphi}$(pa-**na**)$_{\varphi}$-ɲi | another-AUG.IPFV-PRS | ‘change (trans.)’ |
| | e. | (wiː)$_{\varphi}$(ta-**na**)$_{\varphi}$-ɲi | wet-AUG.IPFV-PRS | ‘make wet’ |
| | f | (aɳa)$_{\varphi}$(ŋu-**na**)$_{\varphi}$-ɲi | person-AUG.IPFV-PRS | ‘bring person up’ |

#### *5.2.2* Inchoative *-ri*

The inchoative *-ri* provides further evidence for the role of metrical structure in class assignment. This highly productive stem formative may attach to any nominal, resulting in verbs with mostly compositional semantics (see Goddard, 1985, pp. 108–111 for a discussion of its semantics beyond simply ‘becoming’). It is also used to derive intransitive verbs from English loanwords of various classes. Where *-ri* attaches to a consonant-final base, vowel epenthesis is required by the phonotactics (10c). In all cases, the resulting verb is assigned to either Ø-class or ng-class according to whether it ends in a complete foot or not (10). Unlike the derivational processes discussed in §5.1, the class assignment of verbs with *-ri* is determined by metrical parsing of the entire derived stem, rather than the final stem element only. This is significant because it supports a metrical analysis of the verb inflection class system, and neither the derivational suffix *-ri* nor the prosodic structure of the base alone determine the class of the resulting verb.

10. Ø-class

| | | |
|---|---|---|
| a. (muŋar)$_{\varphi}$(ci-ri)$_{\varphi}$-ɲi | afternoon-INCH-PRS | ‘get late’ |
| b. (kapu)$_{\varphi}$(tu-ri)$_{\varphi}$-ɲi | wad-INCH-PRS | ‘get knotted’ |

[8] The *-pa* here is an epenthetic element which attaches to consonant-final nominals, ensuring that all words in Pitjantjatjara are vowel-final.

| | | |
|---|---|---|
| c. (pukuɭ)$_{\varphi}$(-ari)$_{\varphi}$-ɲi | happy-INCH-PRS | 'become happy' |
| d. (aku)$_{\varphi}$ɻi~(aku)$_{\varphi}$(ɻi-ri)$_{\varphi}$-ɲi | REDUP~scent-INCH-PRS | 'sweat' |

ng-class

| | | |
|---|---|---|
| e. (lunki)$_{\varphi}$(-ri-**ŋa**)$_{\varphi}$-ɲi | mature.Cossid.grub-INCH-AUG.IPFV -PRS | 'become mature Cossid moth grub' |
| f. (puɭka)$_{\varphi}$(-ri-**ŋa**)$_{\varphi}$-ɲi | big-INCH-AUG.IPFV-PRS | 'grow' |
| g. (pika)$_{\varphi}$~(pika)$_{\varphi}$(-ri-**ŋa**)$_{\varphi}$-ɲi | REDUP~sore-INCH-AUG.IPFV-PRS | 'get annoyed' |

Examples above show that prosodically sensitive augmentation is found in both common inchoative lexemes such as *puɭkariŋaɲi* 'grow', as well as highly specific inchoatives that are less likely to be memorised, such as *kapuʈuriɲi* '(your tongue) gets knotted (when saying a retroflex sound)' and *lunkiriŋaɲi* 'become a mature Cossid moth grub'. Furthermore, English loan words derived with the inchoative are also assigned to a class according to their metrical structure (11). These observations suggest that prosodic augmentation is synchronically active, rather than being a purely historical relic.

