An EPG and EMA study of apicals in stressed and unstressed position in Arrernte.

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ABSTRACT

We present EPG (electropalatography) and EMA (electro-magnetic articulometry) data from two female speakers of Arrernte, a language of Central Australia. We focus on the apical consonants /t/ and /ʈ/, both of which have previously been shown to have a higher spectral centre of gravity for the stop burst when preceding a stressed syllable. Articulatory results suggest that the tongue is most retracted for the retroflex in the weak (i.e. unstressed) context, but that both apicals have a more advanced tongue position in strong (i.e. stressed) positions. In general, there is more variability in tongue-palate contact patterns for the alveolar /t/ than for the retroflex /ʈ/. In addition, jaw position is highest for /t/ in stressed position, and lowest for /ʈ/ in unstressed position. We suggest that the most prototypical retroflex is the one found in the weak prosodic position.

Keywords: Australian languages, EMA, EPG, stress, articulatory prosody.

1. INTRODUCTION

In a recent study [1], we examined the effect of lexical stress on the spectral and temporal properties of stop bursts in Pitjantjatjara, a language of Central Australia. In Pitjantjatjara, lexical stress occurs on the first syllable of the word [2]. We found that the alveolar /t/ had a higher spectral centre of gravity in this prosodically prominent position, while the velar /k/ had a lower spectral centre of gravity in this same position (as measured by the first spectral moment). Thus, the contrast between a "light" alveolar sound and a "dark" velar sound was enhanced in stressed position. This was interpreted as an enhancement of the feature [grave], where the velar is [+grave] and the alveolar is [-grave].

An interesting situation was observed with the retroflex stop /ʈ/ in Pitjantjatjara. In this language, as in many languages with a /t/~/ʈ/ contrast, including Australian languages where both consonants are apical [3, 4, 5], the contrast between these sounds is neutralized in initial position. However, as just mentioned, lexical stress in Pitjantjatjara occurs in word-initial position. This means that the stressed initial apical (both /t/ and /ʈ/ are apical) is the neutralized apical, which we write /T/. In most vowel contexts, the spectral centre of gravity for /ʈ/ is slightly lower than that for /t/– otherwise their spectra are very similar. This means that both /t/ and /ʈ/ have a higher spectral centre of gravity in stressed position – i.e. /T/. In a sense, then, the prosodically enhanced but phonemically neutralized /T/ is more alveolar than the alveolar, since the alveolar /t/ has a higher spectral centre of gravity than /ʈ/, and /T/ has a higher centre of gravity than /t/.

This result has recently been extended [6] to the neighbouring language, Arrernte [7, 8, 9, 10, 11]. Arrernte differs from Pitjantjatjara in that both alveolars and retroflexes can occur in either stressed or unstressed position, due to the different stress rule in this language (to be precise, stress in Arrernte is on the second underlying VC syllable). In Arrernte, the stressed alveolar /t/ had a significantly higher spectral centre of gravity than the unstressed /t/, whereas there was no significant difference between stressed and unstressed retroflex /ʈ/, even though the centre of gravity for stressed /ʈ/ was a little higher than for its unstressed counterpart. (Although not directly relevant here, the velar /k/ did not show a lower centre of gravity in stressed position, but instead a less diffuse spectrum, as measured by the second spectral moment). These results are based on seven speakers of Arrernte (and nine speakers of Pitjantjatjara).

In the present study, we seek to determine if these acoustic results can be observed in the articulatory data. We present EPG and EMA data for two speakers who had participated in the acoustic recordings mentioned above, focusing on the alveolar and retroflex consonants. We expect to observe a more forward tongue tip position for the apical sounds under stressed condition, since the smaller front resonating cavity would result in a higher spectral centre of gravity for the stop burst.

2. METHOD

2.1 Speakers

Two female native speakers of Central Arrernte participated in both the EMA and the EPG recordings – Sabella Turner (ST) and Janet Turner (JT), who are mother and daughter, respectively.

2.2 Recordings

2.2.1 EMA

The EMA data were recorded in the speech physiology studio at Macquarie University in 2004, using a 2D EMA Carstens system with a 200 Hz sample rate. Articulatory and acoustic data were recorded simultaneously and time-synchronized.

Two EMA sensors were placed on the tongue (one on the Tongue Body and one on the Tongue Tip). Sensors were also placed on the vermilion borders of the lips (one on each of the Upper Lip and Lower Lip); and one sensor for the Jaw was placed on the chin. A reference transducer was placed on the bridge of the nose. Unfortunately, the Tongue Tip sensor failed for speaker ST, and so only data from the Tongue Body sensor are available for the tongue for this speaker. Only Tongue and Jaw data will be shown here.

