Investigation into Mauritian Creole Plosives

Major Research Project

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Abstract

This experiment assesses plosive voice onset time (VOT) and constriction duration, and following vowel F0 (fundamental frequency), in Mauritian Creole. Existing studies on Mauritian Creole have not documented these metrics. This experiment involved recording speakers of Mauritian Creole living in Canada, processing the recordings in Praat (Boersma and Weenink, 2025), calculating the averages of the results, then tabulating and comparing the averages. The results generally indicate that VOT is negative for voiced plosives and positive for voiceless plosives, that constriction duration is shorter for voiced plosives than for voiced ones, and voicelessness is correlated with raising of F0 in the following vowel, as in the lexifier, French. In word-medial position, these cues may be neutralized effects on these phonetic metrics. The data lend support to existing theories about voicing effects on F0.

1. Introduction

1.1. Introduction

Mauritian Creole is a French-lexified creole spoken in Mauritius, population of about 1,288,000 people, as of 2008 (Baker and Kriegel, 2013). It has wide substratic influence, from languages including Wolof, Tamil, Bhojpuri and Chinese, due to the multiethnic population and history of the island. It has the following plosive inventory: three voiced plosives, /b/, /d̪/, /ɡ/, and three voiceless ones, /p/, /t̪/, /k/; /d̪/ and /t̪/ undergo allophonic palatalization before /i/ and /j/. In addition, it also has the affricates /ʤ/ and /tʃ/, which will not be examined in this paper due to the phonetic nature of affrication affecting waveform readings. Stress in Mauritian Creole can either appear on the first or second syllable, depending on the context (Baker and Kriegel, 2013).

1.1. VOT, Constriction Duration, and F0

The three metrics relevant to this MRP are VOT, constriction duration, and F0. VOT, or voice onset time, is a phonetic phenomenon, used to differentiate between voiced and voiceless plosives in many languages. VOT is defined according to Abramson and Whalen (2017) as the temporal relation between the vibration and the burst phase. Voicing preceding the burst phase is referred to as voicing lead, which characterizes voiced plosives, and voicing following the burst phase is referred to as voicing lag, which characterizes voiceless plosives. Some languages contrast long lead versus near-zero lag, as French does, while others contrast short or near-zero lead versus long lag, as English does (McLeod & Stoel-Gammon, 2009; Kehoe & Kannathasan, 2024); the latter languages are thus more accurately described as contrasting unaspirated vs. aspirated plosives, rather than voiced and voiceless plosives. Some languages further differentiate three or more categories of voicing, as in Hindi, which has four plosive voicing categories (Abramson & Whalen, 2017).

Constriction duration, also known as closure duration, is the period of time during which both articulators are closed, entirely blocking airflow in the vocal tract, before the articulators are released; the articulators are the independent parts of the vocal tract which cause turbulence and constriction when brought closer to one another (Miklas & Kelly, 2024). Voicing, and thus VOT, in voiced plosives occurs during the constriction, while no vocal cord vibrations occur during the constriction duration of voiceless plosives; VOT occurs after the release of the closure in voiceless plosives (Abramson & Whalen, 2017). These two phenomena are thus related, but distinct. Constriction duration is also used to differentiate between single and geminate consonants in languages like Swiss German (Ladd and Schmid, 2018) and Kelantan Malay (Hamzah et. al., 2014).

F0 is the fundamental frequency, and is a component of sound originating in vocal cord vibrations during the production of speech. Echoing Fant (1973), Yang (2024) defines it as the sound generated from the vocal cords during the production of speech. It is found in voiced phonemes. Consonants can induce perturbations on following vowels which can affect F0 in those vowels; this is known as CF0, meaning consonant intrinsic pitch (Abramson & Whalen, 2017). More specifically, F0 is claimed to be raised in vowels after voiceless plosives; however, the effects of voiced plosives on F0 don't appear to be as consistent (Kirby, 2018). Halle and Stevens (1971) provide their own explanation, echoed by Kirby and Ladd (2016): F0 is raised after voiceless plosives due to a lack of vibration during voiceless plosive production. Whatever the case, CF0 also appears to be a definitive measure by which to differentiate plosive voicing categories.

2. Background

2.1. Literature Review

Two previous linguistic studies have been conducted on Mauritian Creole, although not specifically on the phonetic variables this paper is concerned with. Grant and Guillemin (2012) looked at previous studies on creoles to assess which typological features common to creoles are reflected in Mauritian Creole. Such features include the absence of productive inflectional morphology, long and short forms of verbs, and equivalents of passive constructions. They found

Mauritian Creole exhibited the majority of typological features they list. Putska et. al (2024) collected phonetic data on Mauritian Creole, primarily the prevalence of /h/ and final consonants among Mauritian Creole speakers, and processed this data in Praat; they found /h/ was optional in most cases depending on influence from other languages like Arabic, and final consonants were less likely to be pronounced by speakers who also speak French than by those who don't.

Conversely, other studies have been conducted on variables relevant to this paper (VOT, constriction duration, and CF0), but on other languages. Considerable research has been conducted on VOT and F0, and to a certain extent, constriction duration (also called closure duration in many studies). Research on VOT dates back to at least the 1960s, with Lisker and Abramson (1964). As reiterated by Abramson and Whalen (2017), their initial definition described VOT as the temporal distance between glottal pulsing and the opening of the vocal tract to speech. Abramson and Whalen (2017), however, studied VOT and determined that the boundaries of voicing between the plosives and adjacent vowels was less clear in intervocalic contexts, and that voicing may not always begin at the transition between plosive and vowel. McLeod and Stoel-Gammon (2009) looked at monolingual and bilingual English and French speakers in Canada to see if either language affected the VOTs of the other language among bilingual speakers. They found minimal, if any, influence on French VOTs among bilinguals, but more influence on English VOTs among bilinguals. Kehoe and Kannathasan (2021) examined the effect of English bilingualism on French VOT, compared to monolingual speakers of French, but found only minimal raising of French voiceless VOT in bilinguals not dominant in French.

Constriction/closure duration has also been studied in terms of assessing its viability as a metric by which to differentiate plosive voicing categories. Lisker (1957) examined spectrograms to see if closure duration could be used to differentiate minimal pairs of word-medial English [p] and [b]. Lisker asserts that closure duration can't be assessed in word-initial positions, and only in word-final positions if the plosive ends in a release burst. Miklas and Kelly (2024) examined the effects of word-medial position on English [t] and [d], which are neutralized as [ɾ] in that position, to determine if closure duration or F0 is more relevant in terms of differentiating the two phonemes in that position. They found closure duration was not the main factor in differentiating the two plosives in word-medial position. Yao (2007) examined VOT and closure duration in English stops from a corpus study, but notably they excluded closure duration from utterance-initial voiceless plosives. Their results indicated [p] had a greater closure duration than [t] and [k] on average. Abdelli-Beruh (2004) examined syllable-initial and syllable-final French voiced and voiceless plosives in Praat to assess whether closure duration differed between the two voicing categories. The study determined that voiceless plosives had longer closure durations than voiced plosives in both environments. Hamzah et. al. (2011) studied closure duration of word-initial single and geminate voiceless plosives in Kelantan Malay, and used words within carrier sentences to allow Praat analysis of closure duration. They determined the closure duration was considerably longer for geminate than voiceless plosives. Ladd and Schmid (2018) conducted a study on Swiss German by phonetically analyzing fortis and lenis stops, and concluded that constriction duration, rather than voicing lead, was relevant in differentiating them.

F0, and specifically CF0, has been the subject of many studies. Kirby (2018) examined the effects of voicing in plosives on the CF0 on the following vowels of three languages: Standard Khmer, Bangkok Thai, and Hanoi Vietnamese. The study assessed CF0 at 10 ms intervals from 40 ms before release to 100 ms after release. They overall concluded that an increase in post-release CF0 was correlated with aspirated [t^h] in all three languages, but less consistently with unaspirated [t] (Kirby, 2018). Kirby and Ladd (2016) conducted a study on the effects of voicing on the F0 of following vowels in French, and observed that voiceless plosives induce higher F0 on the following vowels. Ting et. al. (2024) examined the patterns of variation between CF0 and VF0 (vowel intrinsic F0), using data from 20 different languages, including French. They extracted F0 at intervals of 10 ms. They ultimately concluded that CF0 is more variable across languages than VF0. Ladd and Schmid (2018) also examined obstruent voicing effects on CF0 for voiceless plosive fortis and lenis categories in Swiss German. They found the difference between fortis and lenis plosive effects on CF0 were not significant.

The effects of place of articulation on VOT have also been studied. Starting with Lisker & Abramson (1967), the general tendency observed is that velar articulation is correlated with the more positive values of VOT. Neary & Rochet (1994) studied the effects of place of articulation on both French and English plosives. Their results indicated English had more positive VOTs than French, and that velar plosives had more positive VOTs than other places of articulation. Hitchcock et. al. (2014) examined English-speaking children and their production of English plosives, and determined that VOT values are higher as place of articulation moves towards a velar position in the oral cavity. Conversely, Yao (2007) found that the corpus data in their study didn't corroborate the observation that velar articulation is correlated with more positive VOT because a third of the data they studied showed [k] didn't have the most positive VOTs on average compared to [p] and [t]. Thus, the assertion that backness in place of articulation induces more positive VOT is not universally agreed on.

