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DURATION [a] AND [i] AS PRECEDING VOWELS WITH PLOSIVES IN NEPALI

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Abstract

Nepali language is the sub branch of eastern Pahari and it belongs to the Indo-Aryan language family. Nepali is one of the 22 scheduled languages of India, and has a significant number of speakers in the states of Arunachal Pradesh, Assam, Himachal Pradesh, and Uttarakhand. This study is intended to present an introduction to the Nepali language which includes the vowel sound system of the Nepali language. To date only few studies are available for the language and its dialects. This paper will elaborate the information available on the vocalic system of the Nepali language based on the data collected from the native speakers of Nepali language. During this analysis, it was found that the Nepali vowels |a| and |i| have temporal relationship with the voiced plosives. The controversy of positioning of selective vowel sounds, VOT will be discussed and explained. The analysis of the study justified the universal tendency that the vowel duration is affected by the intrinsic temporal character of a vowel. If all the factors remain constant, the low vowels are longer than high vowels.

Key Words: Phonology, Vocalic system, Voice Onset Time, Indo-Aryan, Scheduled language

Introduction

Nepali is a four category language regarding the plosive phonemes. It has 16 plosives which have four-way contrast in terms of phonation: voiceless vs. voiced and unaspirated vs. aspirated, and four-way contrast in the place of articulation: bilabial, dental, retroflex and velar (Bandhu et al. 1971, Dahal 1974, Pokharel 1989, Acharya 1991, Genetti 1994 and Khatiwada 2009).The Nepali plosives are presented in Table 1.

	Bilabial (voiceless-voiced)	**Dental (voiceless-voiced)**	**Retroflex (voiceless-voiced)**	**Velar (voiceless-voiced)**
Aspirated	pʰ bʰ	t̪ʰ d̪ʰ	ʈʰ ɖʰ	kʰ gʰ
Unaspirated	p b	t̪ d̪	ʈ ɖ	k g

Table 1: The Nepali plosives

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There are six basic vowels /i/, /e/, /ʌ/[1], /a/, /o/ and /u/ (Bandhu et al. 1971, Dahal 1974, Pokharel 1989, Acharya 1991,Genetti 1994 and Khatiwada 2009). Dahal (1974) classifies them in terms of height of the tongue, part of the tongue active and shape of the lips. In terms of height of the tongue /i/ and /u/ are high, /e/, /ʌ/ and /o/ are mid and /a/ is low. In terms of part of the tongue active /i/ and /e/ are front, /ə/ and /a/ are central; and /u/ and /o/ are back. Similarly, in terms of shape of the lips, /u/ and /o/ are rounded and rest are unrounded. Acharya (1991) exactly agrees with Dahal (1974) regarding the classification of the vowels. Pokharel (1989) regards/ʌ/ and /a/ to be back vowels although he accepts /a/ to be central phonetically.

I tried to identify whether [a] is a central vowel or a back vowel. I measured the first formant (f1) and second formant (f2) values of [a] and [i] in the disyllabic words in the exactly same phonetic environment from six speakers (3 males and 3 females). Five tokens of words were taken from each of the speakers and the average values were calculated. Then the average values were plotted in f1×f2 and f1×f2-f1 plane using PRAAT, version 6.1.16 for male (Figure 1 and 2) and for female (Figure 3 and 4) separately. In all the four cases [a] is a low-back vowel and [i] is a high-front vowel.

