# Affricating ejective fricatives: The case of Tigrinya

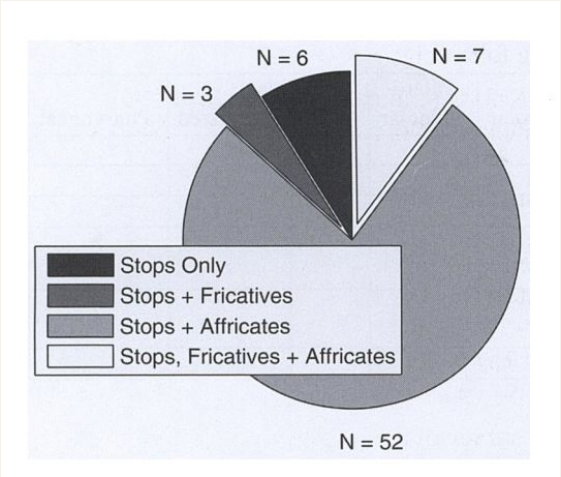
Shosted & Rose 2000

# Introduction

- Ejectives
  - “Ejectives are produced by trapping air between the tightly adducted vocal folds and a constriction at an oral place of articulation. To produce an ejective, the larynx should be raised, thereby compressing the air in the supralaryngeal cavity. Upon release, 'the entrapped high-pressure air will momentarily burst forth in a short sharp explosion'” (Shosted & Rose 2000)

# An Aeroacoustic confound revisited

- Ejective Fricatives
  - Relatively rare sound in the world's languages
    - According to the UPSID-PC, only 10 of the 451 languages reported having ejective fricatives
      - ~ (2.2%)
  - Ejective Fricative ⟹ (at least one) Ejective obstruent
    - Ejective Fricative ⟹ Ejective stop
  - Aeroacoustic dilemma
    - Ejectivity
      - Substantially increase air pressure above the larynx  (greater than pulmonic)
    - Frication
      - Vent air continuously through a narrow constriction



# An Aeroacoustic confound revisited

- Madison (1997, 1998)
  - Reducing the size of constriction to increase pressure
  - Sequence frication and glottal constriction
- Affrication hypothesis
  - Frication is preceded by oral closure which allows for air pressure to build
    - Closure + Frication = Affricate

# Tigrinya and its ejective fricatives

- Contains five ejectives: /t̪' k' kʷ' s' tʃ '/
- [s’] is described as an alveolar ejective fricative
  - /s’/ is a fricative but has a free variant [ᵗs'] (Denais 1990)
  - Transcribed as [ts’] (Palmer 1966) (Walther 1999)
  - Uses an fricative transcription, but placed in the affricate section (Woldu 1985)
- These alternating transcriptions may lead us to believing that the Tigrinya ejective fricative may have some type of initial closure

**Table 1** Phonemic obstruents in Tigrinya.

| | | Bilabial/ Labiodental | Alveolar | Palato-alveolar | Velar | | Pharyngeal | Glottal |
|---|---|---|---|---|---|---|---|---|
| | | | | | plain | labialized | | |
| Stop | voiceless | (p) | t | | k | kʷ | | ʔ |
| | voiced | b | d | | g | gʷ | | |
| | ejective | (p’) | t’ | | k’ | kʷ’ | | |
| Fricative/ Affricate | voiceless | f | s | ʃ (ʧ) | | | ħ | h |
| | voiced | | z | (ʒ) ʤ | | | ʕ | |
| | ejective | | s’ | ʧ’ | | | | |

# Tigrinya and its ejective fricatives

- We see alternation of [s’] with [ts’] in other languages as well
  - Hausa
  - Amharic
    - Godjam
    - Shewa
  - Lowland Oaxaca Chontal
- Dialectal
  - Rural dialects of Tigrinya favor [tʃ’] over [s’]

    [has'ərə] ~ [hatʃ ' ərə]  ‘become short’

    [k' ʷɨns' i] ~ [k' ʷɨntʃ ' i] ‘flea’