In terms of phonetic experiments performed on creoles, Bundgaard-Nielsen et. al. (2024) conducted a study on Kriol, an English-lexified creole from Australia, to examine VOT and constriction duration, and to assess which of these metrics were relevant for distinguishing between plosive voicing categories. They found VOT was more relevant in initial contexts, while constriction duration was more relevant in medial environments (although it's important to note that they didn't observe word-initial constriction duration).

These studies are relevant in terms of methodology, as well as understanding the phonetics of the lexifier, French, and also demonstrate the importance of VOT, constriction duration, and F0 in terms of differentiating voicing categories of plosives in various languages. However, the absence of a comparable study on Mauritian Creole has resulted in a gap which this experiment aims to fill.

2.2. Previous Experiment

I previously conduced a smaller phonetic experiment on a single participant to assess phonetic elements of Mauritian Creole. The experiment entailed recording the participant on a Samsung smartphone, after which I processed their data in Praat to measure VOT of plosives in initial and medial positions, and F0 of the following vowel; F0 was taken from the midpoint of the vowel. The experiment didn't control for the same environments among all the words, meaning some plosives were preceded by consonants and others by vowels. The results of this experiment generally found negative VOTs for voiced plosives and positive ones for voiceless plosives. The average F0 was higher after voiceless plosives than after voiced ones in the majority of cases, but not in all cases, and because of these inconsistencies, an overall trend of the voicing effects on F0 couldn't be verified. This is possibly due to measuring F0 from the midpoint of the vowel duration rather than closer to the beginning of the vowel duration.

Tables 1 and 2 indicate the results of that experiment; Table 1 indicates the average VOT per plosive in word-initial and word-medial positions, and Table 2 indicates the average F0 of the following vowel per plosive in word-initial and word-medial positions. Note that all values in these and all other tables in this paper are rounded to the nearest whole number unless stated otherwise.

Table 1: VOT (in ms)

	Word Initial	**Word Medial**
b	-190	-39
p	16	15
d̪	-237	-30
t̪	21	23
g	-125	-39
k	44	32

Table 2: F0 (in Hz)

	Word Initial	**Word Medial**
b	148	177

p	147	172
d̪	142	163
t̪	148	167
g	142	174
k	164	172

One aim of the current experiment is to assess whether these results are representative of Mauritian Creole in a larger sample than just one participant.

3. Current Experiment and Methodology

3.1. Goals and Hypothesis

The aim of this experiment is to assess the average values VOT of plosives, the constriction duration of plosives, and the F0 of the following vowels in Mauritian Creole, as well as to assess any statistical significance of variation of these values depending on position and place of articulation.

The overall hypothesis tested by this MRP is Mauritian Creole will have highly negative VOTs for voiced plosives, and moderately positive VOTs for voiceless plosives, based on similar data from studies on French VOT (McLeod & Stoel-Gammon, 2009; Kehoe and Kannathasan, 2021). F0 is expected to be raised after voiceless plosives, and possibly lowered after voiced ones (Kirby & Ladd, 2016). For constriction duration, based on the preceding research (Abdelli-

Beruh, 2004), the hypothesis predicts that constriction duration will be shorter on average for voiceless plosives than for voiced ones.

3.2. Research Questions

These are the research questions this MRP will be asking:

- RQ1: What are the average VOTs for Mauritian Creole voiced and voiceless plosives?
- RQ2: What are the average constriction durations for Mauritian Creole voiced and voiceless plosives, and are they as relevant in terms of differentiating voicing in Mauritian Creole plosives?
- RQ3: Do the differences in VOT and constriction duration between voiced and voiceless plosives change depending on word-initial, word-medial, and word-final environments? Do the differences in CF0 on vowels after voiced and voiceless plosives change depending on word-initial and word-medial environments?
- RQ4: Do Mauritian Creole voiceless plosives induce higher average F0s for the following vowels than Mauritian Creole voiced plosives?

3.3. Participants

Six participants participated in this experiment. They were Canadian citizens of Mauritian descent between 21 and 76, who spoke Mauritian Creole and lived in Canada at the time of the experiment; four were male and two were female. All six listed Mauritian Creole as their first language. Participant 3 claimed that his fluency increased in English but decreased in

French after living in Canada. Recruitment was direct as they were known to the primary investigator, and participants were informed verbally and in writing via the informed consent forms that they were under no obligation to continue the experiment for any reason if they didn't want to.

Table 3 indicates the age, gender, first language, second language, and time living in Canada for each participant, who are represented by numbers for confidentiality purposes.

Table 3: Participants' Linguistic and Demographic Information

Participant No.	**Age**	**Gender**	**First Language**	**Second Language(s) (+ Time Speaking Language)**	**Time Living in Canada**
1	41	Male	Mauritian Creole	English (35 years), French (20 years)	25 years
2	21	Female	Mauritian Creole	English (16 years), French (16 years)	13 years
3	22	Male	Mauritian Creole	English (16 years), French (12 years)	13 years
4	76	Male	Mauritian Creole	English (70 years)	54 years
5	65	Male	Mauritian Creole	English (45 years), French (45 years)	25 years

6	51	Female	Mauritian Creole	French (45 years), English (40 years)	13 years

3.4. Measurement of VOT, Constriction Duration and F0 for this Experiment

Voicing was measured from the beginning of the voicing of the plosive to the beginning of the burst phase for voiced plosives, and from the beginning of the burst phase to the beginning of the voicing of the following vowel (Abramson & Whalen, 2017; Kehoe & Kannathasan, 2021). Constriction duration was measured from the beginning to the ending of the closure phase. F0 was measured 10 ms after the beginning of the vowel, from the Praat feature 'show pitch', as indicated by the central blue line along the length of the vowel duration, which itself is the phase of symmetric high-amplitude waveform parallel to the pitch line in the spectrogram (Ladd & Schmid, 2018; Kirby, 2018). Pitch range was 50 to 800 Hz. Figures 1 and 2, below, show segments of participant 5's 1 token each of "madam" and "bato", in order to illustrate how all metrics were measured.

Figure 1: Participant 5's First Token of "madam"; phonemes are indicated in the second tier, VOT and constriction duration in the third tier, and f0 in the fourth tier

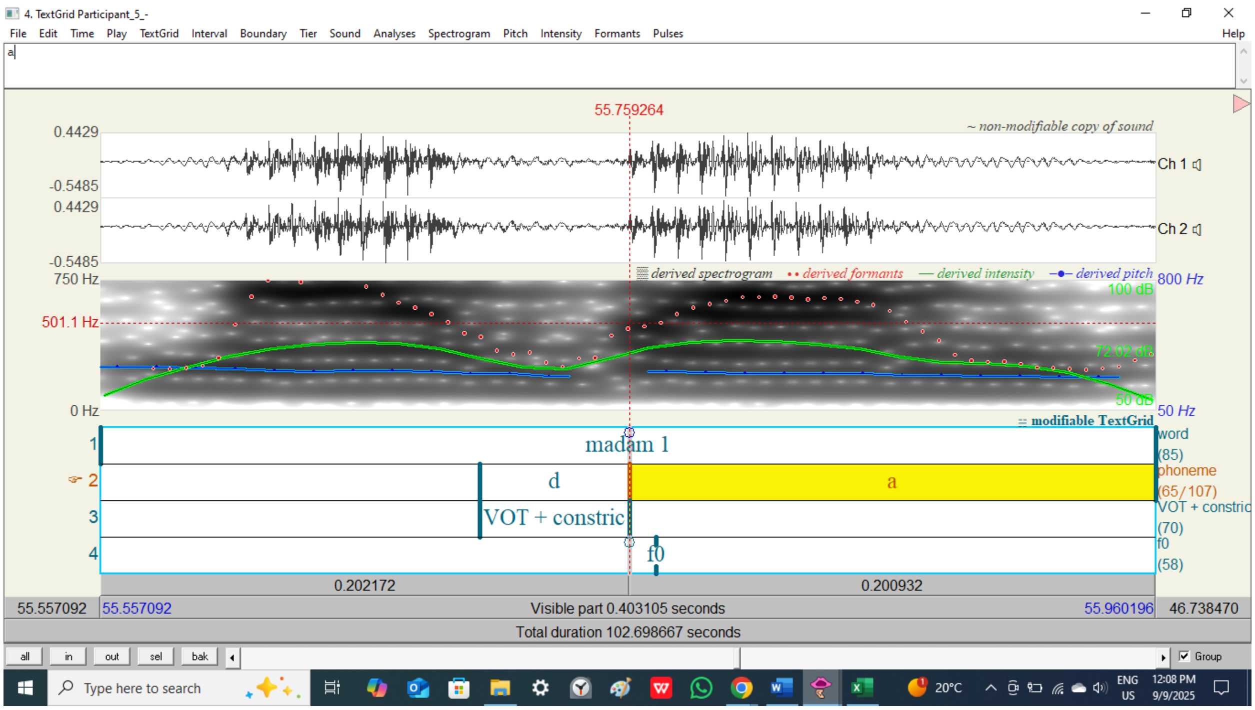
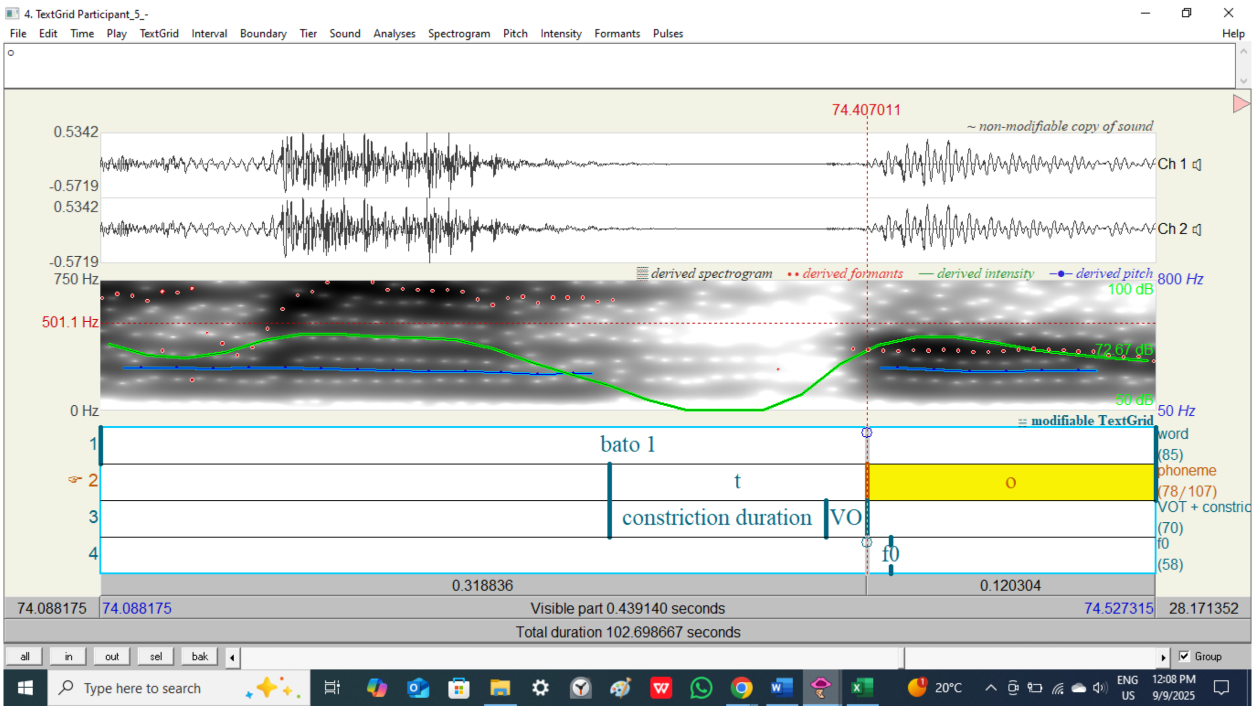


