Voiced Stops in Jamaican Creole*

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1. Introduction

The purpose of this project is to investigate the phonetic implementation of phonologically voiced stops in Jamaican Creole (JC) using spontaneous speech data. As an English-lexifier creole, JC has traditionally been described as having a contrast between voiceless and voiced stops with the voiced stops being pronounced as plosives (Cassidy & LePage 1980). Recent work has shown that this is not always the case for the voiced stops. Devonish & Harry (2004) as well as Harry (2006) have described the voiced stops as phonetically produced as implosives in stressed word-initial position and as plosives elsewhere. Making use of spontaneous speech data, Gooden & Donnelly (2009), have shown implosion to be a variable feature in stressed word-initial context. With acoustic evidence of variation present, this project attempts to address the extent to which this variation may be patterned based on various internal and external factors such as place of articulation, age, gender, or geographical region.

This project has important implications for creole linguistics, contact phonology, and sociophonetics. First of all, there is relatively little published work on creole phonology compared to morpho-syntactic aspects of creoles. Furthermore, implosives appear to be a substrate feature in JC. If this is the case then understanding why they are still present in the language and the contexts in which they are found can lead to a better understanding of creole development. Implosives are also a typologically marked class of sounds. This project, thus, also speaks more generally to the question of how phonological systems develop in contact situations. It has also long been noted that the difference between plosives and implosives is a difference based on a gradient continuum (cf. Ladefoged 1964). With increasing interest in exemplar theory and gradient approaches to sound change, research on this understudied class of sounds from a variationist perspective has much to contribute to the emerging field of sociophonetics more generally. Since there are few models as to how to acoustically measure degrees of implosion, the pilot study presented here aims to provide a methodological foundation for future studies.

Following a review of relevant literature on Jamaican Creole phonology and on implosives in general in the next section, the specific research questions for this pilot study will be presented in Section 3. This will be followed by a presentation of the methodology used in this pilot study of voiced stops in JC in Section 4. The results of this pilot study will be presented in Section 5 followed by a discussion of these results in Section 6. Section 7 will conclude this paper.

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2. Literature Review

2.1 Sociolinguistic Context

In order to understand the modern sociolinguistic situation on the island of Jamaica, the historical development of two main language varieties needs to be presented. These two language varieties are Jamaican Creole (JC), also popularly known as Jamaican Patwa, and Standard English, or more specifically Jamaican English (JE).

Cassidy & Le Page (1980) provides background on the linguistic history of Jamaica. The earliest known inhabitants were the Tainos, who spoke an Arawakan language. The first European settlers on the island were the Spaniards, who arrived in the 1490's and eradicated the indigenous population after a century of settlement. The only remaining linguistic evidence from this period is in the form of a handful of loan words in JC. Spanish settlement also brought the first group of West African slaves to the island. Following the Spaniards, the English took over the island in 1655. The importation of slaves from Africa continued until the abolition of the slave trade in 1807. From 1655-1700, a majority of slaves spoke languages belonging to the Twi-Fante-Ga-Ewe groups. These languages are believed to be the West African substrate languages that contributed to the development of JC.

According to Cassidy & Le Page (1980), it was in the 1700's that English became a lingua franca used among all inhabitants on the island including the slave and free white population. This would have basically set the model for what would eventually develop into modern-day JE. The sources would have included Scottish English and educated southern varieties of British English. For the slave population, the phonetic structure of this lingua franca would have been reinterpreted through the phonology of West African languages such as Twi or Ewe. The resultant creolized language would become modern-day JC.

From the 20th century to the present day, the sociolinguistic relationship between JC and JE has been described in various ways. Following a classic Ferguson (1959) model of diglossia, JC can be described as the low or vernacular language while JE can be described as the high or standard language. According to DeCamp (1971), the speech of most modern-day Jamaicans can be placed along a continuum defined by these two varieties. Under this continuum model, JC is described as the "basilect" while JE is described as the "acrolect". Speech containing features of both the basilect and the acrolect are described as "mesolectal".

Devonish & Harry (2004) have proposed that all speakers of JE are also speakers of JC. JE would basically be a second language acquired by native JC speakers through formal education. Building on De Camp's (1971) proposal for the usage of variable rules, Devonish & Harry (2004) have also described JE speakers as viewing a systematic relationship between these two "idealized" varieties. While diachronically the relationship between cognates in JC and JE can be described as one of correspondence, Devonish & Harry (2004) follow Cassidy & Le Page (1980) in describing JC forms as the reflexes of the JE (or RP English) forms. The use of the term "reflex" is designed to capture the fact that speakers view a synchronic relationship between JC and JE in which JC forms are derived from their corresponding JE forms through a set of correction rules.

Some scholars have complicated this traditional model. Patrick (1999), for example, has argued that this continuum is a uni-dimensional structuralist model that ignores the full range of speech styles used among Jamaicans in urban areas of the island. Adopting an interactional sociolinguistics approach, some scholars have also complicated the model by exploring the role of speaker agency not just for JC but also for other creole continua that have been described elsewhere in the Caribbean (Hinrichs & Farquharson 2011).

Whichever perspective one adopts, what should be clear is that there is quite a bit of intra-speaker and inter-speaker variation in Jamaica. It should, therefore, not be a surprise to see variation in the usage of individual phonetic features such as consonants. Yet, little empirical research using acoustic data has been conducted on JC. The question to be addressed is to what extent variation in voiced stop production is patterned systematically? Would usage of implosives be more indexical of the JC end of the continuum while use of plosives is more indexical of the JE end of the continuum?

2.2 Literature on Jamaican Creole (JC) Voiced Stops

While implosives are likely to be a substrate feature in JC inherited from West African languages, there have been surprisingly very few publications that have described an implosive quality to the voiced stops. Cassidy & Le Page (1980) provides perhaps the most detailed published description of the historical phonology of JC. Yet, nothing is mentioned about the presence of implosives. Instead, all voiced stops are described as plosives (pulmonic egressive). This same publication mentions possible West African substrate languages such as Twi and Ewe. Voiced plosives rather than implosives, however, are described as historically present in these languages. Meade (2001) discusses first language acquisition of JC phonology. Even with recordings of speech available, however, there is no mention of implosives being produced. Instead, all voiced stops are again described as plosives.

Devonish & Harry (2004) is perhaps the first publication to mention implosives in JC. More specifically, the implosives [ɓ], [ɗ], and [ɠ] are described as allophones of the voiced plosives /b/, /d/, and /g/ respectively occurring in the onset of a prominent syllable. Elsewhere, such as in coda position or as the onset of a non-prominent syllable, they argue that stops are realized as plosives. Their description of onset clusters, however, seems to be a notable exception to their claim. The allowable onset clusters with voiced stops that they describe include [br], [dʒr], and [gr]. Yet, in each of these cases, the voiced stop is described as being produced as a plosive rather than as an implosive. Harry (2006), however, includes one word, [ɓreɗa] 'brother/friend', that illustrates the presence of implosion in this environment. For stops involving secondary articulations such as labialization and palatalization, Harry (2006) also describes the presence of plosives rather than implosives. The following words are examples that illustrate this:

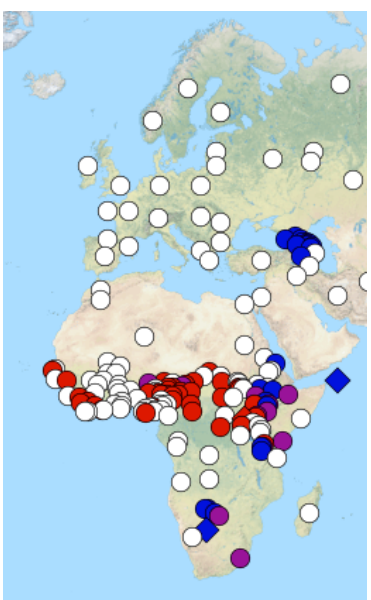
Word	Gloss
[bʷai]	'boy'
[gʷaːn]	'go on'
[kʲuː]	'a quarter quart (of rum)'
[gʲaːd]	'guard'

It is important to note that although Harry (2006) makes reference to acoustic data, none of it is actually discussed and examined in detail in the paper. Gooden & Donnelly (2009) addresses this lacuna by conducting a detailed acoustic examination of JC voiced stops in spontaneous speech data. This study found that implosives were not always produced in the onset position of prominent syllables as described by Harry (2006). Instead, implosives are described as possibly occurring in free variation in this environment. Gooden & Donnelly (2009), however, also involved a limited amount of data. In the pilot study discussed in this present paper, an attempt will be made to take a closer look at acoustic data from additional speakers to determine whether or not this variation can be described in terms of various internal and external factors.

