

Duration of Blackfoot /s/¹
A comparison of assibilant, affricate, singleton, geminate and syllabic /s/

Donald Derrick
University of British Columbia

A study comparing the duration of assibilant, affricate, singleton, geminate and syllabic /s/ from the citation speech of one speaker demonstrated significant differences in the duration of geminate /s/ ($\mu = 300$ ms), syllabic /s/ ($\mu = 240$ ms), singleton /s/ ($\mu = 155$ ms), and affricate /s/ ($\mu = 130$ ms). The results show the expected contrast between short and long /s/, and between inter-consonantal long /s/ and affricate /s/, lending support to the Blackfoot syllabic /s/ analysis in Derrick (2006). Length measurements also showed a significant symmetrical relationship between vowel adjacency and long /s/ duration, demonstrating an inverse relationship between amplitude and duration of Blackfoot /s/. The cross-linguistic implications for sibilants are significant and further research with more participants, more languages and using natural speech, into the relationship between duration and intensity is indicated.

1 Introduction

Blackfoot is an Algonquian language primarily spoken in Alberta and Montana. The inventory of Blackfoot consonant includes /m/, /n/, /p/, /t/, /k/, /tʰ/, /kʰ/, /s/ and /x/² in singleton and geminate contrasts. Blackfoot has only the one sibilant sound, alveolar frication. This Blackfoot /s/ appears in the context of assibilation, affricates, singletons, geminates, syllabic /s/, and “super-long” combinations. While a detailed phonological explanation and justification for each category of /s/ appears in Derrick (2006), a descriptive summary follows:

1.1 Assibilation

Assibilation occurs when an underlying /k/ or /t/ occurs next to an /i/; the sequence /ki/ become /k^si/ across morpheme boundaries and /ti/ always becomes /t^si/. (F&R 1991, 1995; Chávez-Peón, 2006; Armoskaite, 2006).

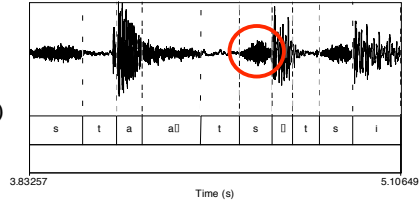
¹ Special thanks to Beatrice Bullshields who provided all the elicitations for the data marked (BB date).

² Blackfoot /x/ is better described as a “back fricative” which always forms the frication noise for a preceding back vowel. The actual place of articulation depends on this preceding vowel (Derrick, 2006).

Example 1: Assibilation

[staʁxtsɪtsi] staajt-itsi
under-pant "underpant"
(F&R 1995:232) (BB 06/02/09)

Figure 1: Assibilation



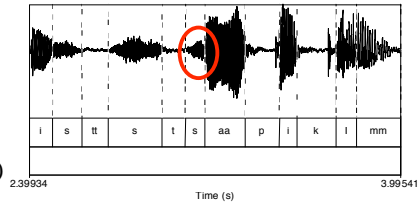
1.2 Affricates

Affricates are /ks/ or /ts/ sequences within a morpheme (Elfner, 2004) and they represent a single phonological segment.

Example 2: Affricates

[ɪst:stsá:pikim:] isttsi-
 tsáápi-kimm
pain-wire/string "barbed wire"
(F&R 1995:97) (BB 06/02/01)

Figure 2: Affricates



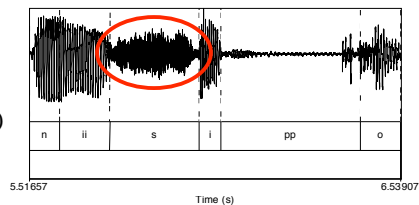
1.3 Singletons

Singleton /s/'s are segmental /s/'s that, when they follow a vowel, do not alter that underlying vowel's length (F&R 1995). A long vowel before a singleton /s/ will stay long:

Example 3: Singletons

[ni:sp:o] niis-kiipo
four-ten "forty"
(F&R, 1995:134) (BB 05/10/12)

Figure 3: Singletons



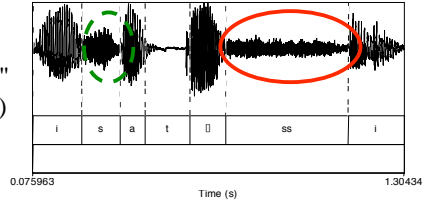
1.4 Geminates

Geminate /s/ is here defined as an /s/ which shortens preceding long vowels or makes preceding short vowels lax (F&R 1995). These /s/ sounds always follow vowels.

