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Research Article

# When more is more: The mixed language Light Warlpiri amalgamates source language phonologies to form a near-maximal inventory

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ABSTRACT

This paper presents a combined analysis of the perception and production study of the mixed language Light Warlpiri (Australia), which systematically combines elements of Warlpiri, Kriol and English. The perception and production results suggest that the Light Warlpiri phonological inventory consists of a voiced and voiceless series of stops and affricates, differentiated by Voice Onset Time (VOT) word-initially and by Constriction Duration (CD) medially, by incorporating English-like VOT differentiation and Constriction duration differences found in Kriol and also in a number of traditional Indigenous Australian languages. The results also show that Light Warlpiri speakers perceptually differentiate stops and fricatives at the same POA, but that voicing distinctions in fricatives are more difficult to discriminate than voicing distinctions in stops. The large phonological inventory of Light Warlpiri combines most features of the source languages, allowing speakers of Light Warlpiri to maintain sufficient phonemic contrasts to accommodate vocabulary items in Light Warlpiri sourced from English/Kriol as well as Warlpiri.


## 1. Introduction

Mixed languages are languages arising from the systematic blending together of significant amounts of elements from two parent languages as a result of conventionalisation of codeswitching patterns in communities where both parent languages are spoken (Matras & Bakker, 2003; Thomason & Kaufman, 1988). Mixed languages offer unique opportunities to witness the interweaving of often dramatically different languages, and much research has focused on the relative contribution of the individual parent languages to the structure of the new languages. Some mixed languages preserve the verbal structure of one of the parent languages and the nominal structure of the other (McConvell & Meakins, 2005; O'Shannessy, 2013), although different typologies of language combining have been described (Bakker & Matras, 2013). In light of reported variation between mixed languages, research into any one of them may provide valuable insights into the range of intermixing phenomena observed in language-genetic classifications and inform reconstructions of pre-historic language phyla.

More focus on the interplay between the morpho-syntactic systems and the lexicons of the parent languages in a mixed language, however, means that what happens in terms of the phonological systems of such amalgamations is less clear: Are such inventories reflective of just one of the parent languages, or are they reflective of the need for contrast maintenance faithful to the inventories of each of the languages, creating a 'super-phonology'? Or, do they form 'patchwork' phonologies, where some contrasts from each parent language are supported, but not all? Answering this question extends our understandings of how Mixed Languages are formed, focusing on an area that is often arguably beyond speakers' deliberate control, and thus complementing research focussing on grammar or lexicon, where use-patterns are sometimes claimed to be shaped by deliberate discourse-strategic exploitation of a multilingual repertoire (Bakker & Matras, 2013).

The present study investigates the question of mixed language phonology in two ways: It first presents an acoustic analysis of stop and affricate production in Light Warlpiri (Section 2). The results suggest that speakers of Light Warlpiri use Voice Onset Time (VOT: the duration from release of the stop constriction to the onset of vocal fold vibration) and Constriction Duration (CD: the duration of the 'hold' phase of the pro-

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duction of a stop consonant) to differentiate voiced and voiceless stops and affricates with English/Kriol origins, and that they produce Warlpiri stops in a manner consistent with voiced English/Kriol stops in initial position, and 'long' voiceless Kriol stops in medial position. Secondly, it presents a study of stop and fricative perception in Light Warlpiri (Section 3). The results from the perception study are consistent with those of the production study: Light Warlpiri speakers are able to discriminate VOT-only and VOT + CD based stop contrasts, as well as fricatives that differ in terms of POA and voicing. The results thus contrast, to some extent, with the reports on Gurindji Kriol (Jones & Meakins, 2013; Stewart, Meakins, Algy, & Joshua, 2018) and Michif (Rosen, Stewart, Pesch-Johnson, & Sammons, 2019), reviewed below. Indeed, in contrast with Gurindji Kriol and Michif, the production and perception studies seem to suggest that Light Warlpiri speakers have adopted a 'super-phonology' which allows almost every source-language contrast to be maintained in the mixed language. At the same time, however, speakers appear to have integrated all Kriol/English and Warlpiri stops into a voiced and voiceless series of stops and affricates, rather than operating with a three-way stop distinction (voiced and voiceless Kriol/English plus Warlpiri stops).

### *1.1. Light Warlpiri and its sources*

Light Warlpiri (LW) is a mixed language spoken (as a first language (L1)) in the community of Lajamanu, in the Northern Territory (NT) of Australia, by adults under approximately age 40 and all children (O'Shannessy, 2005). Speakers are typically bilingual in Warlpiri, which is typically used with older non-Light Warlpiri speaking individuals. Community members also acquire English through the formal education system, and have significant exposure to Kriol from Kriol-speaking visitors to the community and from Kriol-speakers when they travel to other communities or larger cities like Alice Springs, Katherine or Darwin. Like many, perhaps most, Indigenous communities, Lajamanu is thus characterised by multilingualism, and by close linguistic, social and family ties to other communities across the region, including other Warlpiri communities. The documentation of Light Warlpiri arose from the second author's long-term involvement with Warlpiri language and education in the community, with several community members collaborating as research assistants in data collection, transcription and discussion over the years. The second author has reported on the documentation to community members in a variety of in-person and online formats.

Light Warlpiri is a new language which has emerged as a result of language contact between Warlpiri, (ISO 639-3 wbp) English (ISO 639-3 eng) and Kriol (ISO 639-3 rop), and does not currently have its own ISO code. A two-stage process of emergence is documented in O'Shannessy (2012), O'Shannessy (2013). In the process adults spoke to very young children in a baby talk register with specific patterns of code-switching. The children internalised the input as a single system and added morphosyntactic innovations. The structure of Light Warlpiri combines the nominal structure of Warlpiri (a member of the Ngumpin-Yapa subgroup of the Pama-Nyungan family of languages) with the verbal structure of Kriol (an English-lexified Creole), along with innovations in the verbal system (O'Shannessy, 2013). This means that in addition to vocabulary from Warlpiri, Light Warlpiri has significant English and Kriol vocabulary, though it is not always clear which Light Warlpiri words are sourced directly from English, and which from Kriol. This uncertainty is due to a significant overlap between English and Kriol vocabulary: while English and Kriol are separate languages, English has contributed a large proportion of Kriol vocabulary items, some of which share many features with the English form (e.g. Kriol /fɹog/ for English /fɹɒg/), and some of which have undergone substantial changes (e.g. Kriol /tʃabitʃ/, for English (church) /sɜvɪs/). In the latter case, determining the source language is of course easier than in the first case; but there is also the confound that words borrowed from English may take on Warlpiri phonology, making them appear more Kriol-like. For discussions of the formation of Kriol and Kriol phonology, see Harris (1986), Sandefur (1986), Munro (2000), and Bundgaard-Nielsen and Baker (2016). A recent study of fricative production in Light Warlpiri (Hendy, 2019) suggests that the fricative inventory is /f v s ʃ/.

The phonological inventory of Warlpiri (see Appendix 1) is similar to that of other Australian Indigenous languages in having a small vowel inventory (typically 3–5; sometimes with a duration contrast) and a 'long and thin' consonant inventory with up to six places of articulation and no voicing distinctions (Butcher, 2012, 1994, 2006; Dixon, 1980)—a system that contrasts greatly with the vowel- and voicing-contrast and fricative-rich English (and to some extent Kriol). Warlpiri has just three vowels (/i a u/); a single series of stops /p t ʈ c k/ produced at five main places of articulation, and an absence of fricatives (See Table 1 for VOT values of /p t k/). It is also described as having three rhotic phonemes; trill /r/, approximant /ɻ/, and a retroflex flap /ɽ/ (Nash, 1986), which, apart from an absence of build-up of air-pressure resulting in a distinct release burst, is articulatorily similar to a /ʈ/ (Bundgaard-Nielsen & O'Shannessy, 2019).

In contrast to Warlpiri, Australian English uses systematic Voice Onset Time (VOT) differences to maintain stop contrasts. Jones and Meakins (2013) is of particular relevance as it reports on word-initial and medial stops VOT and constriction duration in the variety of Australian English spoken in the town of Katherine also in the Northern Territory, though we also note that English language input received in the community, in particular in school settings, may not reflect the local variety as teachers in remote areas of the Northern Territory are often recruited from across the country. According to Jones and Meakins (2013), voiceless Northern Australian English stops are realised in *word-initial* position with a VOT ranging from approximately 50 ms (for /p/ and /k/) to 70 ms (for /t/) in duration, while the voiced counterparts are realised in the case of /b/ with a negative VOT of approximately −25 ms, while /d/ is realised with a very short positive VOT, and /g/ with a VOT of approximately 10 ms in duration. This appears to differ from Australian English VOTs from other regions (Melbourne; Sydney), but it is not clear whether the differences partly or wholly reflect differences in data collection and analysis, and we would not wish to over-interpret this discrepancy in relation to the characteristics of the English input to Light Warlpiri. *Word-medially*, voiceless stop VOT ranges from 20 ms (for /p/) to 70 ms (for /k/) in duration, while the voiced stops range

**Table 1**
Word-initial VOT in Australian English from Sydney (Antoniou et al., 2010), Melbourne (Clothier & Loakes, 2018), and Katherine (Jones & Meakins, 2013), as well as Roper Kriol (Baker et al., 2015), and Warlpiri (Bundgaard-Nielsen & O'Shannessy, 2019).

| Source | /p/ | /t/ | /k/ | /b/ | /d/ | /g/ |
|---|---|---|---|---|---|---|
| **Aust. Eng., Sydney** (Antoniou et al., 2010; *N* = 8) | 77 | 83 | | −2 | 6 | |
| **Aust. Eng., Melbourne** (Clothier & Loakes, 2018; *N* = 30) | | 83 | | | 19 | |
| **Aust. Eng., Katherine** (Jones & Meakins, 2013; *N* = 4)* | ~50 | ~70 | ~50 | ~−25 | ~5 | ~10 |
| **Roper Kriol** (Baker et al., 2015, Study 1; *N* = 1) | 66 | 56 | 90 | 14 | 24 | 37 |
| **Roper Kriol** (Baker et al., 2015, Study 2; *N* = 2) | 45 | 64 | 56 | 18 | 22 | 29 |
| **Warlpiri** (Bundgaard-Nielsen & O'Shannessy, 2019; *N* = 2) | 36 | 30 | 61 | – | – | – |
| **Warlpiri** (Bundgaard-Nielsen & O'Shannessy, 2019; *N* = 4)** | 36 | 29 | 47 | – | – | – |

* Approximate values available only.
** The first group of speakers (*N* = 2) in Bundgaard-Nielsen & O'Shannessy speak Warlpiri as L1, while the second group (*N* = 4) speak both Light Warlpiri and Warlpiri. There was no statistically significant difference between the VOTs of the two groups.

from a negative VOT of approximately −50 ms in duration for /b/, to a negative VOT of approximately −20 ms for /d/, to a positive VOT of approximately 30 ms in duration for /g/. In general, this suggests that word-medial stops may be produced with a fully or partially voiced constriction period. The pattern of increases in VOT from stops produced at the front versus the back of the oral cavity is consistent with presumed universal articulatory tendencies (see for instance, Lisker & Abramson, 1967). Other studies with speakers from Sydney and Melbourne report word-initial VOT differences at the alveolar POA (/t d/), and bilabial POA (/p b/) (Antoniou, Best, Tyler, & Kroos, 2010; Clothier & Loakes, 2018, see Table 1), showing that the distinction is essentially between a short-lag and a long-lag realisation, at least in initial position, though in both those studies the initial VOTs are much longer than those reported in Jones and Meakins (2013). In initial position, prevoicing is unusual: Clothier and Loakes (2018) report only 12 instance of prevoicing in their dataset (5% of the tokens).