Figure 2: Participant 5's First Token of "bato"; phonemes are indicated in the second tier, VOT and constriction duration in the third tier, and f0 in the fourth tier



3.5. Methodology

15 MC words were chosen for analysis to allow all six target plosives [b], [d̪], [g], [p], [t̪], and [k] to be measured in word-initial prevocalic, word-medial intervocalic, and word-final postvocalic positions; some of the words provided plosives in both word-initial and word-final positions. Words were chosen such that the vowels following the target plosives excluded front vowels, in order to avoid palatalization effects which could affect the coronals. All target words were nouns. Target words were placed in a carrier sentence (Table 4).

The carrier sentence was structured as ‘Mo trouv trwa X isi’, meaning ‘I find/see three X here’; the X in question stands for the target word. The preceding and following words were chosen because they end and begin in a vowel, respectively, allowing a greater distinction between the target plosives and the adjacent words due to differences in waveform amplitude; adjacent words ending or beginning in consonants would produce less distinguishable waveform and spectrogram readings

Participants were recruited in Ontario and recorded either in the soundproof booth in the phonetics lab at York University, Keele Campus, or on Zoom. They first filled out a demographic questionnaire (seen in Appendix A attached to the end of this paper) asking for the following information: age; gender; first language; second language(s), and time spent speaking each language; and time spent living in Canada. The primary purpose of this was to account for any possible linguistic and demographic effects on the data.

Following this, the participants were recorded reading each sentence three times. Participants 1-3 were recorded in the soundproof booth in the phonetics lab at York University, Keele Campus, while participants 4-6 were recorded on Zoom. Participants were instructed to speak at a conversational pace in order to minimize potential gaps between words so that constriction duration in word-initial plosives could be studied. Two participants were asked to record the sentences again due to errors they produced during their first recordings. One participant was asked to record the sentences with “lapaj” again because of errors during the production of those sentences. The recordings resulted in 363 tokens overall, but the erroneous tokens were discarded, resulting in a total of 270 tokens which were processed in Praat.

Table 4: Mauritian Creole Carrier Sentences

Mauritian Creole Sentence	**English Translation**
Mo trouv trwa <u>bag</u> isi.	*I find three <u>rings</u> here.*
Mo trouv trwa <u>dat</u> isi.	*I find three <u>dates</u> here.*
Mo trouv trwa <u>gard</u> isi.	*I find three <u>guards</u> here.*
Mo trouv trwa <u>pas</u> isi.	*I find three <u>passes</u> here.*
Mo trouv trwa <u>tas</u> isi.	*I find three <u>cups</u> here.*
Mo trouv trwa <u>kap</u> isi.	*I find three <u>capes</u> here.*
Mo trouv trwa <u>kaba</u> isi.	*I find three <u>purses</u> here.*
Mo trouv trwa <u>madam</u> isi.	*I find three <u>ladies</u> here.*
Mo trouv trwa <u>lagar</u> isi.	*I find three <u>stations</u> here.*
Mo trouv trwa <u>lapay</u> isi.	*I find three <u>straws</u> here.*
Mo trouv trwa <u>bato</u> isi.	*I find three <u>boats</u> here.*
Mo trouv trwa <u>lakaz</u> isi.	*I find three <u>houses</u> here.*
Mo trouv trwa <u>dyab</u> isi.	*I find three <u>devils</u> here.*
Mo trouv trwa <u>kad</u> isi.	*I find three <u>frames</u> here.*
Mo trouv trwa <u>sak</u> isi.	*I find three <u>sacks</u> here.*

Note that although the experiment was constructed to avoid palatalized alveolars as target plosives, the word "dyab" was only used to measure word-final [b] and not word-initial [d], which was retrieved from "dat". The sentences are also written in Mauritian Creole orthography and not in IPA.

After the individual participants were recorded, their phonetic data was processed in Praat to measure VOT, constriction duration, and F0 on the following vowel. The average for each metric per plosive per each participant per position was calculated first, and then the average for each metric per plosive for all participants per position collectively, all in Microsoft Excel. The averages were compared to one another in Excel to determine any patterns. Following this, the data were compared against the data from the previous experiment to determine whether those results were consistent with the results of the current experiment, as well as to the studies on French to see whether the voicing and F0 patterns in Mauritian Creole reflected those in the lexifier. The individual participants' data were also compared to their demographic information (age, gender, first and second languages) to assess any patterns or variances which may be caused by those factors.

Tables showing the individual values of each token processed in Praat can be found in Appendix C.

4. Results

4.1. VOT

Table 4 indicates the average VOT (in ms) per each plosive in word-initial, word-medial, and word-final positions across all participants.

Table 4: VOT (in ms)

	Word Initial	Word Medial	Word Final
b	-114	-70	-93
p	19	25	12
d̪	-110	-62	-93
t̪	27	27	29
g	-106	-79	-94
k	33	24	28

Average VOT is moderately positive for voiceless plosives and highly negative for voiced plosives. VOTs for voiced plosives are least negative in word-medial position and most negative in word-initial position. VOTs for voiceless plosives are most negative in word-medial position.

4.2. Constriction Duration

Table 5 indicates the average constriction (in ms) per each plosive in word-initial, word-medial and word-final positions across all participants.

Table 5: Constriction Duration (in ms)

	Word Initial	Word-Medial	Word-Final
b	114	70	93
p	140	91	142

d̪	110	62	93
t̪	115	101	119
g	106	79	94
k	120	83	132

Average constriction duration is lower for voiced plosives than for voiceless ones. It is also lower for voiced plosives in word-medial environments than in word-initial or word-final ones, and lower in word-final environments than in word-initial ones; however, neither word-initial nor word-final environments induce consistently higher values than one another. Note that because constriction duration couldn't be assessed for word-initial voiceless plosives for participants 1 and 4 (see section 5.2 for the explanation), the averages of the word-initial voiceless plosives only come from four participants.

4.3. F0

Table 6 indicates the average F0 (in Hz) of every following per each plosive in word-initial and word-medial positions at 10 ms after the beginning of the vowel across all participants.

Table 6: F0 of following vowel (in Hz)

	Word-Initial	**Word-Medial**

b	144	162
p	162	166
d̪	154	154
t̪	182	176
g	162	150
k	179	167

Average F0 at 10 ms of the vowel duration is higher after voiceless plosives than voiced plosives. F0 also is lower on vowels after voiceless plosives in word-medial position than in word-initial position, but higher on vowels after voiced plosives in word-medial position than in word-initial position.

Average values of VOT, constriction duration, and F0, per plosive per participant in each environment are shown in Appendix B.

