Cognition 198 (2020) 104167

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/cognit

Pause acceptability indicates word-internal structure in Wubuy

Rikke L. Bundgaard-Nielsen[a,b], Brett J. Baker[c,*]

[a] MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Bankstown Campus, Locked Bag 1797, Penrith, NSW 2751, Australia
[b] School of Humanities and Social Science, University of Newcastle, Callaghan 2308, New South Wales, Australia
[c] School of Languages and Linguistics, University of Melbourne, Parkville 3010, Victoria, Australia

ARTICLE INFO

Keywords:
Morphology
Pause
Polysynthesis
Psycholinguistics
Speech processing

ABSTRACT

Words in polysynthetic languages, such as the Australian language Wubuy, can be semantically complex and translate into whole phrases in analytic languages such as English. This raises questions about whether such words are like words in English, or whether they are more like phrases. In the following, we examine Wubuy speakers' knowledge of word-internal morphological complexity in a word-preference task, in which we test the acceptability of complex words into which artificial pauses have been embedded at a range of morphological junctures. The results show that participants prefer unmodified words and words with pauses inserted at semantically transparent morphological junctures over words with pauses at other junctures. There is no preference for unmodified words over words with pauses at transparent junctures. These results suggest that speakers have access to some word-internal morphological information, and that complex words may share characteristics of both words and phrases in, for instance, English.

1. Introduction

A key goal for any human language user is to extract words and hence meaning from utterances such as the English sentence [hiwɔztɪklɪŋmiɔnðəhed] 'He was tickling me on the head' or the single word [ŋanijinaŋukuʈukuʈaani], also 'He was tickling me on the head', from the polysynthetic Australian language Wubuy (see e.g. Cutler, 2012, and references therein). To do so, listeners of course rely on many types of information in the speech signal, particularly the sequence of phones produced, and information about the intensity (loudness) and pitch with which they are produced, the duration of individual segments and syllables and any periods of silence. This information provides the listener with clues about which phones and syllables are grouped into larger structures – which are then proposed to activate individual words in the listener's lexicon which can be combined into phrases and sentences (Norris & McQueen, 2008).

To date, however, theories of spoken word processing have overwhelmingly been informed by studies focusing on the major languages of Europe (i.e., Germanic and Romance languages) together with Japanese and Mandarin (see Norcliffe, Harris, & Jaeger, 2015 for a critical review of this focus). Despite obvious differences in the family relationship between these languages, as well as differences in orthographies, these languages are characterised by (relatively) simple words (*'He', 'was', 'on', 'head'*), strung together in phrases—using language-specific syntax—to make meaning as in the English example above. Very little processing research has focused on languages like Wubuy, where highly complex words are often best translated as entire propositions (see example (1)).[1]

(1) [ŋa-wu-ɻuluʈ-kulʈa + ŋi]

1sg-NEUT-bough.shade-cut + PAST.CONT

* Corresponding author.
E-mail address: bjbaker@unimelb.edu.au (B.J. Baker).

[1] We use the International Phonetic Alphabet (2015) for all representations of Wubuy material and the Leipzig Glossing Rules (Bickel et al., 2008), with the following non-obvious additions: NEUT(ER), COLL(ECTIVE), MASC(ULINE), FEM(ININE), RESID(UAL), VEG(ETABLE) are grammatical noun classes/genders; tense/aspect inflections used in the examples are Past Punctual (PAST.PUNC), Past Continuous (PAST.CONT/PC), Present (PRES), Future (FUT); IRR[ealis] is the label for a set of inflectional agreement prefixes which covary with a set of mood, tense and polarity inflections in verbs; MAL/BEN: Malefactive/Benefactive applicative. Wubuy has 6 contrastive places of articulation in stops and nasals: bilabial, lamino-dental, apico-alveolar, apico-postalveolar/retroflex, lamino-alveopalatal, and velar for which we use the symbols {p, t̪, t, ʈ, ʧ, k; m, n̪, n, ɳ, ɲ, ŋ} (see Bundgaard-Nielsen, Baker, & Kroos, 2012). Note that the standard symbol used for lamino-alveopalatal stops in Australian languages is typically 'c' (Fletcher & Butcher, 2014) although we follow (Butcher, 2012) here in using < ʧ > . Note also that there is no voicing contrast in stops, and there are no contrastive fricatives. The inventory of approximants is {l̪, l, ɭ, r, ɻ, j, w} with laterals corresponding to all coronal places of articulation except lamino-alveopalatal, a tap, a retroflex continuant, and a palatal and labio-velar glide.

https://doi.org/10.1016/j.cognition.2019.104167
Received 7 August 2018; Received in revised form 17 December 2019; Accepted 18 December 2019

'I was cutting a bough shade'

In the following, we probe to what extent speakers of Wubuy have access to information about the internal morphological structure of Wubuy words, and to what extent such words are really like words in English, and to what extent they may be more like phrases. We do so by examining the perceptual acceptability of words with artificially-generated word-internal pauses located at a range of morphological boundary types. The results show that speakers accept words containing internal pauses *only* if those pauses occur at what we call morphologically 'legal' positions—generally corresponding to morphemes which carry lexical rather than grammatical meanings such as nouns and verbs. The findings are consistent with research on naturally occurring pauses in the related language Dalabon (Evans, Fletcher, & Ross, 2008; Fletcher, Evans, & Ross, 2004), and indicate that polysynthetic words are *not* like words in English, but prosodically like phrases: a collection of Prosodic Words, potentially separated by pauses and associated with one or more Intonation Phrases (c.f. Fletcher, 2014). Other aspects of the results however suggest that complex words are like words in English in some regards: certain (linguistically analysable) morpheme boundaries, such as tense suffixes, are *not* available for pause insertion, suggesting that some sub-strings behave like individual words in English. We note that this kind of detailed knowledge of the internal structure of words is denied by many current theoretical models of morphology, such as (Anderson, 1992; Beard, 1995; Stump, 2001). More importantly, it raises questions about the nature of the lexicon for speakers of such languages, and what is involved when speakers hear and process the words of these languages (c.f. Blevins, 2016).

The evidence that strings such as (1) are 'words' comes primarily from two sources: phonology and distribution. Numerous phonological rules apply within strings like these (Heath, 1984), none apply outside of it. Secondly, while some sub-strings of (1) can occur independently, others cannot. For instance, *ɻuluʈ* 'bough shade', *wulṯaŋi* '(something) cut (something)'), can both occur as independent words, while other substrings of (1) (*ŋa-*, *wu-*, *ŋa-wu-*) cannot.[2] Furthermore, verb agreement prefixes such as *ŋa-* and *wu-* cannot attach to nouns, such as *ɻuluʈ*, and because of this, we cannot regard (1) as consisting of three words. We refer to strings such as (1) as 'syntactic words' in what follows.

Importantly for our purposes, there are also differences in the transparency of different morphemes. For example, since [wulṯaŋi] and [ɻuluʈ] can occur independently (and be readily translated into English), speakers of Wubuy are expected to recognise both as separate lexical entries, even when they are adjacent in an utterance, and even when this utterance constitutes a single word. Other parts of words are less transparent and presumably less accessible to speakers. For instance, despite the fact that verbs take a number of suffixes for tense (e.g. +ŋi PAST.CONT in our example), and these are thus in a paradigmatic—morphological—relationship, the right edge of the verb root/stem itself (minus the suffix) can never correspond to a word edge. That is, the right edge of the verb stem is never 'visible' to speakers in the same way that the left edge is, because the left edge can take a non-overt (zero) prefix for some combinations of subject and object, while the right edge always has to take an overt tense suffix.