(Roper) Kriol[1] (see phonological inventory in Appendix 2) also makes use of VOT (See Table 1 and Fig. 1) in combination with systematic differences in stop Constriction Duration (CD) to maintain stop and affricate contrasts (see Fig. 2, also adapted from Baker, Bundgaard-Nielsen, & Graetzer, 2015). As the figures illustrate, in Roper Kriol, stops are predominantly phonetically voiceless, the exception being word-medial /b/ and /d/. In Kriol, phonemically voiceless stops are characterised by long CDs, while phonemically voiced stops are characterised by much shorter CDs (Baker et al., 2015; Bundgaard-Nielsen, Baker, & Bell, 2016). This reliance on both VOT and CD in Kriol is also reflected in stop voicing discrimination (Bundgaard-Nielsen & Baker, 2019).

The phonological inventories of the parent languages of Light Warlpiri thus provide an excellent opportunity to examine closely what happens in a mixed language situation when the parent languages have very different inventories; where contrasts in one make use of a feature (e.g. voicing and stop constriction duration in Kriol) to maintain stop contrast, while the other makes use of more places of articulation, creating a larger number of contrasts in another dimension (POA in Warlpiri).

### 1.2. Phonological systems in other mixed languages

Mixed languages combine elements of their sources in different ways (Matras & Bakker, 2003), and the relatively few existing studies of the phonology of mixed languages suggest similar variation, likely reflecting the fact that each mixed language situation poses unique challenges to the speakers. It has also been suggested that the structure of mixed languages can be as complex or more complex that the source languages, though the exact opposite has also been argued for mixed language phonology (Stewart, Meakins, Algy, Ennever, & Joshua, 2020).

> "Most mixed languages combine structures of their donor languages, giving rise to structures that are as complex as their combined components. Bakker (1997) has argued that Michif, a mixed language with Cree verbs and French nouns, combines the most complex parts of the two languages, but that this is accidental and not predetermined by the process of language intertwining itself. [...] Some Australian mixed languages [Gurindji Kriol] tend to elaborate certain structures beyond what is found in the source languages." (Bakker & Matras, 2013, p. 7).

In the Australian context, a substantial amount of research has focussed on the mixed language Gurindji Kriol, also spoken in the Northern Territory of Australia, immediately to the north of the area in which Light Warlpiri is spoken. Gurindji Kriol incorporates Gurindji nominal structure with Kriol verbal structure, in a way that is somewhat similar to Light Warlpiri. In terms of phonology, Gurindji is very similar to Warlpiri in comprising a five-way place of articulation distinction in obstruents and nasals, as well as having three laterals, three glides, and a tap/trill distinction. Like Warlpiri, Gurindji does not make contrasts in terms of voicing or consonant constriction duration (Ennever, Meakins, & Round, 2017). As the phonological systems of Kriol and English incorporate both VOT and constriction duration as contrastive features, examining the perception and production of stop voicing contrasts may be an excellent diagnostic for the degree of mixing, inclusion and exclusion of phonological categories from the contributing languages in both Gurindji Kriol and Light Warlpiri.

In terms of production, the VOT of Gurindji Kriol stop consonants does not vary systematically with respect to the reflexes of English stop voicing distinctions. However some phones in lexical items of English/Kriol origin do show longer constriction durations (Jones & Meakins, 2013: 208) commensurate with that of those same items in Kriol. Jones and Meakins (2013) also observe that VOT values can be longer in English code-switched forms. They list in this category, for instance, the words *team* (English 'sports team'), *dei* (English 'they'), *tetul* (English 'turtle'), and *tebul* (English 'table'), though it is not clear how (recent) loan words or specific Gurindji Kriol lexical items are clearly differentiated from code-switched forms.

[1] Roper Kriol is a variety of Kriol, spoken in at least one geographical area.

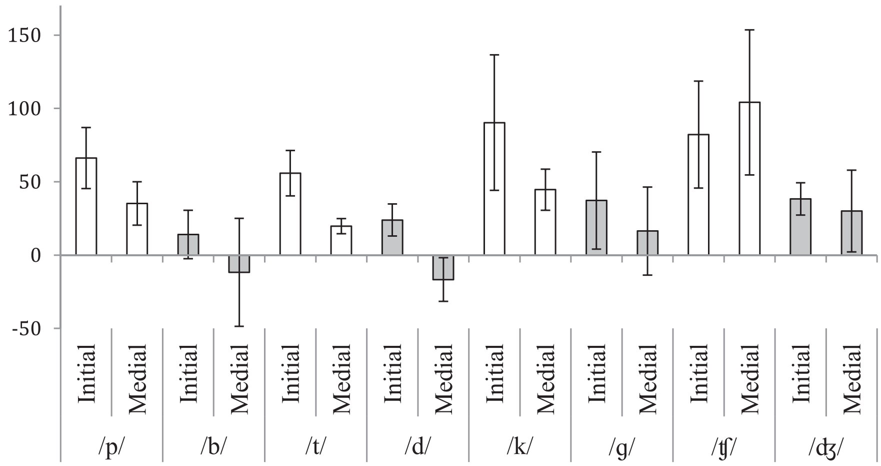


**Fig. 1.** Word-initial and –medial VOT in Roper Kriol (adapted from Baker et al., 2015).

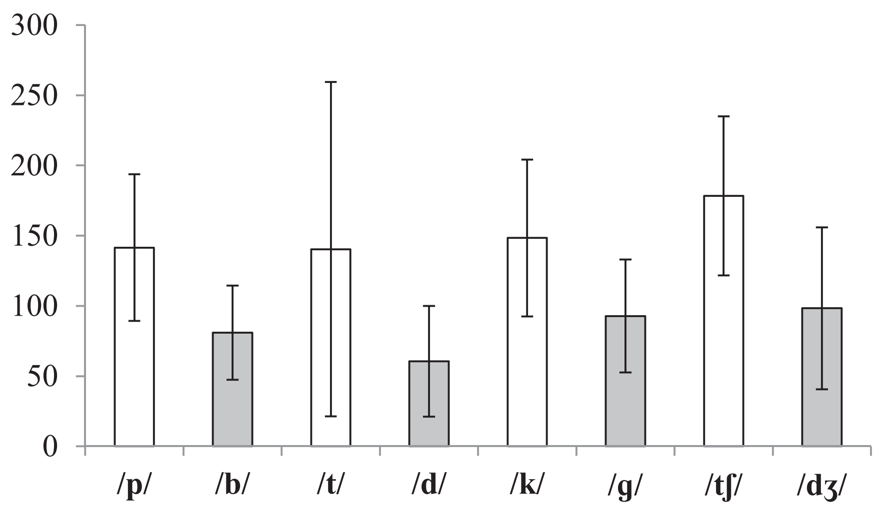


**Fig. 2.** Word-medial Constriction Durations (CD) in Roper Kriol (adapted from Baker et al., 2015).

In terms of stop perception in Gurindji Kriol, a recent study of stop categorisation indicated that child and adult speakers of Gurindji Kriol are able to use onset stop VOT information to match an acoustically presented word to a visual stimulus (images of two nouns, constituting a minimal pair in terms of stop VOT in Roper Kriol) (Stewart et al., 2018). The results however showed more consistent categorisation for bilabial stops /p b/ than for alveolar /t d/ and velar /k g/ stops. Gurindji Kriol speakers also appear to have some ability to correctly categorise fricatives and stops in a task similar to the one described above (Stewart et al., 2020), though again performance is not at ceiling. Here, the authors speculate that this may be due to the fricative-stop contrast being an emerging feature of Gurindji Kriol, and they further suggest that familiarity with English may play a role in improved performance. It is also possible that the particular Kriol lexical items selected for the study influence the result: some of the lexical items included are less familiar to speakers than others ('sail' [on a ship] and 'pork', contrasting with 'tail' [of a kangaroo] and 'fork', respectively). In one case ('foot' vs 'boot'), the chosen word pair differs in also in vowel quality, and is thus not a true minimal pair, potentially affecting the participants willingness to select the voiced stop-initial 'boot', which is in fact an acoustically modified version of 'foot' (Kriol maintains a five vowel system with a duration contrast, and 'foot' has the short vowel /u/ while 'boot' has the long vowel /uː/: Bundgaard-Nielsen & Baker, 2015).

Outside of Australia, particular focus has been on stop consonant voicing distinctions in mixed languages also. Research on Media Lengua, a South American mixed language incorporating Imbabura Quichua systemic elements and Ecuadorian Rural Spanish-derived lexicon, suggests that a Spanish voiced stop series has been adopted in production and perception, though the stops are produced with longer VOT values than their original Spanish counterparts (Stewart, 2018).

On the North American continent, Michif, spoken by a small group of Métis people, primarily in Manitoba and Saskatchewan in Canada and in North Dakota in the United States (Mazzoli, 2019), has been claimed to maintain the phonological grammar of both of its source languages, French and Plains Cree (Bakker & Papen, 1997). However, a small recent study of VOT in stops of French and Cree origin in Michif does not indicate that a (French-like) VOT-based stop contrast is maintained (Rosen et al., 2019), as only small and unsystematic differences in stop realisation were identified in a sample of recorded narratives. It is possible, however, that the amount and type of stop distribution in the dataset obscure systematic differences: of the 446 stop tokens included, 204 were tokens of Plains Cree /k/, resulting in an unbalanced set, with very few data points in some categories (some cells were empty). It is also possible that individual speaker differences, in for instance speaking rate and/or stop realisation, obscure systematic patterns: a total of ten speakers provided material, but it is not clear how the contributions from each speaker distributed over the nine stop categories (French /p b t d k g/; Plains Cree /p t k/).

Mednij Aleut, spoken on Mednij or Copper Island in the Bering Sea, combines Aleut and Russian in an unusual way, in that Aleut verb stems combine with Russian verbal morphology (Golovko & Vakhtin, 1990). Lexical elements are from both languages. The phonology is described as a combination of the inventories of both source languages, including a voicing distinction in stops and fricatives from Russian (Golovko & Vakhtin, 1990; Sekerina, 1994; van Gijn: 100, 2009), but no acoustic analysis has been undertaken.

Taken together, the studies indicate that the parent languages of mixed languages may contribute differentially to the phonological inventory of their shared 'child', although the extent to which small samples and/or experimental design issues contribute to this impression is not clear. Very few studies have examined both speech production and perception in a single mixed language, with a particular focus on the areas in which the parent languages diverge (in the case of Light Warlpiri, differences in the use of VOT/stop constriction duration and the number of places of articulation).