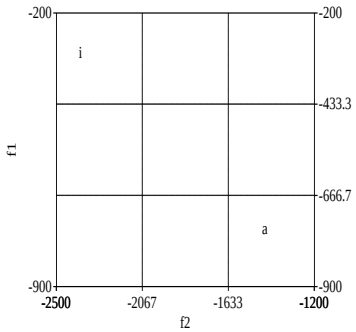

Figure 1: Male [i] and [a] in f1×f2 plane

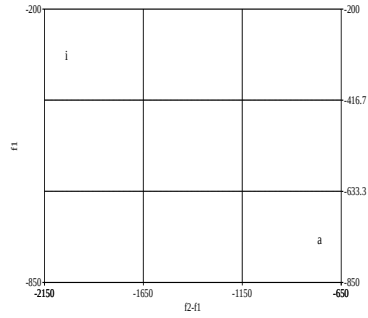

Figure 2: Male [i] and [a] in f1×f2-f1 plane

[1] Pokharel (1989) and Khatiwada (2009) have used [ʌ] and orhers have use [ə]. I prefer using [ʌ] to [ə] because the vowel is very close to [ʌ] in my own instrumental investigations, too.

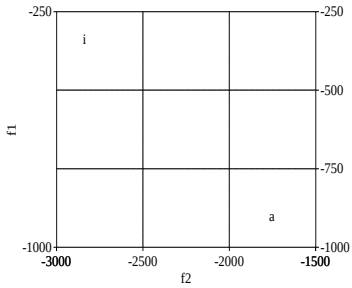

Figure 3: Female [i] and [a] in f1×f2 plane

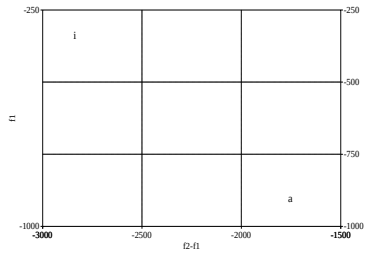

Figure 4: Female [i] and [a] in f1×f2-f1 plane

Although there are long and short vowels in writing system, there is no phonemic length in Nepali. Regarding the nasal vowels, (Bandhu et al. 1971 and Genetti 1994) assert the existence of nasal counterparts of each of the oral vowels, viz. there are six nasal vowels parallel to the oral vowels but (Pokharel1989, Acharya 1991, Khatiwada 2009) don't accept the existence of /õ/, the nasal counterpart of /o/.Dahal (1974) does not accept the existence of any nasal vowel because he supposes all of them to be the nasalized form of the oral vowels.

Pokharel (1989) is the only work that measured the duration of the Nepali vowels empirically. He measured the length of [a] in different environments and made generalizations about the vowel length. His measurement is based on a single token of a single speaker. In his experiment he has made the following generalizations regarding the phonetic duration of the vowels in relation to plosive and intrinsic vowel duration.

a. The vowel before a voiced consonant is significantly longer than before a voiceless consonant.

b. The vowel before a voiced unaspirate is longer than before a voiced aspirate.

c. The vowel before a voiceless aspirate is longer than before a voiceless unaspirate.

d. The intrinsic length of a vowel depends on the vocalic openness of the vowel so vowel length increases form high to low vowels.

This study is concerned with the vowel duration before the plosives in reference to voicing, places of articulation and aspiration. Apart from this, it tries to investigate the vowel duration in the production of a single word and in connected

speech and whether vowels have their own intrinsic length or not. In this connection, the generalizations a, b, c and d made by Pokharel (1989) fall under the scope of this study.

Methodology

Method of Data Collection

The words recorded for the experiment consist the target vowels, i.e., [i] and [a] in [-iCi] and [-aCa] environment where C stands for a plosive sound. Every word was embedded in a carrier sentence as: X, I said X (where X is the target word) where the word is uttered as a single word for the first time and a part of the utterance for the second time, and the speakers were asked to utter for three times. Every utterance was followed by a pause so that the speaker could produce each utterance with equal comfort**.** The utterances were recorded using Sony ECM-MS908C Electret Condenser Microphone and EDIROL, R09HR audio recorder maintaining a distance of 10-12 inches between the microphone and the mouth of the speaker in .wav formant files with 44000 Hz audio sample rate, 1411-bit rate and 24-bit resolution.

The Speakers

Six fluent native speakers of Nepali, three males and three females, with normal speech capacity were recruited for the experiment. The speakers have been included from different age groups as presented in Table 2.