The amalgamation of transparent noun- and verb-like morphemes and less transparent morphemes of various kinds into single words raises fundamental questions about how speakers identify individual morphemes within each word, in order to interpret the intended message. In addition, the existence of some morphemes which appear to be more word-like (more accessible) than others raises the question of the extent to which strings like (1) are truly comparable to words in a language like English. The lack of transparency of some morphological relationships and meanings also raises the issue of whether *all* or just *some* morphemes are identified as individual constituents by speaker/listeners, and thus whether it is possible to identify some strings of morphemes within complex words that behave more like words in English.

For some polysynthetic languages, such as Cree, it has been argued that, if complex words correspond to any phonological units at all, it is the phonological *phrase* (Russell, 1999). Others, such as scholars of Athabaskan languages, have argued for units within the verb complex, marked by boundaries of tone, phonotactics and phonetics (McDonough, 1999, 2003; McDonough & Wood, 2008). Similarly, it has been argued that complex words in Dalabon (an Australian language related to Wubuy) often constitute more than one intonation phrase, associated with typical juncture characteristics including boundary tones and pauses (Evans et al., 2008; Fletcher, 2014; Fletcher et al., 2004). In the latter case, it is further argued that speech pauses are not distributed randomly. Rather, they occur only *between* morphemes, not *within* them, typically before and after lexical stems (verbs, nouns) within the word, as shown in examples (2) and (3), where ellipses indicate pauses of > 150 ms duration, and the hyphens represent morpheme boundaries (Evans et al., 2008: 103). Despite the existence of other kinds of morpheme boundaries in words of this kind (for example, between the verb root and its inflectional suffixes), pauses never occur in these locations in the study reported:

(2) [kaʔ-… ɻak-… m + ijan]

he- wood- get + FUT
'He will get firewood'

(3) [ʈeʔ-… ʈark-… niŋ + ijan]

we.two- together- sit + FUT
'We will sit together'

Interestingly, pauses have also been found to bound frequently used English multi-word strings such as '*in the middle of*' and '*I think that*' (Biber, Johansson, Leech, Conrad, & Finegan, 1999), and ERP studies further show that such strings are retrieved holistically (as opposed to on a word-by-word basis, and then assembled). This suggests that frequently occurring sequences of words are stored not only as individual word entries in the lexicon but also as wholes, even in analytic languages (Tremblay & Baayen, 2010).

The reported mapping of single complex words to multiple intonation phrases and the presence of word-internal deliberate pauses are unusual, and unexpected from the point of view of current speech processing research where these characteristics are generally thought of as features of complex phrases, not words (e.g. Jun, 2007; Watson & Gibson, 2004). Indeed, the patterns observed provide an invitation to examine knowledge of word-internal structure in polysynthetic words through careful analysis of word-internal pausing and the acceptability of word-internal pauses at various morphological boundaries in polysynthetic words, as reported here. Such work is key to informing models of speech processing, such as Shortlist B (Norris & McQueen, 2008), which start from an assumption that speakers have a (relatively simple) concept of word which they use to determine how to segment a string. Further, their studies, and related studies of word processing using for instance eyetracking technology, are generally based on analytic languages with limited morphology, inflection or derivational, and based generally on tasks involving simple nouns and pictured objects. This means that models like Shortlist B make strange predictions for polysynthetic languages, both in terms of processing time and the stability of the system, especially if the languages have prefixal inflections, like

[2] The citation form of the 'cut' verb in the Past Continuous is /wulṯaŋi/. The form /kulṯaŋi/ is a phonologically-conditioned allomorph that occurs following nasals and stops within a word. All stems that begin in one of the approximant set /l̪, r, ɻ, j, w/ have a corresponding stop-initial form in this same environment. This is one of the phonological rules which allow us to distinguish between strings which constitute words *qua* phonological domains vs strings which are multi-word sequences for syntax.

Wubuy. The problems that prefixes cause for processing have been discussed by (Cutler, Hawkins, & Gilligan, 1985). These problems are presumably compounded when the form of the prefixes themselves must be determined by the argument structure of the upcoming verb. In the case of Wubuy, this involves selection of a prefix encoding distinctions between 20 person/number/gender features for two arguments, with two alternants of each determined by the polarity, tense and mood features of the verb (Heath, 1984). In the following study, we show that complex words do indeed share features associated with words in languages like English, but that they also share features with phrases, thereby posing new and significant challenges for theories and models of spoken word processing and theories of morphosyntax.

2. Method

We conducted a two alternate forced choice word preference study, with speakers of Wubuy. We provide a brief discussion of the Wubuy speech community in 2.1. Stimulus recording and acoustic analysis of the stimuli is presented in 2.2.1; Stimulus selection and experimental design of the word preference study and predictions are presented in 2.2.2. Information about the participants and participant selection is in 2.3.

2.1. Wubuy

Wubuy [ˈwʊpʊɪ] is a polysynthetic language spoken in a remote region of eastern Arnhem Land in the Northern Territory of Australia. Wubuy allows both prefixing and suffixing, and words may be semantically very complex, as shown in (1). The language is spoken by perhaps 60 fluent first language (L1) speakers with close affiliation to the settlement of Numbulwar on the Gulf of Carpentaria. It is likely also an L2/L3 for a number of speakers in adjacent communities in north-east Arnhem Land, but the precise number of speakers (L1/L2/L3) is difficult to assess. It is related to other languages of Arnhem Land such as Anindilyakwa (Van Egmond, 2012), and Bininj Gun-wok (Evans, 2003), which have much bigger speaker populations, as well as others, such as Dalabon (Evans et al., 2008), Ngandi (Heath, 1978), and Ngalakgan (Baker, 2008; Merlan, 1983), which are effectively moribund. Wubuy is primarily spoken by people over the age of 55; younger people mostly speak Kriol (an English-lexified creole: see Sandefur, 1982; Bundgaard-Nielsen & Baker, 2016) although they are often addressed in Wubuy by older members of the community and appear to have reasonable receptive language skills.

2.2. Experimental design

2.2.1. Stimulus recording and acoustic analysis

We recruited one female native speaker of Wubuy, age 58: LM. LM produced 3–6 repetitions of 14 stimulus items ($N = 66$), shown in Table 1, in IPA. All responses were recorded using a PMD660 Marantz flash-RAM digital recorder with a DPA d:fine headset microphone. All recordings had a 16-bit sampling depth with a sampling rate of 44.1 kHz. The stimulus items were presented in written form in the Wubuy orthography on a computer monitor, and the speaker was encouraged to read out loud the target word until she had committed the word to memory. The screen was then obscured and the speaker produced the target without visual access to the prompt. All practice productions were discarded, and only targets free of hesitation pauses, errors, and other dysfluencies and produced without access to the prompt were included. This minimises any effect of reading on the productions.

The 14 stimulus items consisted of complex words and phrases in Wubuy consisting either of (a) a verbal complex with an incorporated noun or (b) a corresponding phrase with a syntactic noun and verb, because we were interested in the effects of this difference on prosodic features such as pausing and intonation. Not all noun incorporation constructions had a corresponding phrasal equivalent (e.g. items 5 and 6), but where possible, we elicited both forms. Wubuy is syntactically non-configurational (Heath, 1986), and differences in word order affect information structure but not syntactic interpretation, the same is true of noun incorporation constructions and their phrasal equivalents (Baker, 2014a, 2018). In addition, there was one example consisting of a simple adjectival predicate (9). Stimulus items were prepared on the basis of (a) frequency of noun and verb stems involved, (b) occurrence of stops at stem boundaries to facilitate segmentation.