## 2. Stop and affricate production in Light Warlpiri

The following section presents an acoustic study of stop and affricate production in Light Warlpiri words with Kriol/English and Warlpiri origins. The outline of the phonological inventories of the parent languages (English, Kriol, Warlpiri) provide us a number of possible competing hypotheses:

1. Light Warlpiri relies on Warlpiri phonology, resulting in no VOT or Constriction Duration-based stop or affricate contrasts.
2. Light Warlpiri relies on English phonology, resulting in a full range of VOT-based stop, affricate and fricative contrasts (though the latter are not systematically examined here).
3. Light Warlpiri relies on Kriol phonology, resulting in stop and affricate contrasts maintained by VOT and Constriction Duration differences. The realisation of the velar stop contrast (/k g/) may be variable.
4. Light Warlpiri combines elements of Warlpiri and English/Kriol phonology to enhance the number of contrasts maintained and increase lexical differentiation, resulting in a system that preserves Warlpiri's five places of articulation, but includes VOT and/or Constriction Duration contrasts in stops and affricates, and perhaps also in fricatives (though they are not systematically examined here).

### 2.1. Participants

Ten female speakers of Light Warlpiri participated in the production study, including five women who also participated in the perception study reported in Section 3. Four speakers were in their 30s, three in their 20s, and three between 17 and 19 at the time of recording. All of the speakers reported being first generation Light Warlpiri speakers except the youngest participant whose parents also speak Light Warlpiri. All participants were speakers of Light Warlpiri as a first language (L1). In addition to speaking Light Warlpiri, all of the women reported speaking Warlpiri, which continues to be spoken in the community and in other (Warlpiri) communities in the area. The women also reported speaking Australian English which they have acquired as a second language predominantly in a school setting. They have exposure to Kriol through interactions with people in other communities when travelling, and with visitors to Lajamanu, and there are sometimes Kriol features in some speakers' English.

### 2.2. Materials

The participants participated in a picture elicitation task, in which they were asked to produce target words embedded in one of two Light Warlpiri carrier sentences:

1) nyampu ___ am luking it: 'this ___ I'm looking at it'; or
2) nyampu ___ al pudum kuja: 'this ___ I'll put it thus'.

The picture elicitation format resulted in some variation in the targets produced (see Appendix 3), as different participants selected different words to describe the images presented. All recordings took place at the Batchelor Institute for Indigenous Tertiary Education Learning Centre, or in a quiet home, in the community of Lajamanu, in the presence of the second author and other speakers of Light Warlpiri. Recording materials in small groups is common in Australian field-linguistics as it increases the level of comfort of the participants to have the support of fellow community members.

All recordings had a 16-bit sampling depth with a sampling rate of 44.1 KHz. The target words produced were one to four syllables long ('Casuarina', a well-known shopping centre in Darwin, being the only four-syllable word). The words produced included words of Warlpiri origin as well as words of Kriol/English origin. Words of Warlpiri origin typically had 2–3 syllables, while words of English/Kriol origin typically had 1–2 syllables. As indicated in the introduction, it is not always possible to determine whether a word has been sourced directly from English or from Kriol, due to varying degrees of overlap in the phonological specifications of the words in the two languages. A consistent cue, relevant here, however, is the use of fricatives (indicating a likely English source) and long stop constriction durations, which are not found in Australian English, but in Kriol only and thus indicative of a Kriol source. We also note that it is possible that speakers will use an English-sourced word in some contexts and a Kriol sourced word in other contexts, for sociolinguistic reasons, though we did not investigate this systematically. In our data (see Appendix 3), for instance, some participants produced the likely English-sourced *pussycat*, *cave,* and *graveyard*, while others produced the likely Kriol-sourced *pujikat*, *keib* (English 'cave') and *greibyard* (English 'graveyard').

The target words elicited all Warlpiri stops in word-initial and word-medial position: /p t ʈ ɽ c k/. Note that the /t ʈ/ distinction is neutralised word-initially, where it is conventionally transcribed as <t>, despite impressionistic descriptions as [ʈ] (Bundgaard-Nielsen & O'Shannessy, 2019; Nash, 1980, 1986; Pentland & Laughren, 2004). The target words also elicited stops corresponding to /p b t d k g/ and affricates /ʧ ʤ/ in words of English/Kriol origin. Finally, the targets included words which are realised in English with fricatives /θ ä/, and impressionistically realised with corresponding voiced stops in Kriol (Baker et al., 2015). We label these as /T D/ to distinguish them from /t ʈ d/.

All consonant targets were hand-segmented in *praat* (Boersma & Weenink, 2018). VOT was defined (after, e.g., Klatt, 1975; Lisker & Abramson, 1964, 1967) as the time of voicing onset minus the time of stop and affricate release. Time of stop and affricate release was usually associated with a burst of frication noise following the closure interval. The time of voicing onset was indicated by periodicity in the waveform and the presence of either a voicing bar immediately preceding the release or higher formants associated with a segment immediately following the release. Therefore, if the voicing onset precedes or leads the stop or affricate release, the VOT is negative (measured in milliseconds), whereas if voicing onset lags behind the release, the VOT is positive. Constriction duration was defined as the duration of the obstruent closure interval where stop, affricate and fricative segmental boundaries were determined by examining perturbations in F0 and in the waveform and spectrogram, and the presence of acoustic cues such as higher formants that were clearly associated with neighbouring segments. For a small number of alveolars, tap realisations made the separation of stop constriction and release phases impossible and a single duration measure obtained (voiced throughout).

We first present the VOT of word-initial stops and affricates (see Section 2.2.1), and secondly, the VOT and CD of word-medial stops and affricates (see Section 2.2.2). In all analyses, we preserve the source language phonological specifications: Words of English/Kriol origin with voiceless/long stops are categorised as 'voiceless/long' stops in Light Warlpiri, while words of English/Kriol origin with historically 'voiced/short' stops are categories as 'voiced/short' stops. Consistent with analyses of stop VOT in Warlpiri (Bundgaard-Nielsen & O'Shannessy, 2019), stops in Warlpiri words in Light Warlpiri are phonetically voiceless. We would like to highlight that the decision to preserve the phonological specifications of the source language (s) is not a trivial matter. Mixed languages and creoles alike often exhibit evidence of rephonologisation of some lexical items (see for instance discussion of English source words in Roper Kriol in Baker et al., 2015), and it is therefore possible that the phonological specifications of all recorded target materials are not preserved, as demonstrated for Roper Kriol in Table 2 (adapted from Baker et al., 2015).

Lexical specifications—the phonemic shape of words—are particularly difficult to determine with certainty in languages without an orthography. In studies like the present, there are thus (at least) three approaches to consider: The best approach would be to rely on linguistically trained native speakers' phonemic transcriptions of the target words. This is not an option available for the present study. The second-best option would be to remain conservative and respect the source language specifications. The third option involves re-organising the materials on the basis of non-native (researcher) perceptions, but we believe that this approach could potentially systematically influence the results by imposing non-native categorical perceptions on the recorded materials (hearing boundaries where none exist, or not hearing boundaries that do exist because they are not aligned with the phonemic boundaries of the L1 of the transcriber). So, in the present study, we chose the conservative approach of maintaining the source language phonological specifications.

**Table 2**
Examples of correspondences between Kriol and English showing both agreement and conflict between the corresponding segments. Adapted from Baker et al. (2015).

| | | | | |
|---|---|---|---|---|
| **Segmental agreement between Kriol and the English source word** | | | | |
| a. | *Tisim* | /**t**isim/ | < tease | /**t**iːz/ |
| b. | *Krasim* | /**k**ɹasim/ | < cross | /**k**ɹɒs/ |
| c. | *frog* | /**f**ɹog/ | < frog | /**f**ɹɒg/ |
| d. | *tjetj* | /**tʃ**e**tʃ**/ | < church | /**tʃ**ɜ**tʃ**/ |
| **Segmental conflict between Kriol and the English source word** | | | | |
| e. | ***d**alim* | /**d**alim/ | < **t**ell | /**t**el/ |
| f. | ***g**abirimap* | /**g**abiɹimap/ | < **c**over them/him up | /**k**ɐvəɹəmɐp/ |
| g. | ***b**oldan* | /**b**oldan/ | < fall down | /**f**ɒldan/ |
| h. | ***tj**abi**tj*** | /**tʃ**abi**tʃ**/ | < [church] service | /**s**ɜvɪ**s**/ |

## 2.3. Results

### 2.3.1. Word-initial VOT

The target words yielded a total of 1133 word-initial VOT measurements (See Fig. 3). It is not possible to extract reliable word-initial constriction duration information, and we do not consider initial constriction duration in the following analysis, as discussed above. A small number of words were excluded from analysis due to environmental noise: doors slamming, chairs scraping across the floor, and dogs barking, were typical cases. We also excluded initial flaps from the analyses presented here due to very large differences in realisation of this phone in Warlpiri, as any of the following [ɻ], [ɻɽ], [ɽɻɽ], [lɽ], and [ɽlɽ] typically with rhotic elements 100+ ms (Bundgaard-Nielsen & O'Shannessy, 2019; see also Ingram & Laughren, 1999), and impressionistically also in Light Warlpiri, demanding a closer analysis than space allows here.

English/Kriol source words contributed 86.5% of the targets in the data set, while Warlpiri contributed the remaining 13.5%. The ten participants contributed unevenly to the dataset (see Table 3[2]). The distribution of the phonemes was also unbalanced (see Fig. 3), and no target words of Warlpiri origin elicited word-initial /t/. English voiced and voiceless fricatives (/T D/) were produced as stops in Light Warlpiri. We conducted a series of separate Linear Mixed Effects Models (LME) (Bates, Maechler, Bolker, & Walker, 2015) models by POA, with speaker included as a random effect (see Appendix 4). The results show that there is a significant effect of 'stop' (English/Kriol voiced; English/Kriol voiceless; Warlpiri: $p < .001$) for the bilabial POA, with post hoc comparisons showing that English/Kriol /b/ and /p/ differed significantly (*df* 347; $p < .001$). For the two English/Kriol alveolar stops /t/ and /d/, the LME indicated a significant difference ($p < .001$), while there was no significant difference for /

[2] Following the suggestion of an anonymous reviewer, we also ran all statistical analyses on only the data from participants who contributed more than 1% to the dataset in *both* initial and medial position, effectively excluding A80. These results do not differ in any substantial way from those reported for the entire cohort. The results for comparisons of groups are the same, and the degrees of difference are the same.