S. N.	Age group	Gender	
1	21-30	male [DA]	female [JA]
2	31-40	male [HR]	female [GY]
3	41-50	male [KR]	female [KL]

Table 2: The sample structure

Analysis of the Data

The recorded data was edited using Audacity, an audio editing software. In total, 1152 [2 (vowels) ×16 (plosives) × 2 (word form and utterance form) × 6 (number of speakers) × 3 (one word was uttered for three times)] tokens were analyzed. Averages were calculated out of the three and were analyzed

using PRAAT sophisticated and widely used software for acoustic analysis. This study has focused on the effect of aspiration on the plosive itself and the preceding vowel and the following vowel. Oscillogram, spectrum and spectrogram of the sounds were used as the devices for analysis. The techniques of measurement are based on Ladefoged (2003). The statistical calculations were made using http://vassarstats.net/, a statistical calculation website.

This research has followed the segmentation model proposed by Mikuteit and Reetz (2007) for the study of the East Bengali plosive sounds. This model proposes four phases in vowel-plosive-vowel sequence as presented in Fig. 1. Preceding vowel duration (PVD) is the duration of the vowel preceding the plosive. Its duration begins with the end of the preceding segment and ends at the beginning of the closure duration of the plosive and closure duration (CD) is the duration of the hold phase of the plosive production. It begins with the end of the preceding vowel and ends at the release of the closure. The end of the preceding vowel is indicated by the sudden cessation of the high amplitude vocal fold vibration of the vowel and beginning of the silence (for voiceless) or very low amplitude buzz (for voiced). Similarly, the end of the closure is indicated by beginning of the release burst indicated by a short spike.

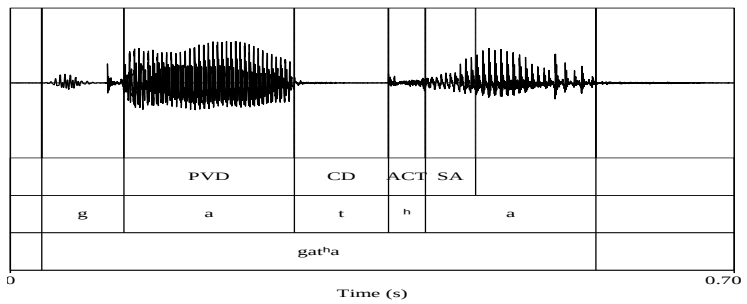

Figure 5: The phases in vowel-plosive-vowel sequence

Findings and Discussion

The Preceding Vowel Duration and Voicing

It is a widely accepted fact that the vowels before a voiced consonant are longer than before a voiceless one. As mentioned by Pokharel (1989), House (1961), Lisker (1974) and Klatt (1976) have supported the fact. From the study of English, French, Russian and Korean, Chen (1970) has the same finding and states, "We have good reasons to assume as language

universal the variability of vocalic duration as a function of the [± voice] feature of the following consonant." This universal tendency is the same in the vowel-plosive sequence in Nepali (Pokharel, 1989), Bengali (Mikuteit and Reetz, 2007; and Kostic and Das, 1972) and Hindi (Maddieson and Gandour, 1976; and Durvasula and Luo, 2014)."

This study supports the universal tendency that the duration of the vowels ([a] and [i]) before voiced plosives are significantly longer than before their voiceless counterparts. In total, the mean duration of [a] before a voiced plosives 184.35ms (sd. = 37.31) and before a voiceless plosives 145.63ms (sd. = 37.18) with high statistical significance to show that the means belong to two distinct groups [$F(1, 95) = 156.42$, $p < 0.0001$].Similarly, the mean duration of [i] before a voiced plosive is 149.78 ms (sd. = 41.31) and before a voiceless plosive is 100.90 ms (sd. = 29.53) with high statistical significance [$F(1, 95) = 218.54$, $p < 0.0001$].

The universal trait is the same in both word and utterance form in both vowels [a] and [i] as presented in Table 3. In both word and utterance forms and in both vowels [a] and [i], the vowels before a voiced consonant are longer than the before their voiceless counterparts and this distinction is highly significant.