11. Ø-class

| | | |
|---|---|---|
| a. (taɻaŋ)$_{\varphi}$(ka-ri)$_{\varphi}$-ɲi | drunk-INCH-PRS | 'get drunk' |
| b. (waː)$_{\varphi}$(ka-ri)$_{\varphi}$-ɲi | work-INCH-PRS | 'work' |
| c. (cain)$_{\varphi}$(ci-ri)$_{\varphi}$-ɲi | change-INCH-PRS | 'change' |

ng-class

| | | |
|---|---|---|
| d. (ʃawa)$_{\varphi}$(-ri-**ŋa**)$_{\varphi}$-ɲi | shower-INCH-AUG.IPFV -PRS | 'shower' |
| e. (ɻiri)$_{\varphi}$(-ri-**ŋa**)$_{\varphi}$-ɲi | ready-INCH-AUG.IPFV -PRS | 'get ready' |
| f. (ɻitu)$_{\varphi}$(wana)$_{\varphi}$(-ri-**ŋa**)$_{\varphi}$-ɲi | red.one-INCH-AUG.IPFV-PRS | 'turn red' |

# 6 Interpredictability of Pitjantjatjara verb forms

We have shown above that Pitjantjatjara stem augmentation produces a completely footed stem in verbs that would otherwise have an unfooted mora in the stem. This is clearly a form of prosodic morphology, i.e. word-formation responding to prosodic shape requirements. The augmentative syllables play a role similar to epenthetic stem-building syllables found in other languages. However, the syllables that produce completely footed stems in Pitjantjatjara do not have a predictable form, as in standard cases of prosodic structure-satisfying syllabic inserts such as Axininca *-ta* (McCarthy & Prince, 1993), Lardil *-na* (Wilkinson, 1988; Prince

& Smolensky, 2004, ch. 7), or Swiss Rumantsch *-esch* (Anderson, 2008, 2013). Instead, in Pitjantjatjara there are four possible syllables, the selection of which is determined by a combination of inflection class and morphosyntactic features.[9]

Pitjantjatjara stem augmentation contributes a new case study illustrating possible solutions to the PCFP. As was seen in studies of Russian and Chatino mentioned above (§2), in Pitjantjatjara these inferences are licensed by multiple and overlapping layers of information. Although suppletive suffix allomorphs and thematic augments appear to be 'unnecessary' complexity in terms of communicating semantic or syntactic information, in concert with prosodic shape they ensure that the relations between inflected forms are completely predictable.

## 6.1 Using thematic and prosodic structure to solve the Paradigm Cell Filling Problem

Every inflected verb in Pitjantjatjara is uniquely identifiable as belonging to one of the four inflection classes. This is an example of a 'maximally transparent' inflectional system (Finkel & Stump, 2009; Stump & Finkel, 2013, p. 317). Pitjantjatjara verbs therefore also conform as strongly as possible to the Low Conditional Entropy Conjecture: although the exponence of morphosyntactic features is fairly unpredictable given no information about other inflected forms, often with four distinct exponence patterns, this uncertainty is reduced to zero whenever one already inflected form is used to predict another. While much previous work on the PCFP has focused on suppletive affix allomorphy, in Pitjantjatjara inflection class is identified by various combinations of suffix allomorphy, stem augment and prosodic stem shape. There is also a striking degree of complementarity between suffix allomorphs and stem augments: usually one or the other licences predictions about other forms, but rarely both.

Table 6 repeats the verb inflection-class information shown above, though we here add explicit metrical structure annotations, and include an additional example for the MV form in the n-class, which differs depending on length of the root (an example of syllable-

[9] An interesting comparison might be made with epenthetic prefixation in the non-Pama-Nyungan languages Alawa and Marra (Harvey & Baker, 2020). In these languages, meaningless CV syllables are inserted to satisfy phonotactic constraints between noun class prefixes and the noun root; these syllables have different forms in Marra depending on morphosyntactic factors. They are argued to originate from 3SG pronouns with a determiner function, which were preserved only in contexts where they prevent a phonological constraint violation. This case has interesting parallels to the augment syllables in Pitjantjatjara which originate from TAM suffixes.

counting affix allomorphy; see Kager, 1996; Paster, 2005 inter alia). Monomoraic n-class roots, such as *cu-* 'put', have an augmented MV ending *-nku-la* (i.e. *cunkula*). Polymoraic n-class roots, such as *kawali-* 'lose' and even compounds with *cu-* such as *tjakatju-* 'stick on', have the MV suffix *-ɻa* affixed directly to the stem (i.e. *kawaliṟa, tjakatjuṟa*). In §7 below, we refer to these as subclasses; the $n_1$-class consists of monomoraic stems, while members of the $n_2$-class are polymoraic. Careful inspection of this table will reveal that every form uniquely identifies its inflectional class.