2.3 Literature on Implosives

2.3.1 Significance to Creole Linguistics

While creole linguistics has looked at a variety of features in support of both universalist and substrate/superstrate theories, very few with the exception of Smith & Haabo (2007) have looked at the presence or absence of implosives. Following a universalist account, the fact that they occur in at least some creoles makes them an anomaly. According to the World Atlas of Linguistic Structures (WALS), implosives are a typologically rare sound found in only 75 out of the 567 (or 13%) languages surveyed (Maddieson 2011). Many of these languages are found in a "middle belt" (illustrated by the red dots in Figure 1 below) stretching from the western end of Africa to the eastern end of the continent. These include languages from the Niger-Congo, Nilo-Saharan, and the Afro-Asiatic families. The widespread presence of implosives in languages from this part of the world and their virtual absence from Western Europe suggests that their presence in JC would have most likely been inherited from an African substrate language.



<u>Figure 1: "The Middle Belt":</u> Home of the largest concentration of languages in the world containing implosives. A red dot indicates a language with implosives. A purple dot indicates a language with both implosives and ejectives. A blue dot indicates a language with ejectives but without implosives. A white dot indicates a language that completely lacks glottalized consonants (implosives, ejectives, and glottalized resonants). <u>Source:</u> *Online version of the World Atlas of Linguistic Structures: Map 7A*

Both Twi and Ewe, mentioned in Section 2.1, do in fact belong to the Niger-Congo Family and more specifically to the Gbe branch. Cassidy & Le Page (1980), however, also mention that these languages have plosives rather than implosives. Capo (1991), which featured a comparative phonological study of the entire Gbe branch, also describes plosives to the exclusion of implosives for this entire group of languages. As suggested by the name, however, the Gbe languages do contain doubly articulated labio-velar sounds represented as g͡b and k͡p. Ladefoged & Maddieson (1996) have speculated that the articulatory nature of these sounds might actually make them implosives. They also note that the labial implosives in Central Igbo are in fact derived from these sounds. Thus it seems possible that a labial implosive in JC could have been derived from the g͡b found in one of the West African substrate languages.

It should be noted that the description of these possible West African substrate languages is based on 19th and 20th Century textual sources. Thus, the possibility that the voiced stops were pronounced as implosives at an earlier stage of Twi and Ewe such as during the time of arrival of slavery in Jamaica should not be ruled out. Although, Cassidy & LePage (1980) focus on Twi and Ewe, there were many other languages spoken by the slaves. It could also be possible that one of the less commonly spoken languages among the slave population was the source of the implosives. The fact is actual sound recordings of the African substrate languages as spoken during the time of slavery do not exist. Thus, it is impossible to know for sure whether or not any of the potential substrate languages had implosives in the 17th Century.

Smith & Haabo (2007) have described a similar scenario in their analysis of the development of implosives in Saramaccan Creole. In this case, Fon and Kikongo have been identified as the most important African substrate languages in the development of Saramaccan. Yet, like modern-day Twi and Ewe, published sources show that Fon and Kikongo lack implosives. Thus, the question that needs to be addressed is how modern Saramaccan would have developed implosives if its African substrate languages have been described as lacking these sounds. It turns out that the ancestor of these languages, Proto-Volta-Congo, has been reconstructed as having implosives. This suggests the possibility that some of the descendant languages also had implosives. Smith & Haabo raise the possibility that these stops have been continuously pronounced as implosives up until at least the 1700's when Fon speakers arrived in the New World. It would have been after the 1700's that these implosives became plosives in Africa but retained their implosive pronunciation in what would develop into modern Saramaccan. Even if this account seems to contradict written descriptions of these West African languages, Smith & Haabo (2007) suggest that perhaps modern Saramaccan may actually provide evidence challenging these descriptions. If it is possible that implosives were retained from West African substrate languages in Saramaccan, it seems like this could have equally been possible for JC. Investigating variation in voiced stops in modern JC could provide evidence for how JC phonology developed.

2.3.2 Phonetic Research on Implosives

The previous phonetics literature on implosives has examined articulatory, aerodynamic, and acoustic properties of their production. In terms of articulation, implosives can be defined as "stops that are produced with a greater than average amount of lowering of the larynx during the time that the oral closure for the stop is maintained" (Ladefoged & Maddieson 1996: 82). Implosives are glottalic ingressive and thus involve the use of the glottalic airstream mechanism as opposed to plosives which are pulmonic egressive and involve the use of the lungs as the airstream mechanism. There is, thus, a suction of air pushing the larynx downwards.

While this articulatory definition seems clear, the aerodynamic effects of this articulation appear to be more variable. For voiced implosives, in particular, the lowering of the larynx occurs while the vocal folds are also vibrating. If the downward movement occurs rapidly enough, negative pressure develops in the oral cavity leading to air flowing into the mouth upon release of the stop. This would result in a "true" implosive. Sometimes, however, the airflow through the glottis that is needed to vibrate the vocal folds is great enough to counteract the effects of the air flowing into the mouth. When this happens, the pressure in the oral cavity is not negative and consequently there is no ingressive airflow at the time of stop closure. For this reason, Ladefoged and Maddieson (1996) have described a gradient continuum between voiced plosives and "true" implosives. This variability has been observed since Ladefoged's (1964) seminal "Phonetic Study of West African Languages". In this earlier study, he described voiced implosives as both glottalic ingressive and pulmonic egressive. In contrast, voiced plosives were described as not necessarily involving any downward movement of the glottis at all. Thus it may be more accurate to describe voiced implosives as both glottalic ingressive and pulmonic egressive rather than as simply glottalic ingressive.

In terms of acoustic effects, the general consensus seems to be that voiced implosives involve a greater degree of overall voicing than for plosives. This can be illustrated in Lindau's (1984) comparison of voiced plosive and voiced implosive stops in Degema, a Nigerian language with a contrast between these two classes of sounds. While the waveform of the implosive is characterized by increasing amplitude, the plosive is characterized by decreasing amplitude. Since implosives involve a downward movement of the larynx and hence an expansion in the oral cavity leading to a decrease in supraglottal pressure, the net effect is that it is easier to maintain the greater pressure differential required for voicing. This results in the extra voicing involved in implosive production. The difference between the Degema stops is illustrated below in Figure 2.

[INSERT IMAGE HERE]
Figure 2: The above image is from Lindau (1984).

It should also be noted that not all voiced implosives in all languages are articulated in the same way or look the same acoustically. For example, Nihalani (1986) shows that the voiced implosives in Sindhi are "true" implosives in the sense that they consistently involve ingressive airflow without a sufficient level of counteracting pulmonic egressive airflow. In addition, the average duration of implosives was shown to be longer than for voiced plosives in Sindhi. This contrasts with the implosives found in Hausa in which there is a tendency for sufficient counteracting pulmonic egressive airflow. Nihalani attributes this difference to a difference in timing of the oral closure in these two languages.

Demolin et al (2002) also discusses a different type of voiced implosive. This study examined what is referred to as the "unexploded palatal implosive" in Hendo, a

Bantu language spoken in the Democratic Republic of Congo. This sound, represented as [ʄ ̚], occurs as an allophonic variant of /dʒ/ preceding consonants. Rather than showing rising voicing amplitude during the duration of the implosive, the data from Hendo show the opposite. Demolin et al attribute this difference to the fact that the implosive is always followed by a vowel in the data from Lindau (1984) while in the case of Hendo, [ʄ ̚] occurs only preceding consonants. Rising amplitude alone, thus, is not always a reliable indicator of implosion as the following segment can potentially effect whether or not this rise occurs. Because of the various aerodynamic factors that can interact with the production of voiced implosives, many studies that have examined them including Demolin et al (2002) have incorporated a variety of measurements including acoustic analysis, oral air flow tests, MRI data, and even video images. Any one of these measurements alone is not adequate to get the full picture of what goes on during implosive production.

While the variable nature of implosive production appears to pose a challenge to research, this variable nature also lends itself to being an ideal type of sound to examine from a variationist perspective. Hamann & Fuchs (2010) have argued that the plosive-implosive continuum makes it possible for plosives to diachronically become implosives and vice-versa. If this turns out to be true, then it would be possible to measure degrees of implosion as a measurement of diachronic change in voiced stop production in a language such as JC. For instance, could different degrees of implosion correlate with membership in various social groups or at least be indexical of these groups?

In order to address this question, it would be important to first identify an appropriate method for measuring degrees of implosion. First of all, due to practical limitations, the methodology would have to be limited to acoustic data. While it would hypothetically be possible to collect other types of data such as oral airflow measurements, video images, etc. from JC speakers, this study also aims to bring in historic recordings from the 1950's as a basis of comparison to see if change has occurred. Secondly, although the literature has shown implosives to have variable acoustic properties it would be important to look at more than one way of measuring implosion.

Gooden & Donnely (2009) provides a point of departure. This study examined four acoustic correlates indicative of implosion: increasing amplitude in the waveform at the point of stop closure, increasing darkness of the voice bar on the spectrogram at the point of stop closure, steepness of the intensity contour, and similarity of an LPC spectral slice to a prototypical implosive in Sindhi. The problem with this methodology, however, is that the measurements were all qualitative and highly subjective. One potential route that could be pursued for this project would be to quantify each of these measures.