Example 4: Geminate

[ɪsətɛs:i] i-sataɪssɪ
 VERB-offended "be offended!"
 (F&R 1995:204) (BB 06/02/01)

Figure 4: Geminate



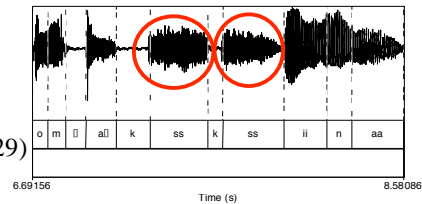
1.5 Syllabic /s/

Syllabic /s/ is here defined as long /s/ preceded by a consonant (Derrick, forthcoming). Syllabic /s/'s do not have an effect on the duration of neighboring vowels.

Example 5: Syllabic /s/

[ʔómʔaks:ks:i:na:] omahk-
 sskssiinaa
 big-insect "big insect"
 (F&R 1995:86) (BB 05/11/29)

Figure 5: Syllabic /s/



1.6 Super-long combinations

Super-long combinations are defined as spirantizations and/or affricates followed by syllabic /s/. They show up in F&R's dictionary with an orthographic representation of three s's in a row.

2 Hypotheses

The goal of this research is to examine whether these Blackfoot /s/'s can all be distinguished from each other by duration. Five hypotheses must be tested. Hypothesis 1 and 2 are expected to be true as they represent the definitions of long, short affricate sounds: 1) Blackfoot long /s/ will be longer than singleton /s/ and 2) Singleton /s/ will be longer than affricate /s/.

It is unclear whether hypothesis 3, Blackfoot geminate /s/ and syllabic /s/ will be the same duration, is expected to be true, but is worth testing for because the answer is needed to test hypothesis 5 below:

Assuming there is no sibilant neutralization in Blackfoot, hypothesis 4 is: Blackfoot affricate /s/ will be longer than Blackfoot assibilant /s/. So hypothesis 4 becomes a way to test for neutralization.

Lastly hypothesis 5 states: All Blackfoot /s/'s will be longer when adjacent to vowels than when adjacent to consonants. This final hypothesis conflicts with hypothesis 3 above in that a geminate /s/ will always follow a

vowel and therefore be adjacent to 1 vowel or possibly 2 vowels, whereas a syllabic /s/ cannot follow a vowel and will therefore be adjacent to 0 or 1 vowels.

3 Methods

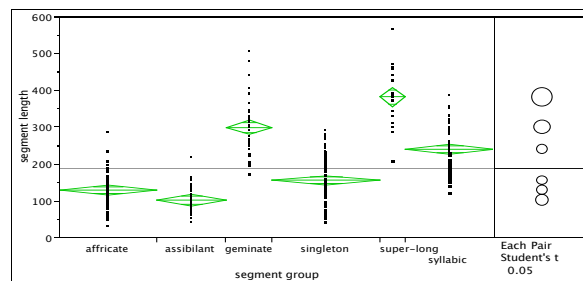
Blackfoot data involving /s/ in all the contexts listed was recorded and /s/ durations were measured in order to test the above 5 hypotheses. One participant (Beatrice Bullshields) provided citation form words containing: Blackfoot assibilations (t-V and k-V³), affricates (t^sC, t^sV, k^sC, k^sC), singletons (VsV, VsC, CsV), geminates (Vs:V, Vs:C), syllabic /s/'s (Cs:V, Cs:C) and super-long /s/'s (C^ss:V). For each type listed above, a minimum of 3 tokens from 6 words for 18 measurements was elicited (except k^sV - 14 only). Recordings were completed using a Marantz 660 solid-state recorder with a countryman (phantom power) wired lapel microphone. Measurements were recorded using text tiers on PRAAT 4.4.0.7 for Mac. Measurements were taken off the waveform at the beginning and end of frication. Data was compiled in Excel 2004 for Mac, and statistics were analyzed using JMP IN 5.1 for Mac.

4 Results

4.1 Results by /s/ category

All of the categories of /s/ were significantly different $F(5,252) 123, P < 0.0001$. Also, each category is statistically different from each other $P < 0.005$. The average (mean) duration ranged from 103 ms for assibilants, 129 ms for affricates, 155 ms for singletons, 240 ms for syllabic /s/'s, 300 ms for geminate /s/, and 382 ms for syllabic + assibilant/affricate combinations (super-long /s/).