*Table 6. The Pitjantjatjara verbal inflection paradigm with metrical structure*

| | | Ø-class<br>waŋka- 'talk' | l-class<br>ampu- 'hug' | n-class<br>cu- 'put'<br>kawali- 'lose' | ng-class<br>u- 'give' |
|---|---|---|---|---|---|
| Bare stem | IMP.PFV | (waŋka)$_\varphi$ | (ampu)$_\varphi$-la | (cu-ra)$_\varphi$ | (u-wa)$_\varphi$ |
| | PST.PFV | (waŋka)$_\varphi$-ŋu | (ampu)$_\varphi$-ɳu | (cu-nu)$_\varphi$ | (u-ŋu)$_\varphi$ |
| IPFV stem | PRS | (waŋka)$_\varphi$-ɲi | (ampu)$_\varphi$-ɳi | (cu-**na**)$_\varphi$-ɲi | (u-**ŋa**)$_\varphi$-ɲi |
| | IMP.IPFV | (waŋka)$_\varphi$-ma | (ampu)$_\varphi$-nma | (cu-**na**)$_\varphi$-ma | (u-**ŋa**)$_\varphi$-ma |
| | PST.IPFV | (waŋka)$_\varphi$-ŋi | (ampu)$_\varphi$(-ɳiŋi)$_\varphi$ | (cu-**na**)$_\varphi$-ŋi | (u-**ŋa**)$_\varphi$-ŋi |
| NEUT stem | FUT | (waŋka)$_\varphi$-ku | (ampu)$_\varphi$-lku | (cu-**nku**)$_\varphi$-ku | (u-**ŋku**)$_\varphi$-ku |
| | CHAR | (waŋka)$_\varphi$(-pai)$_\varphi$ | (ampu)$_\varphi$(-lpai)$_\varphi$ | (cu-**nku**)$_\varphi$(-pai)$_\varphi$ | (u-**ŋku**)$_\varphi$(-pai)$_\varphi$ |
| | NMLZ | (waŋka)$_\varphi$-ɲca | (ampu)$_\varphi$-nca | (cu-**nku**)$_\varphi$-ɲca | (u-**ŋku**)$_\varphi$-ɲca |
| | MV | (waŋka)$_\varphi$-ra | (ampu)$_\varphi$-ɻa | (cu-**nku**)$_\varphi$-la<br>(kawa)$_\varphi$(li-ɻa) | (u-**ŋku**)$_\varphi$-la |

For example, if a speaker encounters the form *u-wa* 'give-IMP.PFV', the suffix form *-wa* indicates that this can only be in the ng-class, thus facilitating reliable predictions about all other forms of this verb. Suffix allomorphs do some discriminative work in PST.PFV as well, where *ampu-ɳu* can only be in l-class, and although the PST.PFV (Ø- and ng-class) *-ŋu* suffix does not completely discriminate, it at least reduces the possibilities from four classes to two. Prosodic structure resolves the residual uncertainty, as we will see below.