The acoustic waveforms were hand-segmented in *Praat* (Boersma & Weenink, 2016): all visually identifiable periods of silence were hand-coded (see (4) for the possible pause categories) and the duration of each was extracted, using a *Praat* script, adapting the method in Fletcher et al. (2004). See Fig. 1 for an illustration.[3]

In some cases, the silent periods fall between morphemes as exemplified in Fig. 1, while in other cases, they correspond to stop constrictions within individual morphemes. When stop consonants are located at morpheme boundaries, it is of course also not always possible to determine whether a pause has been inserted or a stop constriction extended. The duration (in ms) of a total of 136 silent periods was extracted. We do not regard the morpheme-internal stop constrictions as potential pause locations. We include them as they are the closest match to within-morpheme silent periods in English and thus serve as a baseline. We categorise these silent periods according to the following criteria (where ellipsis '…' in (4) indicates this silent period):

(4) a. 'word-word boundary': between two syntactic words ($N = 24$);

b. 'stem-stem boundary': within words, at the boundaries of noun and verb stems ($N = 38$);

c. 'non-stem boundary': at the boundaries between prefix and stem; ($N = 8$) *ŋu-* and stem ($N = 23$); reduplicant and base ($N = 18$); root and root ($N = 14$); total $N = 63$)

d. 'morpheme-internal: i.e. stop constrictions within a morpheme ($N = 44$).

Some of the constructions in type (c) require further comment. The reduplicant-base boundary here specifically refers to inherently reduplicated forms as for example *ŋani-jina-ŋu-kucu#kucaani* 'he tickled my head' in the stimulus items in Table 1. While verbs reduplicate productively in Wubuy to indicate distribution in time, space or participants (Heath, 1984: 37), there are also many lexemes in the language which are inherently reduplicated. These lexemes do not occur in an unreduplicated form, and do not have the meanings associated with productive reduplication. The verb *kucukuca-* 'tickle', in Table 1, only ever occurs in this inherently reduplicated form: *kuca-* is not a verb in Wubuy. We therefore infer that the parts of this verb are no-longer independently meaningful for speakers. The root-root boundary is illustrated by the verb form *wulṯa-* ~ *kulṯa-* 'cut'. This verb can be analysed historically as consisting of a non-inflecting root or stem *wul-* and a finite inflecting verb root *ṯa-* (Heath, 1984: 40, c.f. *kulk-ṯu-* 'cut' in closely related Ngandi), but synchronically neither of these elements is independently meaningful in Wubuy: it is a lexicalised compound. The finite verb root *ṯa-* is synchronically used to inflect loaned verbs from English and Kriol as in *pukun-ṯa-* 'book (a ticket)' from Kriol *bukum* (see Heath, 1984: 625 for discussion and numerous other examples). Unlike the types (a) and (b) then, types (c) and (d) are divisions into parts which (we hypothesise) carry no independent meaning. Under the hypothesis that word-internal breaks can reveal information about a speaker's knowledge of morphological structure, we expected that word-word boundaries (a) and stem-stem boundaries (b) would be 'long' (i.e., exceed 150 ms, see Hieke, Kowal, & O'Connell, 1983; Mattys & Clark, 2002 for this criterion), like those between phrases, or even

[3] The annotation of these files was transcribed in the Wubuy orthography, which is English, rather than IPA, based.

Table 1
Elicited productions, in IPA.

1. /ŋa-wu-ɻuluʈ-kulʈaɲi/ 1sg-NEUT-bough.shade-cut.PAST.CONT			'I was cutting a bough shade'
2. /ana-ɻuluʈ NEUT-bough.shade	ŋa-wu-wulʈaɲi/ 1sg-NEUT-cut.PAST.CONT		'I was cutting a bough shade'
3. /ŋa-Ø-ɻaŋa-kulʈaɲi/ 1sg-RESID-branch-cut.PAST.CONT			'I was cutting a branch'[a]
4. /ana-ɻaŋak NEUT-branch	ŋa-wu-wulʈaɲi/ 1sg-NEUT-cut.PAST.CONT		'I was cutting a branch'
5. /a-jina-ŋu-ʈuɻaŋ/ 1sg/2sg-head-Ø-push.NFUT			'I'm pushing you on the head'[b]
6. /ŋani-jinak-ŋu-ʈuɻiɲ/ 3MASC/1SG-head-Ø-push.PAST.PUNC			'He pushed me on the head'[c]
7. /aɻi maybe	ŋan-ɻina-kaɭaɭiʈ/ 1sgIRR-head-wet		'maybe my head will get wet'
8. /aɻi maybe	ana-jinak NEUT-head	aŋku-waɭaɭiʈ/ NEUT.IRR-wet	'maybe my head will get wet'
9. /ŋa-aɭaɭiʈ/ 1sg-wet			'I'm wet'
10. /ŋanii-ŋu-kukutiɲ/ 3sg/1sg.MAL-Ø-steal.PAST.PUNC			'He stole it from me'
11. /ŋani-jina-ŋu-kuʈukuʈaani/ 3MASC/1SG-head-Ø-tickle.PAST.CONT			'He tickled me on the head'
12. /ana-jinak NEUT-head	ŋani-kuʈukuʈaani/ 3MASC/1sg-tickle.PAST.CONT		'He tickled me on the head'
13. /ŋa-jina-ŋu-kunʈakunʈa/ 1sg-head-Ø-have.sores			'I have sores on my head'
14. /ŋa-'ra-ŋu-kunʈakunʈa/ 1sg-COLL-Ø-have.sores			'I have sores (all over)'

[a] Wubuy has a complex noun class/gender system, classifying all entities into one of nine classes (Heath, 1984). When nouns are incorporated, it is possible for verbs to agree either with the incorporated noun as object, or with an external noun in a possession or part-whole relationship with the noun (Baker, Horrack, Nordlinger, & Sadler, 2010), hence the difference in some of the agreement marking in Table 1 (3 vs. 4, for example).

[b] The empty morpheme ŋu- is inserted before lexical stems (nouns, verbs, adjectives) beginning in underlying stops, when another lexical stem precedes, or when the prefix ends in a consonant (Heath, 1984: 35). It is meaningless, hence we gloss it as 'Ø' following Leipzig Glossing conventions (Bickel, Comrie, & Haspelmath, 2008), and best thought of perhaps as similar to the linking elements in Germanic compounds (Nübling & Szczepaniak, 2008). Heath (1984: 35) suggests that its function is to distinguish underlying stops from underlying approximants that would surface as stops in a subset of the same environments where ŋu- occurs.

[c] Wubuy has a rule of *k*-deletion preceding other consonants (Heath 1984: 48) which should have applied in this case, as in (5), but was not applied here. We had not previously noted this kind of behaviour in speakers and it remains to be investigated further. The representations in this table are of the surface form, after phonological rules such as hardening and deletion have applied, or have failed to apply.