4.4. Statistical Significance of Voiced vs Voiceless Plosive Values

To test whether the differences between voiced and voiceless plosive values for each metric in each environment were significant, t-tests were conducted. The tests were conducted on all the participants' individual tokens and not the averages. The P(T<=t) two-tail values for each word-internal environment are shown in Table 7 below:

Table 7: p-values of T-tests for Variation of Voiced vs Voiceless Plosive VOT, Constriction Duration and F0 between Environments

	Word-initial	**Word-medial**	**Word-final**
VOT	$p < 0.001$	$p < 0.001$	$p < 0.001$
Constriction Duration	$p = 0.18$	$p < 0.001$	$p < 0.001$
F0	$p < 0.001$	$p = 0.158$	

Table 7 indicates all values, except word-initial constriction duration and word-medial f0, are $p < 0.05$, meaning the differences between voiced and voiceless values for all three metrics are generally significant.

4.5. Statistical Significance of Word-internal Environment Effects

Word-internal position was subjected to t-tests to determine if any effects on each of the variables (VOT, constriction duration, and F0) were significant. The results are shown in Tables 8 and 9, below:

Table 8: p-values of T-tests for Variation of VOT, Constriction Duration and F0 between Environments on Voiced Plosives

	Initial vs Medial	**Initial vs Final**	**Medial vs Final**

VOT	$p < 0.001$	$p < 0.001$	$p < 0.001$
Constriction Duration	$p < 0.001$	$p = 0.012$	$p < 0.001$
F0	$p = 0.008$		

All p-values for voiced plosives in Table 8 above are $p < 0.05$, meaning the differences for the values of each metric between environments are significant.

Table 9: p-values of T-tests for Variation of VOT, Constriction Duration and F0 between Environments on Voiceless Plosives

	Initial vs Medial	**Initial vs Final**	**Medial vs Final**
VOT	$p = 0.004$	$p = 0.005$	$p = 0.565$
Constriction Duration	$p = 0.003$	$p = 0.695$	$p < 0.001$
F0	$p = 0.291$		

With the exception of medial vs final contrast for voiceless VOT, initial vs final contrast for voiceless constriction duration, and initial vs medial contrast for voiceless F0, all p-values in Table 9 above are $p < 0.05$, meaning the differences for the values of each metric between environments are significant.

All the differences for each metric between word-internal environments, aside from those three instances mentioned in Table 9, are significant, meaning word-internal positional generally has a significant effect on VOT, constriction duration, and voiced F0 values in Mauritian Creole.

4.6. Statistical Significance of Place of Articulation Effects

Place of articulation was subjected to t-tests to assess whether it had any effect on the VOT, constriction duration, and F0 values. Tables 10 and 11 below indicate the variance between contrasts of place of articulation (bilabial/alveolar, bilabial/velar, alveolar/velar) for all three metrics per plosive voicing category, rounded to the nearest thousandth:

Table 10: p-values from T-test for place of articulation effects on VOT, constriction duration and F0 for voiced plosives in all word-internal environments

	VOT	**Constriction Duration**	**F0**
Bilabial vs Alveolar	p = 0.384	p = 0.508	p = 0.892
Bilabial vs Velar	p = 0.166	p = 0.907	p = 0.748
Alveolar vs Velar	p = 0.178	p = 0.42	p = 0.841

All p-values for each metric are $p > 0.05$, meaning none are significant. This indicates place of articulation generally does not affect the VOT, constriction duration, or f0 values for voiced plosives.

Table 11: p-values from T-test for place of articulation effects on VOT, constriction duration and F0 for voiceless plosives in all word-internal environments

	VOT	Constriction Duration	F0
Bilabial vs Alveolar	$p < 0.001$	$p = 0.359$	$p = 0.064$
Bilabial vs Velar	$p < 0.001$	$p = 0.282$	$p = 0.284$
Alveolar vs Velar	$p = 0.626$	$p = 0.827$	$p = 0.385$

VOT p-values for bilabial/alveolar and bilabial/velar contrasts are < 0.05, meaning they are significant. All other p-values for each metric are $p > 0.05$, meaning they're not significant. This indicates place of articulation only affects VOT for bilabial voiceless plosives.

5. Analysis

5.1. VOT

VOT is highly negative in voiced plosives, and moderately positive in voiceless plosives, as shown in Table 4. The average VOT in voiced plosives is highest in word-medial position, followed by word-final position ($p < 0.001$), and finally by word-initial position ($p < 0.001$). Conversely, no such consistent variation appears for VOT values for voiceless plosives in any of the three positions. Voiced plosives appear to have the highest VOTs in medial position; theoretically this could be due to the reduced constriction duration, which may result from pressure on either side of the closure by preceding and following vowels, whereas in word-initial and word-final position, the plosive is only adjacent to one vowel and thus the vocal pressure of vowel production isn’t as strong.

As shown in Table 7, voiced and voiceless VOTs differ significantly for all environments ($p < 0.001$).

5.2. Constriction Duration

Average constriction duration is consistently longer for voiceless plosives than for voiced ones in all positions. According to Table 5, word-medial position also has an overall shortening effect on the constriction duration for all categories of voicing and place of articulation; word-medial position has the shortest constriction durations for both voiced and voiceless plosives, followed by word-final ($p < 0.001$) and then by word-initial ($p < 0.001$) for voiced plosives, and by word-initial ($p = 0.003$) and then word-final ($p = 0.695$) for voiceless ones. Note that the difference between word-initial and word-final voiceless constriction duration values is not significant because $p > 0.05$.

Assessing constriction duration proved difficult in initial position for some tokens, primarily participant 1’s and participant 4’s word-initial voiceless plosives, as well as one of participant 2’s tokens of word-initial [k], and all of participant 6’s tokens of word-initial [k]. It wasn’t clear as to whether the period of zero amplitude preceding the burst phase indicated closure of the vocal tract or that the vocal tract wasn't producing any activity. The spectrogram in these cases exhibited no darkened areas before plosive voicing or the burst phase, whereas the spectrogram in the remaining cases exhibited some darker coloration even during the closure phase of voiceless plosives. A similar phenomenon occurred for participant 4's word-final voiceless plosives, some of which exhibited no visible burst phase, which also made it unclear as to whether this was closure of the vocal tract or absence of vocal activity. Figures 3 and 4, below, are images of participants 1's and participant 2's first tokens, respectively, of [pas] analyzed in Praat. The constriction durations are highlighted. Participant 1 didn't exhibit any spectrographic activity leading up to the burst phase of the initial [p], while participant 2 did.

Fig. 3. Participant 1's first token of [pas]. The lack of darkened spectrographic activity inhibits determining where the closure for [p] actually begins.

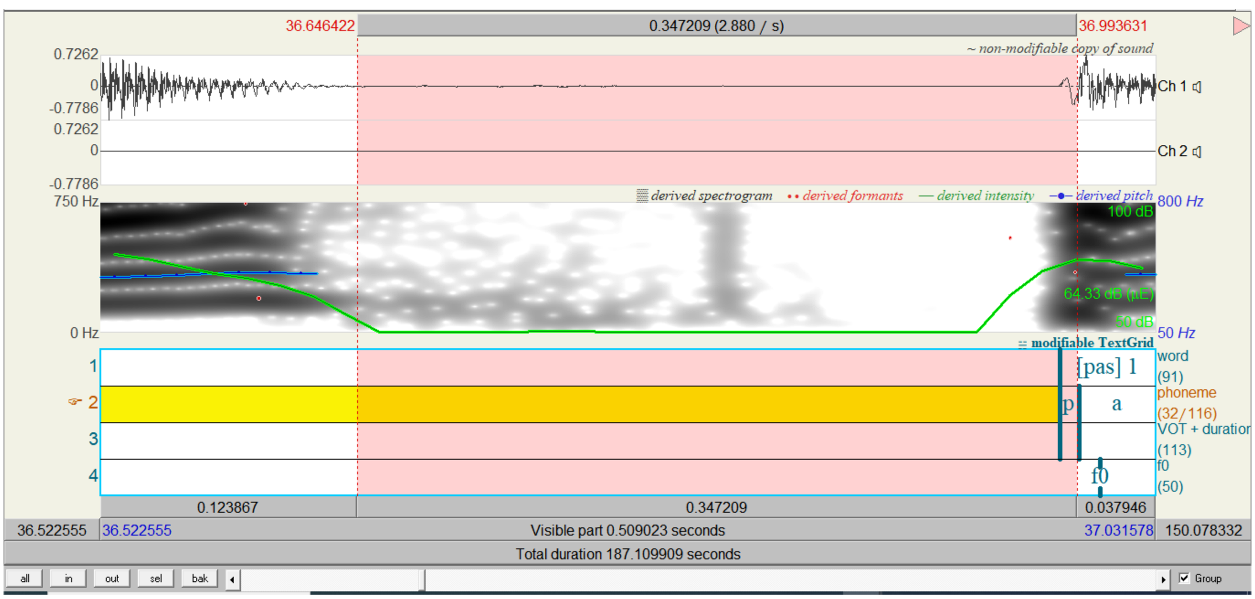
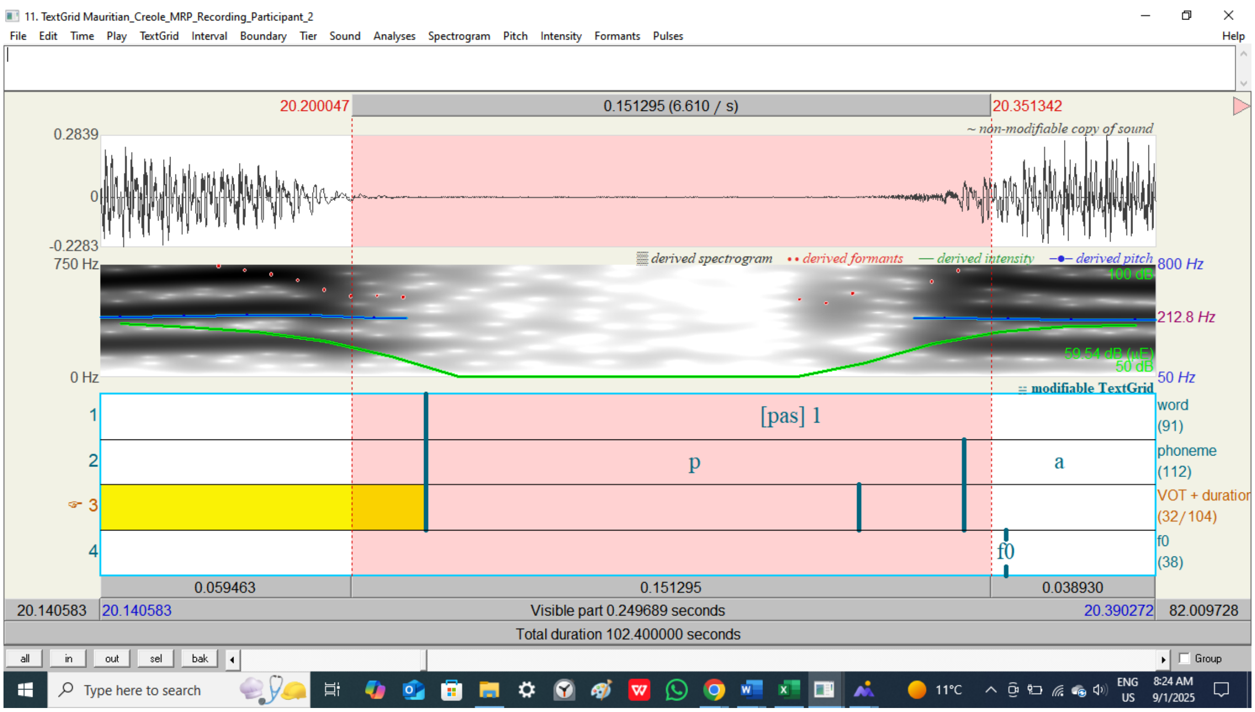