On the other hand, throughout the parts of the paradigm that require IPFV and NEUT stem augments, suffix allomorphs do little to discriminate inflectional classes, with all paradigm cells except MV sharing the same allomorph across the Ø-, n- and ng-classes. In these forms, however, stem augments neatly disambiguate between those three classes, while the l-class suffix allomorphs differentiate between the two unaugmented classes, Ø and l. The augments have a 'vertical' distribution, recurring within inflection classes but not across inflection classes. As mentioned above, this is comparable to thematic elements in other languages, such as the theme vowels in Romance languages (Oltra Massuet, 1999), or the consonant conjugation markers found in other Australian languages such as Yidiny (Dixon, 1977). Although thematic elements do not map neatly onto morphosyntactic property sets, they have great potential as predictive cues. In Pitjantjatjara, distinctive suffix allomorphs and thematic stem augments have a complementary distribution: one or the other always disambiguates verb class, but never simultaneously. That is, the suffix allomorphs are identical between the n- and ng-classes in those parts of the paradigm where an augment is required.

Finally, prosodic structure of the root serves to disambiguate the inflectional class of those forms in which neither affix nor stem augment serves this role. This occurs in PST.PFV, where *waŋka-ŋu* and *u-ŋu* have the same suffix, but the former is identified with the Ø-class by its completely footed stem, while the latter is identified with the ng-class by its incompletely footed stem. The prosodic shape of these forms allows the speaker/learner to deduce that, say, MV forms must be *waŋka-ra* and *u-ŋku-la* respectively. Prosodic disambiguation also applies for MV forms in the n- and l-classes, which share the *-ɻa* suffix allomorph for polymoraic roots. That is, one must attend to prosodic shape to correctly infer other forms of the polymoraic n-class *kawali-ɻa* 'lose-MV' and the l-class *ampu-ɻa* 'hug-MV'.

## 6.2 Segmentation

So far, we have discussed predictability according to our morphological analysis of Pitjantjatjara verbs, which are divided into stem, augment, and inflectional suffix. However, morph boundaries may not always be evident to a speaker given only an individual wordform, and thus the apparent simplicity of the PCFP may be due to the analyst's assumptions about segmentation (see e.g. Beniamine et al., 2017; Bonami & Beniamine, 2016). For example, one can imagine a learner encountering the word *cu-ra* 'put-IMP.PFV' for the first time. If they have not heard any other form of this verb, then they do not have any evidence as to whether this is an n-class verb with the stem *cu-* and imperative suffix *-ra*, or whether it is a Ø-class verb with the stem *cura* which appears as a bare stem in IMP.PFV.

Potential ambiguities such as this arise in Pitjantjatjara either where Ø-class verb stems have the final syllable *-ra* or *-wa* (matching the n- and ng-class IMP.PFV suffixes respectively), or where Ø-class verb stems have the final syllable *-na/-ŋa/-nku/-ŋku* (matching one of the augment syllables). However, there are only two verbs in Pitjantjatjara that fit this description: *mira-* 'yell' and *ɲina-* 'sit'.[10] There are no other documented verbs that would be ambiguous in this way. Thus our assumptions about segmentation do not artificially simplify the difficulty of the PCFP, and we do not include any alternative segmentation-free analyses, or automatic segmentation (although see Malouf, 2016; Cotterell et al., 2019 for examples of neural network analyses without segmentation; and Guzmán Naranjo, 2020 on predictability given automatically detected morph boundaries).

# 7 Relative contributions of different cues

Information-theoretic methods developed to measure inflectional interpredictability (Ackerman et al., 2009; Parker & Sims, 2015; Beniamine, 2018 inter alia) allow us to quantify the relative contributions of prosodic shape, augmentation and suffix allomorphy. Table 7 below reports full results of this analysis, but we first explain our method by focusing on specific examples.[11]

For each paradigm cell (e.g. IMP.PFV), we calculate 'predictiveness', i.e. the entropy of predicting other inflected forms of the same verb, given this form as the input. We need to predict the suffix allomorph and augmentation of the target forms, while prosodic stem shape does not need to be predicted as this is always the same for input and target forms. We begin by calculating the entropy of other forms when they are predicted 'naïvely', ignoring all available cues in the input form. We then calculate the reductions to this entropy when any of the three available cue types (prosodic shape, augment and suffix) is used to narrow the prediction. Finally, we calculate the entropy when all three cue types are simultaneously utilised.