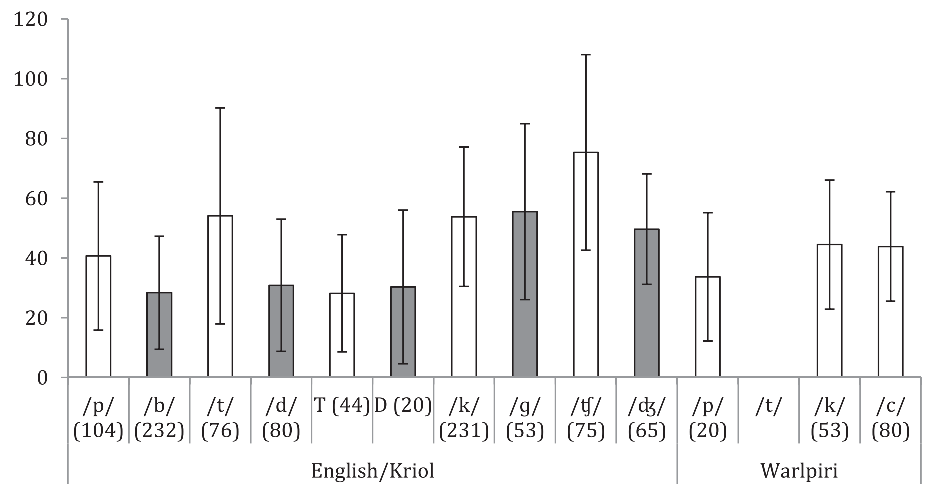


**Fig. 3.** Mean word-initial VOT in ms by source language (English/Kriol v. Warlpiri). Numbers in parentheses indicate number of tokens. Error bars reflect SD. Dark grey indicates a source language voiced stop/affricate.

**Table 3**
Word-initial individual speaker contributions to the dataset. Freq. = number of tokens contributed; % = percentage contribution.

| Speaker | Freq. | % | Speaker | Freq. | % |
|---|---|---|---|---|---|
| A21 | 138 | 12.2 | AC10 | 43 | 3.8 |
| A31 | 36 | 3.2 | AC23 | 240 | 21.2 |
| A80 | 6 | 0.5 | AC43 | 190 | 16.8 |
| A82 | 167 | 14.7 | AC58 | 143 | 12.6 |
| AC09 | 143 | 12.6 | AC66 | 27 | 2.4 |

T D/. There was also a significant effect of ‘stop’ at the Velar POA (*df* 332; $p = .025$), with post hoc comparisons showing that English/Kriol /k/ was longer than Warlpiri /k/. As the initial affricate/laminopalatal VOT dataset was not normally distributed, we subjected the data to a log10 (duration +1) transformation. The LME model revealed a significant effect of ‘stop’, with post hoc comparisons indicating that English/Kriol /ʧ/ differed from English/Kriol /ʤ/ and Warlpiri /c/ (*df* 215; $p < .001$, in both cases), while English/Kriol /ʤ/ differed from Warlpiri /c/ (*df* 214; $p = .0069$).

### *2.3.2. English/Kriol /k g/ differentiation*

The results above indicate that Light Warlpiri speakers do not implement a VOT-based contrast at the velar POA. However, three competing alternative explanatory hypotheses are also possible:

(1) Light Warlpiri has a VOT-based velar stop contrast but does not conform to the lexical specifications of the source languages (in all, or some words);
(2) Some Light Warlpiri speakers have a velar VOT-based stop contrast, while others do not, as a result of on-going language shift in the community;
(3) Some Light Warlpiri speakers have a velar VOT-based stop contrast, while others do not, due to differences in exposure to English.

To address hypothesis (1), a total of 252 VOT measurements were extracted from a total of 14 English/Kriol words, beginning in either /k/ or /g/ in the source language, for which at least 10 individual VOT measurements were available (see Fig. 4). The overall mean VOT by word was 53 ms, and as is clear from Fig. 4 the VOTs of the target words do not give indications of a bimodal distribution: There is no obvious evidence that words with source /g/ cluster in the lower VOT range while words with source /k/ cluster in the higher VOT ranges observed (though impressionistically, Warlpiri words are more likely to occupy the lower VOT ranges in Fig. 4). This does not suggest that the absence of a clear VOT contrast at the velar POA is an artefact of changes to the lexical specifications of the words in question.

To address hypothesis (2) and (3), we calculated individual speaker VOT means for those speakers who produced 6+ tokens in two velar ‘categories’: English/Kriol /k g/ or English/Kriol /k/ and Warlpiri /k/ (see Fig. 5). This allows intra-speaker assessment of VOT realisation and removes confounding factors such as differences in speaking rate and number of tokens. The results of unpaired t-tests of individual VOT means indicate that for the four speakers who satisfied the criteria above, both participant AC23 and AC09 appear to maintain a VOT-based velar distinction (AC23: $p < .001$; AC09: $p < .004$), though small numbers of tokens of course make this conclusion very tentative. The results may also indicate that the English/Kriol /k/ versus Warlpiri /k/ VOT means of participant AC43 do not differ (*p ns*), while A21 produces shorter Warlpiri /k/ than English/Kriol /k/ ($p = .027$).

The present study does not fully allow us to determine whether the individual variation observed for instance in the production of velars /k g/ is due to ongoing language shift (2) or to differences in exposure to English (3). Indeed, we cannot exclude that language change is affecting speakers’ behaviour, and we discuss reasons for language change (establishment of a VOT contrast at the velar POA as well as the likelihood of this in the discussion in Section 2.3 below). Similarly, we cannot exclude that the participants differ to some extent in their exposure to English, and the magnitude of any difference in exposure is difficult to quantify. The participants have, however, all grown up in Lajamanu, and while it is possible that they have differed in their school attendance and therefore in the degree to which they have accessed mainstream—English language—education, we are not in a posi-

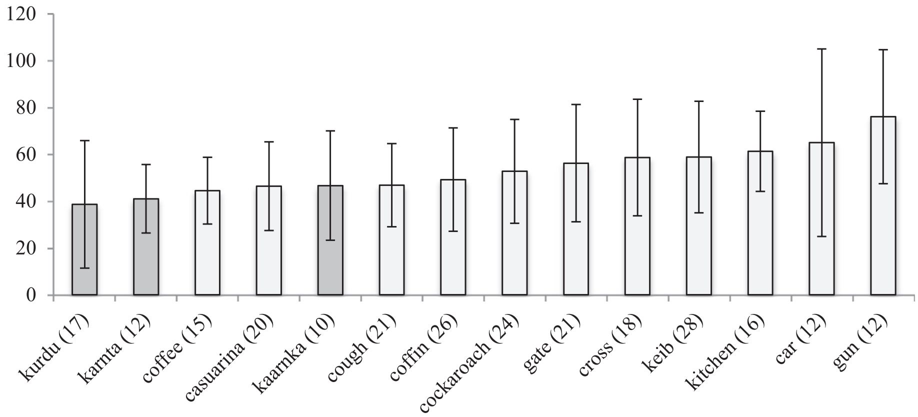


**Fig. 4.** Mean VOT of words with either /g/ or /k/. Number in parenthesis indicates the number of tokens per word. Error bars indicate SD. Darker grey indicates word of Warlpiri origin, while lighter grey indicates words of English/Kriol origins.

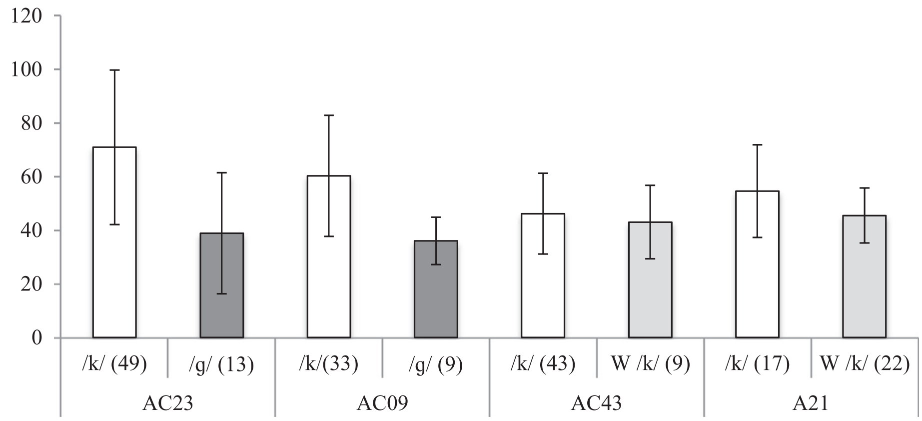


**Fig. 5.** Velar VOTs by speakers who produced 6+ tokens in two categories, organised by VOT. 'W' indicates Warlpiri source word. Numbers in parenthesis indicate number of tokens. Error bars indicate SD. Dark grey indicates a source language voiced stop/affricate.

tion to assess this. All participants were speakers of L2 English, as discussed in Section 2.1.

*2.3.3. Word-medial VOT and constriction duration*

The recordings yielded a total of 787 measurements from 416 individual tokens: 371 VOT and 371 CD measurements, as well as duration measurements of 45 (voiced) tap realisations of stops (English/Kriol: eight /t/s (M 21 ms; SD 7 ms); one /d/ = (33 ms); ten /T/s (*M* 16 ms; *SD* 6 ms); and 26 Warlpiri /ʈ/s (*M* 27 ms; *SD* 8 ms), again not discussed further here. All tokens were extracted from a /VCV/ context, within a single morpheme (no stops at a morpheme boundary). As was the case for the word-initial stops, the targets yielded an unbalanced contribution of tokens by the speakers (see Table 4), as well as an unbalanced distribution of stops and affricates (see Figs. 6 and 7), and words of English/Kriol origin were overrepresented (64% of the dataset).

*2.3.4. VOT in word-medial stops and affricates*

The medial VOT results are presented in Fig. 6. We again conducted a series of Linear Mixed Effects Models (Bates et al., 2015) of medial VOT by POA, with speaker included as a random effect (see Appendix 5). The medial bilabial, alveolar, velar and affricate/laminopalatal stop VOT measurements were not normally distributed, and all medial VOT data was

**Table 4**
Word-medial individual speaker contributions to the dataset. Freq. = number of tokens contributed; % = percentage contribution.

| Speaker | Freq. | % | Speaker | Freq. | % |
|---|---|---|---|---|---|
| A21 | 115 | 14.6 | AC23 | 159 | 20.2 |
| A80 | 16 | 2 | AC31 | 10 | 1.3 |
| A82 | 111 | 14.1 | AC43 | 129 | 16.4 |
| AC09 | 94 | 11.9 | AC58 | 95 | 12.1 |
| AC10 | 39 | 5 | AC66 | 19 | 2.4 |

consequently log transformed log10(duration +1). There was no effect of 'stop' at the bilabial, alveolar, or velar POAs, while there was a significant effect of 'stop' ($p < .001$) for the English/Kriol affricates and Warlpiri laminopalatal stop. Post hoc comparisons revealed that English/Kriol /ʧ/ differed from English/Kriol /ʤ/ (*df* 9.67; $p = .0017$), as well as from Warlpiri /c/ (*df* 57.77; $p < .001$).