2.2.2 EPG

The EPG recordings took place at the Institute for Aboriginal Development in 2008, using the new Articulate palate [12]. EPG and acoustic data were recorded simultaneously onto a PC laptop computer running the Articulate Assistant software (http://www.articulateinstruments.com), with an external recording-quality soundcard to ensure accurate articulatory–acoustic synchronization. EPG data were sampled at 200 Hz.

2.3 Stimuli

For both the EMA and EPG recordings, real Arrernte words were used. For both sets of recordings, the wordlist aimed to present sounds in word-initial, word-medial and word-final position, within lexical and phonotactic limits. The stimulus words were presented in standard Arrernte orthography. Words were uttered in isolation, rather than in a carrier phrase.

2.3 Data analysis

Data were labelled using the EMU Speech Database system (http://emu.sourceforge.net) using standard phonetic labelling criteria, and all data analysis was done using this system interfaced with the R Statistical Package [13]. For the EPG data only, the onset of word-initial consonants and the offset of word-final consonants were located using EPG closure and release.

For the purposes of the current study, only consonants which were produced in either intervocalic context or word-initial position were selected, where adjacent vowels were the non-high vowels /ɐ/ or /ə/. These are both central vowels, with /ɐ/ being a low vowel, and /ə/ being a mid vowel (Arrernte also has a third vowel phoneme, /i/, which is not frequent in root words - see [14] for further details of the vowels). It should be noted that [ə] in final position is non-phonemic, since all words are assumed to end in a consonant underlyingly [8]: the quality of this final vowel varies between [ə] and [ɐ].

Data were coded as either Strong (i.e. Stressed) or Weak (i.e. Unstressed), based on whether or not the following vowel was stressed. Stress in Arrernte occurs on the second underlying vowel of the word, with all words deemed to begin with a vowel underlyingly – in practice, this means that if the word is realized with an initial vowel, stress is on the second vowel, but if the word is realized with an initial consonant, stress is on the first vowel. Given this unusual stress pattern, it may be wondered why the following vowel was chosen as the determiner of stress, rather than the preceding vowel – the reason is that the acoustic data from both Arrernte and other Australian languages examined the stop burst (i.e. the right edge of the consonant), and the present articulatory data aim to see if there is an articulatory confirmation for the acoustic patterns observed.

Note that in the present study, there were insufficient tokens of Weak /t/ data, and so this category is not included in the results presented below.

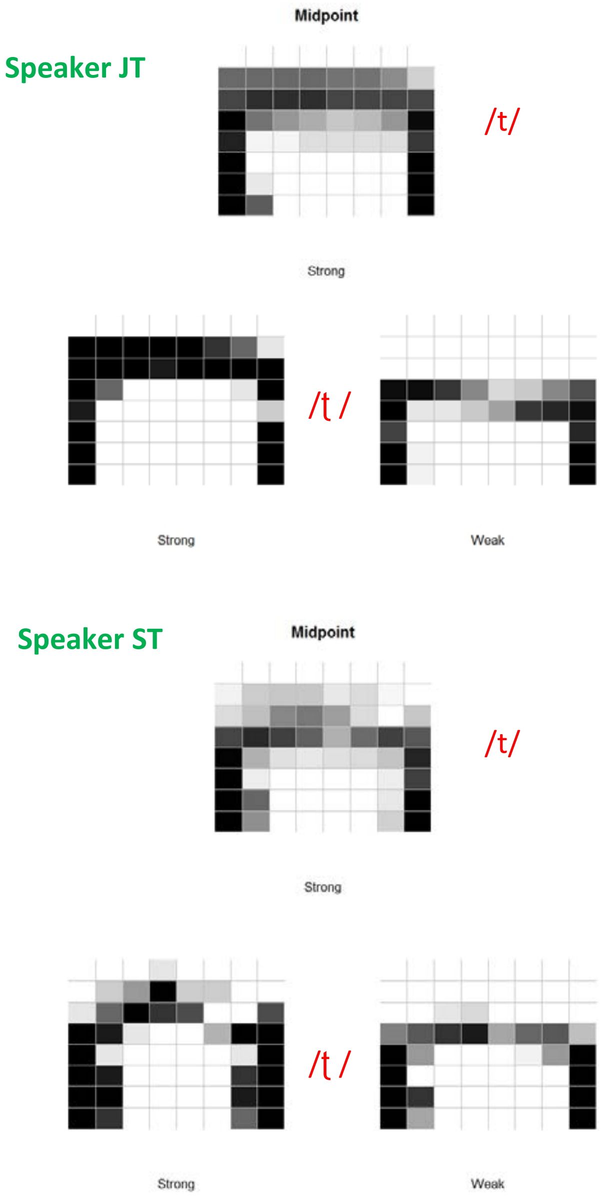
2.3.1 EMA

Data from the reference sensor were smoothed using a Lowess filter – a regression-based filter which uses a first-degree polynomial fit – with the filter span set to 1 second. (A first-degree fit was chosen in this instance because head movement was observed to be linear over the time-span of the filter.) The reference sensor was then subtracted from the other sensors in order to correct for head movement. Data were then rotated to the occlusal plane of the speaker. Articulatory data were sampled at acoustic offset of the stop, that is, at the onset of stop burst.