To keep this initial pilot study focused, the first of these measures that will be explored is steepness of the intensity contour. This measure was chosen because there is another existing model in the literature (Lindau 1984). It appears that the only language in the literature that has not been described as showing increased intensity for implosives is Hendo but in the case of Hendo the implosive occurs only before consonants. For JC, the previous literature discussed suggests that implosives would normally occur preceding a vowel. Because of this, the quantitative methodology used by Lindau (1984) seems appropriate for this study.

3. Specific Research Questions of Pilot Study

The specific research questions for this pilot study are as follows.

1. Is there intra-speaker variation in the production of voiced labial stops?
2. Is there inter-speaker variation in the production of voiced labial stops?
3. Is intensity ratio a good measure of degree of implosion?

Based on results of this initial study, we may attempt to take other quantitative measurements of implosion.

4. Methodology

4.1 The Data

The speech of a total of three speakers is compared for this pilot study. In order to study variation within the context of change, this includes data collected from the 1950's as well as more recent data collected in the early 21st Century. The 1950s data is perhaps one of the earliest available recordings of JC.

Speaker 1

The first speaker is a female speaker in her 20's from the Eastern part of Jamaica. The audio files of her speech were recorded as part of Harry (2006). They include a word list reading and a reading of a passage. The reading passage was "the North Wind" text, which has become a standard passage for articles published in the *Journal of the International Phonetic Association*. There are a total of 16 tokens in the word list data that contain the phoneme /b/. In all of these tokens except for one, the /b/ occurs in word-initial position in a stressed syllable. The one exception is the word [tiabul] 'table', in which the /b/ occurs in intervocalic position. In the reading passage, there were a total of 4 tokens containing /b/. All of these 4 occur in word-initial position in monosyllabic words.

Speaker 2

The second speaker is a male speaker from Moore Town, a rural Maroon community located in Portland Parish on the eastern side of the island. The interviewer was David DeCamp who subsequently published several dialectological studies of Jamaican speech. At the time of the interview in December 1958, there were several people listening in the background. This speaker occasionally code switches to Kromanti, a language similar to Akan that is spoken within the maroon community. There were a total of 10 tokens analyzed containing /b/. All of these occur in word-initial stressed position in monosyllabic words.

Speaker 3

Finally, the third speaker is a female speaker from Top Alston, located in Clarendon Parish in the central part of Jamaica. This is also a rural part of the island. This speaker was recorded as part of Gooden (2003). Only two tokens from this speaker were analyzed for this pilot study. Both of these tokens were of the same word, [alibotn] in two different sentences.

4.2 Procedures

All of the data was analyzed using the phonetic analysis software PRAAT. For each token, the following measurements were taken.

a) Intensity at stop onset
b) Time at stop onset
c) Intensity at stop offset
d) Time at stop offset
e) Intensity at stop midpoint

The procedures for collecting these measurements are as follows. First of all, a three-tier textgrid was created for each sound file. These tiers were labeled as "stop", "phones", and "word". The tier that is most relevant to this study is the "stop" tier. In this tier, both the stop onset and the stop offset were labeled as illustrated in the image below.

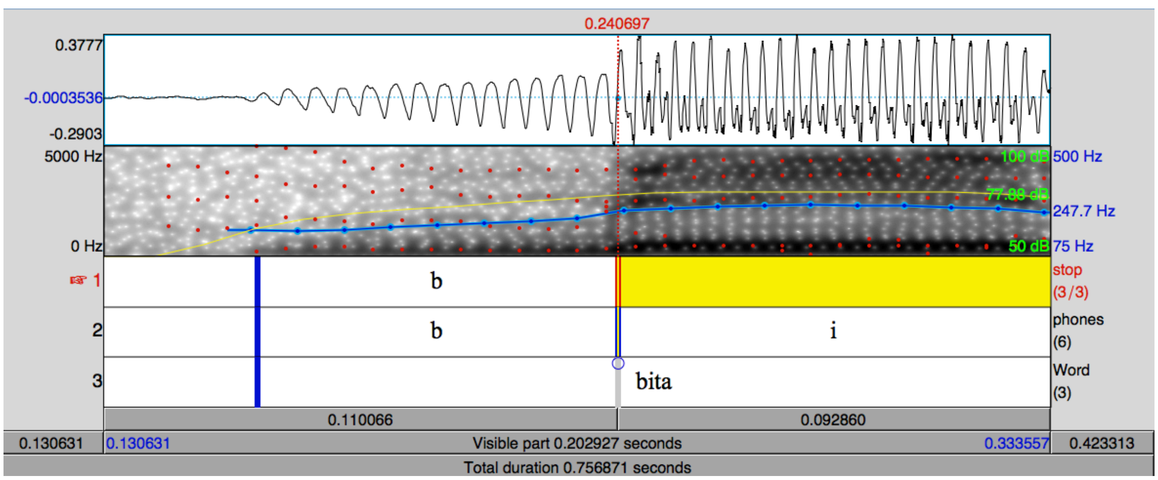


Figure 3: Example of Segmentation

With the stop offset highlighted as shown above, the "Intensity" Menu was selected then the "Intensity Listing" option was chosen. The time for the selected point as well as the intensity value in decibels appeared. These two values were copied and pasted to a MS-Excel spreadsheet. This procedure was repeated for the stop onset. In identifying both the stop onset and the stop offset, an attempt was made to label these boundaries at major transition points in the waveform that correspond to major transitions in the spectrogram. For example, in the image above, the offset was identified at a location in which there is a change in the waveform pattern that also corresponds to a point in the spectrogram in which dark bands indicating the higher formants appear in the spectrogram. Likewise the onset was identified at the point in which a regular periodic wave begins that also corresponds to the appearance of a dark band on the spectrogram that indicates the start of voicing. The "Select" menu and then the "Move cursor to nearest zero crossing" were also chosen to position the cursor at the nearest zero crossing.

Once the time and intensity for the stop onset and the stop offset were entered onto the Excel spreadsheet, an Excel formula was used to determine the location of the midpoint of the stop. To accomplish this, a column was first created with values that are equal to the difference between time at the offset and the time at the onset. This resultant column was labeled as the "duration" of the entire stop. Next, another column was created with a formula that divided the value of the duration by 2 and then added the resulting quotient to the time of the vowel onset. The resulting value became the time location of the midpoint.

The next step involved going back to the PRAAT sound file window and selecting the "Move cursor to" option under the "Select" menu. The midpoint value calculated by MS-Excel was entered as in the example below.

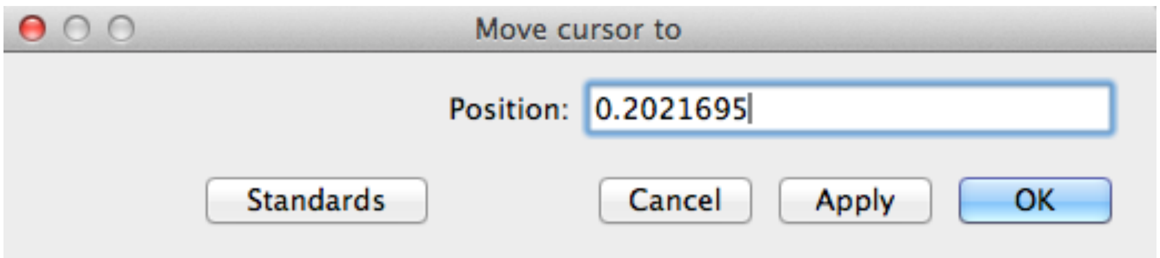


Figure 4: Example of how the stop midpoint was located

The cursor was then automatically placed at the midpoint of the stop. A textgrid with three tiers was created for each stop. The next step was to choose "Get intensity" option under the "Intensity" menu. This value was then entered into the Excel spreadsheet as the midpoint intensity.

Four additional calculated columns were added to the spreadsheet. Two of these included the ratio of the stop offset intensity / midpoint intensity and the ratio of the stop offset intensity / stop onset intensity. These ratios were modeled after the ratio of amplitude at stop release / amplitude at stop midpoint calculated in Lindau (1984). In this study, a ratio equal to one or greater indicates either level or rising amplitude and hence a more implosive-like stop. A ratio of less than one indicates a more plosive-like stop. Lindau (1984), however, did not use the stop onset and says that the midpoint is preferable "due to considerable variation in the onset of implosion." For the JC data used in this study, however, most of the tokens have the stop in word-initial position. Thus, it would be interesting to also include a ratio based on the stop onset to see if it differs significantly from the ratio calculated using the midpoint.

Finally, the other two calculated columns were for the differences in intensity values. One of these was calculated based on the stop offset and midpoint while the other one was calculated based on the stop offset and onset.