Fig. 4. Participant 2's first token of [pas]. The presence of darkened spectrographic activity indicates speech production is ongoing, allowing for a definitive point to find the beginning of constriction duration.



The above images contrast the production of word-initial [p] between participants 1 and 2, and highlight the difficulties in assessing constriction duration in word-initial environments. These appear to result from extended pauses between words during the production of these sentences. Due to this, constriction duration wasn't recorded for any of the instances where there was an absence of spectrographic activity preceding the release burst, meaning the resulting average for voiceless word-initial and word-final VOT comes from a smaller number of tokens.

However, constriction duration is still distinguishable by voicing, and this is statistically significant for word-medial ($p < 0.001$) and word-final positions ($p < 0.001$), as shown in Table

7, meaning it's still useful for differentiating between plosive voicing categories. The above difficulties only indicate that it may not be as easily determined in all environments as VOT.

5.3. F0

F0, at 10 ms after the beginning of the vowel duration, is higher after voiceless plosives than after voiced ones. This is statistically significant in word-initial position ($p < 0.001$) but not word-medial position ($p = 0.015$). This appears to corroborate existing observations about voiceless plosives increasing F0 (Kirby and Ladd, 2016). The difference between F0 values after voiced vs voiceless plosives, however, is reduced in word-medial position ($p = 0.1$) compared to word-initial position ($p < 0.001$), as shown in Table 7. Furthermore, F0 values are lower after voiced plosives in word-initial position than in word-medial position ($p < 0.01$), but higher after voiceless plosives in word-initial position than in word-medial position ($p = 1$), as indicated in Tables 8 and 9, respectively; this indicates the difference between F0 values between environments is significant for voiced plosives, but not for voiceless plosives. This seems to be another minimalization effect caused by word-medial position, parallel to that found in VOT and constriction duration.

Note that in some tokens from participants (primarily participant 1, but also 5 and 6), F0 could not be measured at 10 ms, because Praat didn't appear to indicate it or was unable to retrieve the data from that position. The spectrogram in these cases indicate the F0 began at a later point, so F0 data from these tokens were excluded. Extracting F0 from a later point in the duration risked minimizing the potential effects of consonant perturbations on F0. Figures 5 and 6 show participant 5's first and second tokens of [tas], respectively. The first token shows F0 beginning after 10 ms after the beginning of the duration of [a], as indicated by the increase in periodic amplitude in the waveform, while the second token shows F0 beginning before 10ms after the beginning of the duration of [a].

Fig. 5. Participant 5's first token of [tas]. F0, indicated by the blue pitch line, begins later than 10 ms.

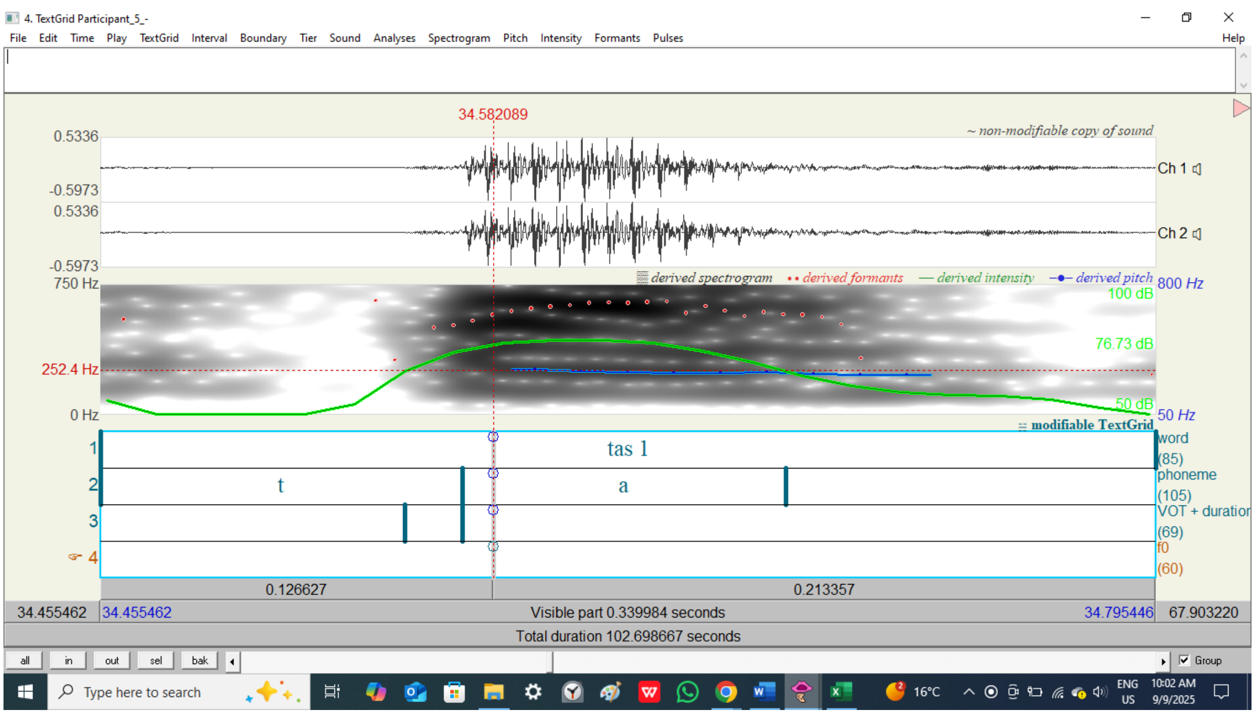
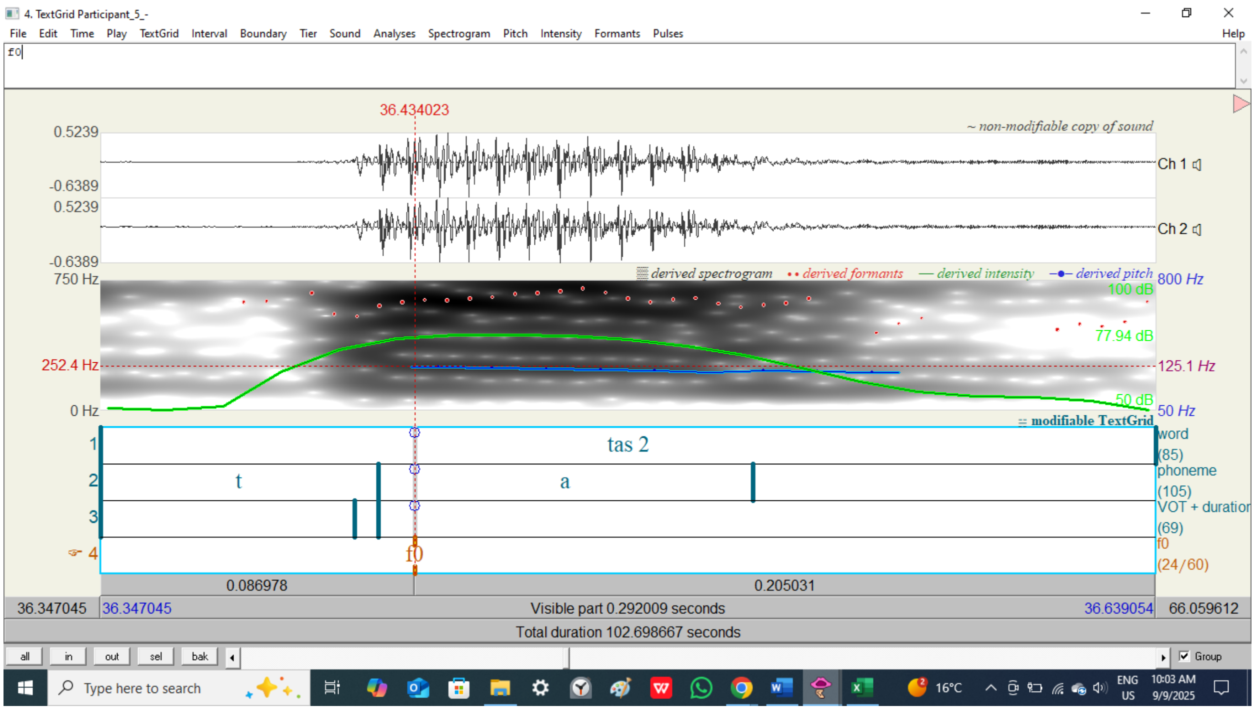