2.3.2 EPG

In addition to presenting averaged palatogram data, Centre of Gravity (COG) data will also be presented. This measures contact across the entire palate, and gives a linearly higher weighting as the rows become more forward [15, 16]. The value of COG varies between 0.5 if the entire back row of electrodes is contacted, and 7.5 if the entire front row of electrodes is contacted. Data were sampled at the temporal midpoint of the consonant.

Figure 1 – Averaged EPG palatograms for two speakers – a darker shaded cell denotes more frequent contact for that electrode. All data are sampled at the temporal midpoint of the stop.



3. RESULTS

3.1. EPG

A total of 51 tokens were analysed for speaker JT (22 Strong /t/, 10 Strong /ʈ/ and 19 Weak /ʈ/), and 85 for speaker ST (55 Strong /t/, 10 Strong /ʈ/ and 20 Weak /ʈ/).

Figure 1 shows averaged palatograms from the two speakers, as sampled at the temporal midpoint of the stop consonant. It can be seen that for both speakers, the retroflex /ʈ/ in the Weak prosodic context (i.e. unstressed) has contact much further back on the palate than either of the apicals in Strong (i.e. stressed) context, including the retroflex. Contact for the Weak /ʈ/ is typically around the fourth and fifth rows of the Articulate palate; by contrast, contact for both of the apicals in Strong prosodic context tends around the second and third rows. Interestingly, the contact is more consistently further forward for the retroflex /ʈ/ than for the alveolar /t/, the latter showing greater variability in contact patterns (as denoted by the lighter shading of the various cells).

Figure 2 shows averaged and time-normalized plots of the centre of gravity for the three types of apicals. They confirm the observations made for Figure 1, that the Centre of Gravity is lowest for the Weak retroflex /ʈ/, reflecting a more consistently back point of contact along the palate. For both speakers, Strong retroflex /ʈ/ has a higher centre of gravity than Strong alveolar /t/ - however, an examination of means and 95% confidence intervals (not shown here) of the Centre of Gravity sampled at the temporal midpoint suggests that the difference between Strong /t/ and Strong /ʈ/ is only significant for speaker JT, and not speaker ST. However, the Weak /ʈ/ clearly has the lowest Centre of Gravity for both speakers.

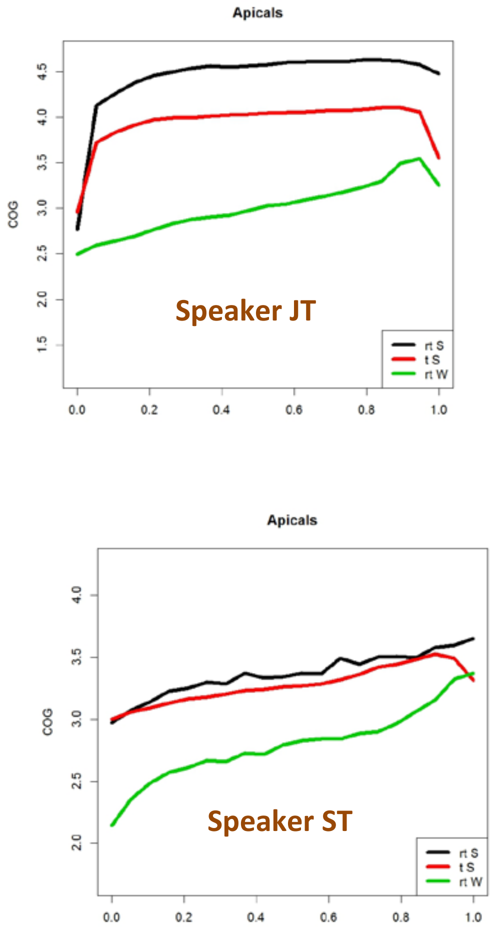
3.2. EMA

A total of 42 tokens were analysed for speaker JT (15 Strong /t/, 17 Strong /ʈ/ and 10 Weak /ʈ/), and 35 for speaker ST (21 Strong /t/, 6 Strong /ʈ/ and 8 Weak /ʈ/). We will interpret speaker ST's data with caution, due to the low tokens numbers for the retroflex.