[10] In its IMP.PFV form *mira*, this verb could potentially be confused for an n-class verb with a stem *mi-*. In reality, children are rarely commanded to yell, and other, unambiguous forms of this verb are more frequent. For *ɲina-* 'sit', the final syllable of the stem could be confused for an augment, if it were heard in the PRS, IMP.IPFV, or PST.IPFV forms, and the learner had not encountered any other forms of this verb. Like *mira-*, other forms of this verb are very frequent as well and this verb should not pose a problem for learners.

[11] Python scripts used to perform these calculations are available at https://github.com/jbmansfield/Pitjantjatjara-inflectional-predictability.

For example, if we take any IMP.PFV verb as an input form, and we do not use any of the available cues, the PST.PFV exponence of the same verb may take any of the forms{*-ŋu, -ɳu, -nu*}. Two of these exponents (*-ɳu* and *-nu*) are each found in just one inflection class, while *-ŋu* is found in two inflection classes. To calculate the probability distribution of these exponents, we estimate the relative frequencies of the inflection classes using lexical type counts from the dictionary (cf. Milin et al., 2009; Parker & Sims, 2015), which are shown as percentages near the top of Table 7 (the number of verbs in each class is also reported in Table 5). (Note that in this table, the monomoraic $n_1$-class occupies its own column separate from the polymoraic $n_2$-class.) In this instance, the three candidate exponents have probabilities 0.42, 0.35 and 0.23 respectively, and this probability distribution has an entropy of 1.54. A similar calculation is made for every other paradigm cell that may be predicted based on the IMP.PFV form as input. Some forms require prediction of both suffix and augment, such as CHAR with candidate exponents {*-pai, -lpai, -nku-pai, -ŋku-pai*}, the respective probabilities of which have an entropy of 1.96. After calculating this for each morphosyntactic target category, we then calculate a weighted average, where morphosyntactic target categories are weighted according to their relative token frequencies in our corpus. For example, the category MV has a greater weight due to its higher corpus frequency relative to less frequent categories such as FUT.[12] Using IMP.PFV verb as an input form, this gives a weighted average entropy of 1.71, as shown by the 'Cueless prediction' figure in the first row of Table 7.

We calculate the information contributions of different cues by running similar calculations, but using these cues to narrow the range of possible target forms instead of the naïve 'cueless' prediction. For example, we take the l-class form of the IMP.PFV, *φ-la*, and use the prosodic structure of the stem to help predict the exponence of the PST.PFV form. The stem shape of this input form (completely footed 'φ') narrows the possible inflection classes of the target to the Ø-class and the l-class, which implies two candidate PST.PFV exponents, {*-ŋu*, *-ɳu*}. The entropy of their probability distribution is 0.96. We calculate this prosodically-informed entropy for each target paradigm cell, which in this instance is the same for each

[12] The corpus is a fully glossed FLEx database with approximately 35,000 word tokens at the time of writing. It includes both Pitjantjatjara and Yankunytjatjara. It primarily consists of narratives, including spontaneous monologic and multi-speaker narratives, as well as elicited narratives from picture and video stimuli. There is also some more naturalistic conversation and interaction with children. There is likely some bias in the frequencies of paradigm cells due to genre, as MV forms are very common in narrative, whereas Defina (2020) finds these only occur in a small percentage of utterances in discourse. Token frequencies of verb lexemes were not included in our calculations due to insufficient data.

target category, as they all result in two possibilities corresponding to Ø-class and the l-class, giving a weighted average of 0.96.