    [s'əmmərə] ~ [tʃ ' əmmərə] ‘add, unite’

# The phonetics of ejective fricatives: A cross-linguistic perspective

- Looked at previous studies of several languages that contain ejective fricatives
  - Characterized as having shorter frication than pulmonic fricatives followed by a silent interval (glottal lag/ laryngealization) before the following vowel
  - Frication is described as “scrapy” or “pulsing”
  - Ejective fricatives have higher intraoral pressure peaks

**Table 2** Characteristics of ejective fricatives compared to pulmonic fricatives (n/r = not recorded or reported).

| | | Amharic s’ | Tlingit s’ ɬ’ x’ x$^{w}$’ χ’ χ$^{w}$’ | Kabardian f’ ʃ’ ɬ’ | Upper Necaxa Totonac s’ ʃ’ ɬ’ |
|---|---|---|---|---|---|
| Frication | Shorter frication | √ | √ | √ | no |
| | Scrapy frication | n/r | √ | √ | n/r |
| Silent interval | Pre-frication silence | √? | √ | √ | n/r |
| | Glottal lag/ laryngealization | √ | √ | √ | √ |
| Amplitude | Constant amplitude | √ | n/r | n/r | n/r |
| Intensity | Low intensity | n/r | n/r | √ | n/r |
| Intra-oral air pressure | High pressure peak | √ | √ | √ | no |
| | Rapid rise | √ | √ | √ | no |
| | Short duration peak | √ | √ | √ | no |
| Air flow | Later peak | n/r | n/r | √ | √ |
| Linguo-palatal contact | Narrower constriction, wider contact, and complete occlusion | √ | n/r | √ | n/r |

# The problem

- Motivation
  - Most languages that have ejective fricatives have ejective affricates
  - Tigrinya ejective fricatives do not contrast with homorganic affricates but are occasionally being transcribed/described as affricates
  - Linguopalatal occlusion is present in Amharic ejective fricatives
  - Build up of intraoral pressure during ejectives can be achieved by creating complete supralaryngeal occlusion while raising larynx
- Affrication Hypothesis
  - Complete occlusion before the onset of frication in Tigrinya ejective fricatives
    - Expect to see /s'/ manifest a silent interval preceding release of fricative but not in /s/
- Closure Duration
  - Will be longer in geminated ejective fricatives
- Acoustic properties
  - Release duration, Vowel duration (preceding & following), Presence & duration of laryngealization, amplitude rise slope, and rise time

# Method

- Speakers
  - Five male subjects
    - 25-45 yrs old
    - All from Asmara, Eritrea
    - Native speakers of Tigrinya
      - Also spoke English and Amharic
- Tokens
  - 183 Tigrinya verb forms in a carrier sentence
    - 132 target and 46 filler (including test consonants /t’/ and /ʃ/

      /təmali ____ ʔilu/ ‘Yesterday ___ he said’

      /təmali fət'iru ʔilu/ ‘Yesterday, he created, he said’

# Tokens

- 5 target consonants
  - /s t s' t' tʃ'/ (Only results for /s s' tʃ'/)
  - Word initial position and intervocalic medial position
    - Medial position was either singleton or geminated
- Triliteral consonant roots
  - Type A,B,C
    - Each has its own distinct vowel pattern and gemination pattern
- Repetition
  - 4 repetitions of each token was planned but this was later changed due to time constraint
    - S1 & S2- 4 repetitions
    - S3 & S4- 3 repetitions
    - S5- 2 repetitions

**Table 3** Word types illustrating position and vocalic context of fricatives under investigation.

| | Singleton | | |
|---|---|---|---|
| Pattern | Initial | Medial | |
| CaCiC-u | s'amiwu | las'iju | 3msg gerundive (Type C) |
| | | ʕas'ibu | 3msg gerundive (guttural Type A) |
| CəCiC-u | s'əgibu | nəs'ilu | 3msg gerundive (Type A) |
| CɨCəC-u | s'ɨgəbu | nɨs'əlu | imperative plural (Type A) |
| | | Geminate | |
| Pattern | Initial | Medial | |
| CaC:iC-u | | ʕas':ix'u | 3msg gerundive (guttural Type B) |
| CəC:iC-u | | gəs':ibu | 3msg gerundive (Type B) |
| mɨ-CɨC:aC-u | | mɨgɨs':abu | 3msg infinitive (Type B) |