Fig. 6. Participant 5's second token of [tas]. F0 begins earlier than 10 ms, so F0 was taken from approximately 10 ms.



5.5. Linguistic Effects

Averages for the individual differences in the average VOT, constriction duration, and F0 for all plosives per each participant can be found in Appendix B. All participants involved listed English and French as their second languages, except for participant 4 who only spike English, and Mauritian Creole as their first. Kehoe and Kannathasan (2021) studied bilingual speakers of English and French to determine if VOT values in one language can be affected by those of another language among multilingual speakers. This study didn't ask for fluency; participant 3 claimed to have decreased fluency in French after living in Canada, and exhibited less extreme VOTs for all voiced plosives than the other two participants did, except for word-final [p].

Otherwise, participants 2 and 3, who arrived in Canada as children, exhibited more positive values for both voiced and voiceless VOTs than the other participants in most cases, including all cases with voiceless plosives, except for participant 2 in the case of word-initial [k]. Voiced plosives didn't appear to exhibit the exact same pattern. English also exhibits more positive VOT values between voicing plosive categories, so this could be an indication of crossover effects from English bilingualism. Other participants also spoke English but arrived in Canada at later periods.

5.6. Gender and Age Effects

Gender was correlated with higher F0, because the female participants, 2 and 6, were found to exhibit higher F0 values on vowels after all plosives than the male participants did; in the other variables, gender wasn't correlated with any other consistent patterns. Age was also not correlated with any other consistent patterns among the three metrics in this study; participant 1, the oldest participant, didn't exhibit any consistent patterns distinguishable from the other two participants in those metrics. The only noticeable difference was the extended pauses between words in participant 1's and 4's tokens, but this could be ascribed to individual speaking patterns instead of age; not enough data exists to indicate which is the contributing factor.

5.7. Comparison with Previous Experiment

The overall results of the current experiment generally align with those of the previous experiment, with some exception. The previous experiment determined that voiceless plosives have moderately positive VOTs and voiced ones have highly negative VOTs in word-initial and word-medial positions. Note that although it was stated earlier that the demographic differences, aside from gender, don't appear to have any notable effect on the differences in these metrics among participants in this experiment, the data in Table 1 show the participant in the previous experiment to have overall lower VOT values than those in this experiment. The participant in that experiment also spoke Hindi and Bhojpuri in addition to Mauritian Creole, French, and English, and this may have affected those results, but the previous experiment didn't factor that into consideration.

In terms of F0, this study found that voiceless phonemes induce higher values on following values than voiced phonemes, although this is only significant in word-initial position ($p < 0.001$) but not word-medial position ($p = 0.158$). In contrast, the previous experiment did not find a correlation between plosive voicing and any F0 effects, since some of the voiced plosives in that experiment induced higher F0s than their voiceless counterparts in the same environment, while others didn't; compare F0 values after bilabial plosives [b] = 144 Hz, [p] = 147 Hz, against alveolar plosives [d] = 142 Hz, [t] = 148 Hz for example. This indicates the previous experiment's results were individual variance of the speaking patterns of the previous experiment's participant. Note also that F0 from the previous experiment was taken from the midpoint of the vowel duration rather than 10 ms after the beginning of the duration as in this experiment, which may account for some of the discrepancies between the results of the two experiments. This indicates drawing pitch values closer to the beginning of the vowel is ideal, because the effects of consonantal perturbations on F0 may not be as robust from the midpoint of the vowel.

5.8. Comparison with French

When compared to French, this data on Mauritian Creole appears to align in terms of VOT; both languages have negative VOTs for voiced plosives and positive VOTs for voiceless ones. This overall isn't surprising, considering the previous experiment indicated generally the same. According to Kirby and Ladd (2016), French exhibits raising effects on F0 after voiceless plosives; they and Kehoe and Kannathasan (2021) also demonstrated that French voiced and voiceless plosives are characterized by negative and positive VOTs, respectively. This indicates Mauritian Creole generally retains its lexifier's voicing contrast.

6. Discussion

6.1. Phonetic Effects of Position

An interesting result from this study is that word-medial position appears to minimize the differences in VOT both voicing categories, meaning VOTs have less highly positive values in word-medial voiced plosives and less highly negative values in word-medial voiceless plosives relative to the other two positions. In addition, word-medial position decreases the overall values of constriction duration and f0 in comparison to word-initial and word-final environments. One possible explanation is the increase in vocal tract pressure during the production of the adjacent vowels could cause a build-up of pressure, which would mean the closure phase would be more difficult to maintain during a longer period, and that in turn minimizes the period of lower amplitude vibrations characteristic of plosives; the result of that is higher VOTs for voiced plosives and lower VOTs in voiceless plosives, which causes the aforementioned less extreme differences in word-medial voicing.

The results of the statistical tests indicated most of the variations of all three metrics in all three word-internal positions are significant. These developments may have implications for further studies on the effects of word-internal position on VOT, constriction duration, and F0.

6.2. Phonetic Effects of Place of Articulation

Place of articulation, however, appears to have fewer effects on the metrics. The results of the statistical analyses, as indicated in Table 10 and 11, indicate that place of articulation had a statistically significant effect on the differences in VOT values between bilabial and non-bilabial voiceless plosives ($p < 0.001$), but not for any other metrics ($p > 0.001$). Previous studies (Lisker, 1957; Hitchcock et. al., 2014) indicated velar position, at least for voiceless plosives, is correlated with more positive VOT values, but this study found no such correlation.

6.3. Comparison with Existing Literature

The data indicating F0 is raised after voiceless plosives reflects the results obtained by Kirby & Ladd (2016), who noted an increase in F0 in vowels after voiceless plosives. Conversely, the data doesn’t provide much evidence on theories about the effects of multilingualism on VOT. Kehoe and Kannathasan (2021) observed that French VOTs were only minimally altered by bilingual English-French speakers to have higher VOTs, but only if the bilinguals were not dominant in French. Participants 2 and 3 mostly exhibited more positive VOT values for voiceless plosives than the other participants in all environments and most tokens; this could be taken as some effect of English multilingualism since these participants arrived in Canada at an earlier stage of their lives than the other participants, but their voiced plosives don't exhibit the same pattern. Other than this, though, the data doesn't indicate any other effects of multilingualism. The data here thus isn't sufficient to investigate any multilingual effects on VOT, meaning a wider pool of participants speaking a wider variety of languages would be necessary to do so.

The data also don't support the observation that velar articulation is correlated with more positive VOT values, so these results are more in line with the results observed by Yao (2007) rather than Lisker & Abramson (1957).

6.4. Limitations

The sample size of this experiment is only six participants, which is the minimum of what was initially intended but less than would necessarily be representative of the majority of speakers of this language. In addition, the participants have all spent considerable time in Canada, more so than in a primarily Mauritian Creole-speaking environment, and are all multilingual, meaning these results aren't completely representative of Mauritian Creole speakers. Participants 2 and 3 also indicated they primarily communicated through spoken, not written, Mauritian Creole, though this doesn't appear to have affected their tokens. Furthermore, participants 4-6 were recorded on Zoom due to logistical issues, meaning the effects of external sound influence could not be entirely counted out in the same way as the results of participants 1-3, which were conducted in a soundproof environment.

The presence of spaces between words in some participants' sentences meant that assessing word-initial and word-final constriction durations wasn't as easy as assessing word-medial ones, leading to values for those instances to be omitted, and reducing the number of tokens which the averages were drawn from. This can be due to individual variance in terms of speaking patterns, but individuals may also be influenced by the cognitive knowledge that they're being tested, meaning some participants chose to be more deliberate, despite being instructed to speak in a regular manner of speaking.