5. Results

The complete raw data is included in the Appendices. It should be noted that there were two tokens of /b/ in intervocalic context. The raw data for these two words are included in Appendices A1 and A2. The /b/ in /tiabul/ is the only word in the Word List data in which the /b/ has negative intensity ratios. This suggest that this /b/ is more plosive-like than the other /b/'s produced by this speaker in this context. There is also one word in Appendices A1 and A2 that includes /b/ in a cluster. This word, /breda/, was excluded from all the calculations shown below although the raw data suggests that it does not seem to pattern very differently from other words in the word list. The positive intensity ratios for /breda/ also seem to provide evidence confirming Harry (2006)'s description of this word as beginning with an implosive.

Below are descriptive statistics for each variable along with box plots.

5.1 Duration

For duration, the most notable patterns is that the average value in Word List Context for Speaker 1 is more than twice the average duration for the narrative context. Similarly, the average duration for Speaker 1 in Word List context is about twice the average duration for the other two speakers. Although the standard deviation is fairly high for the Word List Context values, the box plot shows most tokens in this context to be longer in duration than for all other contexts and speakers.

Speaker	**Duration (ms)**	**Std. Deviation**	**N**
Speaker 1 Word List	98.8377143	35.35779148	14
Speaker 1 Narrative	37.46475	23.35641536	4
Speaker 2	52.3392	29.50016955	14
Speaker 3	58.7395	10.78408552	2

Table 5.1.1: Average stop duration values

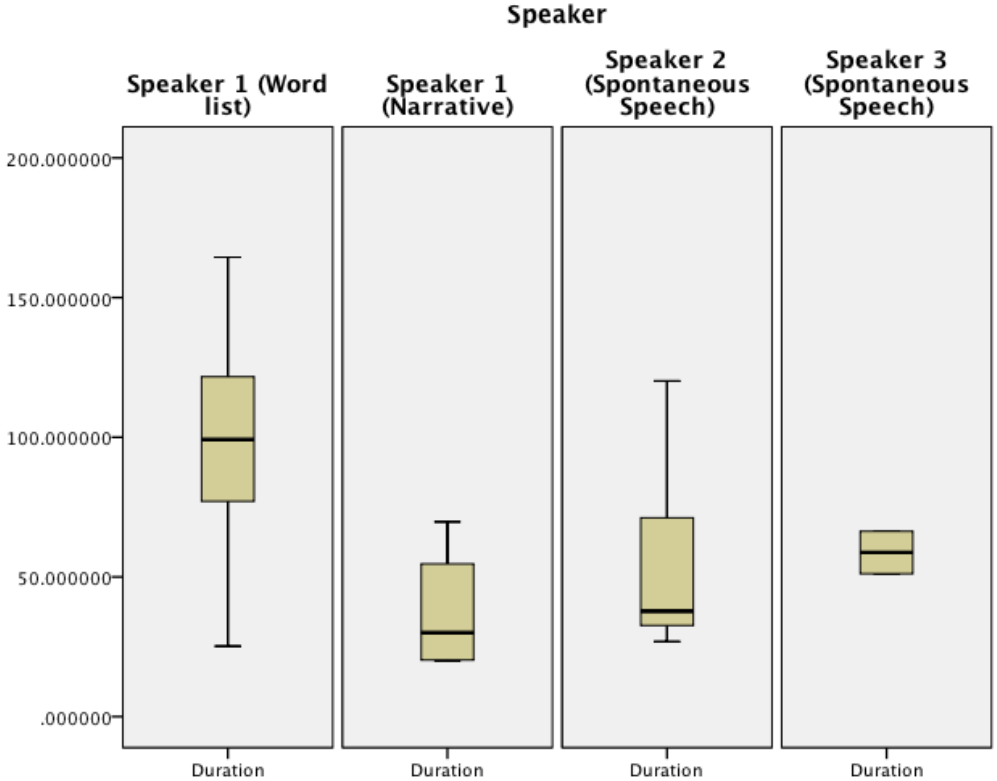


Figure 5.1.2: Boxplot of duration values

5.2 Intensity

For intensity values, we can see a similar contrast between Speaker 1 and the other two speakers. The intensity values are generally higher for Speaker 1 than they are for the other two speakers. The boxplot also shows another pattern. The intensity appears to gradually rise from the stop onset to the stop offset for Speaker 1 in the Word List context as well as for Speaker 2. Speaker 1 in the Narrative Context as well as Speaker 3 seem to have more of a falling-rising pattern for the intensity values.

Speaker	**Intensity (Onset, dB)**		**Intensity (Midpoint, dB)**		**Intensity (Offset, dB)**		**N**
		Std. Dev.		**Std. Dev.**		**Std. Dev.**	
Speaker 1 Word List	62.04	4.63	70.48	4.20	77.45	2.07	14
Speaker 1 Narrative	66.21	4.41	65.56	3.563	69.77	3.65	4
Speaker 2	50.32	2.98	53.89	5.52	65.80	4.85	14
Speaker 3	48.33	0.96	43.54	2.20	46.58	0.29	2

Table 5.2.1: Average intensity values at 3 points

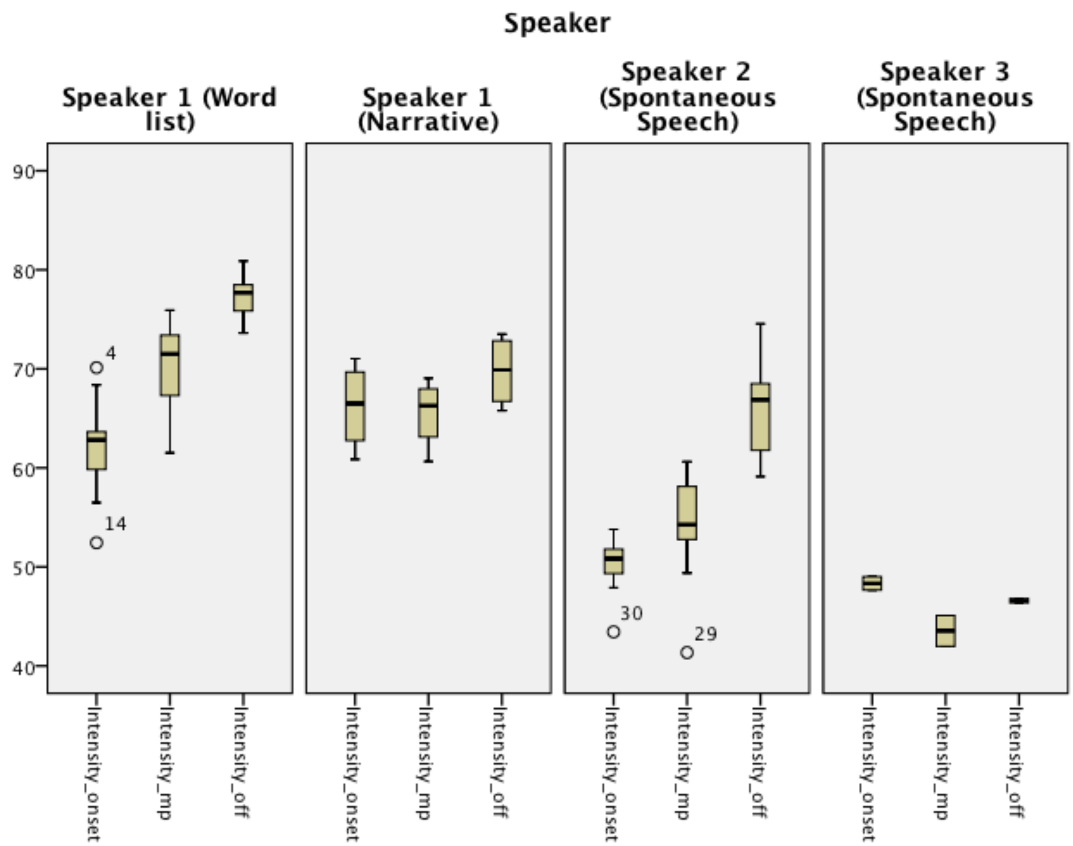


Figure 5.2.2: Boxplot of intensity values at 3 points for each speaker

5.3 Intensity Differences

The intensity differences are a general indication of how sharp the rise in intensity values is. Table 5.3.1 and figure 5.3.2 below show that Speaker 2 generally has the sharpest rise. Speaker 1 in the Word List Context also has a sharp rise but only if measured from the stop offset to the onset rather than starting at the midpoint.