**Table 4** Distribution of target consonants, speakers, repetitions, subtotals and totals.

| | | | | Speakers and (repetitions) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Consonant type | Preceding vowel | Medial singleton | Medial geminate | S1 (4) | S2 (4) | S3 (3) | S4 (3) | S5 (2) | Totals |
| /s'/ | High | 4 | 4 | 32 | 32 | 24 | 24 | 16 | 128 |
| | Mid | 4 | 4 | 32 | 32 | 24 | 24 | 16 | 128 |
| | Low | 4 | 3 | 28 | 28 | 21 | 21 | 14 | 112 |
| /s/ | High | 4 | 4 | 32 | 32 | 24 | 24 | 16 | 128 |
| | Mid | 4 | 4 | 32 | 32 | 24 | 24 | 16 | 128 |
| | Low | 3 | 3 | 24 | 24 | 18 | 18 | 12 | 96 |
| /ʧ'/ | High | 3 | 3 | 24 | 24 | 18 | 18 | 12 | 96 |
| | Mid | 3 | 3 | 24 | 24 | 18 | 18 | 12 | 96 |
| | Low | 3 | 2 | 20 | 20 | 15 | 15 | 10 | 80 |
| | Totals | 32 | 30 | 248 | 248 | 186 | 186 | 124 | 992 |

# Measurements

- Five acoustic landmarks
  - Vowel 1 ( V1 )
    - Vowel preceding the ejective or pulmonic consonant
  - Closure ( C )
    - Period of no noise that follows the voiced vowel and precedes the frication or burst followed by frication
  - Release ( R )
    - High-amplitude aperiodic noise
  - Laryngealization ( Q )
    - Harsh/ Creaky voice phonation following release
  - Vowel 2 ( V2)
    - Vowel following the ejective or pulmonic consonant
- Rise-time slope
  - Time it takes to reach the sound pressure peak after release
  - Long rise times are generally typical of fricatives but not affricates
  - Calculated by finding the maximum amplitude of release and at what point it time it occurred