We have thus far calculated the weighted average predictability of other inflected forms, given the prosodic cue for one IMP.PFV form, *φ-la*. Similar calculations are made for the IMP.PFV form in each class, in which prosodic cues make variable contributions. For example, in the $n_2$-class form *φµ-ɻa*, the incompletely footed, polymoraic stem implies candidate PST.PFV exponents {*-ŋu*, *-nu*}, with an entropy of 0.99 (note we are not yet taking into account the distinctive suffix allomorphy as a cue). In the same way, the predictability of other forms is calculated using each different IMP.PFV form as input, and from these an average value is calculated, again applying weighting for lexical type frequency of the inflection classes. This overall weighted average predictability figure gives the predictiveness of IMP.PFV as input, and with only prosodic cues utilised, this is 0.97. The cueless entropy of 1.71 has thus been reduced by 0.74, which is the information contribution, or 'Uncertainty reduction' of the prosodic cue for IMP.PFV forms. This is shown as the 'Pros.' figure in the first row of Table 7.

Similar figures can be calculated using any combination of cues or indeed the combination of all cues (prosodic, augment and suffix). In Table 7, under the heading 'Uncertainty reduction', we show the results for each cue individually, as well as the entropy given all cues, which is always zero. The all-cues results confirm that any inflected form is completely predictable, given knowledge of any other form of the same verb.

*Table 7. Predictiveness of inflected forms: Relative contributions of prosodic, augment and suffix allomorph cues*

| *Cat.* | *Freq.* | *Ø-class* | *l-class* | *$n_1$-class (monomoraic)* | *$n_2$-class (polymoraic)* | *ng-class* | *Cueless prediction* | *Uncertainty reduction* | | | *All cues* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 22% | 35% | < 1% | 23% | 20% | | Pros. | Aug. | Suff. | |
| *IMP.PFV* | 3% | φ | φ-la | µ-ra | φµ-ra | (φ)µ-wa | 1.71 | -0.74 | 0.00 | -1.70 | 0 |
| *PST.PFV* | 20% | φ-ŋu | φ-ɳu | µ-nu | φµ-nu | (φ)µ-ŋu | 1.76 | -0.79 | 0.00 | -1.33 | 0 |
| *PRS* | 16% | φ-ɲi | φ-ɳi | µ-na-ɲi | φµ-na-ɲi | (φ)µ-ŋa-ɲi | 1.67 | -0.70 | -1.12 | -0.74 | 0 |
| *IMP.IPFV* | 3% | φ-ma | φ-nma | µ-na-ma | φµ-na-ma | (φ)µ-ŋa-ma | 1.71 | -0.74 | -1.16 | -0.77 | 0 |
| *PST.IPFV* | 9% | φ-ŋi | φ-ɳiŋi | µ-na-ŋi | φµ-na-ŋi | (φ)µ-ŋa-ŋi | 1.70 | -0.72 | -1.14 | -0.76 | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *FUT* | 1% | φ-ku | φ-lku | μ-nku-ku | φμ-nku-ku | (φ)μ-ŋku-ku | 1.71 | -0.74 | -1.16 | -0.77 | 0 |
| *CHAR* | 10% | φ-pai | φ-lpai | μ-nku-pai | φμ-nku-pai | (φ)μ-ŋku-pai | 1.69 | -0.72 | -1.13 | -0.76 | 0 |
| *NMLZ* | 9% | φ-ɲca | φ-ntja | μ-nku-ɲca | φμ-nku-ɲca | (φ)μ-ŋku-ɲca | 1.69 | -0.72 | -1.14 | -0.76 | 0 |
| *MV* | 30% | φ-ra | φ-ɻa | μ-nku-la | φμ-ɻa | (φ)μ-ŋku-la | 1.84 | -0.87 | -0.60 | -1.27 | 0 |
| | | | | | | System W.Av | 1.75 | -0.78 | -0.72 | -1.05 | 0 |

Key:
φ = fully footed
μ = incompletely footed, monomoraic
φμ = incompletely footed, polymoraic
(φ)μ = incompletely footed, mono- or polymoraic

The 'System weighted average' figures, shown in the last row of Table 7, are averages across all paradigm cells, again weighted by token frequency. The cueless prediction figure here corresponds to 'Paradigm Cell Entropy' figures reported in Ackerman & Malouf (2013: 443)[13], i.e. the average uncertainty of naïvely guessing an inflectional form. In Pitjantjatjara this involves selection among four or five exponence patterns for each morphosyntactic property set, which after frequency weighting results in an average of 1.75 bits of entropy. This falls within the range of values 0.78–4.92 found by Ackerman and Malouf.