*2.3.5. CD in word-medial stops and affricates*

The medial CD results are presented in Fig. 7. Finally, we conducted a series of LME models of medial Constriction Duration (CD), again with speaker included as a random effect (see Appendix 6). The medial CD measurements at the bilabial and alveolar as well as the affricate/laminopalatal stops were not normally distributed and subjected to a log10 (duration +1). The results of the LME indicated that there was a

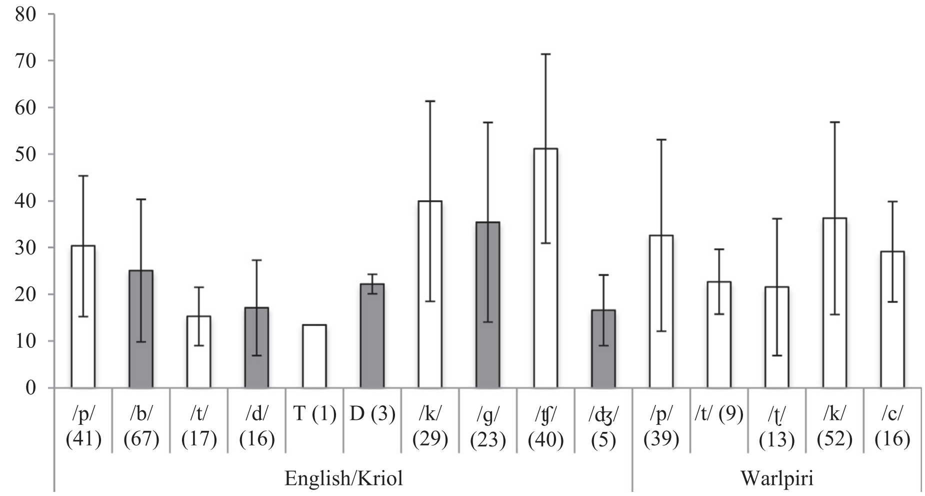


**Fig. 6.** Mean word-medial VOT. Numbers in parentheses indicate number of observations. Error bars indicate SD. Dark grey indicates a source language voiced stop/affricate.

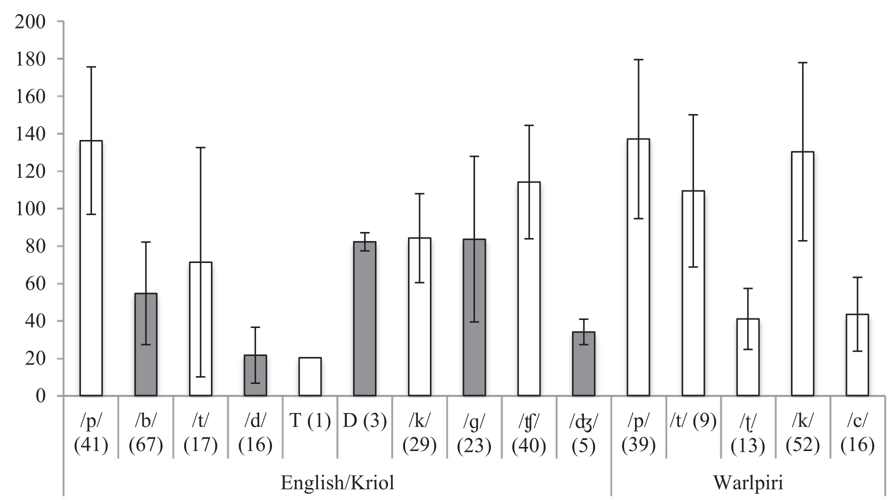


**Fig. 7.** Mean word-medial CD. Numbers in parentheses indicate number of observations. Error bars indicate SD. Dark grey indicates a source language voiced stop/affricate.

significant effect of 'stop' ($p < .001$), and post hoc comparisons showed that English/Kriol /b/ differed from English/Kriol /p/ (*df* 144; $p < .001$) as well as from Warlpiri /p/ (*df* 132; $p < .001$). There was also a significant effect of 'stop' ($p < .001$) at the alveolar POA, with post hoc comparisons showing that English/Kriol /d/ differed from English/Kriol /t/ (*df* 38.4; $p = .045$), and from Warlpiri /t/ (df 36.3; $p < .001$). English/Kriol /t/ also differed from Warlpiri /t/ (*df* 38.6; $p = .0041$). Finally, there was a significant effect of 'stop' ($p < .001$) at the velar POA, and post hoc comparisons showed that Warlpiri /k/ differed from both English/Kriol /k/ (*df* 96.5; $p < .001$) and /g/ (*df* 98.2; $p < .001$). In the case of the English/Kriol affricates /ʧ ʤ/ and the Warlpiri lamino-palatal stop /c/, there was a significant effect of 'stop' ($p < .001$), and a final set of post hoc comparisons indicated that English/Kriol /ʧ/ differed from English/Kriol /ʤ/ (*df* 5.66; $p = .02$) as well as from Warlpiri /c/ (*df* 55.42; $p < .001$).

### 2.4. Discussion: acoustic study

The present study presents an acoustic analysis of the stop and affricate inventory of the Australian mixed language Light Warlpiri, which incorporates elements from the Australian language Warlpiri, and from English/Kriol. Phonologically such a combination poses specific challenges, in particular because the phonemic inventories of the source languages are vastly different. Indeed, adopting a strategy of using one phonological inventory or the other solely will potentially lead to a great deal of lexical confusion. The acoustic study reported here thus suggests that speakers of Light Warlpiri manage this task effectively by having amalgamated the inventories of Warlpiri and English/Kriol in such a way that they (nearly) maintain the largest possible set of contrasting phones: they maintain the five places of articulation in Warlpiri, and incorporate voicing distinctions from English and/or Kriol, and CD contrasts likely from Kriol, to form a comprehensive inventory: /p b t d ʈ ɽ <k> ʧ/, as well as /ʤ/ and/or /c/, and potentially a dental stop (T/D). We incorporate these results, as well as those from the medial context, and the perception study reported below, in a tentative Light Warlpiri consonant inventory, presented in the Conclusion.

It is not clear from the present data how speakers amalgamate the two phonological systems in *word-initial* position, partly due to the absence in our data of instances of Warlpiri

/t/, and partly also due to the variability in the realisation and application of a VOT-based contrast at the velar POA. Three scenarios, however, seem possible to us: One is that speakers have a *voiced* stop series consisting of English/Kriol voiced stops which contrasts with a series of phonetically and phonologically *voiceless* stops into which Warlpiri stops and English/Kriol voiceless stops are fitted. Alternatively, speakers may have incorporated the phonetically voiceless Warlpiri stops and the largely phonetically voiceless—but phonologically voiced—English/Kriol series of stops, and contrast these with English/Kriol phonetically and phonologically voiceless stops. A third possible scenario is that the intermediate VOT values of Warlpiri stops relative to English/Kriol voiced and voiceless stops make systematic amalgamation difficult. It this case, we would expect a high degree of intra- and inter-person variability perhaps in the lexical specification for Warlpiri-sourced words.

*Word-medially*, the pattern is clearer, however. Here, speakers appear to have incorporated a series of short CD stops for English/Kriol words, while enhancing the acoustic saliency of Warlpiri stops and English/Kriol voiceless stops (as opposed to voiced stops) with an extended CD, much like in Kriol. Some evidence suggests that an additional medial VOT distinction is emerging, at least for the affricates, also commensurate with observations made for Kriol, but we note again that the interpretation of the realisation of stops at the velar POA is not straightforward.

The fact that velar stops appear to behave differently to stops at other POAs in terms of VOT deserves comment. Firstly, we highlight that it is well-established that articulatory factors make the realisation of voiced /g/ potentially difficult and may result in contrast loss, or in incomplete or variable acquisition or incorporation of a velar VOT-based contrast (Maddieson, 2013). This is perhaps particularly relevant in the case of Light Warlpiri, where the substrate language Warlpiri is one of the 17% of languages included in the World Atlas of Language Structures Online (Maddieson, 2013) that do not have a VOT-based contrast in stops at all. Secondly, it is not uncommon for languages to have incomplete series of VOT-based stop contrasts. Indeed, out of 567 languages in the WALS Online (Maddieson, 2013), 34 (6%) do not have /g/, while 455 (45%) of languages have /p b t d k g/. The languages that do not make a VOT based distinction at the velar POA are widely distributed and belong to different language families, which is what we would expect, if articulatory constraints are the predominant reason for this gap. With these observations in mind, it is possible that the phonological inventory of Light Warlpiri may not develop this contrast systematically, though we believe it to be possible that the existence of a Constriction Duration-based contrast at the velar POA in medial position may provide a voicing-based contrast with a 'way in' for the development of a system that implements a voicing distinction also at the velar POA.

## 3. Stop and fricative perception by Light Warlpiri speakers

### 3.1. Participants

13 women from Lajamanu Community participated in the study. This group includes five of the women also who participated in the production study reported below (Section 2). The women were aged between 16 and 33 years at the time of testing. All participants were recruited by word of mouth, and tested by the second author in a quiet location in Lajamanu. Prior to participation in the study, we conducted detailed language background interviews with a focus on language exposure and use in infancy and childhood, as well as current language use patterns, to ensure a homogeneous participant population. The speakers' language backgrounds are the same as presented for the production study in Section 2 above.

### 3.2. Materials and method

The study reported here made use of a series of XAB discrimination tasks previously used to test stop voicing and stop-fricative discrimination by speakers of Kriol and the traditional Indigenous Australian language Wubuy, as well as by a control group of Australian English speakers, the latter of whom performed at ceiling level (for details, see Bundgaard-Nielsen & Baker, 2019). The stimulus materials were recorded from three female speakers of Australian English in a recording studio at Melbourne University. We used Australian English stimuli because it is well-established that English maintains VOT based stop contrasts, and this contrast is presumably the source of reported VOT contrasts also in Kriol. The use of English stops also allows testing of the effect of differences in constriction duration information as it is easy to extend silent periods to the duration necessary, even if constriction duration is not contrastive in English. All speakers were from the Greater Melbourne area in Victoria, Australia, and all had L1 English-speaking parents. None reported having fluency in any language other than English, though all had studied other languages in a foreign language program in a high school or university setting. All had substantial phonetics training. During the recording session, the women were instructed to speak in a clear, comfortable voice as though they were speaking to a friend. All dysfluent and mispronounced tokens were rerecorded. All recordings had a 16-bit sampling depth with a sampling rate of 44.1 KHz.

The three speakers produced English /p b/ and /k g/ in medial (/aCa/) and initial (/Ca/) position. Speakers also produced initial /s ʃ/, /b v/ and /s z/ (/Ca/), which allows us to tease apart the likely relative contributions from Warlpiri, Kriol, and English to Light Warlpiri, as these source languages differ in the phonemic status of /s ʃ v z/. Three tokens per target consonant per speaker (9 unique tokens per phoneme) were selected as stimuli for the perception studies on the basis of the greatest possible similarity in terms of speaking rate, vowel duration, F0, and intonation pattern. Each excised token was enveloped with a 20 ms ramp-in and a 10 ms ramp-out.