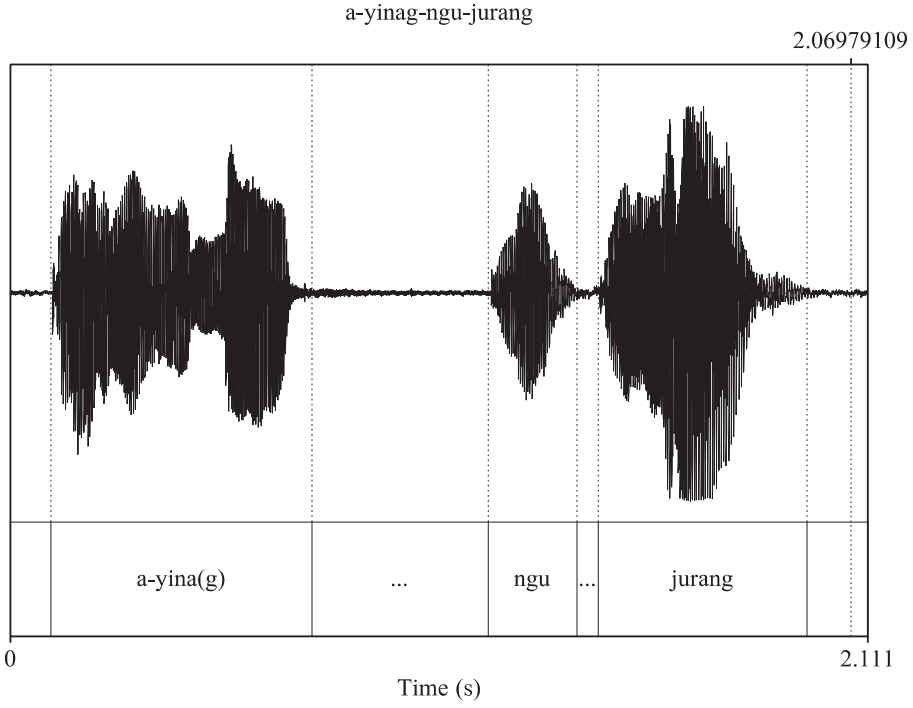

Fig. 1. Waveform of the complex Wubuy word *a-jina(k)-ŋu-ʈuɻaŋ* containing two pauses labelled […] in the textgrid.

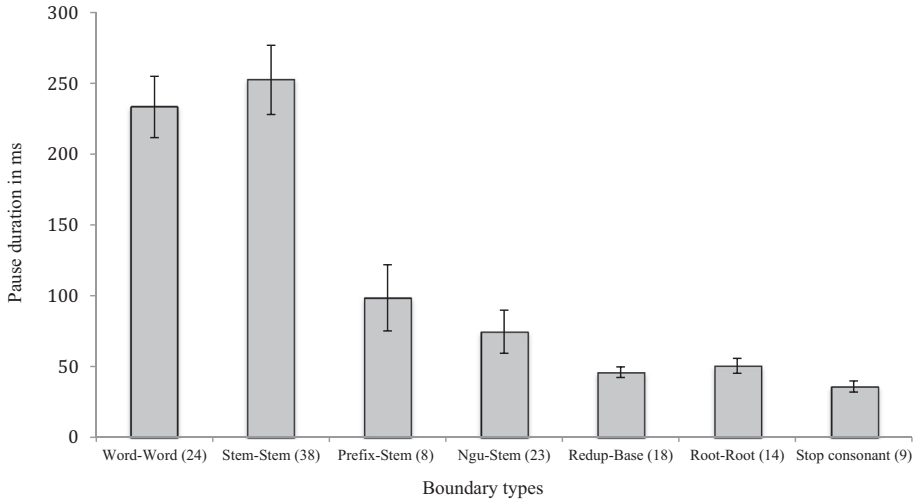

Fig. 2. Average durations of 136 silent periods for one Wubuy speaker across seven boundary types. Numbers in brackets provide the number of observations. Error bars show Standard Error of the mean.

highly frequent sequences of words (Biber et al., 1999), in English. In contrast, pauses between non-stem boundaries (c) and morpheme-internal pauses (d) would be predicted to be'short' (e.g., not exceed 100 ms; again, see Hieke et al., 1983).

Fig. 2 presents the mean duration of silence in the four categories listed in (4). These results show that silent periods between word-word boundaries and stem-stem boundaries have a mean duration exceeding 200 ms. In contrast, the durations of various categories of non-stem boundary silent periods, as well as morpheme-internal durations (stop constrictions), are below 100 ms in duration.

A one-way ANOVA of the duration differences between the seven juncture categories in Fig. 2 showed a main effect of pause type: $F(6, 127) = 19.632$, $p < 0.001$. Post-hoc Bonferroni-corrected comparisons showed the two long pause categories (word-word and stem-stem) differ from each of the short pause categories ($p < 0.05$ for the non-stem boundary, $p < 0.001$ for all others). We interpret the results to be consistent with the predictions in Section 2.2.1: The fact that longer silent periods are located at productive and transparent morphological boundaries even within words we take to be indicative of speakers' knowledge of word-internal complexity, and the likely assignment of multiple intonational phrases to single words. In particular, this is illustrated by the long silent period at stem-stem boundaries, which differ from the much shorter silent periods associated with opaque or unproductive word-internal morphological boundaries.

We note also as a potentially salient cue pre-boundary pitch rises, which have been demonstrated to be the most important local intonational cue to a prosodic boundary in a lexical segmentation tasks with Korean speakers (Kim & Cho, 2009). Fig. 3 a, b, c, and d below provide pitch traces of the four natural utterances selected for the stimulus material in the word preference task.

2.2.2. Stimulus selection, experimental design and predictions

As stimuli for the pause acceptability experiment, we selected one instance of each of four target utterances from the dataset described above (see column one in Table 2 below, and Fig. 3, above). As the aim of the experiment was to examine the preference patterns for Wubuy words in their natural, unmodified, form and with artificial pauses inserted at a range of morphological boundaries, we subsequently modified each of the four utterances in a number of ways, by inserting pauses at a number of positions, corresponding to the categories of morpheme juncture in Fig. 2. We also included a new juncture type (E)—morpheme-internal—which does not correspond to any naturally occurring pauses or silent periods in our data. We regard types (A, B)—stem juncture—as 'legal' pause boundaries, because the relationship between the parts of the word is transparent, corresponding to verbs and nouns with easily identifiable meaning and regularly occurring at word edges. (We discuss the status of *ŋu-* in Section 4 in further detail.) We regard types (C, D, E) as 'illegal' pause boundaries, reflecting the hypothesis that the each of the parts in these cases is much less accessible to speakers. We included (E) for two reasons. Firstly, it acts as a control condition: it provides a point of comparison between pauses at morphological boundaries and pauses within morphemes. Secondly, this condition can be argued to most closely correspond to analytic languages such as English, where a pause occurring within a (free) morpheme is not acceptable. We predict that pauses at E-junctures would be highly dispreferred.[4] The artificial pauses were inserted as follows:

(A) at the (left/right) boundaries of incorporated noun stems and verb stems (stem-stem, prefix-stem juncture)[5];
(B) between the semantically empty *ŋu-* and a following stem (ngu-stem juncture);
(C) between the two parts of an inherently reduplicated verb-stem (reduplicant-base juncture);
(D) between a bound verb root and finite verb root (root-root juncture); or
(E) within a morpheme (such as *ji…na(k)* 'head').