Speaker	**Intensity Difference (Offset - Onset)**	**Intensity Difference (Offset - Midpoint)**	**N**
Speaker 1 Word List	15.4131619	6.97026098	14
Speaker 1 Narrative	3.5584875	4.21238525	4
Speaker 2	15.47812049	11.90666424	14
Speaker 3	-1.7430045	3.047563735	2

Table 5.3.1: Intensity differences

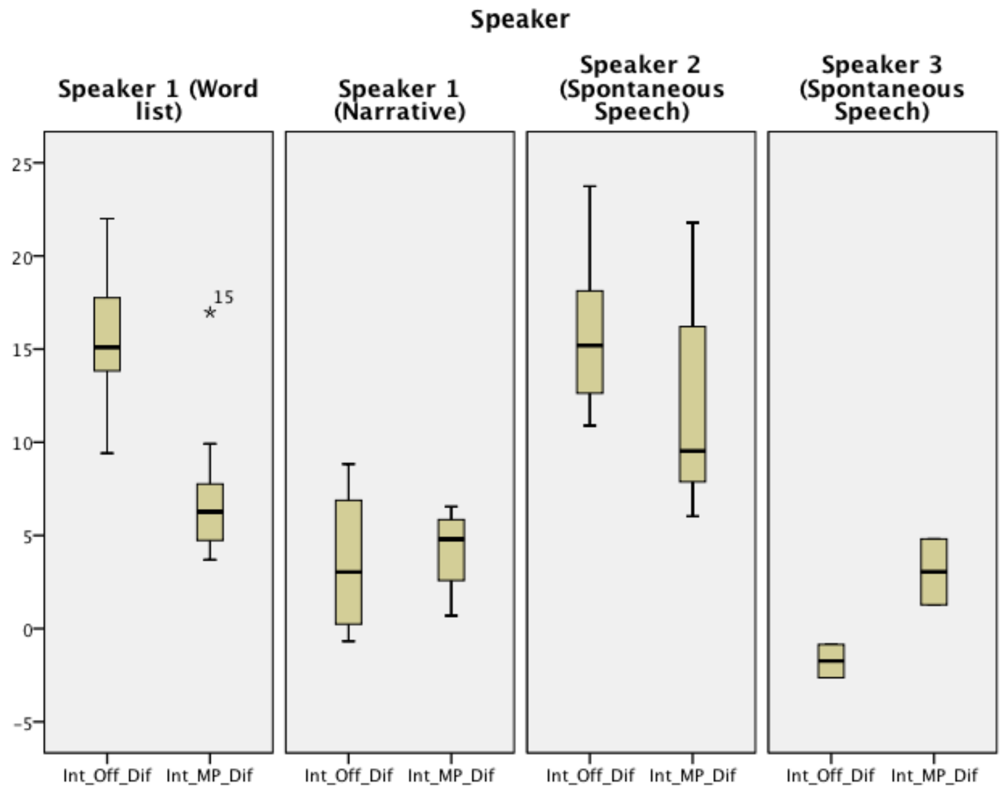


Figure 5.3.2: Boxplot of intensity differences

5.4 Intensity Ratios

Finally, we present the intensity ratios. As shown below in 5.4.1 and illustrated in 5.4.2, Speaker 2 appears to have the highest intensity ratio whether this ratio is measured using the stop midpoint or the stop onset. Speaker 1 in the Word List context also appears to have a high intensity ratio, but only if calculated using the stop onset. In this case, the ratio is also higher than in the Narrative Context. Speaker 3 has the lowest intensity ratio. If the ratio is calculated using the stop onset, this ratio is negative suggesting a more plosive like pronunciation. Aside from Speaker 3, the ratios greater than 1 for the other two speakers suggest more implosive like stops.

Speaker	Intensity Ratio (Offset/Midpoint)	Intensity Ratio (Offset/Onset)	N
Speaker 1 Word List	1.10174734	1.25349001	14
Speaker 1 Narrative	1.063966025	1.055958931	4
Speaker 2	1.230228958	1.308643365	14
Speaker 3	1.071536607	0.964188292	2

Table 5.4.1: Intensity ratios

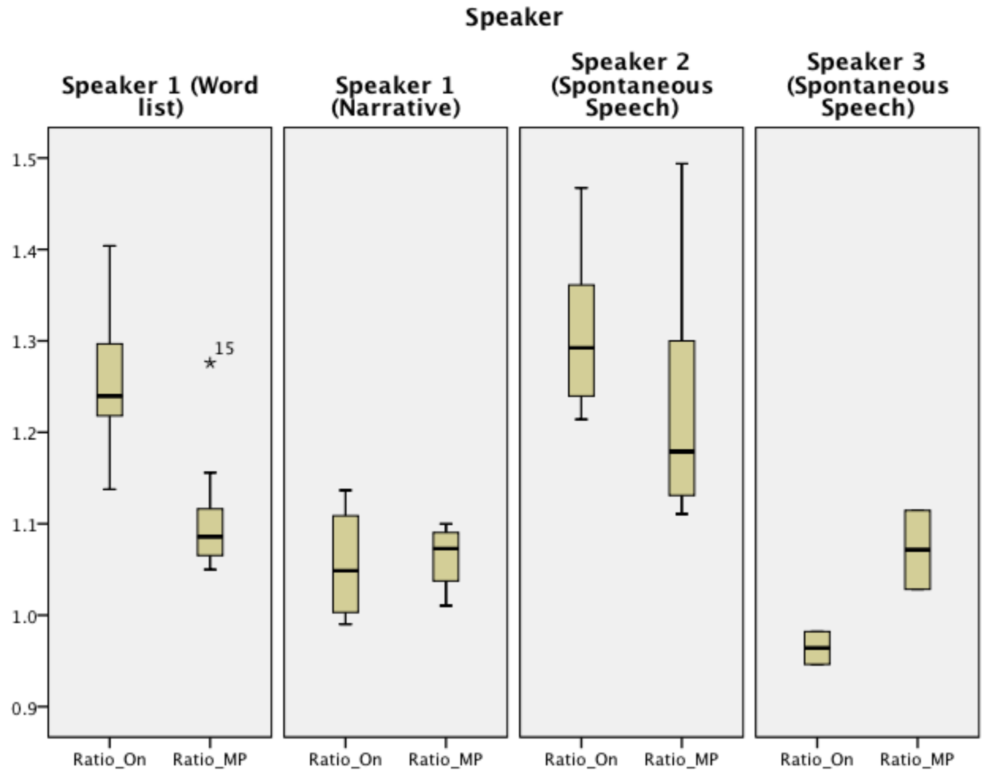


Figure 5.4.2: Boxplots of intensity ratios

6. Discussion

Putting all of the statistics shown in Section 5 together, the complete picture looks like a rather complicated one. Basically, these statistics attempted to measure degree of implosion based on duration and intensity. When placed alongside the waveforms and spectrograms for these sounds, the story becomes even more complicated.

First of all, for duration, there appears to be a clear difference between Speaker 1 in the Word List Context and in the Narrative Context. This, however, may have to do with rate of speech since the words in the word list were pronounced slowly and more carefully than in the Narrative Context. This type of context could also socially encourage more hyperarticulated stops. The standard deviation also appears to be relatively high. Yet, for the token that had a /b/ pronounced with the shortest duration, the waveform still shows a pattern that is typical of implosives. This token was for the word /baaba/, ‘barber’. As illustrated in Figure 6.1 below, there is a gradual increase in the amplitude of the waveform from the onset to the offset of the stop. This is one of the characteristics of implosives and was a pattern that consistently occurred across all tokens from the Word List Context.

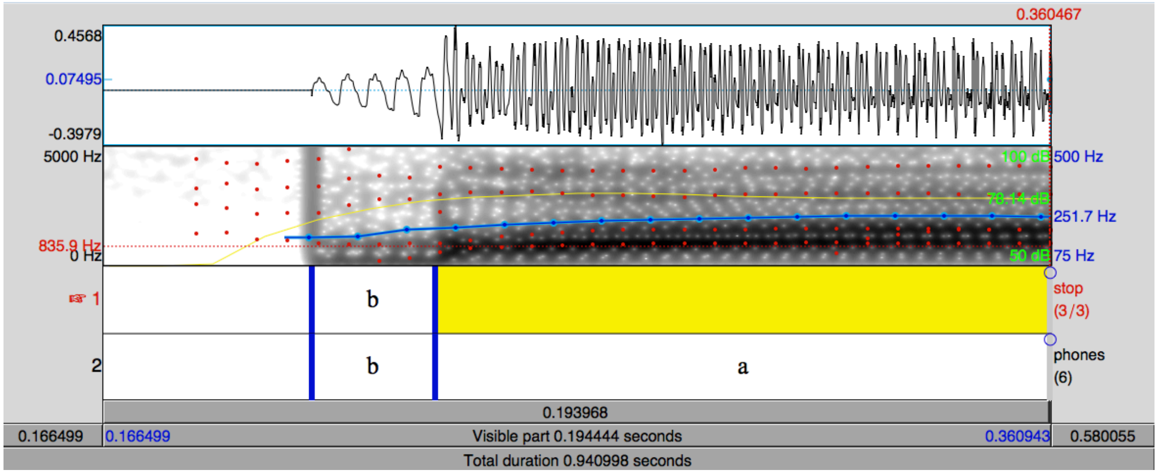


Figure 6.1: Implosive in /baaba/

Duration alone, however, does not seem to be adequate for distinguishing between plosives and implosives. If we take a look at the two tokens in which /b/ occurs in intervocalic position in the Word List reading, we see that both of these are over 70 milliseconds (see Appendix A1) long as opposed to only about 25 milliseconds in Figure 6.1. Does this mean that these two tokens are more implosive-like than the first /b/ in /baaba/ illustrated in 6.1? The waveform and spectrogram of these two tokens appear below in Figures 6.2 and 6.3. They do not show a sharp rise in amplitude as shown in 6.1. Rather, they both appear relatively flat. In any case, both of these tokens do have relatively high intensity values, which would be another characteristic of implosives. Thus, can we say that these two tokens are also implosives? That seems to be uncertain.