Vowel	Environ.	Mean before vd. plosive (ms)	Mean before vl. plosive (ms)	Significance
[a]	word	207.37 (sd. = 34.53)	169.16 (sd. = 34.59)	$F(1, 47) = 56.24$, $p < 0.0001$
	utterance	161.00 (sd. = 23.21)	122.10 (sd. = 21.62)	$F(1, 47) = 120.47$, $p < 0.0001$
[i]	word	177.43 (sd. = 32.76)	121.41 (sd. = 23.28)	$F(1,47) = 111.99$, $p<0.0001$
	utterance	122.12 (sd. = 28.52)	80.39 (sd. = 18.34)	$F(1,47) = 124.47$, $p<0.0001$

Table 3: The duration of [a] and [i] before voiced and voiceless plosives

Pokharel (1989) has measured the duration of [a] in both monosyllabic and disyllabic words. I took the duration of [a] before voiced and voiceless plosives in disyllabic words from his work and calculated the means which are 164.75 ms before voiced plosive and 131.12 ms before voiceless plosive respectively. The values are very close to the corresponding durations of [a] in utterance in this study (before voiced 161.00 ms and 122.10 ms).

The Preceding Vowel Duration and Aspiration

It is supposed that the vowels are longer before aspirated plosives than before unaspirated ones but it is a debated issue. Pokharel (1989) supports the issue in the voiceless plosives but it is just opposite in voiced plosives. Similarly, Ohala and Ohala (1972) explain that the aspiration effect in Hindi is not consistent, but Durvasula and Luo (2014) have justified that the vowels are longer before aspirated plosives than before unaspirated ones.

This study finds this issue to be controversial as the result varies between the vowels and the phonetic context. Including the samples in both word and utterance form (overall mean), [a] is longer before aspirated plosive (mean 151 ms and sd. = 38.78) than before unaspirated plosive (mean = 140.06 ms and sd. = 35.02). A one-way ANOVA on correlated samples shows that the relation is significant [F (1,47) = 5.24, p = 0.02]. But the same thing is opposite with [i] as it is shorter before aspirated one (mean = 96.93, sd. 27.88) than before unaspirated one (mean = 104.87 ms and sd. = 30.88) and the difference is significant [F (1, 47) = 8.28, p = 0.006].

The same trend is found with voiceless plosives. In word form [a] is longer before aspirated plosive than before unaspirated one. Similarly, it follows the same trend in utterance but the different is not significant. [i] is shorter before aspirated plosive than before unaspirated one with significant difference and the trend is the same in utterance (see Table 4).

Vowel	Environment	Mean before vl. asp. plosive (ms)	Mean before vl.unasp. plosive (ms)	Significance
[a]	word	176.08 (sd. 30.35)	162.25 (sd. 37.73)	F (1, 23) = 3.99, p = 0.057
	utterance	126.33 (sd. 17.13)	117.87 (sd. 24.99)	F (1, 23) = 3.99, p = 0.23
[i]	word	115.58 (sd. 22.38)	127.25 (sd. 24.24)	F (1, 23) = 8.59 , p = 0.007
	utterance	78.29 (sd. 19.02)	82.50 (sd. 17.78)	F (1, 23) = 1.26, p = 0.27

Table 4: The duration of [a] and [i] before voiceless aspirated and unaspirated plosives

With voiced plosives, both [a] and [i] show the opposite trend that they showed with voiceless plosives. In word and utterance form, [a] is slightly shorter before aspirated plosive than before unaspirated one without any significant difference. In word and utterance form, [i] is slightly shorter before aspirated plosive

than before unaspirated one without any significant difference (see Table 5).