We inserted 500 ms of silence at each of the target junctures to ensure that the artificially generated pause is on par with (or longer) than the majority of the pauses identified between lexical morphemes in the acoustic analysis of stimuli reported above. This is also close to the average found across deliberate pauses in a recent study of French and German speakers (Trouvain, Fauth, & Möbius, 2016). Note that when an utterance is so divided, neither part constitutes a licit word in Wubuy in this context. That is, listeners could not misinterpret a string XXX#YYY divided by pause as a syntactic word sequence $[\ldots \mathrm{XXX}]_{\mathrm{word}}[\mathrm{YYY}\ \ldots]_{\mathrm{word}}$.

From the unmodified and modified words, we constructed a total of 17 contrasting word pairs (Appendix A), testing the preference patterns

[4] We are not aware of any similar findings in, for instance, English of word-internal pauses.

[5] We included in this category pauses inserted before the empty element *ŋu-*. Pauses inserted between *ŋu-* and the following stem are classified as type (B), partly because of differences in the durations of pauses found at each of these positions in the study reported in Section 2.2.1. We discuss this issue further in Section 4.

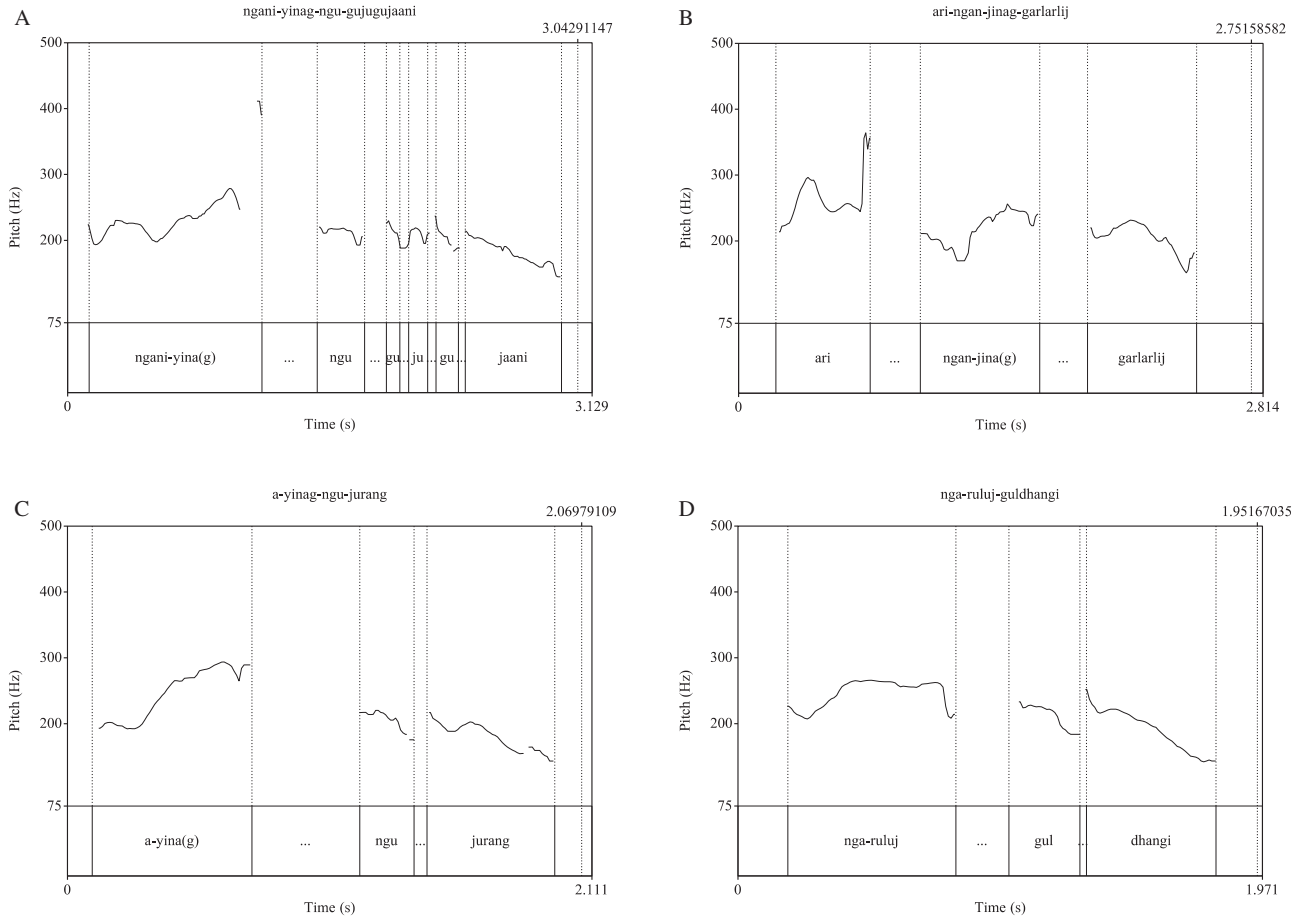

Fig. 3. a: Praat pitch trace of the Wubuy target word *ŋani-jina(k)-ŋu-kuʈukuʈaani.* Pitch in Hz on the Y-axis; time in ms on the X-axis.
b: Praat pitch trace of the Wubuy target phrase *aɻi ŋan-ʈina(k)-kaɭaɭiʈ.* Pitch in Hz on the Y-axis; time in ms on the X-axis.
c: Praat pitch trace of the Wubuy target word *a-jina(k)-ŋu-ʈuɻaŋ*. Pitch in Hz on the Y-axis; time in ms on the X-axis.
d: Praat pitch trace of the Wubuy target word *ŋa-ɻuluʈ-kuɭʈaŋi*. Pitch in Hz on the Y-axis; time in ms on the X-axis.

Table 2
Stimulus list in Wubuy with translations. '#' indicates location of inserted pause of 500 ms, Labels (A, B, C, D, E) indicate the category of juncture; N indicates an unmodified word.

Natural speech	Legal breaks	Illegal breaks
ŋa-ɻuluʈ-kuɭʈaŋi (N) 1sg-shade-cut.through.PC 'I cut the bough shade'	ŋa-ɻuluʈ-#kuɭʈaŋi (A)	ŋa-ɻuluʈ-kul#ʈaŋi (D)
a-jina-ŋu-ʈuɻang (N) 1sg/2sg-head-Ø-push.FUT 'I'll push your head'	(1) a-jina-#ŋu-ʈuɻang (A) (2) a-jina-ŋu-#ʈuɻang (B)	
aɻi ŋan-ʈina-kaɭaɭiʈ (N) maybe 1sgIRR-head-wet 'maybe my head will get wet'	(1) aɻi ŋan-ʈina-#kaɭaɭiʈ (A) (2) aɻi ŋan-#ʈina-kaɭaɭiʈ (A)	aɻi ŋan-ʈi#na-kaɭaɭiʈ (E)
ŋani-jina-ŋu-kuʈukuʈaani (N) 3MASC/1sg-head-Ø-tickle.PC 'He tickled my head'	(1) ŋani-jina-#ŋu-kuʈukuʈaani (A) (2) ŋani-jina-ŋu-#kucukucaani (B) (3) ŋani-#jina-ŋu-kucukucaani (A)	ŋani-jina-ŋu-kuʈu#kuʈaani (C)

for words which contain No Manipulations (N), words which contain pauses inserted at a Legal juncture A or B (L), and words that contain pauses inserted at illegal junctures C, D, E (IL). Each pair was presented to the participants twice, counterbalancing the order of presentation, in a pseudo-randomised task where no adjacent trials consisted of manipulations of the same word.