In order to test discrimination of a Kriol-like /p b/ and /k g/ distinction (maintained by both VOT as in English and by constriction duration), we artificially generated Kriol-like (voiceless) medial /p/ and /k/. We did so by increasing the duration of the silent constriction phase of the English /p/ and /k/ tokens, which we refer to as /p+/ and /k+/ in what follows. The average constriction duration difference between Kriol /p/ and /b/ is approximately 60 ms (/p/ = 141 ms vs /b/ 81 ms; see Fig. 2), in clear lab-like speech, commensurate with the type of stimulus materials used in the present study, while the average /p b/ stop constriction (CD) difference in the English targets recorded for this study is less than 10 ms (/p/ = 66 ms vs /b/ 58 ms; see Fig. 8). Consequently, 50 ms of silence was generated, mid closure, for each intervocalic English /p/ and /k/ in order to create plausible Kriol-like /p+/ and /k+/ tokens, which maintain their natural variation in VOT.

The stimulus materials described above were used to generate a total of ten discrimination tasks (see Table 5): one training task (/p k/, native to Kriol/English as well as Warlpiri), and nine test contrasts. Six contrasts tested discrimination of bilabial and velar stops, differing in terms of VOT in initial and medial position, as well as the discrimination of bilabial and velar stops with Kriol-like phonetic realisation. The final three contrasts tested stop-fricative discrimination (/b v/), fricative voicing discrimination (/s z/) and fricative POA discrimination (/s ʃ/).

During the XAB discrimination tasks, participants listened to 12 presentations of six unique triads per contrast, equaling 72 triads/contrast per listener. The XAB task was explained to the participants as one in which a ‘teacher’ (X, the first voice) was being imitated by both a ‘good student’ and a ‘bad student’ (voices two or three). Each triad consisted of a token from each of the three speakers to ensure phonological processing and avoid any effect of voice familiarity or identity, and all speakers provided a third of each of the X, A, and B tokens. In half the triads, the X provided a phonological match to A, and in the other half, to B. The order of presentation of each triad was randomly generated for each participant. The participants then had to indicate (with a key press on the keyboard) which was the ‘good student’ who copied the teacher correctly. This type of contextualization is not generally provided in speech research of this type, but has previously proved very helpful to participants from an Indigenous Australian background, and with limited computer literacy (see Bundgaard-Nielsen et al., 2015; Bundgaard-Nielsen & Baker, 2019). As is clear from Table 5, not every contrast was presented in both initial and medial position: this decision was made to ensure that the participants would be able to complete the set of tasks within a reasonable time-frame. We included initial and medial contexts only for those contrasts where the medial constriction duration was a factor of interest.

**Table 5**
Discrimination tasks by type (training; stop; stop-fricative; and fricative-fricative) and position (initial; medial).

| Contrasts tested | Word Initial | Word Medial |
|---|---|---|
| Training task | /p k/ | |
| Stop contrasts | /p b/ | /p b/ |
| | | /p + b/ |
| | /k g/ | /k g/ |
| | | /k+ g/ |
| Stop-fricative | /b v/ | |
| Fricative-fricative | /s z/ | |
| | /s ʃ/ | |

The discrimination tasks were programmed in Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993), with the stimuli presented over headphones from a MacBook computer. The inter-stimulus interval (ISI) was 500 ms, while the response window was presented for three seconds. The inter-trial interval was one second. All missed trials were replayed, at a random time, during the remainder of the test. The duration of the experiment ranged from approximately 30 minutes to an hour.

Despite widely accepted best-practice recommendations of counterbalancing the order in which participants in perception studies complete the relevant tasks, all participants completed the discrimination tasks in the following set order: training task /p k/, followed by medial /p b/, /p+ b/, /s ʃ/, /b v/, /s z/, medial /k g/, /k+ g/, initial /k g/, and finally initially /p b/. As discussed also in Bundgaard-Nielsen and Baker (2019), this decision reflects high rates of participant loss in research conducted with similar non-WEIRD (Western Educated Industrialised Rich Democratic) Indigenous Australian populations. Participant loss is greater when ‘difficult’ contrasts are presented before participants are confident with the testing procedure, or when multiple contrasts are presented in random order, rather than blocked, as they are here. The particular order of presentation in the present study was intended to present participants with what we expected to be ‘easy’ contrasts first, and then more challenging ones (/s z/ in particular, on the basis of our understanding of the phonological inventories of the source languages) only once a certain task confidence had been established. Participants were informed that they could stop

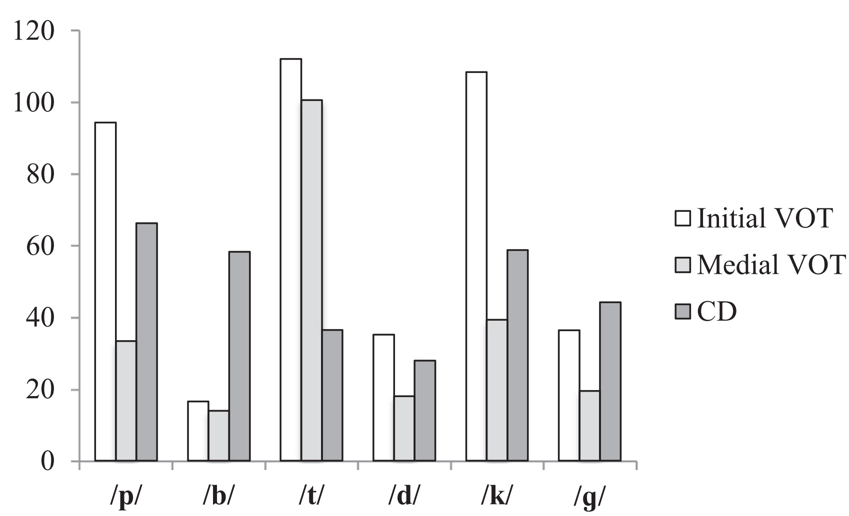


**Fig. 8.** VOT and Constriction Duration (CD) measures in milliseconds by position in word in the stimuli used in the perception study.

at any moment, and that they could take as many breaks as they wanted.

In order to ensure that all participants included in the statistical analysis understood the task, we required an individual average discrimination accuracy in the native POA /p k/ contrast above 60% (chance performance is 50% accuracy on the task). This criterion did not result in exclusion of any participants: the individual participant means for the set of discrimination tasks ranged from 74% to 99%, with a group *M* of 88%. This level of accuracy indicates that all participants understood the task as it was presented to them, and importantly that their responses are meaningful and that differences in accuracy across the set of contrasts tested pertain to the variables of interest.

### 3.3. Analysis and results

The mean discrimination accuracy of the perception study is presented in Fig. 9. In order to determine whether the participants are able to successfully discriminate stop consonant contrasts at the bilabial and velar place of articulation, differing in terms of only VOT and in terms of VOT and Constriction Duration, we conducted an analysis using a Generalised Linear Mixed-effects Model (binomial) (GLMM) (Bates et al., 2015) on the discrimination accuracy of medial /p k/, /p b/, /p + b/, /s ʃ/, /b v/, /s z/, medial /k g/, /k+ g/, initial /k g/, and finally initially /p b/.

#### 3.3.1. Stop discrimination

A Generalised Linear Mixed-effects Model (binomial) (GLMM) (Bates et al., 2015) was run, with ‘choice’ of phone as the dependent variable, ‘position’ in the word (initial, medial) and ‘contrast’ (/k g/, /k+ g/, /p b/, /p+ b/) as fixed effects, and ‘participant’ and ‘trial’ as random effects (see Appendix 7). A comparison of models with and without each random effect showed that ‘participant’ significantly contributed to the model (*df* 1, $p < .001$) but ‘trial’ did not (*df* 1, $p = .68$), so ‘trial’ was omitted as a random effect (models are given in the Appendix). In the final model, the only random effect is ‘participant’. The model designates the levels of ‘contrast: /k g/’ and ‘position: initial’ as reference levels, included in the intercept values, and all other levels are compared to them. Estimate coefficient values given in the model are log odds ratios, and these are back-transformed and reported here as odds ratios. For the variable ‘position’, contrasts in medial position are more likely to be identified ($\beta = 0.566$, $p = .005$) than in initial position. Compared to ‘contrast: /k g/’, all other contrasts are more likely to be discriminated (k+ g/: $\beta = 0.73$, $p < .001$; /p b/: $\beta = 0.6$, $p < .001$; /p k/: $\beta = 0.845$, $p < .001$, /p+ b/, $\beta = 0.644$, $p < .001$), consistent with the results also from the production study. An interaction of ‘position: medial’ and ‘contrast: /p b/’ contributes significantly to the model ($\beta = 0.34$, $p = .002$), but is less likely to be identified than ‘contrast: /k g/’, seen in the negative *z*-value (−3.068). Estimated marginal means were calculated using the R package ‘emmeans’ (Lenth, Singmann, Love, Buerkner, & Herve, 2018), and back-transformed to give the response scale. They show the order of likelihood of identification of each contrast. The likelihood of the training contrast /p k/ being identified is the highest (estimated mean 2.067), followed by, in order, /k+ g/ (1.574), /p+ b/ (1.171), /p b/ (0.688), and /k g/ (0.475)—in other words, those contrasts that were exclusively VOT-based (/p b/ and / k g/) were much more difficult to discriminate for the participants than contrasts involving also CD differences.

#### 3.3.2. Fricative discrimination

A similar GLMM (binomial) model was run for the fricatives data, with ‘choice’ of phone as the dependent variable, but with only ‘contrast’ (/b v/, /s ʃ/, and /s z/) as a fixed effect, and ‘participant’ and ‘trial’ as random effects. Model comparison showed that both ‘participant’ (ANOVA *df* 1, $p < 0.001$) and ‘trial’ (*df* 1, $p = .01$) should be included as random effects. In the model the ‘contrast: /b v/’ is included in the intercept, and other contrasts are compared to it. The results, reported here in odds ratios, show that the likelihood of identifying ‘contrast: /b v/’ and ‘contrast: /s ʃ/’ is similar ($\beta = 0.514$, $p = .6$), while identifying ‘contrast: /s z/’ is more difficult ($\beta = 0.243$, $p < .001$). Estimated marginal means were calculated using the R package ‘emmeans’ (Lenth et al., 2018), and back-transformed to give the response scale. They show the order of likelihood of identification of each contrast: the likelihood of the contrasts /s ʃ/ and /b v/ being identified is the highest (estimated means 0.82 and 0.81 respectively, not significantly different), followed by /s z/ (0.58).

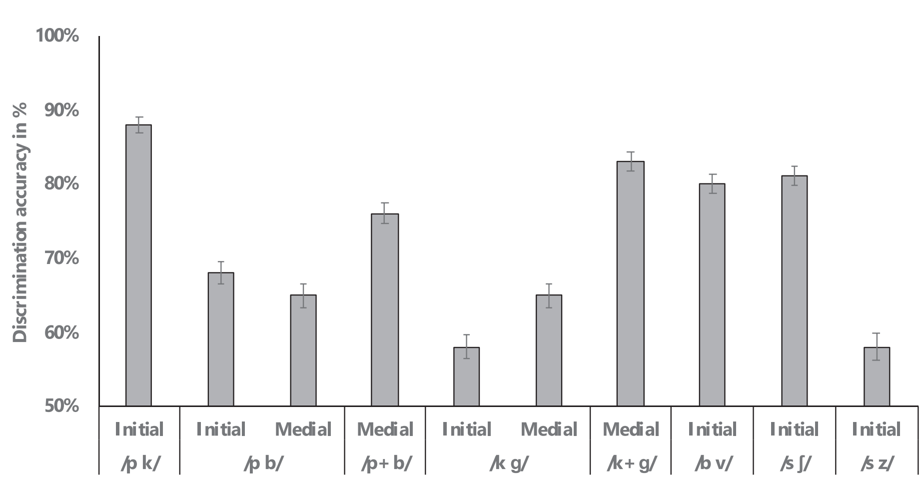


**Fig. 9.** Mean discrimination accuracy for each contrast by position. 50% indicates chance performance. Error bars indicate SE.