Figure 3 shows averaged trajectory plots in the XY-plane for the EMA data. It can be seen that for speaker ST, the Jaw is higher for Strong alveolar /t/ than for either of the retroflex categories; however, for speaker JT, although the Jaw appears higher for Strong /t/, it may not be significantly higher than Strong /ʈ/, based on confidence intervals of data sampled at the endpoint of the consonant (confidence intervals not shown here). It appears that for JT, the two Strong apicals pattern together as being higher in Jaw position, while for speaker ST, the two retroflexes pattern as being lower in Jaw position. In general, however, it could be said that the Jaw is higher for Strong alveolar /t/, and lower for Weak retroflex /ʈ/.

The Tongue Body data also shows differences between speakers. For speaker JT, the Tongue Body has a lower and more forward position for Strong /t/, while both the retroflexes are higher and more back; by contrast, for speaker ST, the Tongue is highest for the Strong retroflex /ʈ/, with the confidence plots suggesting no significant differences in front-back.

Figure 2 – EPG Centre of Gravity plots, averaged and time-normalized, for two speakers. A higher CoG value denotes a more forward articulation. 'rt' denotes /ʈ/, 'S' denotes Strong and 'W' denotes Weak.

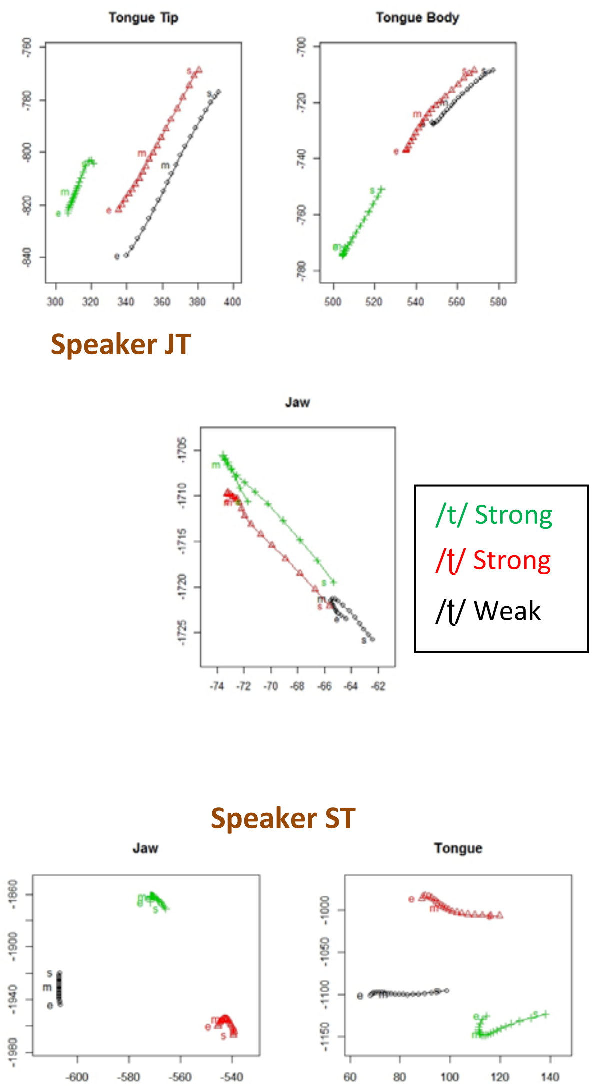


Only speaker JT has Tongue Tip data, which confirms the more forward position observed for Strong /t/ in the Tongue Body data. Although the Strong /ʈ/ data is more forward than the Weak /ʈ/ data, examination of confidence intervals suggests this is not likely to be significant. Likewise, the apparently lower Tongue Tip position for Weak /ʈ/ is likely not significant.

4. CONCLUSION

For both speakers, the most retracted tongue position is found for the retroflex /ʈ/ in Weak prosodic position, and in Strong prosodic position, both apicals have a more forward articulation. There is some contradiction between the EPG and EMA data for speaker JT, with the former suggesting the tongue position is on average more forward for the Strong retroflex than for the Strong alveolar, and the latter suggesting the opposite – however, this may be explained by the overall greater variability evident in the alveolar contact patterns observed here. For both speakers, jaw position is highest for the Strong alveolar /t/, and lowest for the Weak retroflex /ʈ/. Overall, these results suggest that the most prototypical retroflex is in fact the one found in the weak prosodic position.

Figure 3 – EMA trajectory plots, averaged and time-normalized, for two speakers. 's' marks the start of the trajectory, 'm' the middle, and 'e' the end.



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7. REFERENCES

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