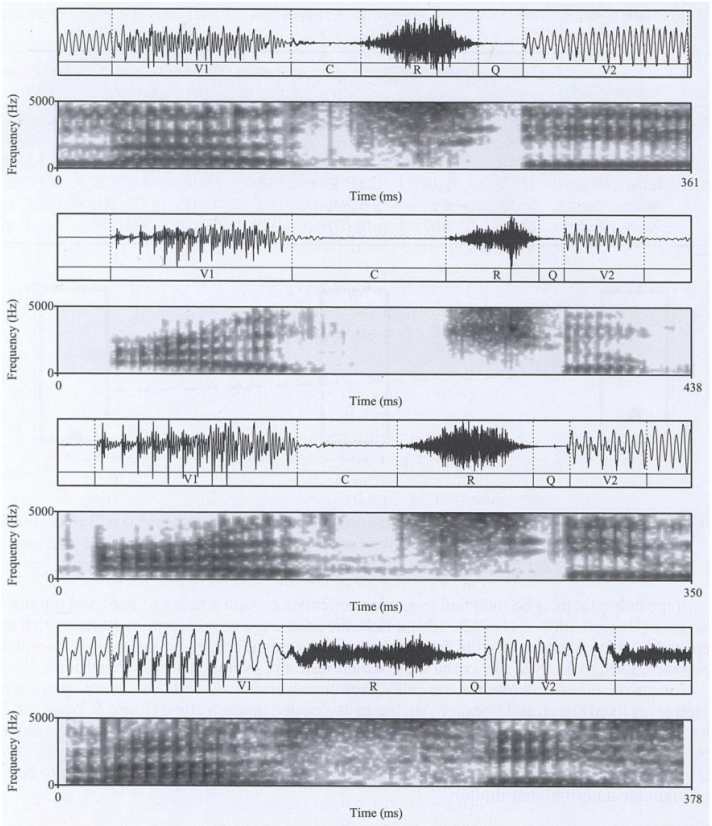



**Figure 3** From top to bottom, the tokens [las'iju] 'he shaved', [ʕatʃ'ix'u] 'he stuffed himself with food', [ʕas':imu] 'it was hard and stiff' (uttered by S4), and [masisu] 'he caressed' (uttered by S3). Up to five intervals were labeled according to definitions set forth in Section 2.3: V1 = Vowel 1; C = Closure; R = Release; Q = Post-release laryngealization; V2 = Vowel 2.

[las'iju] ‘he shaved’

[ʕatʃ'ix'u] ‘he stuffed himself with food’

[ʕas':imu] ‘It was hard and stiff’

[masisu] ‘he caressed’

# Results

- Ejective and pulmonic fricatives
  - Release: /s'/ < /s/
  - Laryngealization: /s'/ > /s/
  - Amplitude slope: /s'/ > /s/
  - Closure duration: N/A
- Ejective fricatives and ejective affricates
  - Manner was a fixed effect
    - Showed that manner is associated with closure duration (P < .05)
    - Closure duration: Greater for affricates in both singleton and geminate

**Table 6** Results of linear mixed effects models for fricatives with Airstream as fixed effect and Speaker as random effect.

| Dependent variable | nDF | dDF | F | p(F) | Direction |
|---|---|---|---|---|---|
| V1 duration (log) | 1 | 4 | 26.36 | ** | /s'/ > /s/ |
| Release duration (log) | 1 | 4 | 33.02 | ** | /s'/ < /s/ |
| Amplitude slope | 1 | 4 | 17.98 | * | /s'/ > /s/ |
| Laryngealized duration (log) | 1 | 3 | 107.65 | ** | /s'/ > /s/ |

* = p < .05, ** = p < .01
nDF = numerator degrees of freedom; dDF = denominator degrees of freedom; F = F-statistic; p(F) = probability

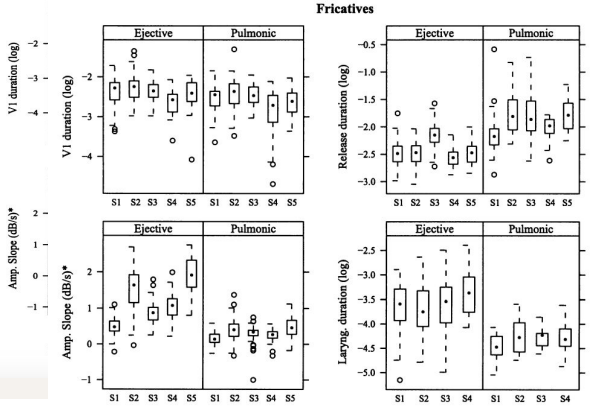



**Figure 5** Repeated measures (averages) pertaining to mixed linear effects model presented in Table 6. X-axis labels are speaker identifiers.

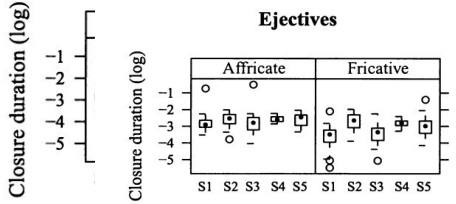



**Figure 6** Boxplots of logarithmically-transformed closure duration for ejective fricatives and (ejective) affricates.

# Results

- Ejective fricatives
  - Closure duration: longer for geminates than singletons (P < .01)
- Ejective fricatives w/o closure and pulmonic fricatives
  - 20% of ejective fricatives did not manifest closure
  - How do ejective fricatives w/o closure differentiate from pulmonic fricatives?
    - Judge what other acoustic cues differentiate the two when closure is not present
  - Glottal duration longer for no-closure ejectives than pulmonics
  - Amplitude slope also greater
    - Suggests that even without closure, there are other cues differentiating ejective vs. pulmonic fricatives