Figure 6: Standard Deviation and Student's t by /s/ Category



While there is a lot of variance within each group, student's t tests nevertheless divide each of these groups into their own distinct levels:

³ C = Consonant, V = Vowel, “-” = morpheme boundary, ^s = affrication, s = singleton /s/, s: = long /s/.

Table 1: Means for oneway anovas and student's t levels

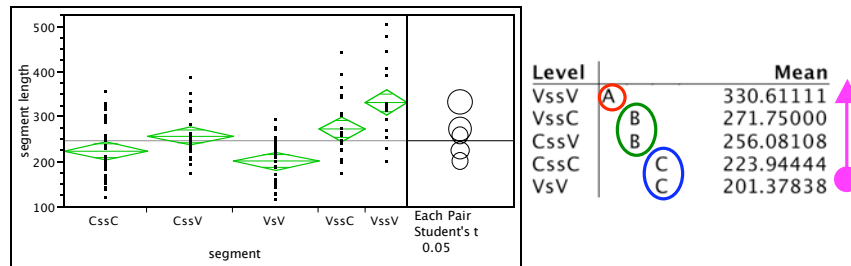
Means for Oneway Anova						Level	Mean
Level	Number	Mean	Std Error	Lower 95%	Upper 95%		
affricate	80	129.588	6.744	116.32	142.85	super-long	A 381.52381
assibilant	57	102.579	7.990	86.87	118.29	geminate	B 299.63158
geminate	38	299.632	9.786	280.39	318.88	syllabic	C 240.23288
singleton	89	155.348	6.394	142.77	167.92	singleton	D 155.34831
super-long	21	381.524	13.163	355.63	407.41	affricate	E 129.58750
syllabic	73	240.233	7.060	226.35	254.12	assibilant	F 102.57895

Std Error uses a pooled estimate of error variance

4.2 Results by vowel adjacency

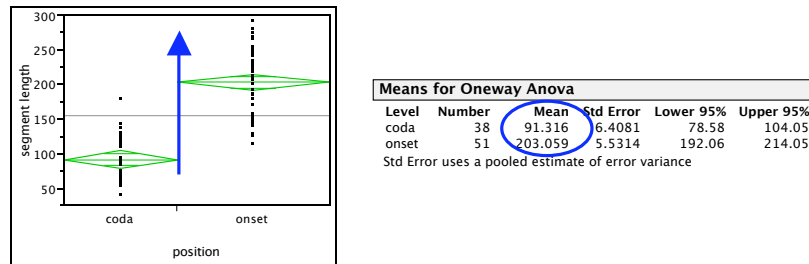
Vowel adjacency to either edge of a long /s/ correlates to greater duration. The resulting duration of a geminate /s/ followed by a consonant is similar to the duration of a syllabic /s/ followed by a vowel. Duration of a consonant-bounded syllabic /s/ similar to intervocalic singleton /s/. However, intervocalic geminates are much longer than intervocalic singletons.

Figure 7: SD Graph and student's t level table for short and long /s/



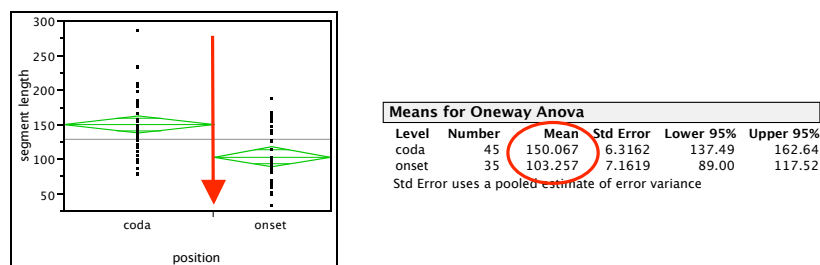
Singleton /s/ in onset position, with a mean duration of 203 ms, is over 100% longer than singleton /s/ in coda position (mean duration 91 ms).

Figure 8: comparison of singleton /s/ onset and coda duration



In contract, affricate /s/ in onset position, with a mean duration of 103 ms, is 33% shorter than affricate /s/ in coda (mean duration 151 ms):

Figure 9: Comparison of duration of affricate /s/ in onset and coda position



Both results are highly significant ($P < 0.0001$).

5 Discussion

5.1 Hypothesis 1: Blackfoot long /s/ will be longer than singleton /s/

This hypothesis is supported. Geminate /s/ is 100% longer than singleton /s/, just like other geminates in Blackfoot (Derrick, 2005).