In addition, I, the primary investigator, am not a Mauritian Creole speaker, and thus required external sources to verify the word list.

7. Conclusion

The study began by asking the research questions: what are the average VOT and constriction duration values of Mauritian Creole plosives, and the average F0 values on following vowels; which of these values is the most useful cue by which to differentiate the voicing plosive categories; and whether the word-internal environments affect any of these averages. The overall hypothesis predicted more negative VOTs, shorter constriction durations, and higher F0 on the following vowels, for voiced plosives than for voiceless ones. The average VOT in Mauritian Creole is moderately positive in voiceless plosives, and highly negative in voiced plosives, and this contrast is minimalized in word-medial intervocalic positions. Constriction duration similarly exhibited distinct contrast in all three word-internal positions, where it's longer on average for voiceless plosives than voiced plosives. Finally, F0 is found to be lower in vowels after voiced plosives, and higher in vowels after voiceless plosives. The effects of word-internal position were shown to have statistical significance as well. VOT was determined to be the most useful cue for differentiating voicing plosive categories because it could be assessed in all environments, whereas constriction duration wasn't able to be assessed in all environments. This indicates Mauritian Creole has retained the general pattern of voicing contrast from its lexifier, French, which exhibits a similar dichotomy, and confirms the hypothesis this MRP initially set out to investigate.

This experiment also provides support for some existing theories and observations of phonetics, namely the observation that voiceless plosives increase F0 on following vowels (Kirby and Ladd, 2016). Conversely, it didn't provide any significant support for the theory about interlingual effects on VOT among multilingual speakers (Kehoe and Kannathasan, 2021). In terms of implications for phonetics, the effects of word-medial position, namely minimizing the contrasts between voicing categories, as well as F0 values, could be of further interest to the linguistic community, especially as it may pertain to acoustic and physiological effects of vocal speech, which are beyond the scope of this study. The effect of in-word position on phonemes thus is of value to further studies on phonetics.

As for creole studies, further direct comparisons between French and Mauritian Creole would be necessary to see how much divergence there is from the lexifier in terms of all metrics, because this study only took a general look at the differences between the two languages. Despite the limitations discussed, including the limited participant pool, the results provide a basic description of voicing effects and contrasts in Mauritian Creole. Further research should be conducted on Mauritian Creole phonetics to understand creole history and evolution at the acoustic level.

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Appendix A: Demographic and Linguistic Questionnaire

1. Age:

2. Gender:

3. First language:

4. Second language(s) (any language learned after first language), including the duration of time speaking this language:

Second Language	**Duration of Time Speaking Language**

5. Time spent living in Canada:

Appendix B: Participants' Individual Average Values for VOT, Constriction Duration, and F0

Tables 10-27 show all the individual average values for VOT (in ms), constriction duration (in ms), and F0 (in Hz) per plosive per participant. All values are rounded to the nearest whole number.

Participant 1 Average Values

Table 12: Average VOT (in ms)

	Word-Initial	Word-Medial	Word-Final
b	-90	-57	-125
p	15	29	50
d	-100	-59	-126
t	16	17	39
g	-91	-70	-75
k	28	22	49

Table 13: Average Constriction Duration (in ms)

	Word-Initial	Word-Medial	Word-Final
b	90	57	125
p	N/A	66	124
d	100	59	126

t	N/A	76	129
g	91	70	109
k	N/A	72	131

Table 14: Average F0 (in Hz)

	Word-Initial	**Word-Medial**
b	138	144
p	167	167
d	137	140
t	181	170
g	140	151
k	173	149

Participant 2 Values

Table 15: VOT (in ms)

	Word-Initial	**Word-Medial**	**Word-Final**
b	-96	-74	-97
p	32	39	0
d	-62	-53	-78
t	37	39	49
g	-58	-62	-103

k	28	31	27

Table 16: Constriction Duration (in ms)

	Word-Initial	**Word-Medial**	**Word-Final**
b	96	74	97
p	97	83	175
d	62	53	78
t	83	70	66
g	58	63	76
k	111	66	157

Table 17: F0 (in Hz)

	Word-Initial	**Word-Medial**
b	200	144
p	203	154
d	200	140
t	209	145
g	199	144
k	212	149

Participant 3 Values

Table 18: VOT (in ms)

	Word-Initial	**Word-Medial**	**Word-Final**
b	-124	-84	-112
p	37	44	5
d	-150	-50	-103
t	57	52	59
g	-114	-83	-126
k	49	33	41

Table 19: Constriction Duration (in ms)

	Word-Initial	**Word-Medial**	**Word-Final**
b	124	84	112
p	214	72	146
d	150	50	103
t	157	84	115
g	114	83	115
k	170	62	120

Table 20: F0 (in Hz)

	Word-Initial	**Word-Medial**
b	148	146

p	153	153
d	149	141
t	152	155
g	151	147
k	159	156

Participant 4 Values

Table 21: VOT (in ms)

	Word-Initial	Word-Medial	Word-Final
b	-144	-86	-115
p	10	9	2
d	-150	-79	-105
t	19	10	5
g	-153	-92	-110
k	26	21	5

Table 22: Constriction Duration (in ms)

	Word-Initial	Word-Medial	Word-Final

b	144	86	115
p	N/A	135	117
d	150	80	106
t	N/A	111	135
g	153	92	111
k	N/A	96	199

Table 23: F0 (in Hz)

	Word-Initial	**Word-Medial**
b	128	157
p	141	169
d	153	169
t	188	191
g	137	153
k	203	162

Participant 5 Values

Table 24: VOT (in ms)

	Word-Initial	**Word-Medial**	**Word-Final**

b	-118	-50	-70
p	11	9	2
d	-93	-48	-61
t	13	17	0
g	-85	-80	-82
k	34	8	5

Table 25: Constriction Duration (in ms)

	Word-Initial	**Word-Medial**	**Word-Final**
b	-118	-50	-70
p	109	93	160
d	-93	-48	-61
t	81	144	172
g	-85	-80	-82
k	77	80	144

Table 26: F0 (in Hz)

	Word-Initial	**Word-Medial**
b	112	108
p	119	129
d	113	109

t	127	114
g	105	120
k	147	113

Participant 6 Values

Table 27: VOT (in ms)

	Word-Initial	Word-Medial	Word-Final
b	-115	-68	-42
p	11	19	12
d	-106	-80	-83
t	18	30	20
g	-137	-89	-80
k	30	26	23

Table 28: Constriction Duration (in ms)

	Word-Initial	Word-Medial	Word-Final
b	-115	-68	-42
p	139	98	112

d	-106	-80	-83
t	153	119	95
g	-137	-89	-80
k	N/A	122	88

Table 29: F0 (in Hz)

	Word-Initial	**Word-Medial**
b	187	170
p	189	178
d	186	161
t	202	182
g	189	170
k	190	184

Appendix C: Individual Tokens Recorded by Participants for VOT (in ms), Constriction Duration (in ms), and F0 (in Hz)

Tables 28-44 contain all the data from each individual token produced by each participant for each target word. The tables are organized as word-initial, word-medial, and word-final, respectively, for each participant. N/A means that data wasn't able to be calculated.

Participant 1 Data Tables

Table 30: Participant 1 Word-Initial Data

Word	Target plosive	Following Vowel	VOT (in ms)	constriction duration (in ms)	F0 (in Hz)
bag	**b**	**a**	-98	98	138
			-96	96	N/A
			-76	76	N/A
pas	**p**		10	N/A	N/A
			18	N/A	167
			16	N/A	N/A
dat	**d**		-78	78	138
			-112	112	134
			-110	110	138
tas	**t**		14	N/A	181
			15	N/A	N/A

			17	N/A	182
gaɣd	**g**		-117	117	140
			-76	76	146
			-81	81	143
kap	**k**		25	N/A	178
			37	N/A	170
			26	N/A	170

Table 31: Participant 1 Word-Medial Data

Word	**Target plosive**	**Following Vowel**	**VOT (in ms)**	**constriction duration (in ms)**	**F0 (in Hz)**
ka**b**a	**b**	**a**	-59	59	N/A
			-55	55	155
			-57	57	N/A
la**p**aj	**p**		28	74	N/A
			32	60	N/A
			27	65	159
ma**d**am	**d**		-54	54	N/A
			-63	63	N/A
			-62	62	147
ba**t**o	**t**	**o**	11	73	207

			22	78	203
			18	78	199
la**g**aɣ	**g**	**a**	-69	69	145
			-71	71	158
			-69	69	147
la**k**az	**k**		25	74	170
			23	73	167
			20	69	168

Table 32: Participant 1 Word-Final Data

Word	**Target plosive**	**Following Vowel**	**VOT (in ms)**	**constriction duration (in ms)**
dja**b**	**b**	**a**	-142	142
			-119	119
			-113	113
ka**p**	**p**		51	109
			56	131
			48	132
ka**d**	**d**		-133	133
			-124	124
			-119	119
da**t**	**t**		66	129

			49	112
			2	149
ba**g**	**g**		-75	75
			-76	76
			-73	73
sa**k**	**k**		62	130
			77	131
			74	131