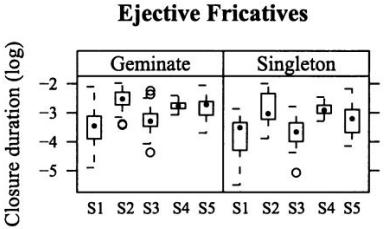



**Figure 7** Boxplots of log-transformed closure duration of geminate and singleton ejective fricatives.

**Table 7** Results of linear mixed effects models with Speaker as random effect. The corpus contains ejective fricatives with no closure (NC) and pulmonic fricatives.

| Dependent variable | nDF | dDF | F | p(F) | Direction |
|---|---|---|---|---|---|
| Laryngealized duration (log) | 1 | 3 | 33.24 | * | /s'/$_{NC}$ > /s/ |
| Amplitude slope | 1 | 3 | 54.93 | ** | /s'/$_{NC}$ > /s/ |

* = p < .05; ** = p < .01
nDF = numerator degrees of freedom; dDF = denominator degrees of freedom; F = F-statistic; p(F) = probability

**Figure 8** Boxplots relating to the linear mixed effects models presented in Table 7.

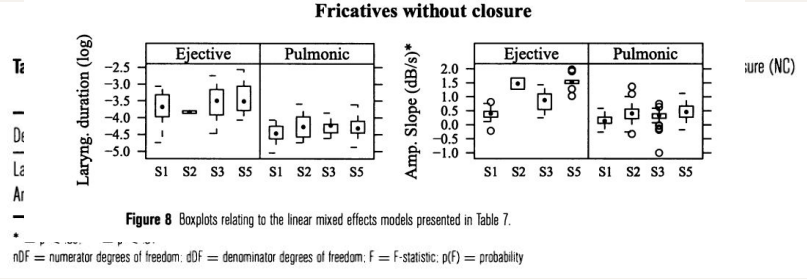



**Figure 8** Boxplots relating to the linear mixed effects models presented in Table 7.

nDF = numerator degrees of freedom; dDF = denominator degrees of freedom; F = F-statistic; p(F) = probability

# Results

- Ejective fricatives w/o closure and ejective affricates
  - Determine the characteristics that differentiate them
    - Release duration of ejective fricative w/o closure was greater than affricates

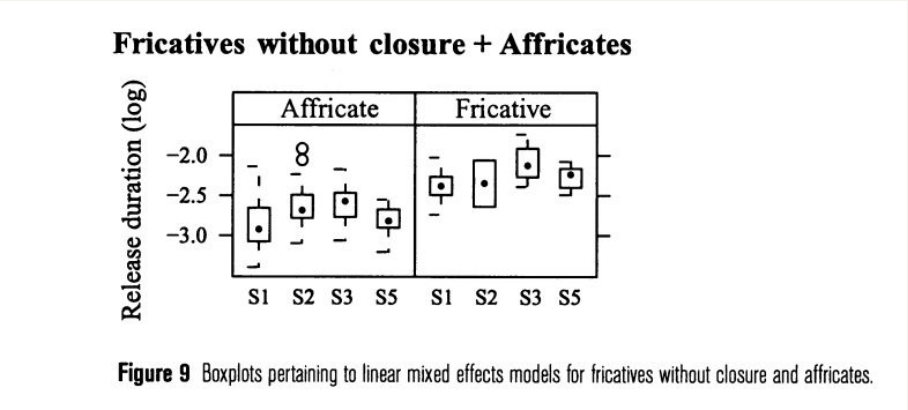



**Figure 9** Boxplots pertaining to linear mixed effects models for fricatives without closure and affricates.

# Results

- Count Data: Presence of laryngealization and closure
  - Chi-square test used to “determine whether the properties of pulmonic & ejective fricatives that manifested closure differed significantly”
    - $P < .01$
  - Geminate ejectives fricatives more likely to manifest closure than singleton
    - $P < .001$
  - Ejective fricatives more likely to manifest laryngealization than pulmonic
    - $P < .001$
  - 78% of ejective fricatives manifest both closure and laryngealization
  - Relationship between closure and laryngealization on ejective fricatives alone was not significant
    - $P > .05$