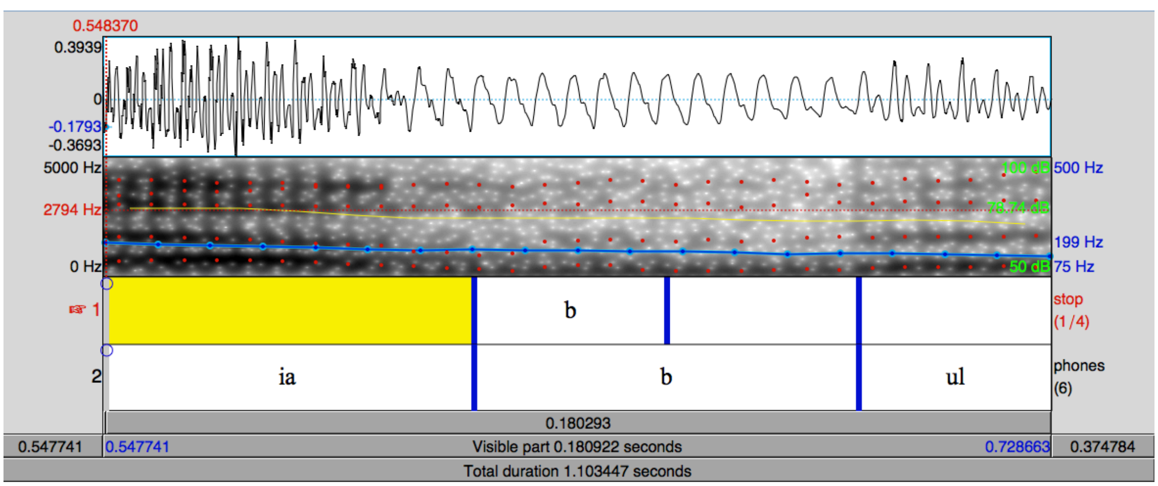


Figure 6.2: Waveform and Spectrogram for /tiabul/

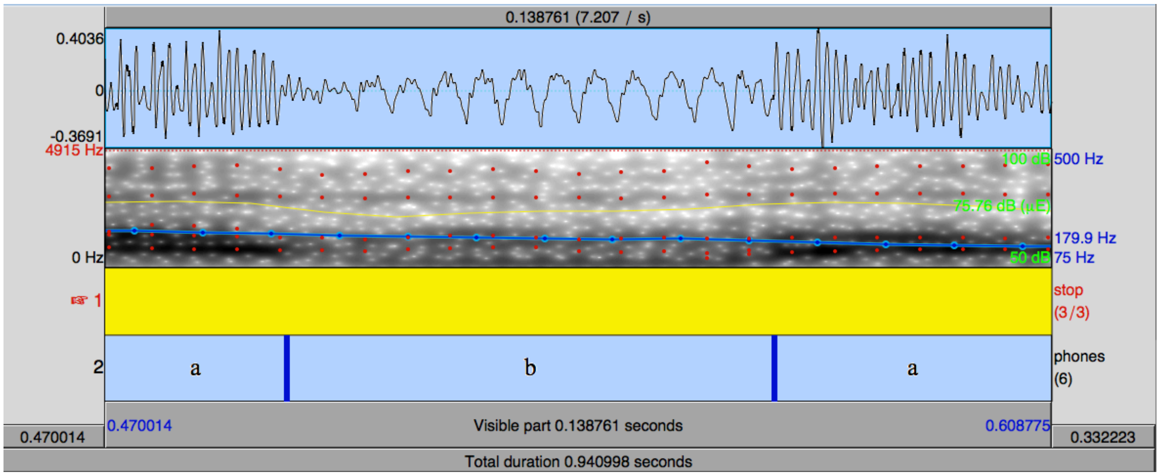


Figure 6.3: Waveform and Spectrogram for the second /b/ in /baaba/

If we take a closer look at the data for Speaker 1 in the Narrative Context, we can see that there is some variation within this context. It turns out that only two of the four tokens collected in this context occur in both word-initial position and in utterance-initial position. /bout/, for example, occurs in word-initial position but not in utterance-initial position as shown in Figure 6.4 below. This looks similar to the intervocalic contexts discussed for Figures 6.2 and 6.3.

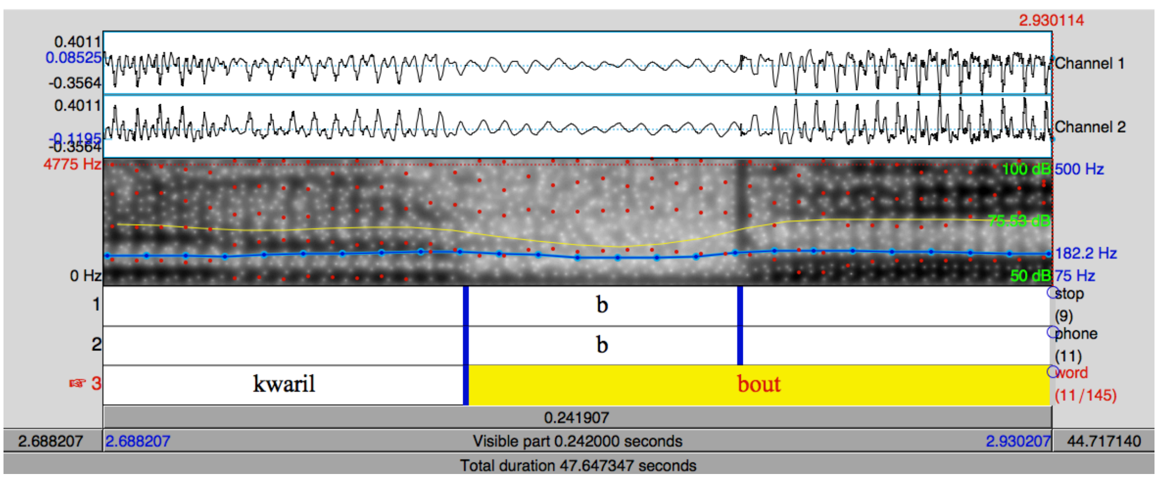


Figure 6.4: /bout/

In contrast, the word /bot/ shown in Figure 6.5 does have the /b/ occurring in utterance-initial position. Yet, in spite of this fact, the amplitude does not show a clear rising pattern as for all of the tokens occurring in the Word List. Nevertheless, there does appear to be a sharp rise in the intensity curve. Thus, even though this particular token occurs in both word-initial and utterance-initial context, it does not show the same prototypical pattern of implosives found in the tokens in the Word List. Yet, at the same time, it does not appear to be pre-voiced. There does not even seem to be a clear voice bar anywhere except for the vowel portion. This particular token actually looks more like a short-lag slightly aspirated stop, which seems surprising given that previous literature has described /b/ as either pre-voiced or as implosive but not as having short-lag VOT.