We predict that natural, unmodified utterances ('N' in what follows) and utterances with pause at a legal boundary ('L': Category A, B boundaries) will be preferred over utterances with pause at an illegal boundary, irrespective of the type ('IL': Categories C-E). We also predict that natural utterances will be preferred over utterances with a pause inserted at a legal boundary (A, B).

2.3. Participants

We recruited 14 L1 speakers of Wubuy (one male). One was excluded from analysis because she was presented with a slightly different stimulus list due to error. The participants ranged in age from approximately 40 to approximately 65. All spoke North Australian Kriol and English to varying levels of competence.

The participants were informed (in English, Kriol and Wubuy, depending on participant preference) that they would hear pairs of utterances from a familiar Wubuy speaker. Participants heard each pair of utterances through headphones from a laptop. For each pair of utterances, the listeners were instructed to choose the one which sounded 'best' to them, by means of a hand gesture or by saying 'first one' or 'last one', in any of the languages they commanded. Participants

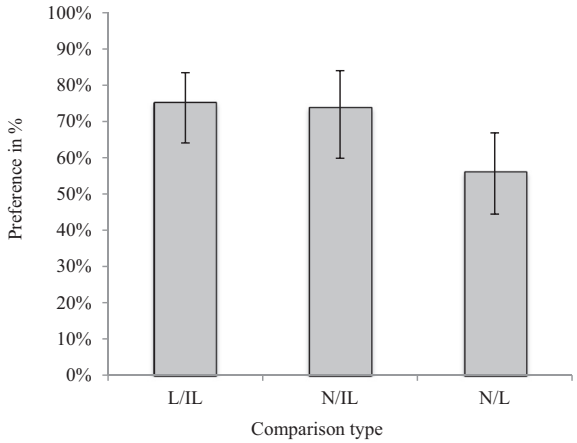

Fig. 4. Estimated mean word preferences (error bars indicate 95% confidence interval). N = natural utterance; L = pause inserted at a legal boundary; IL = pause inserted at an illegal boundary.

were allowed to listen to each pair as many times as they liked, and to take as long as they liked, before making their decision. Testing took place in quiet homes in either Darwin or Numbulwar. All participants were compensated for their time and effort by a payment of $50. The study was approved by a human ethics panel of the University of Melbourne.

3. Results

Responses consistent with our predictions for each of the three types of comparisons (N vs. L; N vs. IL; L vs IL) above were given a score of 1, while responses selecting the competitor were given a score of 0 in our analyses. A mixed-effects logistic regression model was fit to these results; estimated group means are represented in Fig. 4. We included each type of contrast (L vs N; IL vs N, and L vs IL) as a fixed effect, while participant and item (each word pairing) were included as crossed random effects. A likelihood ratio test indicated that the effect of item was statistically significant ($\chi^2(2) = 13.959$; $p < 0.001$).

The results indicate that natural, unmodified (N) utterances are preferred over illegal (IL) pause-modified utterances 75% of the time (95% CI: 64% to 84%; $p < 0.001$ when compared to 50% chance), and legal (L) pause-modified utterances are preferred over illegal (IL) pause-modified utterances 74% of the time (95% CI: 60% to 84%; $p = 0.0014$). Natural (N) utterances were preferred over legally modified utterances (L) 56% of the time, which was not statistically significantly different from chance (95% CI: 44% to 67%; $p = 0.3119$).

Tukey-adjusted pairwise comparisons indicated that the preference pattern for N > L was different from the preference pattern for both N > IL (Odds Ratio = 2.21; 95% CI: 1.09 to 4.46; $p = 0.023$) and L > IL (Odds Ratio = 2.36; 95% CI: 1.35 to 4.14; $p < 0.001$). However, the difference between the preference pattern for N > IL and L > IL was not statistically significant (Odds Ratio = 1.09; 95% CI: 0.53 to 2.10; $p = 0.9745$).

These results are consistent with our predictions that participants prefer natural, unmodified words (N) over words into which 500 ms silence has been inserted at what we have called illegal junctures here (C, D, E). The results are also consistent with the prediction that, when presented with pairs of utterances both containing artificial pauses, that participants prefer pauses at transparent, legal junctures (A, B) over illegal junctures (C, D, E). Importantly, the results also reveal that the participants as a group do not prefer natural, unmodified words (N) over those with legal pauses (A, B), and that pauses at C and D junctures *as well as* morpheme-internal pauses (E) are dispreferred. Fig. 5 presents the preference patterns organised by individual word pair (17 unique pairs, counterbalanced), as well as comparison type (L vs IL; N vs IL; N vs L).

Finally, individual preference patterns are presented in Fig. 6. These results suggest that most participants preferred the natural utterances (N > L), while three listeners preferred the legal utterances (i.e. with artificially inserted pause) over the natural ones (L > N). We speculate that some speakers might prefer complex words to have internal pauses, as long as they are at meaningful junctures, because they are easier to process. We note, again, that all participants were familiar with the individual who produced the stimuli. This is unavoidable in the case of Wubuy, as the speaker group is limited: We estimate approximately 60 L1 speakers, closely linked by family and clan ties. This familiarity however, importantly, did not result in consistent rejection of *all* modified words over unmodified, natural words, and we take this to indicate that pauses inserted at A and B junctures are perceived as possible and acceptable natural variation (at least for the speaker who produced the materials).

4. Discussion

The present study examined the effect of intra-word pausing on word acceptability in the polysynthetic language Wubuy. Wubuy allows both prefixing and suffixing, and words may be semantically very complex, often best translated as phrases in analytic languages such as English. The complexity of such words raises questions about whether they might be different in kind, and involve a different kind of processing, from morphologically much simpler words in languages such as English.

In the present study, Wubuy listeners were presented with pairings of Wubuy words which were either unmodified (N) or into which 500 ms of pause had been inserted at morphologically transparent legal boundaries (A, B), morphologically opaque illegal boundaries (C, D), or morpheme-internally (E), also illegal. The results show that the participants disprefer words into which pauses have been inserted at illegal (C, D, and E) positions, whether the alternative choice is a natural, unmodified (N) word, or a word modified by the insertion of a legal pause (A, B). They do not show a preference for unmodified words over words with legal pauses as a group. The individual results suggest that, in some positions, word-internal pauses are in fact preferred by some speakers, over utterances lacking internal pause, perhaps because productions of the former kind are perceived as careful or slow speech. We take this pattern of behaviour to be inconsistent with, for instance, an exemplar-based alternative account. If speakers rely on stored exemplars of words from the familiar speaker in order to respond to the task, we would predict that they would reject all modified utterances as they are not consistent with the typical productions of the particular speaker. However, as demonstrated in Section 3, words modified by pause insertion at certain junctures (A, B) are regarded on average as being as acceptable as unmodified words, and as indicated by Fig. 5, some participants preferred the modified words over the unmodified words.

The reported preference results are consistent with the locations of pauses in the speech sample from which the stimuli were selected. Here, the speaker produced much longer silent periods at A and B junctures, than she did at C, D, and E-type junctures, though we acknowledge that we cannot necessarily generalise this pattern to the rest of the Wubuy speaker population on the basis of a single speaker's behaviour.