Prosodic shape on its own reduces the average system entropy by 0.78 bits, which is a slightly greater contribution than augment syllables (0.72), but less than suffix allomorphs (1.05). (Note that these figures add up to greater than the weighted average system entropy; this is because different cues may provide information redundantly.) The prosodic cue is fairly consistent across morphosyntactic property sets because stem shape is consistently present in all inflected forms. Augments are more inconsistent cues: they reduce uncertainty by up to 1.16 bits in those paradigm cells where they distinguish between classes, but they provide no information in the IMP.PFV and PST.PFV categories where they are absent in all classes. Augments are also less informative in the MV category, where they distinguish only two out of five (sub-)classes, one of which is the type-infrequent monomoraic $n_1$-class.[14] Suffixes have an inverse pattern to augments: they are highly informative in IMP.PFV and

[13] A formatting error in the original means that 'Paradigm Cell Entropy' figures should be read off the last column of Ackerman & Malouf (2013, p. 443), while 'Average Conditional Entropy' figures should be read off the second-last column, in contradiction to the column headers.
[14] Although the lexical type frequency of the $n_1$-class is low, its token frequency would be substantial, as it includes very frequent verbs such as *cu-* 'put' and *(y)a-* 'go'.

PST.PFV, reducing uncertainty by 1.70 and 1.33 bits respectively, since these are the categories in which suffix allomorphs are most distinctive. But suffix allomorphy is a much less informative cue in categories that have augment syllables. As mentioned above, these categories only have suffix allomorph distinctions in the l-class (which is, however, the most type-frequent).

Given augment cues alone, the system weighted average entropy is reduced to 1.03 bits, and with suffix cues alone, it is reduced to 0.70 bits. If one combines both augment and suffix cues, the system weighted average is reduced to 0.25 bits (not shown in Table 7). This residual uncertainty can only be resolved by attending to prosodic shape; this is especially pertinent in the PST.PFV and MV categories where the combination of augment and suffix does not always licence reliable predictions about other forms. Interestingly, the PST.PFV and MV categories have the highest token frequencies in our corpus, which substantially increases the residual uncertainty that can only be resolved by the prosodic cue (this would be only 0.14 bits without frequency weighting).

While this residual uncertainty figure shows that prosodic cues may play an important role in solving the PCFP, we are not implying that speakers attend to cues sequentially in the manner described above, or that any one cue is privileged above the others. We make no claims about what speakers or hearers actually do in reality, rather, we are concerned with predictability as a property of the system itself; further experimental research would be required to understand how speakers actually solve the PCFP in Pitjantjatjara (see e.g. Parker, 2018; Johnson, Culbertson, et al., 2020; Johnson, Gao, et al., 2020).

# 8 Conclusion

In this paper we have demonstrated the role of prosodic structure in Pitjantjatjara verbal inflection. Vowel deletion provides clear evidence for bimoraic feet in Pitjantjatjara, despite equivocal phonetic evidence regarding secondary stress (§4). Prosodic shape constrains verb inflection class selection, once the morphological structure of stems is taken into account (§5). However, prosodic shape does not fully predict inflectional class; a fully footed verb stem can be either Ø- or l-class, while a stem with an unfooted mora can be either n- or ng-class. In the n- and ng-classes there are four possible syllables that are appended in order to produce fully footed verb stems before further inflection: *na* ~ *ŋa* 'AUG.IPFV' and *nku* ~ *ŋku* 'AUG.NEUT'. The IPFV augment occurs with the PRS, PST.IPFV, and IMP.IPFV suffixes. The

NEUTral augment occurs with the MV, NMLZ, FUT, and CHAR suffixes. The PST.PFV and IMP.PFV suffixes need not align to a fully footed stem, regardless of inflection class. We have also shown that the system extends productively to new words (§5.2), and thus the prosodic requirement is synchronically active. The system of augmentation is a typologically unusual instance of prosodic morphology, which usually involves the insertion of unmarked and predictable material, or the copying of existing material, rather than the selection of a syllable according to lexical and morphosyntactic criteria.