Vowel	Environment	Mean before asp. plosive (ms)	Mean before unasp. plosive (ms)	Significance
[a]	word	205.58 (sd. = 38.22)	209.16 (sd. = 31.13)	F (1, 23) = 0.2, p = 0.65
	utterance	159.66 (sd. = 25.30)	163.00 (sd. = 21.32)	F (1, 23) = 0.35, p = 0.55
[i]	word	180.95 (sd. = 34.46)	173.91 (sd. = 31.31)	F (1,23) = 1.44 <p=0.24
	utterance	125.50 (sd. = 31.94)	118.75 (sd. = 24.87)	F (1,23) = 1.36 <p=0.25

Table 5: The duration of [a] and [i] before voiced aspirated and unaspirated plosives

The Preceding Vowel Duration and Closure Duration of the Following Plosive

Mikuteit and Reetz (2007) state that '… it has been claimed for some languages that there is a trade-off between the durations,such that V+CD (closure duration) is highly similar for voiced and voiceless consonants'. In word form, the average sum of vowel and closure duration in voiced plosives is 257 ms (sd. = 12.70) and in voiceless plosives it is 241.37ms (sd. = 19.99), [F (1,7) = 4.31, p = 0.07]. Similarly, in the utterance form, the average sum of vowel and closure duration in voiced plosives is 191 ms (sd. = 7.67) and in voiceless plosives it is 179.37 ms (sd. = 13.98), [F (1,7) = 3.1, p = 0.12]. In both of the situations, the values for voiced and voiceless plosives are close to each other and there is no significant difference between the means. In both of the situations, the value for voiced is greater than it for voiceless but (Mikuteit and Reetz 2007) has found the reverse result, i.e., the value for voiceless plosives is higher than for the voiced ones.

Although there is no exact match, there seems a tendency that when the vowel duration increases, the closure duration decreases and vice versa. I tried to test the linear correlation between the vowel duration and the closure duration of plosives with vowels [a] and [i] separately, and the results in both of the cases show that there is strong (inverse) correlation between them: when vowel duration increases, the closure duration decreases and vice versa as presented in Table 6.

	r	Slope	y-intercept	t- value	Df	p value (two-tailed test)
[a]	-0.7691	-0.5495	173.98	-4.5	14	< 0.0004
[i]	-0.8449	-0.667	144.70	-5.91	14	< 0.0001

Table 6: The duration of [a] and [i] and the closure duration of the following plosives

The Vowel Duration and Places of Articulation

It is believed to be a universal tendency that closure duration of plosives gradually decreases from bilabial to velar places of articulation. But Mikuteit and Reetz (2007) investigate for Bengali, that there is not such a clear cut distinction among the places of articulation but bilabials, dentals and retroflexes make a group against velars. The findings of Benguerel and Bhatia (1980) for Hindi, and Pokharel (1989) and Chalise (2017) for Nepali are comparable to Mikuteit and Reetz (2007). All the researches assert that there is interaction between the closure durations and place of articulations of the plosives.

If there is interaction between the preceding vowel duration and closure duration of the plosive and interaction between closure duration and place of articulation there must be interaction between preceding vowel durations and the place of articulation of the plosives. This study finds out that the mean vowel duration before bilabials is 139.39ms (sd. = 43.15), dentals 133.71ms (sd. = 43.89), retroflex 150.14 (sd. = 52.41) and velar 154.75 (sd. 47.54). Tukey HSD Test was carried out to investigate the degree of significance between the intergroup means which shows that there is no significant difference between bilabials and dentals, and between retroflex and velar butthere is significant difference between dental and retroflex (Table 7). It indicates that bilabial and dental make a group and retroflex and velar make another group.