### 3.4. Discussion: discrimination study

The discrimination study reported above suggests that speakers of Light Warlpiri are able to use both VOT and constriction duration information to discriminate stop contrasts. They are also able to discriminate stop-fricative contrasts, and fricatives that differ in place of articulation. Speakers of Light Warlpiri, however, struggle to discriminate fricatives /s z/ that differ in voicing, much like what has been reported for speakers of Wubuy, and for speakers of Kriol (Bundgaard-Nielsen & Baker, 2019). If, as reported elsewhere (Hendy, 2019), Light Warlpiri has a voicing distinction for labiodentals (/f/ vs /v/), speakers would of course be expected to discriminate those, but we did not include that contrast here. The results suggest that the phonemic inventory of speakers of Light Warlpiri has expanded to include Constriction Duration-based stop contrasts from Kriol in word-medial position, with some evidence that VOT contrasts are maintained in word-initial position at least at the bilabial and alveolar POA. Speakers of Light Warlpiri are even able to discriminate stop contrasts relying exclusively on VOT to some extent. This expanded inventory likely accommodates vocabulary from Kriol and potentially also English better than a system relying exclusively on Warlpiri phonology. The reliance on CD in word-medial position suggests that the more significant source languages for stop phonology are Warlpiri and Kriol, over English.

## 4. Conclusions

The present paper presents a two-part examination of the phonological inventory of Light Warlpiri, an Australian mixed language incorporating elements of Warlpiri and English/Kriol. We first presented a detailed acoustic analysis of stop and affricate production in Light Warlpiri words of Warlpiri and Kriol/English origins. The results here are consistent with the results of the perception study and strongly suggest that Light Warlpiri speakers make use of a large integrated phonological inventory for words of Kriol/English and Warlpiri origins.

This integrated inventory largely preserves the source language voicing distinctions *word-initially* in Kriol/English words, while it is not completely clear whether Light Warlpiri stops pattern with the voiceless or the voiced English/Kriol words in word-initial position. This is partly due to a gap in the dataset (we did not successfully elicit word-initial Warlpiri /t/), and the interpretation of the statistical comparisons of Warlpiri-sourced /p/ and /k/ to the corresponding English/Kriol voiced and voiceless stops are not straight-forward. As outlined in Section 2.3, we can see (at least) three possible scenarios in the case of the word-initial stops, and we note (as per Table 1) that Warlpiri word-initial stops produced by Warlpiri-only speakers (Bundgaard-Nielsen & O'Shannessy, 2019) appear to be intermediate in VOT between the VOT of English/Kriol voiced and voiceless stops, perhaps making it challenging for speakers to straightforwardly and systematically assign Warlpiri-sourced stops to one or the other. This would be consistent with the third scenario outlined, but we are reluctant to adjudicate on the matter on the basis of the current study. We note also that this difficulty may be compounded by the articulatory challenges of producing VOT-based stop distinctions at the velar POA, discussed also in Section 2.3.

*Word-medially,* it appears that voiceless Warlpiri-based stops are grouped with the acoustically most-similar English/Kriol phoneme category—the voiceless stops. We argue this with some conviction, in particular on the basis of the constriction duration distinctions. In terms of the affricates, the lamino-palatal stop /c/ in Warlpiri appears to have merged with the English/Kriol voiced affricate /ʤ/ in word-medial position, and this merged affricate contrasts with English/Kriol voiceless /ʧ/. As in the case of the perception study discussed above, we would argue that the source languages for Light Warlpiri stop phonology (in addition to Warlpiri) *must* include Kriol, but likely also (Standard Australian) English: speakers of Light Warlpiri produce voiceless stops and affricates that differ from their voiced counterparts not only in VOT (as in English) but also in CD, which is a characteristic of Kriol. The influence from (Standard Australian) English is perhaps clearest in the use of lexical items with English phonological specifications (*cave*, *graveyard*, *pussycat*; see discussion in Section 2.2) for which stable Kriol counterparts are also in use (*keib*, *greibyard*, *pujikat*). The influence of (Standard Australian) English is perhaps less convincing in terms of the use of VOT in word-medial stops.

Secondly, we presented a perception study testing the ability of Light Warlpiri speakers to discriminate English and Kriol-like stop voicing contrasts, as well as fricatives and a fricative-stop contrast. The results indicate that Light Warlpiri speakers are sensitive to VOT-based contrasts, and that Kriol-like use of stop constriction duration increases discrimination accuracy. The results also indicate that speakers of Light Warlpiri are able to discriminate fricatives differing in terms of POA, and fricatives from stops at the same POA, but that they have great difficulty with the voicing-based contrast /s z/. The results are thus similar (though not identical) to stop and fricative perception by speakers of Kriol, which is one of the source languages of Light Warlpiri (see Bundgaard-Nielsen & Baker, 2019), but different from what has been reported for Gurindji Kriol stop production (see Jones & Meakins, 2013), and to some extent to what has been reported for perception, though there is some evidence for the emergence of a similar system (see Stewart et al., 2018, 2020). The stop discrimination results lead us to suggest that in the domain of stop phonology, Kriol, rather than (Standard Australian) English, is the main contributor to Light Warlpiri, in addition to Warlpiri. Indeed, if English were the source of the voicing distinction in Light Warlpiri, we would expect much better performance on the English-like VOT-based contrasts (/p b/, /k g/) than what we observe, and less reliance on CD information, resulting in improved performance for Kriol-like contrasts (/p+ b/, /k+ g/). This position is supported also by the observed difficulty experienced by Light Warlpiri speakers in discriminating English /s z/ which is not a Kriol contrast, but better performance for the /s ʃ/ contrast, which is maintained in Kriol as well as English. Warlpiri, like many Indigenous Australian languages, does not have fricatives and is an unlikely source.

The consistency of results of the perception and production studies presented here allow us to propose a consonant inventory for Light Warlpiri (see Table 6). This Light Warlpiri inventory includes voicing and constriction duration-based stop contrasts at the bilabial (/p b/), alveolar (/t d/) and velar (/k g/) places of articulation, as well as voicing and constriction

**Table 6**
Tentative consonant inventory of Light Warlpiri.

| | Labial | Dental | Alveolar | Retroflex | Alveo-palatal | Velar | Glottal |
|---|---|---|---|---|---|---|---|
| Stops | p b | t̪/d̪ | t d | ɖ | | k g* | |
| Nasal | m | | n | ɳ | ɲ | ŋ | |
| Trill | | | | | r | | |
| Flap | | | | ɽ*** | | | |
| Lateral | | | l | ɭ | ʎ | | |
| Affricates | | | | | tʃ dʒ** | | |
| Fricatives | f | | s z**** | | ʃ | | h***** |
| Approximants | w | | ɻ | | j | | |

* Likely emerging; produced and perceived by at least some speakers.
** We argue that it is likely that English/Kriol /dʒ/ and Warlpiri /c/ form a single phoneme, here given as /dʒ/.
*** The phonemic status of the flap has recently been questioned (Bundgaard-Nielsen & O'Shannessy, 2019).
**** Hendy (2019) suggests a voicing distinction.
***** Hendy (2019) suggests /h/ is a Light Warlpiri phoneme.

duration-based affricate contrasts (/tʃ ʤ/). There is likely a dental POA stop as well (here T/D), though it is not clear that this POA has a voicing or constriction duration-based contrast. It is possible that VOT is the primary cue in word-initial position, while CD is the primary cue in word-medial position. We note also that, just as has been reported for both production and perception in Kriol (Baker et al., 2015; Bundgaard-Nielsen & Baker, 2019; Bundgaard-Nielsen et al., 2016) and Gurindji Kriol (Stewart et al., 2018), contrast maintenance seems to be weaker for the velar POA than for the bilabial and alveolar POAs. It is not clear what underpins this pattern. We further propose, also in the light of Hendy (2019), that Light Warlpiri maintains a series of fricatives: /f s ʃ/, with the status of /h/ unclear, as the perception and production of /h/ was not examined here. We tentatively include the voiced fricative /v/ also, particularly on the basis of recent acoustic analysis (Hendy, 2019), suggesting that Light Warlpiri has a /f v/ contrast. However, we note that it is also possible that the inability of speakers to discriminate the English /s z/ indicates that voicing is not contrastive in Light Warlpiri fricatives at all POAs, and under that analysis, it can be argued that the ability of the participants to discriminate between /b v/ is due to reliance on a single labio-dental fricative (likely phonetically voiceless).

We note that the reported results and the characteristics of the proposed inventory outlined above differ from analyses of the phonological systems of other mixed languages, both in Australia (Gurindji Kriol: Jones & Meakins, 2013; Stewart et al., 2018) and elsewhere (Media Lengua: Stewart, 2018; and Michif: Rosen et al., 2019). In these languages, the phonological systems have not been found to exhibit systematic and expansive integration of the phonological systems of the parent languages. Rather, the reports suggest that the phonologies of these mixed languages are very similar to one of the source languages—typically the ancestral language of the respective group of speakers. Of particular relevance here is perhaps the lack of voicing-based stop contrasts in Gurindji Kriol, which is spoken in an area relatively close to Light Warlpiri, and whose source languages share many of the phonological characteristics of the source languages of Light Warlpiri. There is of course no expectation that the phonological systems of mixed languages must behave identically, nor that they will necessarily involve near-maximal preservation of the source language contrasts. The question as to why such variation is seen between languages remains open, but phonetic realisation of the phonemes of each contributing language may play a role. All else being equal, we would predict that we would be more likely to find large systems where not just the phonological systems, but also the phonetic realisations of the phones, are dissimilar (perceptually, as well as acoustically and articulatorily). We do, however, speculate that some explanation may be found in greater overlaps between the respective phonologies of some source languages, or differences mainly in terms of phonetic realisations, though this seems to be an unlikely explanation of the differences observed between Light Warlpiri and Gurindji Kriol. Another contributing factor could be differences in the relative contribution to the lexicon of the source languages. It may also be that mixed languages undergo change as they are formed (perhaps through elaborate code-switching by speakers whose production exhibits systematic L2 characteristics) and transmitted to, and acquired by, L1 speakers, as has often been reported for Creoles. And importantly, it may also be that language shift to a mixed language or Creole does not happen in (all) communities in one fell swoop. If language shift is more gradual, we would expect individual differences in use patterns and in the acquisition histories of its speakers (including L2 phenomena) to be evident, and perhaps to create 'messy stories' that are difficult to detangle with synchronic research approaches alone. A similar argument is also invoked by Stewart et al. (2020) to account for signs of an emerging distinction between fricatives and stops in Gurindji Kriol. It is possible that Light Warlpiri speakers acquired the relevant phonological systems from the code-switching input they received and internalised as a single system (O'Shannessy, 2012). This has then been integrated into one larger system, with speakers relying on phonetic similarities to 'match' Kriol and Warlpiri stops to form unified phonemic and phonetic categories.