Participant 2 Data Tables

Table 33: Participant 2 Word-Initial Data

Word	**Target plosive**	**Following Vowel**	**VOT (in ms)**	**constriction duration (in ms)**	**f0 (in Hz)**
bag	**b**	**a**	-95	95	213
			-98	98	197
			-95	95	191
pas	**p**		25	102	209
			45	91	207
			27	98	193
dat	**d**		-17	17	210
			-92	92	201

			-76	76	190
tas	**t**		34	85	211
			42	87	202
			34	78	215
gaɣd	**g**		-46	46	208
			-46	46	201
			-81	81	190
kap	**k**		44	N/A	226
			19	122	205
			20	99	206

Table 34: Participant 2 Word-Medial Data

Word	**Target plosive**	**Following Vowel**	**VOT (in ms)**	**constriction duration (in ms)**	**F0 (in Hz)**
ka**b**a	**b**	**a**	-69	69	200
			-73	73	200
			-80	80	199
la**p**aj	**p**		34	94	214
			54	68	200
			28	85	204
ma**d**am	**d**		-56	56	194

			-52	52	193
			-49	49	186
ba**t**o	**t**	**o**	29	79	222
			47	68	212
			40	62	192
la**g**aɣ	**g**	**a**	-76	76	197
			-65	65	202
			-47	47	96
la**k**az	**k**		36	57	212
			15	81	198
			41	59	198

Table 35: Participant 2 Word-Final Data

Word	Target plosive	Following Vowel	VOT (in ms)	constriction duration (in ms)
dja**b**	**b**		-110	110
			-96	96
			-84	84
ka**p**	**p**		0	133
			0	284
			0	109
ka**d**	**d**		-86	86

			-96	96
			-52	52
da**t**	**t**		67	73
			34	70
			46	57
ba**g**	**g**		-78	78
			-102	102
			-129	129
sa**k**	**k**		34	185
			0	166
			31	106

Participant 3 Data Tables

Table 36: Participant 3 Word-Initial Data

Word	**Target plosive**	**Following Vowel**	**VOT (in ms)**	**constriction duration (in ms)**	**F0 (in Hz)**
bag	**b**	**a**	-109	109	148
			-88	88	146
			-174	174	150
pas	**p**		27	109	161

			48	157	152
			33	375	146
dat	**d**		-181	181	152
			-123	123	147
			-147	147	149
tas	**t**		51	198	158
			57	117	154
			61	157	160
gaɣd	**g**		-102	102	151
			-110	110	151
			-130	130	151
kap	**k**		45	121	166
			56	107	156
			47	282	155

Table 37: Participant 3 Word-Medial Data

Word	**Target plosive**	**Following Vowel**	**VOT (in ms)**	**constriction duration (in ms)**	**F0 (in Hz)**
ka**b**a	**b**	**a**	-93	93	151
			-84	84	145
			-76	76	142

la**p**aj	**p**		37	82	162
			44	77	151
			52	57	147
ma**d**am	**d**		-45	45	142
			-45	45	141
			-61	61	141
ba**t**o	**t**	**o**	53	91	156
			58	76	151
			45	87	157
la**g**aɣ	**g**	**a**	-82	82	150
			-82	82	144
			-84	84	147
la**k**az	**k**		41	53	153
			9	86	159
			49	46	158

Table 38: Participant 3 Word-Final Data

Word	**Target plosive**	**Following Vowel**	**VOT (in ms)**	**constriction duration (in ms)**
dja**b**	**b**		-142	142
			-91	91
			-103	103

ka**p**	**p**		3	162
			6	154
			5	124
ka**d**	**d**		-87	87
			-121	121
			-102	102
da**t**	**t**		74	120
			91	147
			13	78
ba**g**	**g**		-125	125
			-97	97
			-124	124
sa**k**	**k**		34	185
			41	69
			48	105

Participant 4 Data Tables

Table 39: Participant 4 Word-Initial Data

Word	Target plosive	Following Vowel	VOT (in ms)	constriction duration (in ms)	F0 (in Hz)

bag	**b**	**a**	-175	175	144
			-130	130	124
			-126	126	117
pas	**p**		7	N/A	131
			11	N/A	147
			11	N/A	145
dat	**d**		-154	154	153
			-149	149	153
			-147	147	153
tas	**t**		14	N/A	197
			17	N/A	190
			25	N/A	178
gaɣd	**g**		-210	210	132
			-148	148	137
			-101	101	142
kap	**k**		22	N/A	205
			18	N/A	200
			39	N/A	N/A

Table 40: Participant 4 Word-Medial Data

Word	Target plosive	Following Vowel	VOT (in ms)	constriction duration (in ms)	F0 (in Hz)
ka**b**a	**b**	**a**	-94	94	178
			-92	92	151
			-72	72	142
la**p**aj	**p**		8	147	167
			8	136	171
			10	122	170
ma**d**am	**d**		-88	88	172
			-86	86	171
			-65	65	163
ba**t**o	**t**	**o**	7	126	207
			16	100	197
			6	107	170
la**g**aɣ	**g**	**a**	-92	92	154
			-92	92	155
			-93	93	151
la**k**az	**k**		19	117	169
			23	83	163
			20	89	154

Table 41: Participant 4 Word-Final Data

Word	Target plosive	Following Vowel	VOT (in ms)	constriction duration (in ms)
dja**b**	**b**		-144	144
			-88	88
			-114	114
ka**p**	**p**		N/A	N/A
			0	173
			5.344	61.263
ka**d**	**d**		-110	110
			-112	112
			-96	96
da**t**	**t**		14.561	71.984
			0	150
			0	182
ba**g**	**g**		-86	86
			-118	118
			-127	127
sa**k**	**k**		N/A	N/A
			N/A	N/A
			14	199

Participant 5 Data Tables

Table 42: Participant 5 Word-Initial Data

Word	Target plosive	Following Vowel	VOT (in ms)	constriction duration (in ms)	F0 (in Hz)
bag	**b**	**a**	-78	78	121
			-100	100	108
			-174	174	108
pas	**p**		7	139	127
			16	94	N/A
			9	93	111
dat	**d**		-110	110	112.1
			-89	889	118
			-78	78	112
tas	**t**		19	98	N/A
			7	70	127
			14	75	N/A
gaɣd	**g**		-119	119	110
			-86	86	106
			-52	52	100
kap	**k**		33	98	144
			40	50	119
			-78	78	121

Table 43: Participant 5 Word-Medial Data

Word	Target plosive	Following Vowel	VOT (in ms)	constriction duration (in ms)	F0 (in Hz)
ka**b**a	**b**	**a**	-45	45	114
			-54	54	104
			-52	52	107
la**p**aj	**p**		8	91	138
			8	128	131
			12	62	117
ma**d**am	**d**		-57.	57	115
			-42	42	107
			-44	44	104
ba**t**o	**t**	**o**	17	90	122
			17	299	112
			18	42	107
la**g**aɣ	**g**	**a**	-84	84	122
			-91	91	108
			-63	63	106
la**k**az	**k**		7	86	123
			7	83	109
			9	72	108

Table 44: Participant 5 Word-Final Data

Word	**Target plosive**	**Following Vowel**	**VOT (in ms)**	**constriction duration (in ms)**
dja**b**	**b**		-94	94
			-69	69
			-45	45
ka**p**	**p**		0	159
			0	198
			5	122
ka**d**	**d**		-62	62
			-73	73
			-47	47
da**t**	**t**		0	168
			0	210
			0	138
ba**g**	**g**		-85	85
			-64	64
			-97	97
sa**k**	**k**		0	128
			0	95
			14	208

Participant 6 Data Tables

Table 45: Participant 6 Word-Initial Data

Word	**Target plosive**	**Following Vowel**	**VOT (in ms)**	**constriction duration (in ms)**	**F0 (in Hz)**
bag	**b**	**a**	-155	155	195
			-100	100	186
			-91	91	181
pas	**p**		7.391	N/A	197
			9	133	N/A
			15	144	181
dat	**d**		-174	174	197
			-77	77	184
			-164	164	187
tas	**t**		22	N/A	209
			18	186	195
			13	120	N/A
gaɣd	**g**		-174	174	197
			-74	74	184
			-164	164	187
kap	**k**		27	N/A	209
			34	N/A	180

			230	N/A	182

Table 46: Participant 6 Word-Medial Data

Word	**Target plosive**	**Following Vowel**	**VOT (in ms)**	**constriction duration (in ms)**	**F0 (in Hz)**
ka**b**a	**b**	**a**	-74	74	174
			-64	64	172
			-67	67	162
la**p**aj	**p**		19	97	183
			18	106	169
			20	91	172
ma**d**am	**d**		-82	82	166
			-98	98	155
			-58	58	161
ba**t**o	**t**	**o**	20	91	172
			26	120	176
			32	109	188
la**g**aɣ	**g**	**a**	-91	91	179
			-91	91	164
			-86	86	167
la**k**az	**k**		25	113	182

			34	147	176
			18	105	196

Table 47: Participant 6 Word-Final Data

Word	Target plosive	Following Vowel	VOT (in ms)	constriction duration (in ms)
dja**b**	**b**		-82	82
			-23	23
			-21	21
ka**p**	**p**		18	123
			N/A	N/A
			6	100
ka**d**	**d**		-53	53
			-101	101
			-96	96
da**t**	**t**		21	97
			20	94
			18	90
ba**g**	**g**		-78	78
			-65	65
			-97	97
sa**k**	**k**		29	94

			18	76
			21	93