The results contribute to our understanding of wordhood in polysynthetic languages in a number of ways. Firstly, they illustrate that not all word-internal morphological boundaries have the same status in the speakers mind: some can be temporally extended without interfering with the acceptability of the word in which they occur, while others, similarly to morpheme-internal stop constrictions, cannot. The existence of acceptable, and to some participants even preferable, words with artificially generated pauses at meaningful morphological junctures in Wubuy contrasts with what is expected in, for instance, English. To exemplify, morphologically complex '*mis-[500 ms of silence]-place*' is

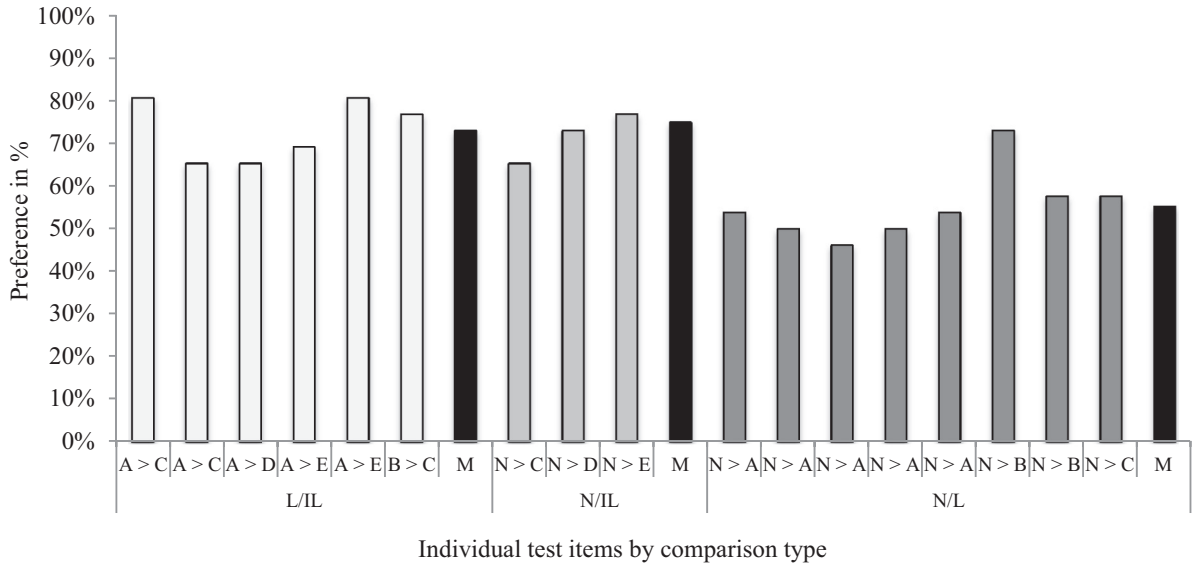

Fig. 5. Preference pattern by item, organised by comparison (N, L, IL), and juncture type (A, B, C, D, E). *M* indicates the observed mean preference score. Each column represents 26 data points.

likely to be dispreferred over '*misplace*', even when speakers are aware that '*mis-*' is a productive bound morpheme in English, just as morphologically simple '*ti-[500 ms of silence]-ger*' is likely to be dispreferred over '*tiger*', even though both interrupted words may be fully comprehensible. In this sense, some types of morphological boundaries (A-type junctures in particular) make Wubuy words similar to *phrases* in English as they may subdivide complex words into multiple parts, which themselves may consist of several morphemes with (less transparent) boundaries/meanings (C, D junctures), the latter more closely aligned to the types of words we find in languages such as English. We highlight type A (stem-stem, prefix-stem) junctures in particular here (and return to a discussion of *ŋu*-junctures below). Type A junctures are located between transparent, segmentable morphemes that correspond to the edges of nouns and (inflected) verbs. The behaviour of the speaker who produced the stimuli for the present study, as well as the participants in the preference task, are consistent with the interpretation that these junctures are, or at least can be, associated with an Intonational Phrase boundary (or with Intermediate Phrases, so far as pause insertion at the juncture is accepted to be a plausible correlate for either: Beckman & Pierrehumbert, 1986).

Throughout the present paper, we have relied on notions of morphological transparency in our discussions of the differences between A and B junctures where translations into English of the participating morphemes is relatively direct (noun to noun, verb to verb) versus C and D junctures. Logically, this position rests on the observation that speaker/listeners must recognise strings of phonemes as sequences of discrete meaningful constituents in order for them to be analysed as separate constituents, potentially assignable to individual prosodic phrases (of some kind) or as constituents in different (word-internal) Intonational Phrases. Also important is the observation that not all linguistically identifiable morphemes are necessarily identified as such by (all) speakers: individuals differ in the degree to which they (are able to) decompose polymorphemic words into their constituents (see for instance Medeiros & Duñabeitia, 2016; c.f. also Hay & Plag, 2004 for

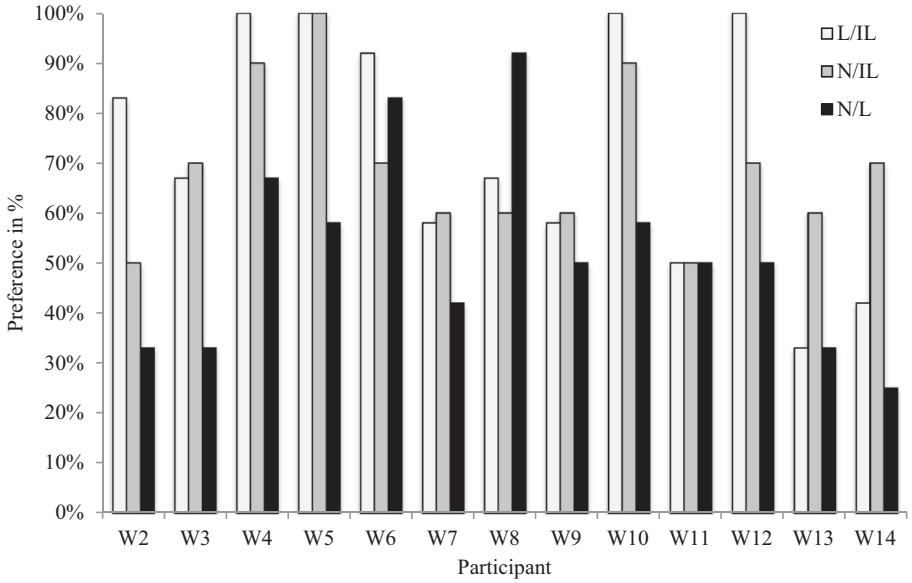

Fig. 6. Individual word preferences for the 13 participants (W = Wubuy participant). N = natural utterance; L = pause inserted at legal boundary; IL = pause inserted at illegal boundary.

the gradability of affix decomposibility in terms of frequency). Some researchers further claim that both early and late decomposition mechanisms may guide the decomposition of polymorphemic words, and that early decomposition relies heavily on morpho-orthographic information (e.g., Baayen, Dijkstra, & Schreuder, 1997; Diependaele, Sandra, & Grainger, 2009). The limited (Wubuy or other) literacy skills of the participants in this study could potentially block this avenue of analysis for the participants, though we note that the reliance of morpho-orthographic information may also reflect task specific demands in the masked priming tasks employed in those studies (and on which we did not rely). We also recall the findings of Tremblay and Baayen (2010) that highly frequent sequences of English words may be retrieved holistically rather than generated on the fly under some circumstances, and that this is considered to reduce processing cost (it is less costly to retrieve a single item than it is to retrieve four in the example '*in the middle of*') as well as lower response time in experimental tasks. The notion of morphological transparency, and the possibility that not all linguistically analysable morphemes (here C and D junctures) are identified as individual constituents is also reminiscent of accounts of unparsed holistic phrases operating as single units in child language (especially under usage based theories, for a review see Ghalebi & Sadighi, 2015), and support the proposal that strings of unparsed morphemes will stick together and be incorporated into the same intonational structure.