In conclusion, we argue that the mixed language Light Warlpiri, spoken in the Northern Territory community of Lajamanu, has incorporated most aspects of the discrepant source language phonologies, resulting in a near-maximal system of contrast maintenance. This allows speakers to incorporate lexical items from all source languages in forms that are, for the large part, phonologically and phonetically similar to the respective source language. This differs from what has been reported for some other mixed languages, including Gurindji Kriol (e.g. Stewart et al., 2020), and demonstrates the linguistic agility of speakers of contact varieties such as Light Warlpiri, and provides evidence that such languages do not necessarily involve reduction of linguistic complexity.

**Author Contributions**

Carmel O'Shannessy (CO'S) designed the production data collection protocol and collected the production data. Rikke Bundgaard-Nielsen (RBN) designed and prepared the perception study, and CO'S collected the perception data. RBN undertook the acoustic segmentation labeling, acoustic measurements, and descriptive statistics, and the collating and organising of the perception data. CO'S and RBN jointly decided on the statistical procedures, which were run by CO'S. Interpretation of the statistical results was undertaken jointly. RBN drafted the manuscript. CO'S provided comments and suggestions.

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**Competing interest statement**

We have no competing interests.

**Appendix A. Supplementary data**

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wocn.2021.101037.

**References**

Antoniou, M., Best, C. T., Tyler, M. D., & Kroos, C. (2010). Language context elicits native-like stop voicing in early bilinguals' productions in both L1 and L2. *Journal of phonetics, 38*(4), 640–653. https://doi.org/10.1016/j.wocn.2010.09.005.

Baker, B., Bundgaard-Nielsen, R. L., & Graetzer, S. (2015). The obstruent inventory of Roper Kriol. *Australian Journal of Linguistics, 34*, 307–344.

Bakker, P., & Matras, Y. (2013). Introduction. In P. Bakker & Y. Matras (Eds.), *Contact languages: A comprehensive guide* (pp. 1–14). Berlin: Walter de Gruyter.

Bakker, P., & Papen, R. (1997). Michif: A mixed language based on Cree and French. In S. Thomason (Ed.), *Contact Languages: A Wider Perspective* (pp. 295–363). Amsterdam: Benjamins.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01.

Boersma, P. & Weenink, D. (2018). Praat: doing phonetics by computer [Computer program]. Version 6.0.37, retrieved 14 March 2018 from http://www.praat.org/.

Bundgaard-Nielsen, R. L., & Baker, B. J. (2019). Paa, paa, plack sheep: Nonnative VOT perception in the absence of native VOT experience. In A. M. Nyvad, M. Hejná, A. Højen, A. Bothe Jespersen, & M. Hjortshøj Sørensen (Eds.), *A sound approach to language matters. In Honor of Ocke-Schwen Bohn*. Aarhus: Dept. of English, School of Communication and Culture, Aarhus University.

Bundgaard-Nielsen, R. L., & Baker, B. J. (2016). Fact or Furphy? The continuum in Kriol. In F. Meakins & C. Ohannessy (Eds.), *Loss and renewal: Australian languages since colonisation* (pp. 177–216). Berlin: Mouton de Gruyter.

Bundgaard-Nielsen, R. L., Baker, B. J., & Bell, E. (2016). Child Kriol has stop distinctions based on VOT and Constriction Duration. *Proceedings of the 16th Australasian International Speech Science and Technology (SST) conference, Sydney*.

Bundgaard-Nielsen, R. L., & Baker, B. (2015). The vowel inventory of Roper Kriol. *Proceedings of the 18th International Congress of Phonetic Sciences, Glasgow*.

Bundgaard-Nielsen, R. L., & O'Shannessy, C. (2019). Voice onset time and constriction duration in Warlpiri stops (Australia). *Proceedings of the 2019 International Congress of Phonetic Sciences, Melbourne, Australia*.

Butcher, A. R. (1994). On the phonetics of small vowel systems. In R. Togneri (Ed.), *Proceedings of the 5th Australian International Conference on Speech Science and Technology* (pp. 28–33). Canberra: Australian Speech Science and Technology Association.

Butcher, A. R. (2006). Australian Aboriginal languages: Consonant-salient phonologies and the "Place-of-Articulation Imperative. In J. Harrington & M. Tabain (Eds.), *Speech production: Models, phonetic processes, and techniques* (pp. 187–210). New York, NY: Psychology Press.

Butcher, A. R. (2012). On the phonetics of long, thin phonologies: the expression and maintenance of distinctive features in the place-rich, manner-poor consonant systems of Australian languages. In (Eds. C. Donohue, S. Ishihara and W. Steed) Quantitative Approaches to Problems in Linguistics. Studies in honour of Phil Rose, p. 133–154. Munich: Lincom Europa. Retrieved from https://www.academia.edu/5131502/On_the_phonetics_of_long_thin_phonologies_the_Expression_and_Maintenance_of_Distinctive_Features_in_the_Place_rich_Manner_poor_Consonant_Systems_of_Australian_Languages, 5th of August, 2020

Clothier, J., & Loakes, D. (2018). Coronal stop VOT in Australian English: Lebanese Australians and mainstream Australian English speakers. *Proceedings of the 17th Australasian International Speech Science and Technology (SST) conference, Sydney 2018*.

Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments, & Computers, 25*(2), 257–271.

Dixon, R. M. W. (1980). *The languages of Australia*. Cambridge: Cambridge University Press.

Ennever, T., Meakins, F., & Round, E. (2017). A replicable acoustic measure of lenition and the nature of variability in Gurindji stops. *Laboratory Phonology: Journal of the Association for Laboratory Phonology, 8*(1), 1–32. https://doi.org/10.5334/labphon.18.

Golovko, E., & Vakhtin, N. (1990). Aleut in contact: The CIA enigma. *Acta Linguistica Hafniensia, 22*(1), 97–125.

Harris, J. W. (1986). *Northern Territory pidgins and the origin of Kriol (Series C vol 89)*. Canberra: Pacific Linguistics.

Hendy, C. (2019). *The distribution and acoustic properties of fricatives in Light Warlpiri* BA Honours Thesis. College of Arts and Social Sciences, Australian National University.

Ingram, L., & Laughren, M. (1999). The stop flap contrast in Western Warlpiri. *Talk presented at the annual meeting of the Australian Linguistics Society*.

Jones, C., & Meakins, F. (2013). Variation in voice onset time in stops in Gurindji Kriol: Picture naming and conversational speech. *Australian Journal of Linguistics, 33*, 196–220.

Klatt, D. (1975). Voice onset time, frication, and aspiration in word-initial consonant clusters. *Journal of Speech and Hearing Research, 18*, 686–706.

Lenth, R., Singmann, H., Love, J., Buerkner, P., & Herve, M. (2018). Emmeans: Estimated marginal means, aka least-squares means. *R package version, 1*(1), 3.

Lisker, L., & Abramson, A. S. (1964). A cross-language study of voicing in initial stops: Acoustical measurements. *Word, 20*, 384–422.

Lisker, L., & Abramson, A. S. (1967). Some effects of context on voice onset time in English stops. *Language and Speech, 10*, 1–28.

Maddieson, I. (2013). Voicing and gaps in plosive systems. In M. S. Dryer & M. Haspelmath (Eds.), *The world atlas of language structures online*. Leipzig: Max Planck Institute for Evolutionary Anthropology (Available online at http://wals.info/chapter/5, Accessed on 2020-06-05.).

Matras, Y., & Bakker, P. (2003). The study of mixed languages. In Y. Matras & P. Bakker (Eds.), *The Mixed Language Debate* (pp. 1–20). Berlin & New York: Mouton de Gruyter.

Mazzoli, M. (2019). Michif loss and resistance in four Metis communities. Kahkiyaw mashchineenaan, "All of us are disappearing as in a plague". *Zeitschrift für Kanada-Studien*, 96–117.

McConvell, P., & Meakins, F. (2005). Gurindji Kriol: A mixed language emerges from code-switching. *Australian Journal of Linguistics, 25*(1), 9–30.

Munro, J. (2000). Kriol on the move: A case of language spread and shift in Northern Australia. In J. Siegel (Ed.), *Processes of language contact: Studies from Australia and the South Pacific* (pp. 245–270). Montreal: Fides.

Nash, D. G. (1986). *Topics in Warlpiri grammar*. New York and London: Garland.

Nash, D. G. (1980). *Topics in Warlpiri grammar* Unpublished PhD thesis. Department of Linguistics and Philosophy, Massachusetts Institute for Technology.

O'Shannessy, C. (2013). The role of multiple sources in the formation of an innovative auxiliary category in Light Warlpiri, a new Australian mixed language. *Language, 89*(2), 328–353.

O'Shannessy, C. (2012). Code-switched input to children leads to a new mixed language. *Linguistics, 50*(2), 305–340.

O'Shannessy, C. (2005). Light Warlpiri: A new language. *Australian Journal of Linguistics, 25*, 31–57.

Pentland, C., & Laughren, M. (2004). Distinguishing prosodic word and phonological word in Warlpiri: Prosodic constituency in morphologically complex words. *Proceedings of the 2004 Conference of the Australian Linguistic Society*.

Rosen, N., Stewart, J., Pesch-Johnson, M., & Sammons, O. (2019). Michif VOT. *Proceedings of the 2019 International Congress of Phonetic Sciences, Melbourne, Australia*.

Sandefur, J. (1986). *Kriol of North Australia: A language coming of age*. Darwin: Summer Institute of Linguistics.

Sekerina, I. (1994). Copper Island (Mednyj) Aleut (CIA): A mixed language. *Languages of the World, 8*(1), 14–31.

Stewart, J., Meakins, F., Algy, C., Ennever, T., & Joshua, A. (2020). Fickle fricatives: Fricative and stop perception in Gurindji Kriol, Roper Kriol, and Standard Australian English. *Journal of the Acoustical Society of America, 147*(4), 2766–2778.

Stewart, J. (2018). Voice onset time production in Spanish, Quichua, and Media Lengua. *Journal of the International Phonetic Association, 48*(2), 173–197. https://doi.org/10.1017/S002510031700024X.

Stewart, J., Meakins, F., Algy, C., & Joshua, A. (2018). The development of phonological stratification: Evidence from stop voicing perception in Gurindji Kriol and Roper Kriol. *Journal of Language Contact, 11*(1), 71–112.

Thomason, S. G., & Kaufman, T. (1988). *Language contact, creolization, and genetic linguistics*. Berkeley: University of California Press.

van Gijn, R. (2009). The phonology of mixed languages. *Journal of Pidgin and Creole Languages, 24*(1), 91–117.

## Further reading

Boersma, P. & Weenink, D. (2007). Praat: doing phonetics by computer (Version 5.0.27) [Computer program]. Retrieved 28/06/08.