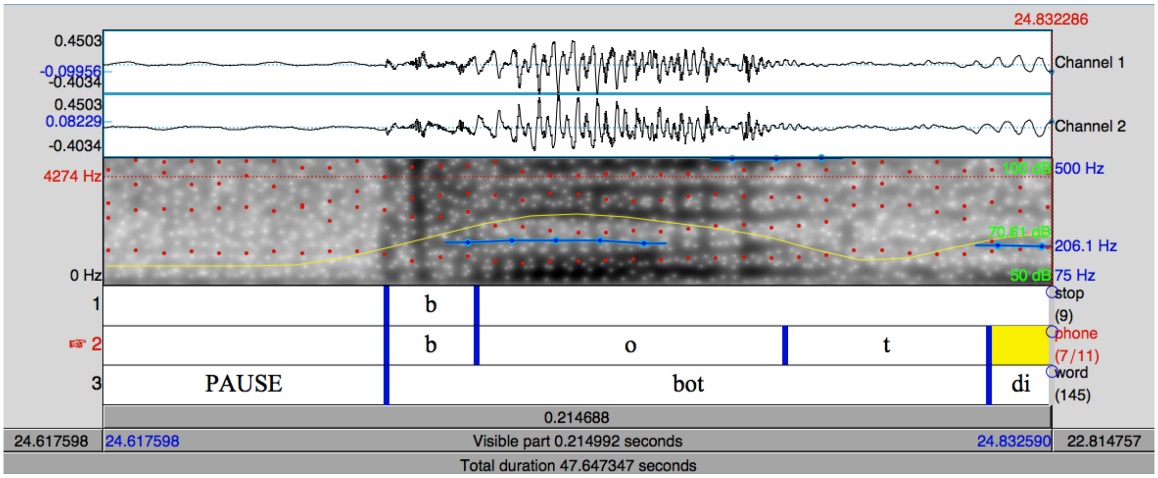


Figure 6.5: /bot/

Going back to the numbers, we saw earlier that Speaker 2 appears to show characteristics of implosives more so than the other two speakers. If we take a look at the waveforms and spectrograms for this speaker, however, we get a completely different story. None of the tokens show a waveform and spectrogram pattern similar to the ones found for Speaker 1 in the Word List Context. Instead, we get tokens such as the one illustrated in Figure 6.6 below in which the /b/ appears to be more like a short-lag slightly aspirated stop. Figure 6.6, however, does show a faint voice bar but there is a lack of a corresponding periodic waveform. There is also a sharp rise in the intensity curve. The scale, however, may be misleading. The bottom of the intensity curve is actually about 50 dB, which is considered relatively high. Thus it appears that there may have been issues with the recording quality such that the recording instrument was not sensitive enough to detect a corresponding periodic waveform. But if this were true, then it certainly did not prevent a much clearer voice bar from appearing in Figure 6.7. In this case, the /b/ is clearly pre-voiced. Yet it also shows higher formants, which suggests the possibility that this token may actually be a pre-nasalized stop

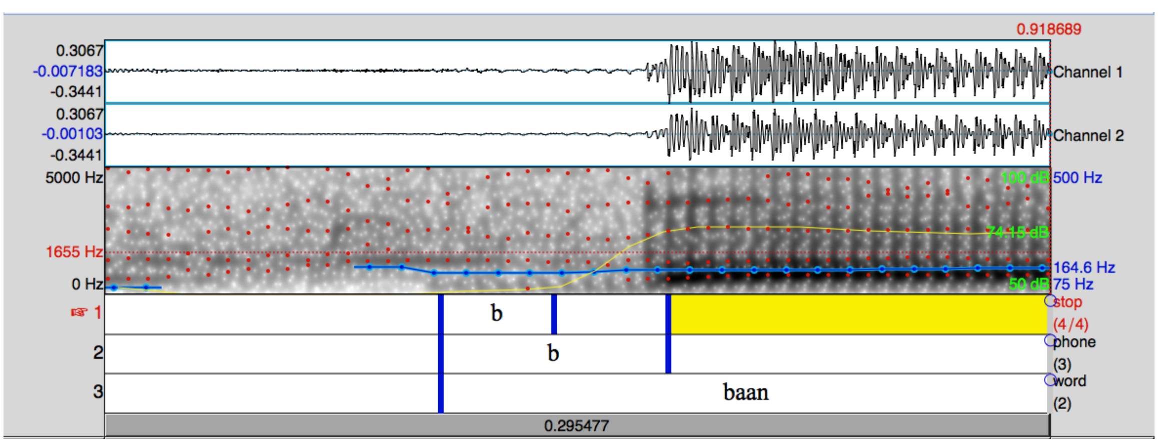


Figure 6.6: /baan/

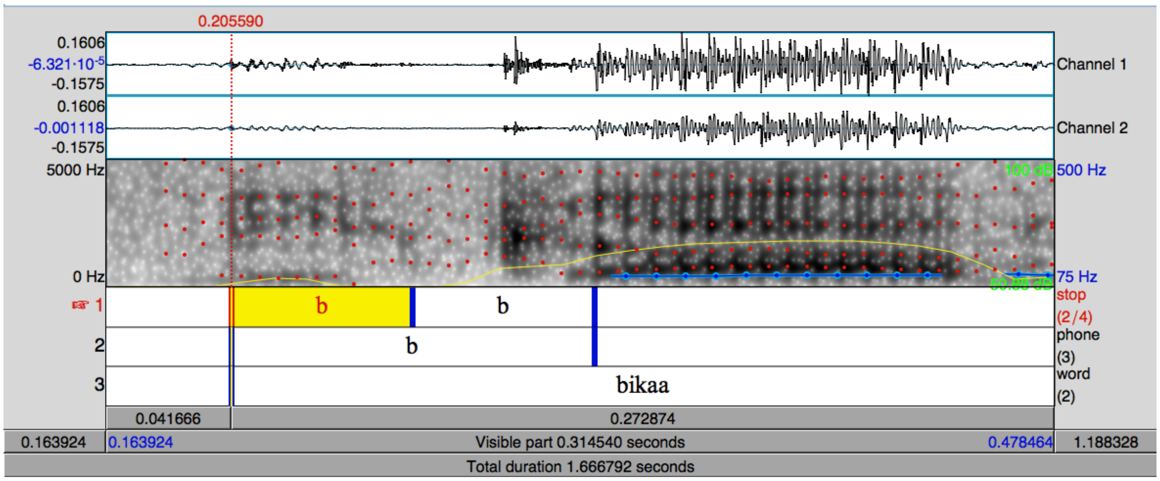


Figure 6.7: Pre-voicing in /bikaa/

So, can we say that Speaker 2 produces implosives? Although the numbers suggest the possibility, the images suggest otherwise. The images even suggest the possibility that some of these stops may be pre-voiced or slightly aspirated short-lag stops. In any case, there certainly seems to be variability in stop production for this speaker. There also seems to be the possibility that the conditions of the recording may have obscured part of what is going on.

Finally, we move on to Speaker 3. Only two tokens are available for this speaker. The waveforms and spectrograms for both of these tokens are shown in Figures 6.8 and 6.9 below. These tokens are two separate utterances of the same word in different sentences. In both cases, we can see a clear periodic waveform but the amplitude remains relatively flat throughout the production of the stop. The intensity values are relatively low and also appear to neither rise nor fall significantly. The numbers confirm that the change in intensity is relatively small and that the overall intensity is generally the lowest among the three speakers. Thus, can we conclude that these are plosives rather than implosives? The fact that both of these tokens occur in an intervocalic environment makes it difficult to say for sure, but these two tokens do appear to be more plosive-like than other stops in the data that occur in an intervocalic context.

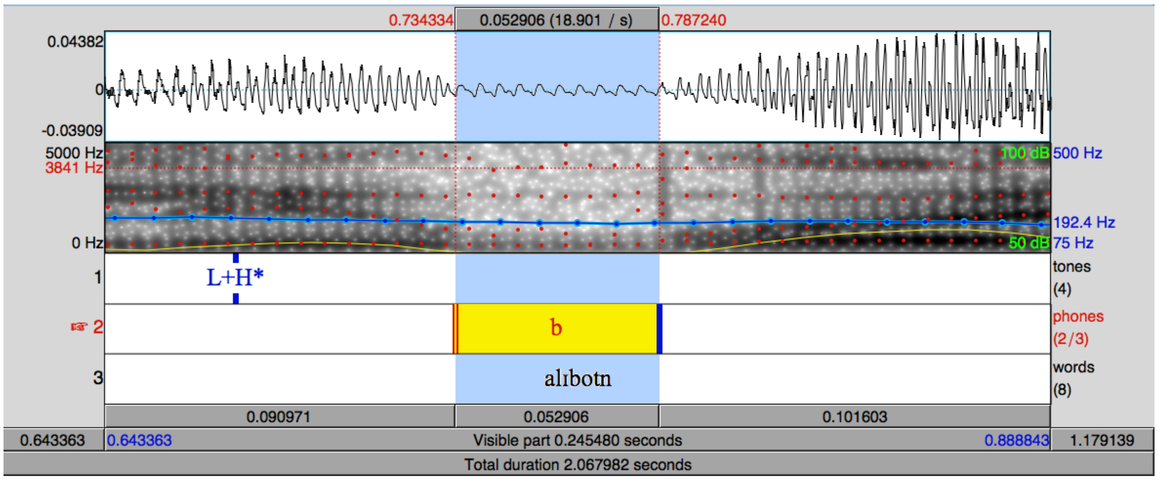


Figure 6.8: Token 1 of /alibotn/ (from 13-149)