**Table 8** Counts of ejective and pulmonic fricatives with respect to closure.

| | Pulmonic /s/ | Ejective /sʼ/ | Total |
|---|---|---|---|
| No closure | 278 | 66 | 344 |
| Closure | 0 | 261 | 261 |
| Total | 278 | 327 | 605 |

**Table 9** Counts of ejective fricatives manifesting closure, grouped by phonological length.

| | Geminate /sː'/ | Singleton /sʼ/ | Total |
|---|---|---|---|
| No closure | 19 | 47 | 66 |
| Closure | 145 | 116 | 261 |
| Total | 164 | 163 | 327 |

**Table 10** Counts of ejective fricatives and affricates with respect to closure.

| | /ʧʼ/ | /sʼ/ | Total |
|---|---|---|---|
| No closure | 5 | 66 | 71 |
| Closure | 216 | 261 | 477 |
| Total | 221 | 327 | 548 |

**Table 11** Counts of ejective and pulmonic fricatives with respect to laryngealization.

| | Pulmonic /s/ | Ejective /sʼ/ | Total |
|---|---|---|---|
| No laryngealization | 173 | 7 | 180 |
| Laryngealization | 105 | 320 | 425 |
| Total | 278 | 327 | 605 |

**Table 12** Counts of ejective fricatives with respect to closure and laryngealization.

| | No laryngealization | Laryngealization | Total |
|---|---|---|---|
| No closure | 2 | 64 | 66 |
| Closure | 5 | 256 | 261 |
| Total | 7 | 320 | 327 |

# Discussion

- Affrication Hypothesis
  - Ejective fricatives are more likely to manifest prerelease silence than pulmonic
    - 80% of tokens (261/327)
  - However, no conclusive physiological evidence of /s'/ → [ts']
- Closure duration
  - Differentiates phonological length for /s'/ & /s':/
    - Also differentiates singleton and geminate affricates
  - /s':/ more likely to manifest closure
  - Suggest that when closure is manifested in /s':/, it is realized as [t:s']
  - Also suggest that when accompanied by closure, the ejective fricative is phonologically similar to an affricate
  - Closure duration, not release duration, signals phonological length among ejective fricatives
    - Seen in affricates in Hungarian

# Discussion

- Acoustic properties
  - Pulmonic release is significantly longer than ejective (for fricatives)
    - Was expected and supported by findings in similar languages
  - Laryngeal duration  is greater for ejective fricatives
    - Also seen in other languages ejective fricatives
  - Vowels preceding ejective fricatives are significantly longer than vowel preceding pulmonic fricatives
    - None is said about following vowels
  - Ejective fricatives have a higher amplitude slope than pulmonic
    - High amplitude slope have been associated with differentiating affricates and fricatives
      - However, this is not the case for Tigrinya
  - Rise time results were not significant

# Conclusion

- In 80% of tokens, /s'/ showed signs of closure
  - "The pre-release closure was significantly shorter than the closure of phonological ejective affricates "
  - Closure was not present in all cases
- There are several other acoustic cues that aid in differentiating ejectives from pulmonic fricatives
- Overall, it's too early to reclassify /s'/ as [ts']
  - However, this may be a "phonologically-natural, aerodynamically-conditioned sound change in progress"
  - Since there is no ejective affricate located in the same place of articulation, it is possible to have speaker produce this phoneme without consequence

# Works cited

Shosted, R. K., & Rose, S. (2011). Affricating ejective fricatives: The case of Tigrinya. *Journal of the International Phonetic Association*, *41*(1), 41–65. http://www.jstor.org/stable/44526590