5.2 Hypothesis 2: Singleton /s/ will be longer than affricate /s/

This hypothesis is supported; Blackfoot singleton /s/ is about 25% longer than affricate /s/. Careful analysis of the results show this effect is more robust when conditions are carefully controlled. In onset position, the difference is much greater with affricate /s/ at mean 103 ms and singleton /s/ at mean 201 ms, or 100% longer. However, coda /s/ and affricate /s/ are nearly identical in duration.

5.3 Hypothesis 3: Geminate and syllabic /s/ will be the same duration

This hypothesis was falsified; syllabic /s/ is on average 25% shorter than geminate /s/. However, this observation obscures the relevant details: In Blackfoot, long /s/'s are approximately 50 ms longer per edge adjacent to a vowel regardless of whether the edge precedes or follows the long /s/. This duration effect is symmetrical and phonetic in origin and is discussed in greater detail below.

5.4 Hypothesis 4: Affricate /s/ will be longer than assibilant /s/

This hypothesis at first appears to be supported. Blackfoot affricate /s/ is about 25% longer than assibilant /s/. However, assibilant and affricate /s/ are similar lengths when in onset position. Since all assibilants are by definition in onset position then the only relevant comparison is onset position comparison. There is no difference in duration in onset position, so this hypothesis is falsified.

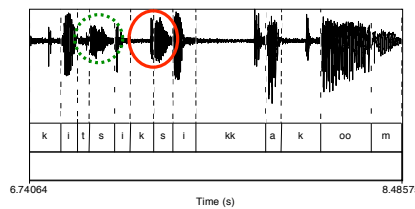
5.5 Hypothesis 5: /s/'s will be longer when adjacent to V vs. C

This hypothesis, as stated, is falsified. Blackfoot singleton and geminate /s/ are longer when adjacent to vowels (The /s/ in VsV is longer than VsC and the /s/ in Vs:V is longer than Vs:C, but affricates are shorter when adjacent to vowels (the frication in Vt^sV, Vk^sV is shorter than the frication in Vt^sC, Vk^sC)

5.6 Discussion of symmetrical effects

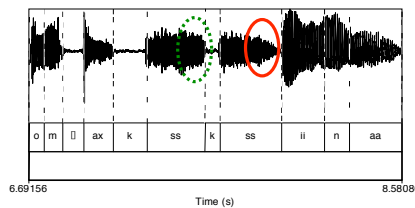
Slower energy changes on either side of /s/ sounds may correlate with longer durations in /s/ sounds. The energy of /s/ builds slower off of /t/ than /k/ onset, as shown in this example. The result is that the frication in /t^s/ affricates has a slightly longer duration than the frication in /k^s/ affricates:

Figure 10: /ts/ and /ks/ energy transitions



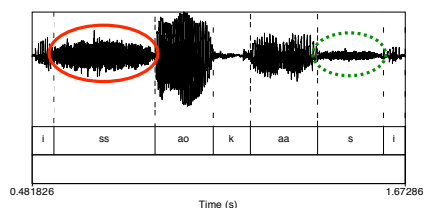
The same result occurs with long /s/. The /s/ energy decreases slowly into a vowel, quickly into a consonant. This effect may be responsible for the durations differences observed between /s/ bound by consonants and /s/ bound by a vowel on either side:

Figure 11: /s/ Energy transitions into consonants and vowels



Note that singleton /s/ is shorter and sometimes quieter than geminate /s/. This energy difference may also help distinguish short and long /s/:

Figure 12: Energy and duration differences between short and long /s/



These energy differences support the idea that /s/ in Blackfoot may be distinguished not only by duration, but also by energy (loudness), and that it is the combination of the two that help a learner distinguish between affricate /s/, short /s/, and long /s/. This hypothesis bears further research and testing.

6 Conclusion

The results strongly support the distinction between long /s/, short /s/ and the fricative portion of affricate /s/, as they should. These results provide support for the syllabic /s/ analysis proposed in Derrick (2006), and confirm the distinction of both t^s and k^s affrication from singleton /s/. Assibilant and underlying affricate /s/ have statistically similar duration in onset position. Despite the underlying differences these differences are neutralized: affricates and assibilants have similar surface representations in citation speech.

The results also show that with long /s/, vowel adjacency effects are symmetrical and phonetically motivated. The implication is that short and long /s/ are distinguished through a combination of duration and energy (loudness and long-ness). The cross-linguistic typological implications of an inverse relationship between duration and energy in sibilant frication is extremely important, and bears further research with more speakers, more languages, natural speech, and a careful control of recording volume.

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