We have shown how suffix allomorphy, prosodic structure, and stem augmentation together contribute to inflectional interpredictability, and that the informativity of suffixes and stem augments has a largely complementary distribution across the paradigm (§6). Where augments distinguish between classes, suffix allomorphy is usually not informative, and vice versa. Prosody is the most consistent cue across morphosyntactic property sets, since stem shape is equally present in all inflected forms. Prosodic shape on its own reduces the average system entropy by 0.78 bits, a greater contribution than either augment syllables (0.72), but less than suffix allomorphs (1.05). At a minimum, prosodic shape resolves 0.25 bits of uncertainty that remains when both augment and suffix cues are taken into account.

We take the view that paradigms, or networks of interconnected wordforms, are a crucial mechanism by which speakers learn a language, and by which they can produce novel wordforms. On this assumption, low conditional entropy would constitute a learnability pressure during transmission of a language, whereby the preference for interpredictability constrains the evolution of inflectional paradigms (Ackerman & Malouf, 2015). Pitjantjatjara conforms strikingly with the Low Conditional Entropy Conjecture because it has perfect interpredictability: the average conditional entropy of the paradigm is precisely zero. Maximally transparent systems such as these are not often discussed in detail; they are sometimes treated as a canonical extreme, but without discussion of any particular language (e.g. Finkel & Stump, 2009; Stump & Finkel, 2013, p. 81). Alternatively, they may be assumed to have a very simple internal structure, with unique suffix allomorphs in each cell of the paradigm as in Czech (Baerman et al., 2017, pp. 100–101) or Burmeso (Corbett, 2009, p, 9). Pitjantjatjara verbal inflection is maximally transparent, yet it achieves this through various non-canonical means such as ‘stem effects’ (prosodically conditioned augmentation), and class assignment being motivated by prosodic structure. This shows how systems can be fully canonical in one dimension while being deeply non-canonical in other respects (see Round & Corbett, 2020). Future typological research into the complexity of morphological paradigms would benefit from considering the structures and origins of fully interpredictable systems, not only those with medium or high complexity that challenge learners and linguists alike.

Research in other language families, particularly Romance, shows the significant role that interpredictability plays in diachronic change (e.g. Maiden, 2018; Herce, 2020 inter alia). However, there is relatively little historical-comparative work on Australian languages that specifically focusses on paradigm structure (two examples being Koch, 2014 on Pama-Nyungan; and Bowern, 2012 on the non-Pama-Nyungan language Nyikina). Although a full diachronic account of the Pitjantjatjara system is outside the scope of this study, we hope to have shown that the evolution of verbal inflection in Pama-Nyungan languages is a promising avenue for further research on inflectional interpredictability. Do other Pama-Nyungan languages also achieve low system-wide average conditional entropy, and if so by what means? Semantic bleaching and subsequent 'double-marking' of TAM suffixes, like the stem augments in Pitjantjatjara, are common in Pama-Nyungan languages (these are dubbed "parasitic formatives" in Koch, 2014). Correlations with transitivity and root length are also common (see e.g. Dixon, 2002, pp. 215–237). Further research may show how these and other features, as well as factors such as frequency, constrain the evolution of verbal inflection in Pama-Nyungan. This paper, and further research along this line, can help us to answer not only the question of *whether* and *to what extent* inflectional systems are interpredictable, but also *how* such interpredictability is achieved in different languages.

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