The standard assumption is that Intonational Phrases are assigned to utterances at a late stage of processing, after the assembly of a syntactic skeleton and the selection of lexemes (Bock & Levelt, 1994; but see Ferreira, 1993 for a slightly different view). This view is compatible with the results reported here. In the current proposal, some morphemes constitute possible word-internal phonological or prosodic words. These are morphemes which are both segmentable and lexical in meaning (corresponding to nouns, verbs and adjectives). In turn, the edges of these prosodic words may provide anchoring points for the edges of higher prosodic constituents such as Intonational Phrase or Phonological Phrase, as proposed in much work in Prosodic Phonology (starting with Selkirk, 1980; Nespor & Vogel, 1986; Chen, 1987; Truckenbrodt, 1999; see Selkirk & Lee, 2015 for a recent review of this literature).

Finally, we return to the semantically empty *ŋu*-morpheme, and suggest that *ŋu-* may constitute a special third category. This is a semantically empty and regularly applied co-variate of a particular morpho-phonological rule in Wubuy in which it signals whether or not a phonemic alternation has occurred in the following segment as a function of the final segment preceding the inserted *ŋu-* or else the presence of a morpheme boundary of a particular type (stem). As such it is difficult to determine theoretically which of the potential two Intonational Phrases will be tasked with incorporating *ŋu-*, but on the basis of our acoustic analyses of the stimulus materials used in the present study, we tentatively suggest that it is incorporated into the second IP. We argue this, due to the shorter duration of pausing after *ŋu-* than before. Further, we note that the participants in the word preference study systematically dispreferred a word with pause inserted after *ŋu-* in comparison with an unmodified word. We are reluctant, however, to classify post-*ŋu-* junctures as C, D, or E junctures, and further research must determine whether it is indeed a legal, acceptable pause juncture as we have classed it here, or whether it is systematically dispreferred.

We conclude that the behaviour of Wubuy speakers in this experiment, taken together with existing prosodic descriptions, casts serious doubt on the proposition that constructs like those in (1) are words in the traditional sense. Words in Wubuy can contain a number of items which are prosodically free in the sense that they can be followed or preceded by pauses, have a semantic interpretation which is compositional rather than idiosyncratic (see Baker, 2018), and an internal structure which is accessible to speaker consciousness to the extent that speakers are able to judge whether pauses are acceptable or not depending on their location with respect to this structure, none of which appear to be applicable to words in the languages which are typically the objects of inquiry for speech processing.

Author contribution

For both authors: Conceptualization, Funding acquisition, Project administration, Supervision, Roles/Writing - original draft, Data curation, Investigation, Resources, Validation, Formal analysis, Methodology, Software, Visualization.

Acknowledgements

We would like to thank our participants, and Leonie Murrungun who worked with us on the stimulus materials for this study. We also thank participants at ALS2015, SST2016, AMP2016 and LabPhon2018 for their comments, particularly Andy Butcher, Anne Cutler, Katherine Demuth, Nick Evans, Janet Fletcher, Mark Harvey, and Volya Kapatsinski. Special thanks to Elise Bell for her assistance in running these experiments, and Cameron Patrick, of the University of Melbourne Statistical Consulting Centre, for his invaluable help in running the statistical analysis. This study was funded by the Australian Research Council (DP130102624), and an ARC Centre of Excellence for the Dynamics of Language Trans-disciplinary and Innovation Grant, whose assistance we also gratefully acknowledge. This paper was much improved due to the comments and assistance of the editor and three anonymous reviewers, whom we also thank.

Appendix A

List of stimulus materials in order of presentation

1. a-jinak-#ŋu-cuɻaŋ	a-jinak-ŋu-cuɻaŋ
2. ŋani-jina-ŋu-kucukucaani	ŋani-#jina-ŋu-kucukucaani
3. aɻi ŋan-ci#na-kaɭaḷic	aɻi ŋan-cina-#kaɭaḷic
4. ŋani-jina-ŋu-kucukucaani	ŋani-jina-ŋu-#kucukucaani
5. a-jinak-ŋu-cuɻaŋ	a-jinak-#ŋu-cuɻaŋ
6. ŋani-#jina-ŋu-kucukucaani	ŋani-jina-ŋu-kucu#kucaani
7. aɻi ŋan-#cina-kaɭaḷic	aɻi ŋan-cina-kaɭaḷic
8. a-jinak-ŋu-cuɻaŋ	a-jinak-ŋu-#cuɻaŋ
9. aɻi ŋan-cina-kaɭaḷic	aɻi ŋan-#cina-kaɭaḷic
10. ŋa-ɻuluc-kul#ṭaŋi	ŋa-ɻuluc-#kulṭaŋi
11. ŋani-jina-ŋu-#kucukucaani	ŋani-jina-ŋu-kucu#kucaani
12. aɻi ŋan-cina-#kaɭaḷic	aɻi ŋan-cina-kaɭaḷic
13. ŋa-ɻuluc-#kulṭaŋi	ŋa-ɻuluc-kulṭaŋi
14. aɻi ŋan-ci#na-kaɭaḷic	aɻi ŋan-#cina-kaɭaḷic
15. ŋa-ɻuluc-kulṭaŋi	ŋa-ɻuluc-kul#ṭaŋi
16. ŋani-jina-ŋu-kucu#kucaani	ŋani-jina-#ŋu-kucukucaani

17. aɻi ŋan-ci#na-kaɭaɭic	aɻi ŋan-cina-kaɭaɭic
18. ŋani-jina-ŋu-kucu#kucaani	ŋani-jina-ŋu-#kucukucaani
19. ŋa-ɻuluc-kul#ʈaŋi	ŋa-ɻuluc-kulʈaŋi
20. ŋani-jina-ŋu-kucu#kucaani	ŋani-#jina-ŋu-kucukucaani
21. aɻi ŋan-#cina-kaɭaɭic	aɻi ŋan-ci#na-kaɭaɭic
22. ŋani-jina-#ŋu-kucukucaani	ŋani-jina-ŋu-kucu#kucaani
23. ŋa-ɻuluc-#kulʈaŋi	ŋa-ɻuluc-kul#ʈaŋi
24. ŋani-jina-#ŋu-kucukucaani	ŋani-jina-ŋu-kucukucaani
25. aɻi ŋan-cina-kaɭaɭic	aɻi ŋan-ci#na-kaɭaɭic
26. ŋani-jina-ŋu-#kucukucaani	ŋani-jina-ŋu-kucukucaani
27. aɻi ŋan-cina-kaɭaɭic	aɻi ŋan-cina-#kaɭaɭic
28. ŋani-#jina-ŋu-kucukucaani	ŋani-jina-ŋu-kucukucaani
29. ŋa-ɻuluc-kulʈaŋi	ŋa-ɻuluc-#kulʈaŋi
30. ŋani-jina-ŋu-kucu#kucaani	ŋani-jina-ŋu-kucukucaani
31. aɻi ŋan-cina-#kaɭaɭic	aɻi ŋan-ci#na-kaɭaɭic
32. ŋani-jina-ŋu-kucukucaani	ŋani-jina-ŋu-kucu#kucaani
33. a-jinak-ŋu-#cuɻaŋ	a-jinak-ŋu-cuɻaŋ
34. ŋani-jina-ŋu-kucukucaani	ŋani-jina-#ŋu-kucukucaani

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