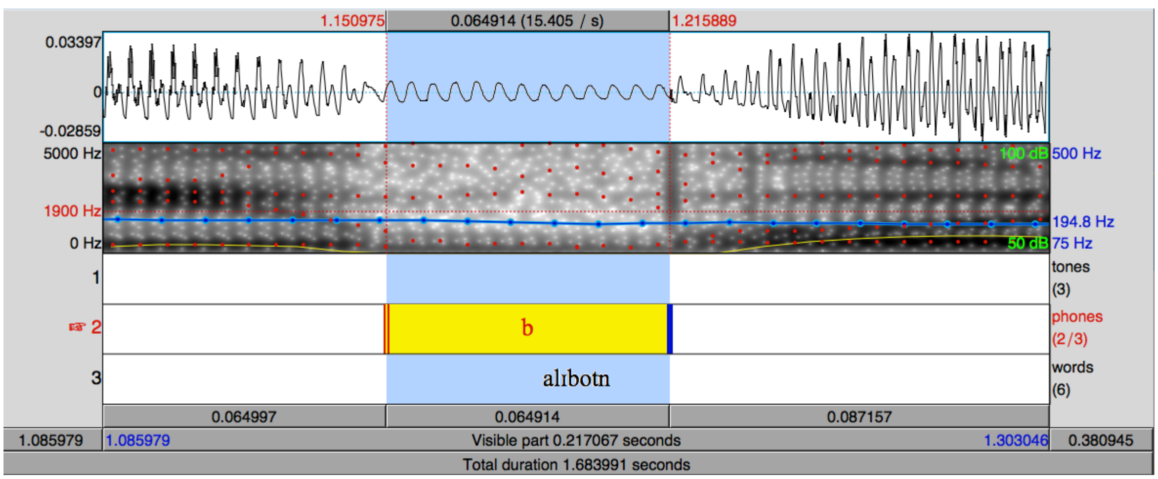


Figure 6.9: Token 2 of /alibotn/ (from 13-150)

7. Conclusion

In conclusion, a much larger sample size is needed in order to further develop this project. In response to the research questions posed earlier, we can reasonably say that yes, there is both inter-speaker and intra-speaker variation in voiced stop production in JC. The source of this variation seems much more difficult to address with the limited data, however. The third question related to the methodological utility of intensity seems more difficult to address. Based on the results of this current pilot study, it appears that intensity values and intensity curves can be affected by a wide variety of factors including preceding and following segments. These factors need to be better controlled for in future work. The current study provided too little data to address how exactly each of these environments affect the intensity of voiced stops. Without knowing about these differential effects, it seems difficult to say whether or not an increase in intensity from the midpoint of a stop to the release always indicates a more implosive like articulation.

The preceding and following segments clearly have an effect on the intensity curve. We also need to consider the fact that different types of segments may have different effects.

This pilot study also revealed some clear differences between Word List reading and other contexts. The stops produced under the Word List Reading context appeared to be the most prototypical of implosives. Could it be that this type of context encourages speakers to hyperarticulate their voiced stops thereby making them sound more implosive than in other contexts? This seems to be a possibility. It does not seem to be an accident that the stops produced in this context showed a more consistent pattern in their waveforms and spectrograms. For the spontaneous speech data, however, there was quite a bit of variability but in no case did a pattern similar to the Word List data emerge. Although the numbers suggest the possibility that Speaker 2 does produce implosives, a larger amount of data needs to be examined before we can reliably interpret what these numbers mean. The visual images of these tokens suggest a different story from what the numbers say.

Finally, the data was also too small to say anything about potential social factors other than the role of style in terms of Word List reading versus Narrative reading. Although all three speakers come from different social backgrounds, the three speakers also spoke differently for many possible reasons making it difficult to say anything conclusive about why.

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Appendix A1: Raw Data for Speaker 1 (Word List Part 1)

Word	Duration (ms)	Intensity (Onset, dB)	Intensity (Midpoint, dB)	Intensity (Offset, dB)
baaba (1st /b/)	25.191	68.371997	74.09590729	77.79
bada	121.626	56.49229	61.51943943	78.496068
baik	76.656	61.267666	71.34294972	75.172816
bakl	47.439	63.288683	71.6662007	78.232829
biak	94.7	52.434469	63.69391894	73.618561
biini	102.34	59.836069	70.77594673	77.587872
biit	129.313	70.125285	75.91367705	80.454213
bita	77.055	62.701077	72.26072001	77.949423
bota	116.799	62.949258	67.30226166	75.859741
buai	91.436	64.871386	74.897095	80.875714
buat	96.1	63.447711	72.55247015	77.284381
buts	112.215	62.550089	73.397697	78.946576
butu	128.416	56.63657782	66.81218607	74.575537
buut	164.442	63.64433	70.5870316	77.557424
Intervocalic and Cluster Contexts				
baaba (2nd /b/)	71.36	75.30255401	73.89298791	76.90043289
tiabul	73.323	74.572359	74.63403649	73.514637
breda	116.624	62.028977	70.33507678	72.454012

Appendix A2: Raw Data for Speaker 1 (Word List Part 2)

Word	Intensity Difference (Offset - Onset)	Intensity Difference (Offset - Midpoint)	Intensity Ratio (Offset/Midpoint)	Intensity Ratio (Offset/Onset)
baaba (1st /b/)	9.418003	3.694092709	1.049855557	1.137746496
bada	22.003778	16.97662857	1.275955515	1.38950055
baik	13.90515	3.829866284	1.053682477	1.226957397
bakl	14.944146	6.5666283	1.091627967	1.236126671
biak	21.184092	9.92464206	1.155817733	1.404010804
biini	17.751803	6.811925274	1.096246332	1.296673951
biit	10.328928	4.540535954	1.05981183	1.147292492
bita	15.248346	5.688702994	1.078724693	1.243191134
bota	12.910483	8.557479337	1.127149952	1.20509349
buai	16.004328	5.978619	1.079824444	1.246708587
buat	13.83667	4.731910853	1.065220534	1.218079893
buts	16.396487	5.548879	1.075600179	1.262133712
butu	17.93895918	7.763350929	1.116196631	1.316738049
buut	13.913094	6.970392402	1.09874891	1.218606968
Intervocalic and Cluster Contexts				
baaba (2nd /b/)	1.597878874	3.007444975	1.040700005	1.021219451
tiabul	-1.057722	-1.119399495	0.985001488	0.985816165
breda	10.425035	2.118935219	1.030126294	1.168067176

Appendix B1: Speaker 1 (Narrative Context Part 1)

Word	Duration (ms)	Intensity (Onset, dB)	Intensity (Midpoint, dB)	Intensity (Offset, dB)
bout	69.7	71.016579	65.617857	72.169729
bot	20.476	64.669111	69.037813	73.501384
bluo	20.028	68.316746	66.941528	67.638415
bwai	39.655	60.86238	60.652027	65.789238

Appendix B2: Speaker 1 (Narrative Context Part 2)

Word	**Intensity Difference (Offset - Onset)**	**Intensity Differnce (Offset - Midpoint)**	**Intensity Ratio (Offset/Midpoint)**	**Intensity Ratio (Offset/Onset)**
bout	1.15315	6.551872	1.099848918	1.016237758
bot	8.832273	4.463571	1.064654003	1.136576379
bluo	-0.678331	0.696887	1.010410384	0.990070795
bwai	4.926858	5.137211	1.080950794	1.080950794

Appendix C1: Speaker 2 (Part 1)

Word	**Duration (ms)**	**Intensity (Onset, dB)**	**Intensity (Midpoint, dB)**	**Intensity (Offset, dB)**
baan	71.159	50.807572	52.763237	74.546185
bakra	33.869	47.908221	54.5084425	60.537501
bakra 2	60.75	51.79852	54.051813	70.26404
balantoo	29.85	49.328212	58.121354	67.4489199
back	26.857	51.512577	59.517819	67.561785
but	32.637	50.354151	54.842813	62.023303
back	33.202	53.802301	60.629368	68.509416
bika	120.178	50.872162	41.349039	61.767747
but	41.594	43.439459	49.386864	59.129837
bit	73.296	53.459933	53.826921	66.275579

Appendix C2: Speaker 2 (Part 2)

Word	Intensity Difference (Offset - Onset)	Intensity Difference (Offset - Midpoint)	Intensity Ratio (Offset/Midpoint)	Intensity Ratio (Offset/Onset)
baan	23.738613	21.782948	1.412843283	1.467225889
bakra	12.62928	6.029058502	1.110607793	1.263614047
bakra 2	18.46552	16.212227	1.299938635	1.356487405
balantoo	18.1207079	9.327565895	1.160484319	1.367349781
back	16.049208	8.043966	1.135152231	1.31155902
but	11.669152	7.18049	1.13092855	1.23174161
back	14.707115	7.880048	1.129970809	1.273354759
bika	10.895585	20.418708	1.493813363	1.21417578
but	15.690378	9.742973	1.197278633	1.361201045
bit	12.815646	12.448658	1.231271969	1.239724318

Appendix D1: Speaker 3 (Part 1)

File	Word	Duration (ms)	Intensity (Onset, dB)	Intensity (Midpoint, dB)	Intensity (Offset, dB)
13-149	alibotn	51.114	47.650165	41.98308353	46.797142
13-150	alibotn	66.365	49.011654	45.097599	46.378668

Appendix D2: Speaker 3 (Part 2)

File	Word	Intensity Difference (Offset - Onset)	Intensity Differnce (Offset - Midpoint)	Intensity Ratio (Offset/Midpoint)	Intensity Ratio (Offset/Onset)
13-149	alibotn	-0.853023	4.81405847	1.114666624	0.982098215
13-150	alibotn	-2.632986	1.281069	1.02840659	0.946278369