Total (96) samples per group	Bilabial-dental	bilabial-retroflex	bilabial-velar	dental-retroflex	dental-velar	retroflex-velar
	non-significant	p < 0.05	p < 0.01	p < 0.01	p < 0.01	non-significant

Table 7: The relation between the duration of [a] and [i] and the places of articulation of the following plosives

The interaction between preceding vowel durations and the place of articulation of the plosives was investigated for [a] and [i] in word form and utterance form separately. The result is presented in Table 8. The result shows that in every case the bilabial and dental make a significant group and the retroflex and velar make another significant group. The vowels before velars and retroflexes are longer than the vowels before the bilabials and dentals. It justifies that if the closure duration of the plosive is long, the duration of the preceding vowel is short and vice versa.

			bilabial	dental	retroflex	velar	Remark
[a]	word	mean (ms)	180.66	171.95	200.35	193.87	r>v>b>d
		sd.	41.68	40.06	35.67	39.92	
	utterance	mean (ms)	133.79	137.33	151.95	145.25	r>v>d>b
		sd.	27.08	35.54	29.11	34.47	
[i]	word	mean (ms)	143.54	135.16	148.58	168.75	v>r>b>d
		sd.	32.31	30.07	49.77	39.64	
	utterance	mean (ms)	99.58	90.41	99.66	111.12	v>r>b>d
		sd.	26.33	26.23	38.11	33.16	

Table 8: The duration of [a] and [i] and the places of articulation of the following plosives

The Intrinsic Vowel Duration

The vowel duration is also affected by the intrinsic temporal character of a vowel. If all other factors remain constant, low vowels are longer than high vowels by 20-25 ms and it has been reported for a variety of languages. So, it is regarded to be a universal feature of languages (Reetz and Jongman 2009: 215). This research supports the universal trend as the overall mean of [a] is 164.40 ms(sd. 42.67) and [i] is 124.60 ms(sd. 43.57) with very high statistical significance, [$F(1, 191) = 269.08$, $p<0.0001$]. This universal trend is found in the production individual words as well as in the utterance form.

In the production of word form, the duration of [a] is 186.71ms (sd. 40.34) and in the production of utterance it is 142.08 ms (sd. 32.04), [$F(1,95) = 143.18$, $p<0.0001$]. Similarly, in the production of word form, the duration of [i] is 149.01ms (sd. 40.08) in utterance it is 100.19 ms (sd. 31.73), [$F(1,95) = 230.44$, $p<0.0001$].

It reveals another intrinsic feature of vowels that in all instances, the vowel duration is longer in the production of individual

words than in the connected speech. The (F) values and (p) values clearly indicate that the distinctions are consistent and significant (see annex A and B).

Summary of the Findings

This research reveals some facts about the Nepali vowels [a] and [i] and their temporal relation with the following plosives on the basis of which we can make generalizations about the other vowels.

There is a controversy about the position of [a] in the Nepali phonetics whether [a] is a low-back vowel or a low-central vowel. It justifies that Nepali [a] is phonetically a low-back vowel, not a low-central vowel.

This study supports the universal tendency that the duration of vowel before a voiced plosive is larger than before a voiceless one. The durations of both [a] and [i] are longer before voiced plosive than before a voiceless one, consistently, in every context.

It is assumed that the vowels before an aspirated plosive is longer than before an unaspirated one but this tendency has not been found consistent in this research. The overall impression follows the general assumption but there are variations in different contexts. Regarding the voiceless plosives, [a] is longer before aspirates but [i] is shorter. But, regarding the voiced plosives, the result is just opposite. As the relation is constant in both the word form and in the utterance form, we can assume that there might be an interaction among the voicing and aspiration of the plosive and the height and frontness /backness of the vowel that precedes it. It is an important research question for further researches.

The relation between the preceding vowel duration and the closure duration of the following plosive have strong negative correlation when the closure duration increases, the duration of the preceding vowel decreases and vice versa.

There is interaction between the duration of the preceding vowel and the place of articulation of the following plosive. But this relation is categorical in which the bilabial and the dental make one category and the retroflex and the velar make another category. The vowel before the first category is shorter than the vowel before the second category.

This research justifies that the universal tendency that the vowel duration is affected by the intrinsic temporal character of a

vowel. If all other factors remain constant, low vowels are longer than high vowels. This research supports the universal trend as the overall mean of [a] is 40 ms longer than that of [i] with very high statistical significance. This universal trend is found in the production in individual words as well as in the utterance form.

Annexes

Annex A: The duration of [a] as a preceding vowel with individual plosives in different contexts

	[a]				
	word form		**utterance from**		**F- value**
	duration (ms)	**sd.**	**duration (ms)**	**sd.**	
[-p]	154.50	27.70	114.4	9.75	F (1, 5) = 19.78, p=0.006
[-t]	123.33	28.11	84.16	11.83	F (1, 5) = 20.56, p = 0.006
[-t̪]	191.83	30.94	143.16	9.36	F(1, 5) = 15.74, p = 0.010
[-k]	179.33	27.30	129.83	15.27	F (1, 5) = 18.45, p = 0.007
[-pʰ]	156.33	22.8	125.33	5.57	F (1, 5) = 12.93, p = 0.015
[-tʰ]	171.33	22.77	141.00	17.39	F (1, 5) = 6.70, p = 0.040
[-t̪ʰ]	176.00	35.93	122.83	16.05	F (1, 5) = 9.50, p = 0.027
[-kʰ]	200.66	26.42	116.16	19.09	F (1, 5) = 22.76, p = 0.005
[-b]	197.16	32.98	146.5	16.57	F (1, 5) = 29.74, p = 0.002
[-d]	193.33	24.64	157.66	12.90	F (1, 5) = 8.66, p = 0.032
[-d̪]	211.83	19.03	167.66	15.05	F (1, 5) = 31.35, p = 0.002
[-g]	234.33	34.05	180.16	26.13	F (1, 5) = 12.35, p = 0.017
[-bʱ]	211.66	37.95	196.60	27.03	F (1 ,5)= 11.92, p=0.018
[-dʱ]	201.33	32.33	165.83	16.64	F (1, 5) = 11.76, p = 0.018
[-d̪ʱ]	230.16	30.53	168.16	22.92	F (1, 5) = 35.9, p = 0.001
[-gʱ]	179.16	40.91	145	31.96	F (1, 5) = 3.44, p = 0.122

Annex B: The duration of [i] as a preceding vowel with individual plosives in different contexts

	[i]				
	word form		**utterance from**		**F- value**
	duration (ms)	**sd.**	**duration (ms)**	**sd.**	
[-p]	128.66	22.26	87.00	10.44	F (1,5) = 46.12, p = 0.001
[-t]	121.16	29.71	68.50	12.24	F (1, 5) = 11.22, p = 0.020
[-t̪]	116.60	21.94	79.33	10.63	F (1,5) = 15.93, p = 0.010
[-k]	142.50	19.56	95.16	24.87	F (1,5) = 10.99, p = 0.020
[-pʰ]	110.33	20.99	75.16	14.71	F (1,5) = 25.61, p = 0.003
[-tʰ]	118.50	20.31	82.66	27.00	F (1,5) = 8.14, p = 0.035
[-t̪ʰ]	97.50	19.14	70.83	16.79	F (1, 5) = 24.37, p = 0.004
[-kʰ]	136.00	12.19	84.50	17.00	F (1, 5) = 39.6, p = 0.001
[-b]	173.16	16.96	133.83	15.05	F (1, 5) = 19.07, p = 0.007
[-d]	144.00	32.26	100.66	24.88	F (1, 5) = 12.49, p = 0.016
[-d̪]	190.16	31.54	116.50	30.46	F (1, 5) = 28.34, p = 0.003
[-g]	188.33	23.34	124.00	19.20	F (1, 5) = 21.18, p = 0.005
[-bʱ]	168.66	15.35	115.16	17.84	F (1, 5) = 43.51, p=0.001
[-dʱ]	157.00	24.26	109.83	20.98	F (1, 5) = 17.26, p = 0.008
[-d̪ʱ]	190.00	32.67	135.00	43.99	F (1, 5) = 17.5, p = 0.008
[-gʱ]	208.16	41.40	142.00	33.80	F (1, 5) = 8.02, p = 0.036

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